Option FM – WLM02 describes a pipe upgrade between the bend on Earl Street and its connection to the Victoria Street pipe system. The upgrade has been designed with the goal of preventing ingress of floodwaters into properties at the hotspot in the 5% AEP event. The pipe would also provide benefit in larger flood events. The upgrade consists of a 750 mm diameter pipe (currently 300 mm) combined with upgrades to the area's pits to ensure they convey adequate runoff into the pipe.

Modelled Impacts

The drainage upgrade achieves a significant reduction in the peak flood level in the hotspot; however, it also increases the peak flood level in Victoria Street. Figure 27 shows the location of the upgrade and its impact on the 5% AEP peak flood level. The impact includes a decrease of up to 0.3 m and an increase of up to 0.2 m on Victoria Street. It also removes the overland flowpath through the properties. The flow in the upgraded pipe has a peak of 0.15 m^3/s in the 5% AEP event, up from 0.07 m^3/s in the existing case.

Evaluation

The option is unlikely to be feasible, based on its downstream impact, but it does demonstrate that a small increase in flow away from the hotspot will significantly alleviate the existing flood issue. The downstream impact, which is approximately 0.1 m in the 5% AEP event, is widespread and affects an area that has its own flooding issue (Victoria Street). The upgraded pipe, which is not significantly larger than what already exists, achieves an improvement in the area by slightly increasing the low point's drainage. However, whether this improved drainage is via a pipe (as was assessed) or via improved overland conveyance, it will result in additional runoff to Victoria Street, which has been shown to have an adverse impact. The high cost of upgrading the pipe (see Section 9.3.7), relative to its limited benefit, also reduces the option's feasibility.

Given the localised nature of the hotspot, personal property measures on the flood-affected properties may be more feasible than modification of the flood behaviour. Flood-proofing on the rear of the properties could protect against overfloor inundation, while also allowing the area to continue to act as a storage. Furthermore, there is a manageable depth of water that requires protection against (0.3 m in the 10% AEP event, 0.5 m in the 1% AEP event), and the rear of the properties is already mostly walled off, with gates and doors as the current point of ingress. Section 9.4.6 has further description of flood proofing as a management option.

9.3.3. Investigate Kerb/Gutter Enhancement – Victoria Street West (FM – WLM06)

As per Section 4.4 several resident submissions indicated that the kerb/gutter interface on the western side of Victoria Street is subject to blockage due to parked cars and the placement of bins at this location. Further the submissions indicated that flooding is exacerbated by this blockage. These submissions follow on from the flood event of August 24th 2015 and as such come to the study in its latter stages. To make the best use of these observations the following future work is recommended:

- Examine design flood level sensitivity to kerb/gutter blockage. Note actual obstruction

of the kerb/gutter is recommended rather than just increase of roughness value used;

- Presuming a degree of sensitivity, reassess works recommendations herein in that context; and
- Examine the flood impact of works suggested by City of Sydney which aim to displace vehicles out of the kerb/gutter interface via an offset kerb. An area would then be retained between the current kerb location and the new kerb line, which would be available for flood flow.

It is suggested this investigation be carried out in a stand alone fashion as a high priority. It is recommended that an allocation of funds of $2.5 million be set aside for further investigation and then capital works based on this further investigation.

9.3.4. Trunk Drainage Upgrade – New Drainage on Victoria Street (FM - WLM03)

Note this option will be reconsidered in the context of an updated investigation of Victoria St as noted above.

Option Description

Option FM – WLM03 describes a new pipe along Victoria Street from Earl Street to Challis Avenue. The pipe is approximately 540 m long and has dimensions of 1 m x 1 m. The upgrade has been assessed for a 50% AEP flood event.

Modelled Impacts

The upgrade achieves a significant reduction in the 50% AEP peak flood level, but does not provide uniform benefit across the area. The location of the upgrade and the flood level impact are shown in Figure 29. The figure shows that the first three properties downstream of Butlers Stairs have negligible change in flood level, while those further downstream have a reduction of between 0.1 and 0.2 m.

Evaluation

The drainage upgrade provides limited benefit in relation to the scale of works. That is, the benefit is either negligible or of small magnitude while the required pipe is over half a kilometre long and therefore of considerable cost. Furthermore, there is an abundance of services within the road reserve (Reference 4) and the street is littered with protected London Plane trees, both of which affect the cost and feasibility of any pipe upgrade.

As with FM - WLM02, the localised nature of the issue and the depths involved mean that personal property measures are more cost-effective and technically feasible than flood modification options.

Augmentations to the existing fence/gate line along the properties' frontage are likely to be capable of preventing ingress of floodwaters into the properties, preventing the overfloor inundation which currently occurs. Protection along the fence/gate to a height of 0.4 m above the footpath would be above design flood events up to and including the 1% AEP. Section 9.4.6

has further description of flood proofing as a management option.

9.3.5. Overland Flowpath – Lowered Footpath on Victoria Street (FM – WLM04)

Note this option will be reconsidered in the context of an updated investigation of Victoria St as noted above.

Option Description

Option FM – WLM04 describes works on a section of the Victoria Street footpath in the Victoria Street hotspot. Specifically, 90 m of footpath starting from south of Butlers Stairs is lowered by 150 mm, in order to increase the conveyance in the overland flowpath. The upgrade has been assessed for a 50% AEP flood event.

Modelled Impacts

The upgrade achieves a significant reduction in the 50% AEP peak flood level, with the section of lowered footpath having a 50-70 mm decrease in peak flood level. The location of the upgrade and the flood level impact are shown in Figure 30. The figure shows that the impact is limited to the area of lowered footpath, with no adverse impacts downstream. The option increases the conveyance of the footpath which decreases the peak flood level.

Evaluation

The drainage upgrade provides some benefit to the flood-affected properties on Victoria Street; however, the works have a number of constraints, as identified by City of Sydney. The reduction in peak flood level (50-70 mm) is comparable to the existing depth in frequent events (e.g. 100-200 mm in the 50% AEP event) and will reduce the frequency of overfloor flooding for properties along the section of lowered footpath. However, there are numerous constraints in the design of the upgrade, including:

1. The works must be fit within the existing driveways, which limit the length of the upgrade and the grading at either end.
2. All trees within the extent of works will need to be removed. These trees are listed as Significant Trees (see Section 2.1.3).
3. There are a number of services in the footpath that will be required to be moved.
4. Other constraints relating to the re-design of the kerb-gutter system along the section.

As with FM - WLM03, the localised nature of the issue and the depths involved mean that personal property measures should be investigated as a potentially more cost-effective and technically feasible option. Section 9.4.6 has further description of flood proofing as a management option.

9.3.6. Trunk Drainage Upgrade – Upgraded Pipe on Victoria Street (FM – WLM05)

Note this option will be reconsidered in the context of an updated investigation of Victoria St as noted above.

Option Description

Option FM – WLM03 describes a pipe upgrade along Victoria Street from upstream of Butlers Stairs to downstream of Hughes Street, as well as a smaller upgrade on Orwell Street. The Victoria Street upgrade is 190 m of the existing 450 mm diameter pipe increased to 900 mm, while the Orwell Street upgrade consists of 35 m of the existing 375 mm diameter pipe increased to 600 mm. The upgrade has been assessed for a 50% AEP flood event.

Modelled Impacts

The upgrade achieves limited reduction in the 50% AEP peak flood level, and does not result in adverse impacts downstream of the upgrade. The location of the upgrade and the flood level impact are shown in Figure 31. The figure shows that the upgrade benefits an area around Butlers Stairs (20 mm reduction), a larger area around and downstream of Orwell Street (20-30 mm reduction), and does not improve flooding for three affected properties at the Orwell Street – Victoria Street intersection.

Evaluation

The drainage upgrade provides limited benefit to the flood-affected properties in the area, and as with FM – WLM03, there are significant constraints in implementing the upgrade. The benefit to the frequently affected properties is between 20 and 30 mm reduction in the 50% AEP peak flood level, except for three of the properties which have no benefit. Constraints on the design of the upgrade include the multiple protected trees along the street, and the number of sub-surface services. Section 9.4.6 has further description of flood proofing as a management option.

As with previous measures, the localised nature of the issue and the depths involved mean that personal property measures should be investigated as a potentially more cost-effective and technically feasible option.

9.3.7. Economic Assessment of Site Specific Options

The cost effectiveness of the site specific management options in reducing flood liability within the catchment was determined using the benefit/cost (B/C) approach. A costing was estimated for each option and this was compared, where appropriate, to the option's reduction in AAD. Where no significant benefit to AAD was found, the option's cost effectiveness was assessed qualitatively.

Costing

Detailed cost estimates have been prepared for each works option and these are summarised in Table 17, with detailed costing in Appendix C. Note FM-WLM06 is not included as it is a further study, not a works option. It is important to note that these are estimates and should be revised prior to the detailed design phase of the options to obtain a more accurate costing. For FM-WLM01, the very large capacity of the upgrade's pipes meant that the width of the upgrade was comparable to the width of the available area (i.e. roadway and footpaths). Such a large upgrade would incur additional costs due to the re-location of existing services, and this has been accounted for by a higher contingency multiplier in the costing estimates.

Table 17: Costings of Management Options

SUMMARY	Capital	Maintenance per year
FM - WLM01 - Trunk drainage upgrade from Stream Street to outlet	$32,324,300	$18,800
FM - WLM02 - Drainage upgrade for Earl Street pipe connecting to Victoria Street	$585,200	$1,300
FM - WLM03 - Drainage upgrade for 500 m section of Victoria Street	$3,495,600	$5,300
FM - WLM04 – Lowering 90 m of footpath on Victoria Street	$1,150,000*	n/a
FM - WLM05 - Drainage upgrade for 190 m section of Victoria Street and 35 m on Orwell Street	$1,009,500	$2,250

*Cost estimated by City of Sydney

Table 17 shows that the drainage capacity upgrade Option FM – WLM01 is the most costly followed by Option FM – WLM02, both of which involve significant drainage upgrades. Although FM-WLM01 is a far more expensive option, it addresses a number of hotspots in the catchment and as such the works have a far wider scope than other options. Drainage upgrades on Victoria Street cost between $1 million and $3.5 million, however, the number of services that require moving as part of these options means their cost could be much higher.

Damage Assessment

The total damage costs were also evaluated for FM – WLM01 (Trunk drainage upgrade from Stream Street to outlet). The assessment was carried out in accordance with OEH guidelines utilising data obtained from the flood level survey and height-damage curves that relate the depth of water above the floor with tangible damages, and was then compared to the same assessment under existing conditions. FM – WLM01 was found to have an annual average damages cost of $2,099,700, which is a reduction of $733,000 from the existing AAD. The damages estimation under the option is given in detail in Appendix D.

Damages calculations for other management options were not assessed, as they either produced negligible benefit in large events, or produced downstream impacts that meant the options were generally unfeasible.

Benefit Cost Ratio

Following estimation of the option's cost and AAD, the benefit/cost ratio (B/C) of FM – WLM01 was calculated. The B/C is the ratio of the net present worth of the reduction in flood damages (benefit) compared to the cost of the works and is used to compare the economic worth of a set of works to others in the area. The net present worth (NPW) of the AAD reduction was calculated to be $10,827,010, based on a lifespan of 50 years and a 7% discount rate, while the NPW of the cost of the option (capital + maintenance costs) was calculated to be $32,601,342. This gives the option a B/C of 0.3, which indicates the economic benefit of the option is less than half of its economic cost.

The analysis does not consider social factors, environmental factors and risk to life which cannot be quantified in monetary terms but would have been a net contributor to the benefits that could be gained from these management options.

9.3.8. Other Site Specific Management Options Considered

Each hotspot had a range of management options that were assessed to manage the flood risk in the area. Of these options, those that were determined to have the greatest benefit, or were the most technically or economically feasible, were assessed in detail. For the Woolloomooloo catchment, these are the previously described options, FM – WLM01 to FM - WLM05. Other options were assessed in the hotspots that were discarded, and these are presented in Table 18. The table also lists why the option was not considered further. For example, a number of options that addressed sections of the western trunk upgrade were found to cause downstream impacts and so the western trunk upgrade was presented as a single option.

Table 18: Other Site Specific Management Options Considered

Hotspot	Option	Reason Discarded
Stream Street	Upgrade pipes draining Stream Street and pits on William Street	Significant downstream impacts
Crown Street	Upgrading drainage from intersection of Crown and Cathedral Streets to the outlet	Achieves reduction on Crown Street, only addresses Crown Street in isolation
Palmer Street	Lower park beneath rail overpass and upgrade drainage until the outlet	Lowered park has limited storage capacity, drainage achieves benefit, only addresses in Palmer Street in isolation
Bourke Street	Lower Cowper Wharf Road at end of Bourke Street to relieve topographic depression on Bourke Street	Significant benefit, but very localised – does not extend south of Bland Street.
Victoria Street	Several options assessed by memorandum (Reference 4)	Options achieve minimal benefit, further discussion given in memorandum.
Victoria Street	Constructing a raised median strip in the middle of Victoria Street in the hotspot, so as to capture and re-direct runoff prior to it accumulating on the western kerb/footpath.	The median strip has negligible benefit to flooding in the hotspot, as there is little to no flow across the street (i.e. east-west direction).
Dowling Street (not identified as hotspot)	On the section of Dowling Street immediately north of William Street, the drainage line has a 400 mm diameter pipe, with a 750 mm diameter pipe up and downstream of it. Option modelled upgrading 400 mm diameter section to 750 mm diameter.	The upgraded pipe has negligible benefit on Dowling Street (and no impact elsewhere).

9.4. Catchment Wide Management Options

9.4.1. Response Modification – Variable Message Display (RM-WLM01)

DESCRIPTION

Although a catchment wide flood warning system has been excluded as described in Section 9.2.3, there may be an opportunity to develop localised warning and notifications to alert the community during a flood to areas that are flooded or will be in the near future. Variable message displays on main roads in the area would be able to warn drivers not to enter floodwaters. William Street, which is inundated in frequent flood events near Riley Street, is the main arterial road in the area. The displays would likely be operated by Roads and Maritime Services (RMS).

DISCUSSION

Variable Message Displays on major roads, such as William Street, would reduce the flood risk associated with vehicles entering floodwaters and becoming stranded. The William Street low point has 0.2 – 0.5 m in the 10% AEP event and is therefore capable of disabling a vehicle that drives through the ponding. The nature of urban areas means vehicles or pedestrians may underestimate flood hazard, and unknowingly try to cross the floodwaters. For example, in October 2014, a small flood inundated part of Parramatta Road in Summer Hill, and people became stranded in their cars and required SES assistance. The written warnings would aim to avoid this scenario by communicating the risk to people in the area and suggesting an alternative route.

EVALUATION

The measure is inexpensive relative to other options and it has the ability to manage the risk associated with people and vehicles entering floodwaters. However, people do not always heed flood warnings. Consideration should also be given to possible diversion routes and how traffic in a flood can be managed.

9.4.2. Response Modification - Evacuation Planning (RM – WLM02)

DESCRIPTION

Significant property inundation in a rare flood may force residents to evacuate their homes. Residents will either leave of their own accord, as they feel their property is uninhabitable, or they will be issued an evacuation order. The SES has responsibility for evacuating people due to flooding. The sudden nature of flooding in the catchment means little to no warning is available for a flood event, and so the evacuation would almost certainly take place during or after the storm event.

DISCUSSION

The main issues with all flood evacuations are:

- they must be carried out quickly and efficiently,
- they are hazardous for both rescuers and evacuees,
- residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers,
- people do not appreciate the dangers of crossing floodwaters.

The nature of flooding in Woolloomooloo creates additional issues for evacuation. These include:

- The short duration of flooding in the catchment means that the evacuation itself will be of comparable time to remaining indoors and waiting for the flood to recede.
- The limited warning time means that many residents may evacuate at the same time, creating gridlock and placing them in a more dangerous situation than not evacuating. Furthermore, areas that require evacuation the most (i.e. where significant depths occur) will likely not be accessible in a standard vehicle, forcing residents to leave on foot.

EVALUATION

Evacuation of residents in the catchment has significant associated risks and may increase the flood risk in the brief time (typically, hours) that residents are flood affected. Furthermore, the more widespread the evacuation is, the greater the risk of gridlock and people becoming stranded. In general, evacuation should not be undertaken, unless there is exceptionally hazardous flooding at a property.

9.4.3. Response Modification - Public Information and Raising Flood Awareness (RM – WLM03)

DESCRIPTION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are knowledgeable about the flood and what is required of them. The success of any flood warning system and the evacuation process depends on:

Flood Awareness: How aware is the community to the threat of flooding? Has it been adequately informed or educated?

Flood Preparedness: How prepared is the community to react to the threat? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?

Flood Evacuation: How prepared are the authorities and the residents to evacuate households to minimise damages and the potential risk to life? How will the evacuation be done, where will the evacuees be moved to?

DISCUSSION

In catchments which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc. The level of trauma or anxiety may be reduced as people have "survived" previous floods and know how to handle both the immediate emergency and the post rehabilitation phase in a calm and efficient manner.

The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including:

- *Frequency and impact of previous floods*. A major flood causing a high degree of flood damage in relatively recent times will increase flood awareness. If no floods have occurred, or there have been a number of small floods which cause little damage or inconvenience, then the level of flood awareness may be low. In Woolloomooloo, there is little experience of flooding that has caused major disruption to residents (e.g. overfloor flooding). There are, however, localised hotspots that have a high awareness of flooding, for example in Victoria Street.

- *History of residence.* Families who have owned properties for a long time will

have established a considerable depth of knowledge regarding flooding and a high level of flood awareness. A community which consists predominantly of short lease rental homes will have a low level of flood awareness. As discussed in Section 2.1.2, a high portion of residents have only recently moved into the catchment and the most residents live in rented accommodation.

- *Whether an effective public awareness has been implemented.* It is understood that no large scale awareness program has been implemented in the catchment. However, flooding information is available via the publicly available Flood Study (Reference 2) completed for the catchment, and residents are well informed of the floodplain risk management process through newsletters sent out as part of each study.

For flood risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of information and levels of awareness diminishes as the time since the last flood increases. Often a major hurdle is convincing residents that major floods, larger than those previously experienced, will occur in the future. Table 19 lists tools that can be used to promote public awareness of flooding in an area.

Table 19: Public Information Tools

Method	Comment
Letter/Pamphlet from Council	These may be sent annually or biannually with the rate notice or separately. The pamphlet can inform residents of subsidies, changes to flood levels or any other relevant information.
School Project or Local Historical Society	This provides an excellent means of informing the younger generation about flooding. It may involve talks from various authorities and can be combined with topics relating to the natural environment, etc.
Displays at Libraries / community centres	This is an inexpensive, passive, way of informing the community and may be combined with related information.
Historical Flood Markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advice of potential hazards.
Articles in Local Newspapers	Ongoing articles in newspapers will ensure that the problem is not forgotten. Historical features and remembrance of the anniversary of past events make good copy.
Collection of Data from Future Floods	Collection of data 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.
Types of Information Available	Council may wish to advice interested parties on the flood information currently available and how it can be obtained at cost when they inquire during the property purchase process.
Establishment of Flood Affectation Database	A database would provide information on (say) which houses require evacuation, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event.
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, led by the SES would ensure that the community is adequately prepared.
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. Residents have a responsibility to advice Council if they see a problem such as potential debris blockage.

EVALUATION

A program aimed at raising flood awareness in the catchment is a cost-effective measure that will reduce the flood risk in the area. There is generally little perception of the risk of high hazard flooding in the area. In similar studies in urban areas that are not perceived as having a flood issue, photos of historical floods communicate well the possible floods that can occur.

9.4.4. Response Modification – Local Flood Plan and DISPLAN (RM – WLM04)

DESCRIPTION

As described previously, it may be necessary for a small number of residents to evacuate their homes in a major flood. This would usually be undertaken under the authority of the lead agency under the DISPLAN, the SES. Based on the duration of flooding in the catchment (typically, hours) and the risks associated with evacuation, it may be that evacuation is undertaken on a case by case basis. Some residents may choose to leave on their own accord based on flood information from the radio or other warnings, and may be assisted by local residents.

The preparation of a flood emergency response plan aims to minimise the risk associated with evacuations (described in Section 9.4.2) by providing information regarding evacuation routes, refuge areas, and generally what processes should be followed in a flood. It is the role of the SES to develop this plan for flood-affected communities.

DISCUSSION

As recommended in Section 6.2, a DISPLAN should be prepared for the Sydney East Emergency Management District (of which the Woolloomooloo catchment is part of) to outline emergency response arrangement specific to the district. In particular the purpose of a District DISPLAN is to:

- Identify responsibilities at a District and Local level in regards to the prevention, preparation, response and recovery for each type of emergency situation likely to affect the district;
- Detail arrangements for coordinating resource support during emergency operations at both a District and Local level;
- Outline the tasks to be performed in the event of an emergency at a District and Local level;
- Specifies the responsibilities of the East Metropolitan District Emergency Operations Controller and Local Emergency Operations Controllers within the District;
- Detail the responsibilities for the identification, development and implementation of prevention and mitigation strategies;

- Detail the responsibilities of the District and Local Emergency Management Committees within the District;
- Detail agreed Agency and Functional Area roles and responsibilities in preparation for, response to and recovery from, emergencies;
- Outline the control, coordination and liaison arrangements at District and Local levels;
- Detail arrangements for the acquisition and coordination of resources;
- Detail public warning systems and responsibility for implementation;
- Detail public information arrangements and public education responsibilities;
- Specifies arrangements for reporting before, during and after an operation; and
- Detail the arrangements for the review, testing, evaluation and maintenance of the Plan.

Further, it is recommended that the SES prepare a Local Flood Plan in conjunction with the City of Sydney (who shall supply the necessary data) to outline the following details:

- Evacuation centres in close proximity to the floodplain which are flood free sites with flood free access;
- Organise use of Variable Message Signs for use during a flood event for flood affected roads (specifically recommended in Section 9.4.1).
- Inclusion of a description of local flooding conditions;
- Identification of potentially flood affected vulnerable facilities; and
- Identification of key access road subject to flooding.

Details of access road flooding and recommended inclusions for the flood plan are provided in Section 6.

Although flood warning is limited, a local disaster plan should be continually updated to include the latest information on design flood levels and details on roads, properties, and other facilities which would be flood affected.

OUTCOME

The SES should ensure that a DISPLAN be prepared for the Sydney East Emergency Management District, and Council, with the help of the SES should prepare a Local Flood Plan for the study catchment. This should also take into account those properties not directly flood affected but which may have had access cut and become flood islands. These plans should be regularly kept up to date and should include feedback from recent major flood events and the recommendations of this Study once finalised.

9.4.5. Property Modification - Flood Planning Levels (PM – WLM01)

DESCRIPTION

The flood planning level (FPL) is used to define land subject to flood related development controls and is generally adopted as the minimum level to which floor levels in the flood affected areas must be built. The FPL includes a freeboard above the design flood level. It is common practice to set minimum floor levels for residential buildings, garages, driveways and even

commercial floors as this reduces the frequency and extent of flood damages. Freeboards provide reasonable certainty that the reduced level of risk exposure selected (by deciding upon a particular event to provide flood protection for) is actually provided.

DISCUSSION

The main aim of the FPLs is to reduce the damages experienced by the property owner during a flood. Elevating a house floor level above the FPL will ensure that flood damages are significantly reduced. Council have specified FPL requirements in their *Interim Floodplain Management Policy* (Reference 6) prior to the completion of the Floodplain Risk Management Plans for the entire LGA and this study supports that measure. It is important that the same requirements are applied throughout the LGA to new development or redevelopments regardless of whether the Floodplain Risk Management Plan have been completed for the catchment or not.

EVALUATION

A review of the FPLs put forward by Council in their *Interim Floodplain Management Policy* (Reference 6) was carried out as part of this study. In order to ensure consistency throughout the LGA, the same principle for FPLs should be applied regardless of whether a Floodplain Risk Management Plan have been completed for the catchment or not. The only exception would be if the Floodplain Risk Management Plan proposes a change to these FPLs.

9.4.6. Property Modification - Flood Proofing (PM – WLM02)

DESCRIPTION

Flood Proofing involves the sealing of entrances, windows, vents, etc., to prevent or limit the ingress of floodwaters. It is only suitable for brick buildings with concrete floors and can prevent ingress for outside depths of approximately one metre. Greater depths may cause collapse of the structure unless water is allowed to enter.

DISCUSSION

In general, flood proofing requires sealing of doors (new frame, seal and door); sealing and re-routing of ventilation gaps in brickwork; sealing of all underfloor entrances and checking of brickwork to ensure that there are no gaps or weaknesses in the mortar. It will not reduce the flood hazard, and in fact may increase the true hazard if residents stay in their houses and a large flood eventually inundates the building. A typical benefit/cost ratio is high and there are no significant environmental and social problems.

An assessment of the variation in types of flood proofing, the flood depths to which can be protected, and the costs involved, is required before the option can be fully recommended. Past experience indicates that some types of flood proofing are affordable relative to the cost of flooding, for example, in some cases, an existing house could be sealed for approximately $20,000. In the case of a new house of extension, the cost of flood proofing would be less if included as part of the construction. There is also variation in the types of property that can be proofed, for example, it is easier to apply to commercial premises where there are only one or two entrances, and maintenance and operation procedures can be better enforced.

As an example, such works have already been implemented at 123 Victoria Street, which uses a temporary flood barrier across the doorway that is installed each night (and presumably during the day if there is heavy rain). These barriers require daily use; however, the flood-affected properties immediately upstream on Victoria Street (see Section 3.3.6) already have a gate/fence barrier that, if made impermeable, would provide a permanent barrier. In the case of Victoria Street, it would only need to be to a height of 0.4 m to protect against all events below the PMF.

EVALUATION

Preliminary assessment has indicated that flood proofing is a good solution to reducing flood risk to commercial and industrial properties. Based on previous experience, the option can be cost-effective relative to drainage upgrades or other structural works, and easier to implement. Further assessment should be undertaken to ascertain the depth of ponding that flood proofing can protect against, what types of properties can be flood-proofed, the variation in cost for different cases, where responsibility lies for carrying out and funding the works, and any associated risks with the approach.

9.4.7. Property Modification – Feasibility Study for City of Sydney Flood Proofing (PM – WLM03)

DESCRIPTION

As discussed in the previous option, flood proofing involves modifications to a building's exterior in order to prevent the ingress of floodwater. Where flood proofing is not undertaken by property owners, it may be possible for City of Sydney to undertake mitigation works if the property is put up for sale. That is, for a severely flood affected properties, City of Sydney may purchase the property so that works on it can be undertaken, and then the property is put up for sale soon after. Such a scheme would be most suited to areas with significant overfloor flood affectation where structural measures (for example, drainage upgrades) are not feasible.

DISCUSSION

A Council-led program that involves the purchase, renovation and selling of flood-affected land is a straightforward variation on other Council-led property modification measures, and will provide benefit to properties that do not have other available options. The nature of the flood issue in Woolloomooloo is that although there is significant overfloor flood affectation, it is concentrated in several localised areas. This makes structural options difficult to justify, and it is possible that a property's flood risk will remain indefinitely.

As the option can only be implemented when an affected property is put on sale, such a program's implementation would be very gradual and would be undertaken over a long period of time. In this sense, the option is an extension of Council's FPL policy, whereby minimum floor levels are required when a flood-affected property is re-developed. A Council-led flood proofing program would account for the flood affected properties that are not re-developed and therefore would not otherwise have their floor levels raised.

Although such a program has some similarity to a voluntary purchase scheme, it would be markedly less obtrusive and would not reduce the number of dwellings in the catchment. Voluntary purchase involves returning severely-affected land on a floodway to the floodplain, whereas in Woolloomooloo, affected properties are not necessarily on a floodway and restoring an area's natural flowpath (for example, in a trapped depression) would adversely impact downstream properties and may impact an area's streetscape and character. Most significantly, a flood proofing program would only involve properties that are available for purchase, meaning there would be no disruption to the existing property market. This would be further ensured by having no publicly available information on which properties would be targeted by such a program.

EVALUATION

A flood proofing program undertaken by the City of Sydney could significantly alleviate property affectation and give Council an alternative to drainage upgrades in areas where they are prohibitively expensive and not cost-effective. It would also allow Council to extend their objective of raising flood affected properties (via an FPL) to affected properties by improving properties that may not otherwise have their floor level raised. Although such a program has several apparent benefits, its feasibility should be investigated further to determine whether it can be cost-effective (based on the cost of purchasing, flood-proofing and re-selling a property compared to the existing economic cost of flooding) and what social impacts may exist.

9.4.8. Property Modification - Development Control Planning (PM – WLM04)

DESCRIPTION

The catchment's location in inner Sydney means there is continuing pressures for both redevelopments of existing buildings as well as for new developments. The strategic assessment of flood risk can prevent development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. It can also reduce the potential damage to new or redeveloped properties likely to be affected by flooding to acceptable levels.

DISCUSSION

The Interim Floodplain Management Policy (Reference 6) provides general requirements for new developments on flood liable land within the catchment, Flood Planning Level requirements for different development types and guidelines on flood compatible materials. This document serves as an interim policy for managing floodplain within the Council LGA which will be withdrawn once Council complete Floodplain Risk Management Plans for the entire LGA and then integrate outcomes from these plans into planning controls. A review of this document as well as the Sydney LEP 2012 and Sydney DCP 2012 has been undertaken and discussed in Section 7.1.2. Nevertheless the success of these policies can only be determined once implemented and specific problems/issues addressed as they arise.

OUTCOME

Recommendation for an update of the planning documents (i.e. Sydney DCP 2012 and Sydney

LEP 2012) has been discussed in Section 7.2 in order to inform of the development controls as published in the Interim Floodplain Management Policy (Reference 6). Inclusion of these provisions would ensure that the controls can be enforced which also take into consideration the potential impact of climate change.

9.5. Assessment Matrix

9.5.1. Background

Multi-variate decision matrices are recommended in the Floodplain Development Manual (Reference 1) and therefore it is also a recommendation of this report that multi-variate decision matrices be developed for specific management areas, allowing detailed benefit/cost estimates, community involvement in determining social and other intangible values, and local assessment of environmental impacts.

The criteria assigned a value in the management matrix are:

- Risk to life;
- Impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation) over the range of flood events;
- Number of properties benefited by measure;
- Technical feasibility (design considerations, construction constraints, long-term performance);
- Community acceptance and social impacts;
- Economic merits (capital and recurring costs versus reduction in flood damages);
- Financial feasibility to fund the measure;
- Long term performance;
- Environmental and ecological benefits;
- Impacts on the State Emergency Services;
- Political and/or administrative issues; and
- Long-term performance given the potential impacts of climate change.

The scoring system for the above criteria is provided in Table 20 and largely relates to the impacts in a 1% AEP event. The matrix below is designed to set out a general scheme to illustrate how a local matrix might be developed. These criteria and their relative weighting may be adjusted in the light of community consultations and local conditions.

Tangible costs and damages are also used as the basis of B/C analysis for some measures.

Table 20: Matrix Scoring System

SCORE:	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefited	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straight-forward	Straight-forward	no issues
Community Acceptance	majority against	most against	some against	neutral	minor	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental & Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political / administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

A draft assessment matrix has been included in the following section. It will be updated for the final report with the results of the community consultation.

9.5.2. Results

The assessment matrix is given in Table 21, with each of the assessed management options scored against the range of criteria. 'Community Acceptance' has not been scored at this time, as the community information session is yet to be held (the matrix will be updated when the information is available). Also, it is important to note that the approach undertaken does not provide an absolute "right" answer as to what should be included in the Management Plan but is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis which stakeholders can then use to make a decision. For the same reason, the total score given to each option, and the subsequent rank, is only an indicator to be used for general comparison.

Table 21: Multi-Criteria Assessment of Management Options

Ref	Options	Section in Report	Design Event (AEP)	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental/Ecological Benefits	Impact on SES	Political/Admin Issues	Long Term Performance	Risk to Life	Total Score	Rank (Total)
Flood Modification Measures																
FM-WLM01	Trunk Drainage Upgrade - Stream Street to Outlet	9.3.1	10%	3	3	-3	N/A	-2	-3	-1	2	-3	1	3	0	8=
FM-WLM02	Drainage Upgrade - Upgraded Pipe on Earl Street	9.3.2	5%	1	2	-1	N/A	-2	-2	0	0	-2	1	0	-3	11
FM-WLM03	Trunk Drainage Upgrade - New Drainage on Victoria Street	9.3.3	50%	2	2	-2	N/A	-2	-3	-1	1	0	1	2	0	8=
FM-WLM04	Overland Flowpath - Lowered Footpath on Victoria Street	9.3.4	50%	1	1	-1	N/A	-3	-2	-1	0	0	1	0	-4	12
FM-WLM05	Trunk Drainage Upgrade - Upgraded Pipe on Victoria Street	9.3.5	50%	1	1	-2	N/A	-3	-2	-1	0	0	1	0	-5	13
Response Modification Measures																
RM-WLM01	Variable Message Display	9.4.1	N/A	0	0	2	N/A	2	2	0	2	1	0	1	10	2=
RM- WLM02	Evacuation Planning	9.4.2	N/A	0	0	-1	N/A	0	2	0	1	2	0	1	5	7
RM-WLM03	Public Information and Raising Flood Awareness	9.4.3	N/A	0	0	1	N/A	1	2	0	2	1	-2	1	6	6
RM-WLM04	Local Flood Plan and DISPLAN	9.4.4	N/A	0	0	0	N/A	2	2	0	2	2	1	2	11	1
Property Modification Measures																
PM-WLM01	Flood Planning Levels	9.4.5	N/A	0	0	0	N/A	2	2	0	1	0	3	1	9	5
PM-WLM02	Investigate Flood Proofing	9.4.6	N/A	0	0	0	N/A	1	3	0	1	2	2	1	10	2=
PM-WLM03	Voluntary Purchase	9.4.7	N/A	0	0	-2	N/A	1	-1	0	1	-2	2	1	0	8=
PM-WLM04	Development Control Planning	9.4.8	N/A	0	0	0	N/A	2	2	0	1	1	3	1	10	2=

*'Community Acceptance' will be completed following a community information session as part of the Public Exhibition

As shown in the matrix, the structural measures score lowly on economic merit, as they do not have favourable B/C ratios, and on financial feasibility, as all require a large capital outlay. In addition, they have technical feasibility issues, either relating to the potential issues in the design of the required drainage, or due to their adverse downstream impacts. Low scores in these three categories result in a much lower score than most of the response modification and property modification measures.

The five highest ranking measures scored between 9 and 11, which indicates that they are all generally equivalent under this assessment. They all require relatively little financial outlay, and will lower the economic cost of flooding in the catchment. Public information and flood awareness also scores well, but ranks lower due to its limited long term performance, an issue also associated with evacuation planning. Voluntary purchase is difficult to justify as it is has issues with its technical feasibility, in that it would be very different to a typical VP scheme, and the political/administrative issues associated with buying flood-affected houses.

Based on the matrix, the options for future implementation are ranked in the order as tabulated in Table 22.

Table 22: Ranking of Management Options

Rank	Ref	Options	Score
1	RM-WLM04	Local Flood Plan and DISPLAN	11
2=	PM-WLM02	Investigate Flood Proofing	10
2=	RM-WLM01	Variable Message Display	10
2=	PM-WLM04	Development Control Planning	10
5	PM-WLM01	Flood Planning Levels	9
6	RM-WLM03	Public Information and Raising Flood Awareness	6
7	RM-WLM02	Evacuation Planning	5
8=	FM-WLM01	Trunk Drainage Upgrade - Stream Street to Outlet	0
8=	FM-WLM03	Trunk Drainage Upgrade - New Drainage on Victoria Street	0
8=	PM-WLM03	Voluntary Purchase	0
11	FM-WLM02	Drainage Upgrade - Upgraded Pipe on Earl Street	-3
12	FM-WLM04	Overland Flowpath - Lowered Footpath on Victoria Street	-4
13	FM-WLM05	Trunk Drainage Upgrade - Upgraded Pipe on Victoria Street	-5

Note: '=' denotes equal position. E.g. '3=' refers to equal third rank.

Of the 13 management options presented here, 11 have been recommended for implementation as part of the Woolloomooloo Catchment Floodplain Risk Management Plan. The two discarded options are FM-WLM02 and FM-WLM05. The former has an adverse impact downstream of the upgrade that increases downstream flood risk by an unacceptable amount. The latter produces minimal benefit to the Victoria Street hotspot and will have little to no effect on the property inundation in the area.

10. REFERENCES

1. NSW Government
   Floodplain Development Manual
   April 2005

2. WMAwater
   Woolloomooloo Flood Study
   Draft Report, July 2013

3. Sydney Water Corporation
   City Area SWC 30 Capacity Assessment
   Sydney Water Corporation, July 1996

4. WMAwater
   137 Victoria Street, Woolloomooloo Flood Mitigation
   November 2013

5. City of Sydney
   Sydney Local Environmental Plan 2012
   2012

6. City of Sydney
   Interim Floodplain Management Policy
   July 2013

7. NSW Department of Environment and Climate Change
   Flood Emergency Response Classification of Communities
   October 2010

8. Howells *et. al.*
   Defining the Floodway – Can One Size Fit All?
   2004

9. NSW Department of Environment and Climate Change
   Floodplain Risk Management Guideline – Residential Flood Damages
   October 2007

Figures

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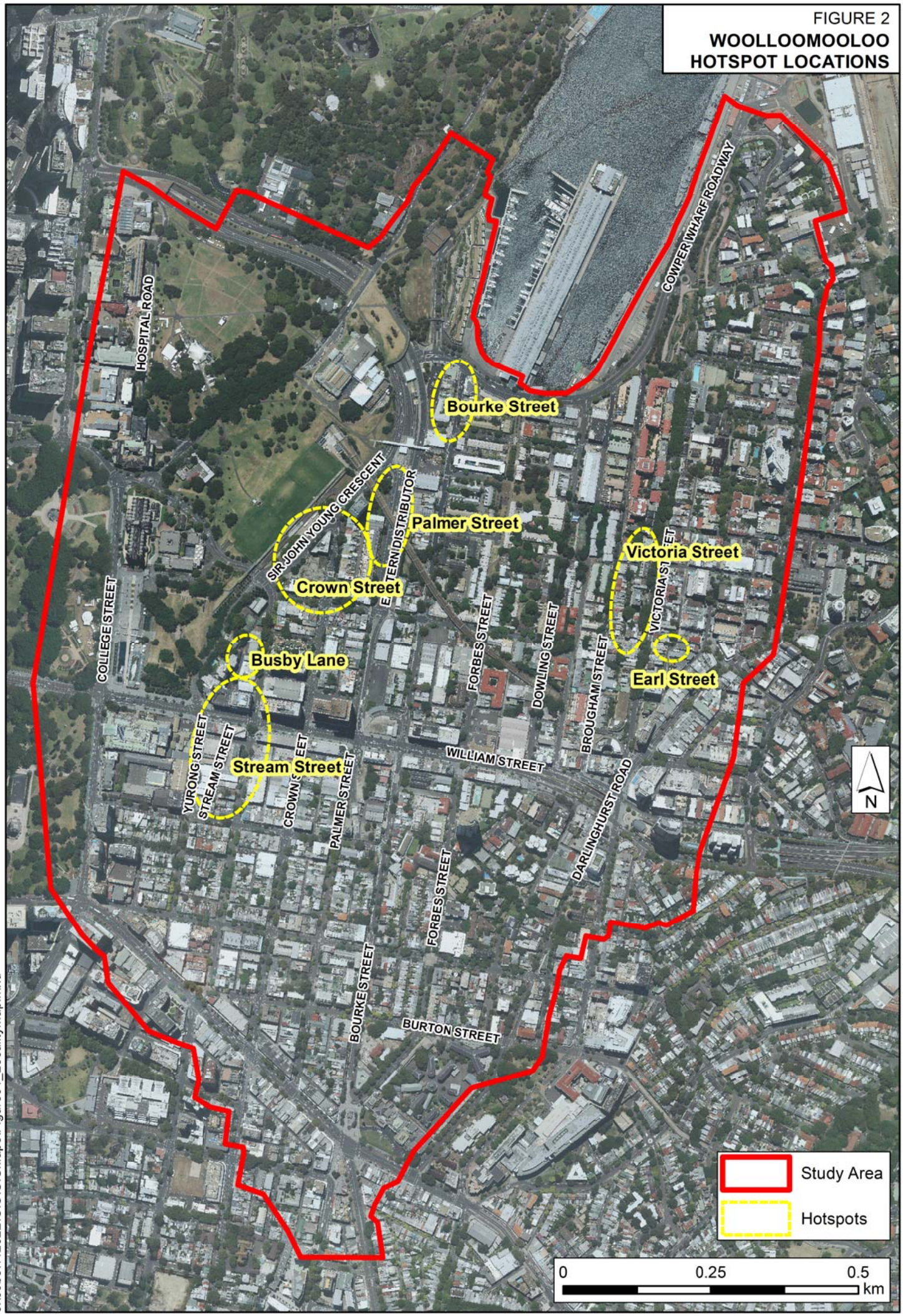

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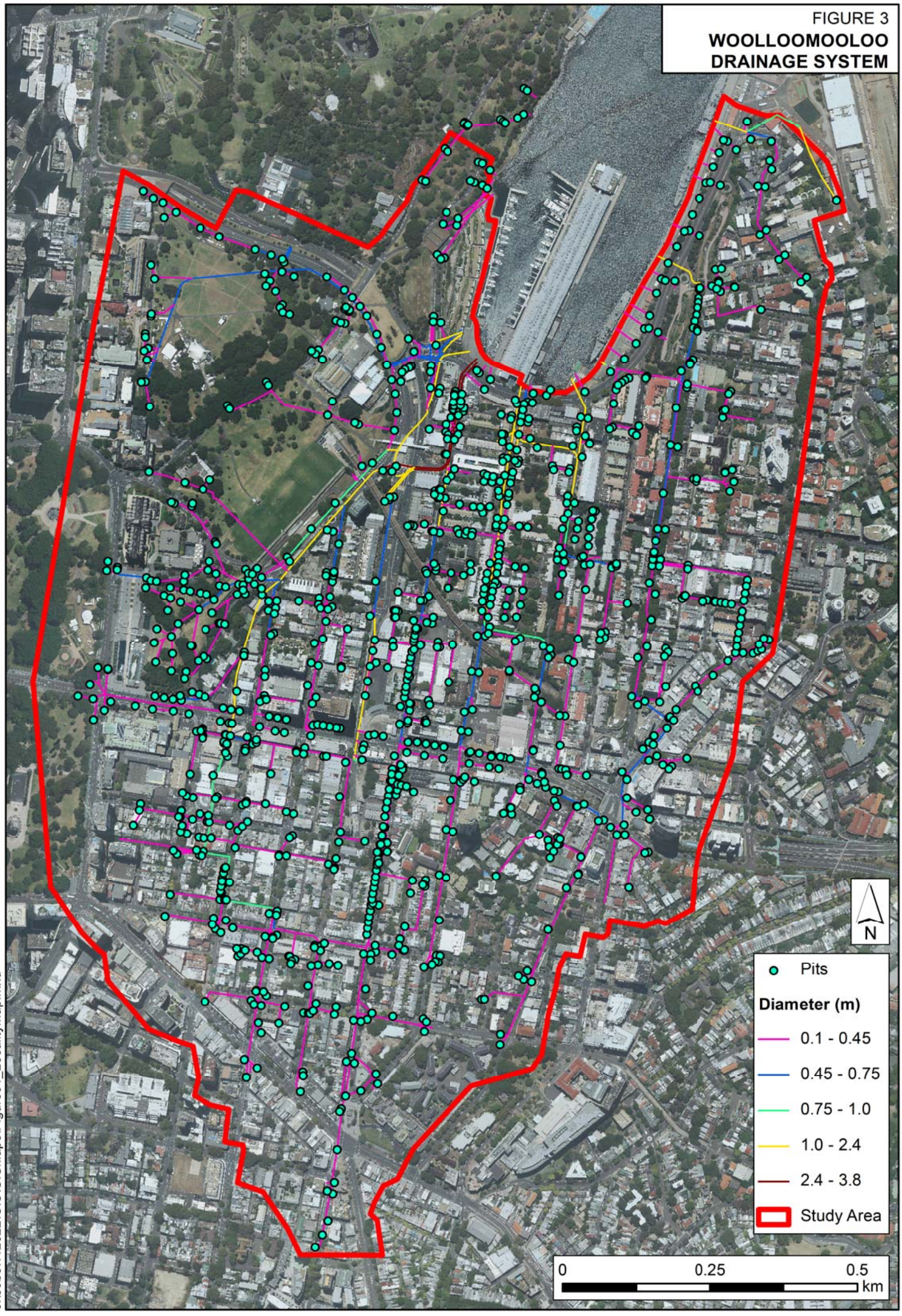
FIGURE 3
WOOLLOOMOOLOO
DRAINAGE SYSTEM
N
Pits
Diameter (m)
0.1 - 0.45
0.45 - 0.75
0.75 - 1.0
1.0 - 2.4
2.4 - 3.8
Study Area
0
0.25
0.5
km
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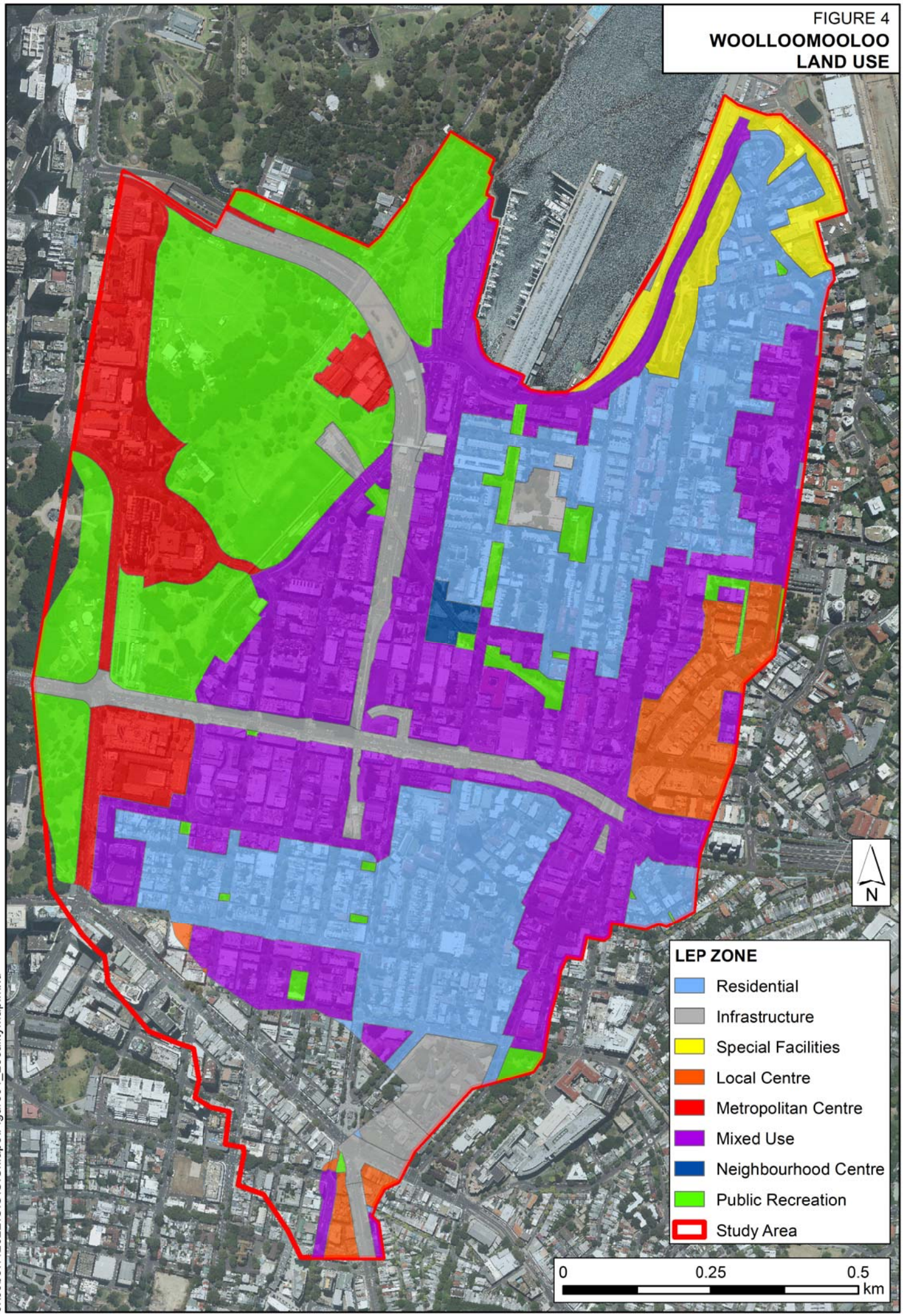
FIGURE 4
WOOLLOOMOOLOO
LAND USE
N
LEP ZONE
Residential
Infrastructure
Special Facilities
Local Centre
Metropolitan Centre
Mixed Use
Neighbourhood Centre
Public Recreation
Study Area
0
0.25
0.5
km
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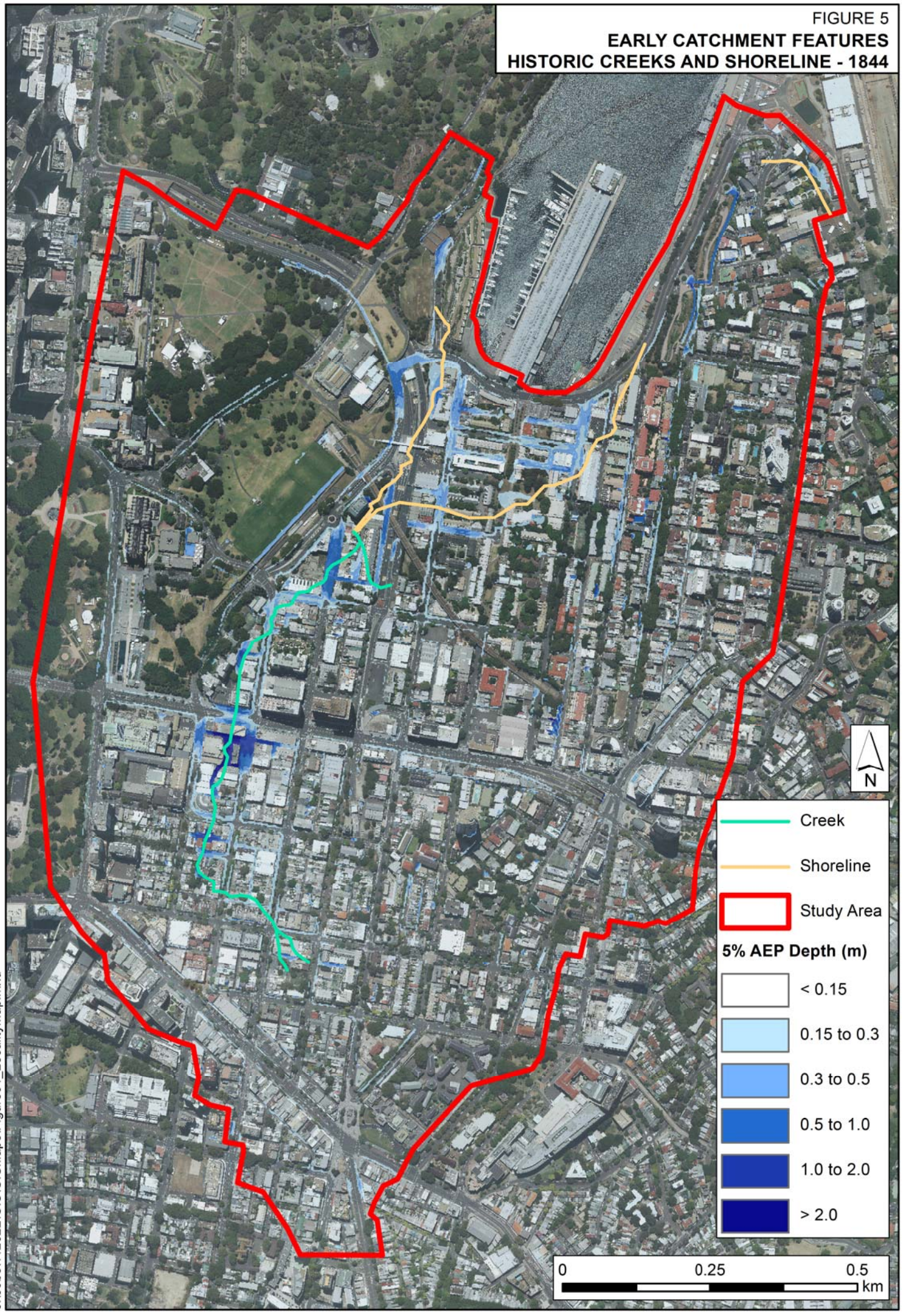
FIGURE 5
EARLY CATCHMENT FEATURES
HISTORIC CREEKS AND SHORELINE - 1844
N
Creek
Shoreline
Study Area
5% AEP Depth (m)
< 0.15
0.15 to 0.3
0.3 to 0.5
0.5 to 1.0
1.0 to 2.0
> 2.0
0
0.25
0.5
km
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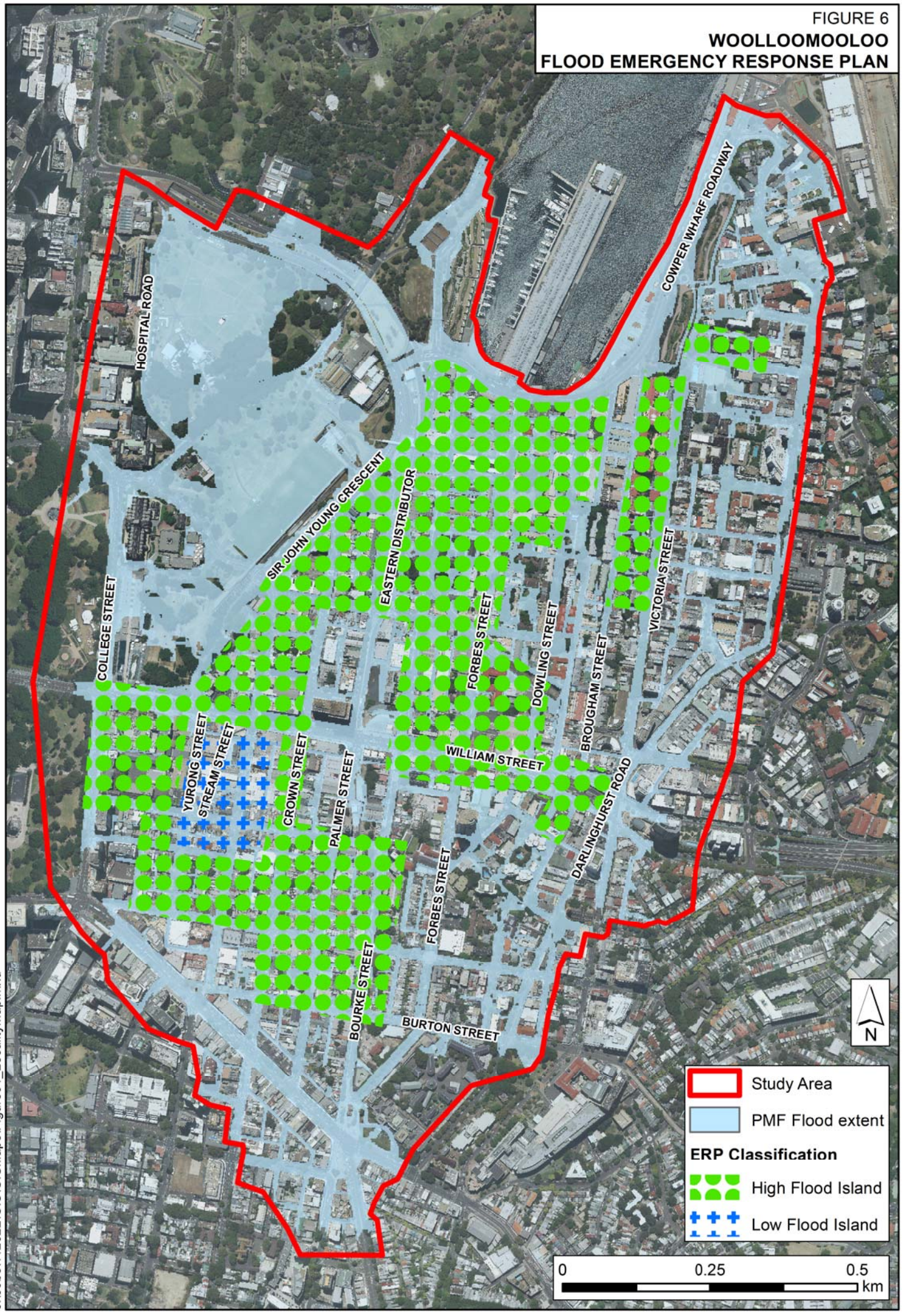
FIGURE 6
WOOLLOOMOOLOO
FLOOD EMERGENCY RESPONSE PLAN
HOSPITAL ROAD
COWPER WHARF ROADWAY
SIR JOHN YOUNG CRESCENT
EASTERN DISTRIBUTOR
COLLEGE STREET
FORBES STREET
DOWLING STREET
BROUGHAM STREET
VICTORIA STREET
YURONG STREET
STREAM STREET
CROWN STREET
PALMER STREET
WILLIAM STREET
DARLINGHURST ROAD
FORBES STREET
BOURKE STREET
BURTON STREET
N
Study Area
PMF Flood extent
ERP Classification
High Flood Island
Low Flood Island
0
0.25
0.5
km
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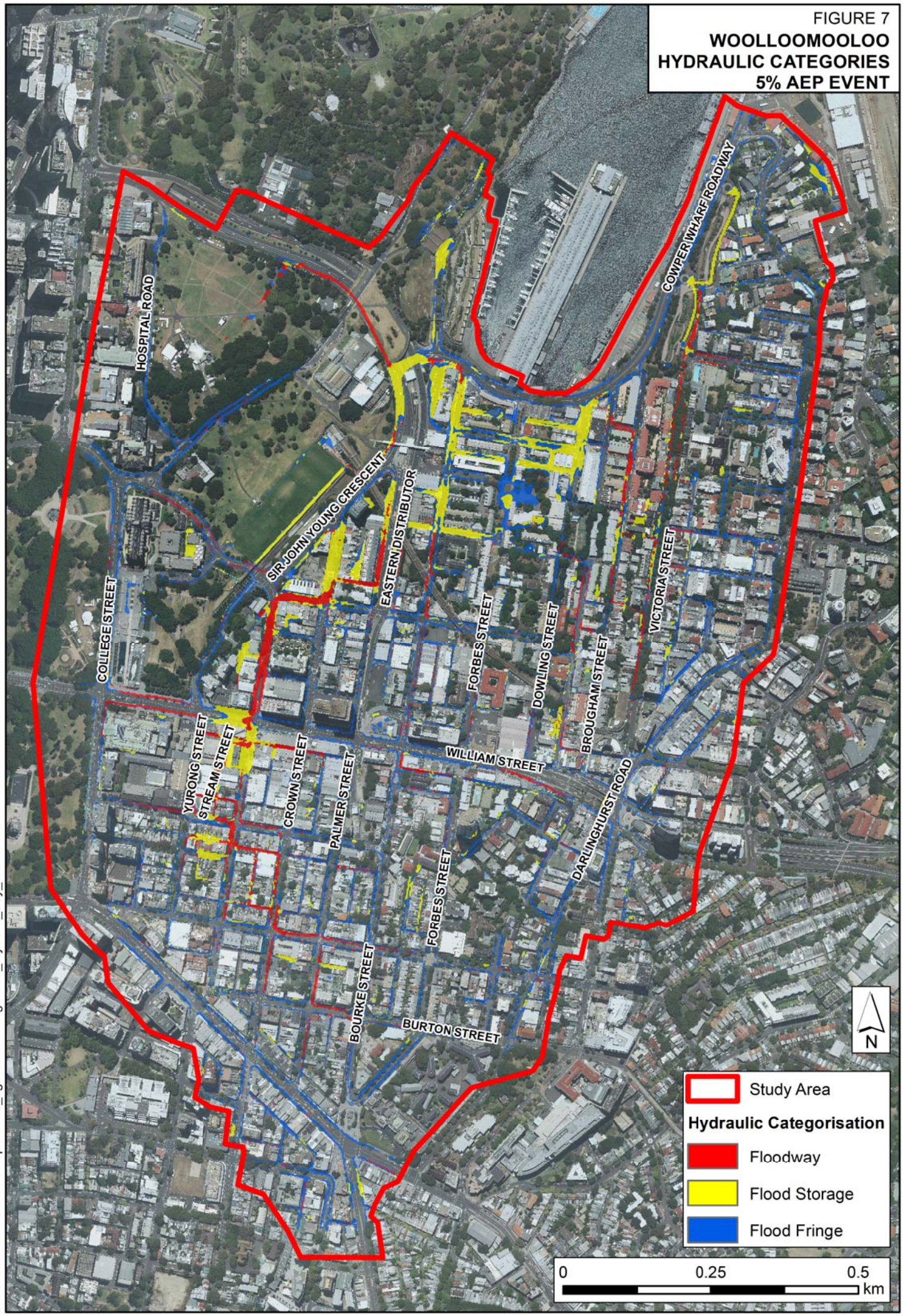
FIGURE 7
WOOLLOOMOOLOO
HYDRAULIC CATEGORIES
5% AEP EVENT
HOSPITAL ROAD
COWPER WHARF ROADWAY
SIR JOHN YOUNG CRESCENT
EASTERN DISTRIBUTOR
COLLEGE STREET
FORBES STREET
DOWLING STREET
BROUGHAM STREET
VICTORIA STREET
YURONG STREET
STREAM STREET
CROWN STREET
PALMER STREET
WILLIAM STREET
DARLINGHURST ROAD
FORBES STREET
BOURKE STREET
BURTON STREET
N
Study Area
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0
0.25
0.5
km
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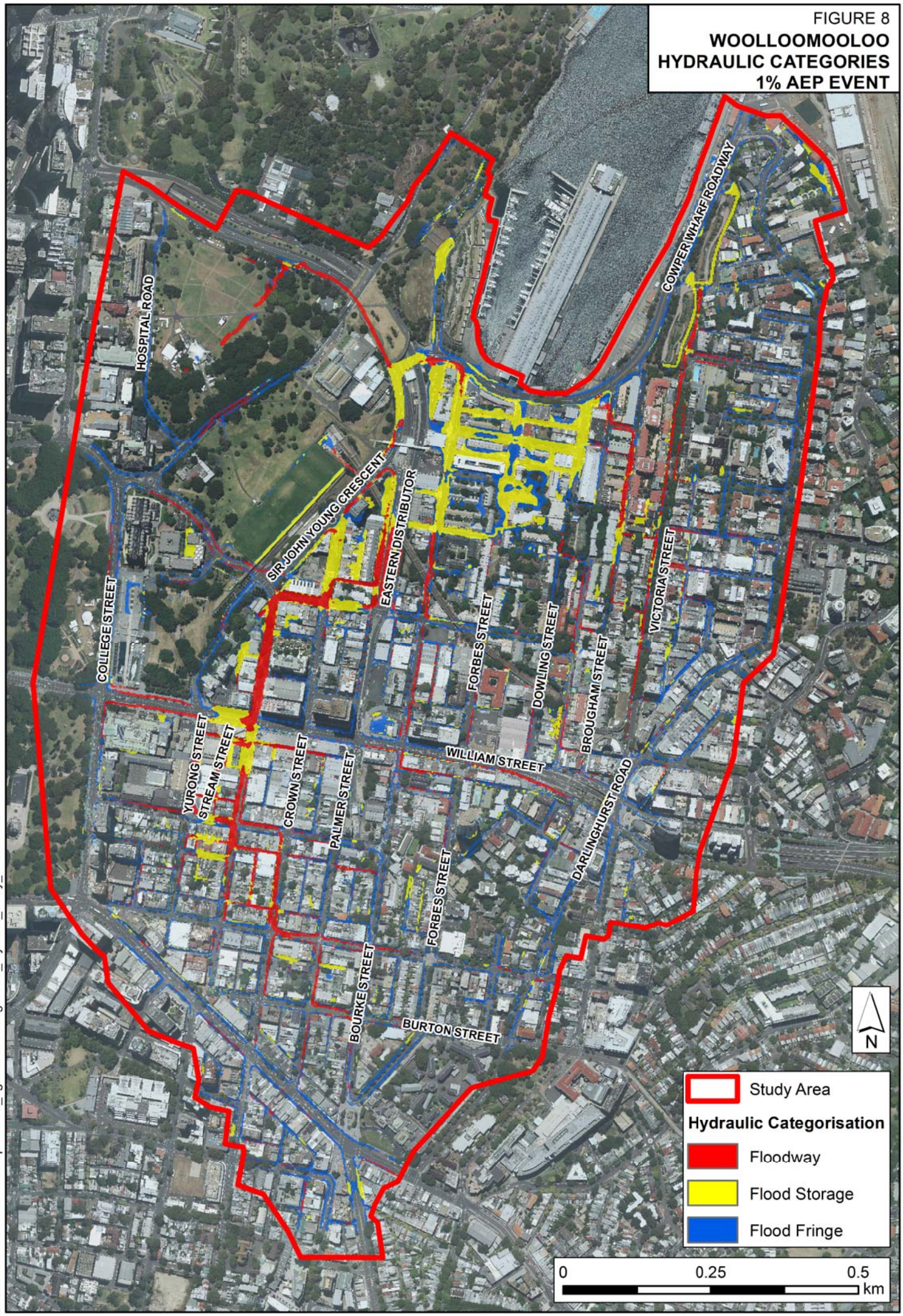
FIGURE 8
WOOLLOOMOOLOO
HYDRAULIC CATEGORIES
1% AEP EVENT
HOSPITAL ROAD
COWPER WHARF ROADWAY
SIR JOHN YOUNG CRESCENT
EASTERN DISTRIBUTOR
COLLEGE STREET
FORBES STREET
DOWLING STREET
BROUGHAM STREET
VICTORIA STREET
YURONG STREET
STREAM STREET
CROWN STREET
PALMER STREET
WILLIAM STREET
DARLINGHURST ROAD
FORBES STREET
BOURKE STREET
BURTON STREET
N
Study Area
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0
0.25
0.5
km
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