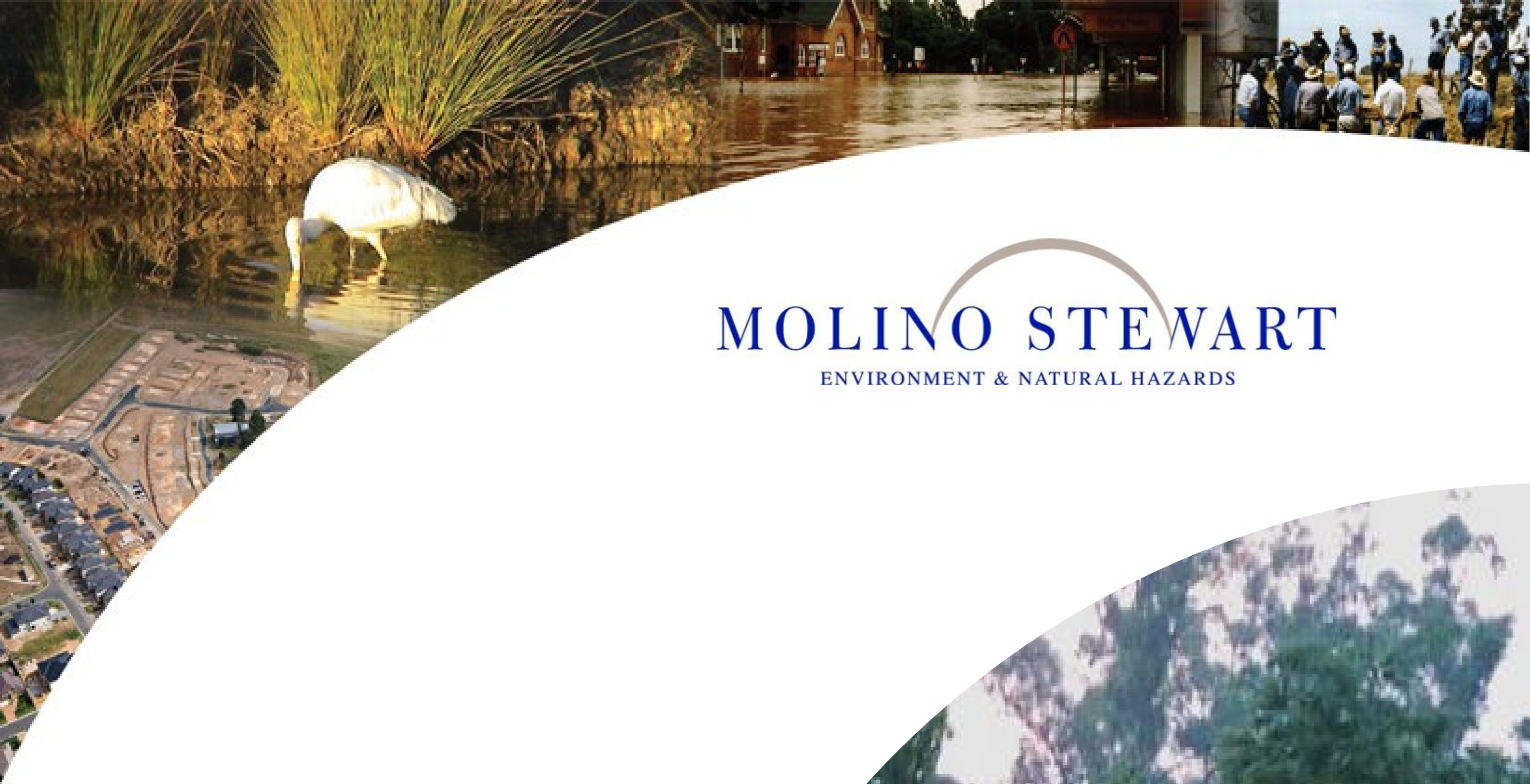

MOLINO STEWART
ENVIRONMENT & NATURAL HAZARDS

Parramatta CBD Flood Evacuation Assessment

Final Revised Report

Parramatta CBD Flood Evacuation Assessment

FINAL REVISED REPORT

for

City of Parramatta

by

Molino Stewart Pty Ltd

ACN 067 774 332

OCTOBER 2021

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DOCUMENT APPROVAL

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EXECUTIVE SUMMARY

The NSW State Government and the City of Parramatta Council have identified Parramatta CBD as a key growth centre for large-scale commercial and residential development. In April 2015, Council adopted the Parramatta CBD Planning Strategy, detailing the type of development envisaged and devising an implementation plan.

One of the main constraints to development in Parramatta CBD is the risk of flooding from the Parramatta River and its tributaries. The flooding is considered to be flash flooding with floodwaters rising within a few hours from the beginning of the rainfall. The short time available for evacuation and the current lack of a flood warning system make flood emergency response in Parramatta CBD a difficult exercise, even with the current CBD population.

The aim of this study was to identify the most suitable flood emergency response strategy for Parramatta CBD, under existing and future conditions. This was achieved by assessing and comparing the following possible flood evacuation strategies:

- Horizontal Street Level (HSL) evacuation, achieved by vehicle before any roads are cut by floodwaters;
- Horizontal High Level (HHL) evacuation, achieved on foot by using a network of elevated walkways which would allow late evacuation. A draft design and costing of the required infrastructure is provided;
- Vertical Evacuation through Sheltering In Place (SIP), in which evacuees would reach a refuge above the flood level within their building and wait for floodwaters to recede.

The analysis was performed using different flood events (20 year ARI, 100 year ARI, PMF), different degrees of implementation of the Parramatta CDB Planning Strategy (year 2016, year 2036 and year 2056), and different times of the day at which a flood emergency response may be necessary (Midnight, Midday, PM Peak). Using Multi-Criteria Analysis (MCA), the evacuation strategies were compared and the most suitable strategy was identified. The following evaluation criteria were used:

- Strategy effectiveness, in terms of capability to safely evacuate the population before routes are cut by floodwaters. The total evacuation time for each strategy was calculated using state of the art flood evacuation models, including the NSW SES Timeline Evacuation Model. The simulations addressed 24 “worst-case” scenarios, combining flood probability, degree of implementation of the Parramatta CBD Planning Strategy, and time of the day. Evacuation time was then compared with the time available to assess the strategy effectiveness;
- Difficulty of implementation of the strategy, arising from setting-up the necessary infrastructure (e.g. elevated walkways) and from the logistics of the response;
- Risks associated with the strategy and the extent to which these can be reduced;
- Impacts on the urban environment (i.e. due to the elevated walkways);
- Cost of implementation and maintenance of the strategy;
- Load on emergency services.

The results showed that:

- Under the assumptions of the NSW SES Timeline Evacuation Model, safe vehicular evacuation would not be realistically achievable under any circumstances;
- A network of elevated walkways would allow safe HHL evacuation (including late evacuation), however evacuation time would be of the same order of magnitude as the flood duration.

- Importantly, a network of elevated walkways catering for events up to the PMF would have a high cost ($324 million) and very significant impacts on the CBD urban landscape and heritage buildings. A smaller network of elevated walkways, catering for events up to the 20 year or the 100 year ARI flood, would have lower costs (i.e. $94.5 million and $111 million respectively), but would need to be paired with SIP to cater for larger flood events, and the impacts on the CBD landscape would still be significant.
- SIP is the optimal flood emergency response strategy for Parramatta CBD. However, SIP could expose people to a number of secondary risks to life, including (but not limited to) those arising from: building structural failure, medical emergencies, building fires or people deciding to leave the shelter and walk through floodwaters. Provision would also need to be made for building access for people in the public domain. Development controls would need to be imposed on development to reduce these risks to a tolerable level and ensure there was not an increased demand for search and rescue operations by the NSW SES. This report suggests ways in which this can be realistically achieved.

CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

1 BACKGROUND AND AIM

1.1 CONTEXT

The NSW Government and the City of Parramatta Council (Council) have identified the Parramatta CBD as a key growth centre for large-scale commercial and residential development. Council has developed the Parramatta CBD Planning Strategy (the "CBD Strategy"), which was adopted in April 2015. Key features are:

- Expand the boundaries of the CBD;
- Increase the floor space ratios in certain areas;
- Alter solar access controls;
- Alter building height restrictions;
- Expand the commercial core of the CBD.

An implementation strategy for the CBD Strategy has been developed, which includes the development of a Planning Proposal to modify the Parramatta Local Environmental Plan (LEP) 2011.

However, one of the most significant constraints for development is that the Parramatta River passes through the middle of the CBD, and most of the CBD is within the floodplain of the river or its tributaries. In addition, the relatively small catchment upstream of the CBD results in flash flooding with very short warning times. Even with the current population of the CBD, this lack of warning of an oncoming flood will create significant evacuation challenges, and the proposed population increase could exacerbate these. Council has implemented a flood warning system but even with this in place the warning time available in floods big enough to enter the main areas of the CBD could be less than two hours.

All development proposed in the CBD Strategy should proceed in such a way that people can be protected from hazardous floodwaters.

The NSW SES has a general policy that evacuation of people away from the floodplain is the safest course of action because if they stay:

- They can be isolated in buildings for some time, possibly without power and water;
- If floodwaters rise above their building they area in severe danger;
- It puts SES and emergency service personal at risk when trying to rescue them

In a letter to the City of Parramatta Council dated 2 December 2016, the NSW SES has expressed a strong preference that this should be achieved by evacuating people out of floodplains before the arrival of floodwaters. They concede that this might not be possible in some flash flood areas and that in these circumstances vertical evacuation (Sheltering In Place, or "SIP") may be preferable to trying to evacuate and finding oneself in hazardous floodwaters. However, they have expressed that this is a concession to existing development only and should not be a method of managing flood risk for new development.

The Parramatta CBD consists of existing development which might fit into this category, but new development is proposed which would increase the number of people in the floodplain. At the same time, the urban planning and development approval process presents the opportunity to include development controls which can minimise the risk of flooding to the occupants of buildings should they choose to SIP.

Risk reduction can be achieved either by providing a means of horizontal evacuation to areas which are not flood-affected, or vertical evacuation in buildings to safe refuge above the reach of floodwaters. While horizontal evacuation is traditionally achieved through vehicular or pedestrian evacuation at street level, this can also be achieved through the use of elevated walkways.

While planning controls can in theory be used to create improved flood risk outcomes in Parramatta CBD, statutory requirements currently limit the controls which Council can impose. Specifically, Section 9.1 Direction 4.3 restricts the imposition of flood planning controls on residential development above the Flood Planning Level (FPL) (which is generally defined as the 1% flood level plus 0.5m freeboard) except in "exceptional circumstances".

Council contends that the flood situation in the Parramatta CBD is such that exceptional circumstances exist and the 2107 version of this report was used to support Council's application for exception circumstances.

In December 2018 the Deputy Secretary of the then Department of Planning and Environment wrote:

"I have decided to grant exceptional circumstances to enable further agency consultation and community consultation. However, consistency with section 9.1 Direction 4.3 Flood Prone Land will require further consideration and agreement from the Department's Secretary."

To support its original case for exceptional circumstances, Council required an evacuation analysis that considered many of the overlapping processes such as warning time, evacuation routes, and population demographics to estimate the ability of people within the Parramatta CBD to evacuate either horizontally or vertically during a flood.

This version of the report includes updates which take into consideration modifications to the Parramatta CBD Planning Proposal.

1.2 PROJECT AIM

City of Parramatta engaged Molino Stewart Pty Ltd to explore, at a high level, the various means of horizontal and vertical evacuation which might be feasible for Parramatta CBD now and into the future. The aim of this project was to assess and compare their feasibility in light of the number of people, the estimated evacuation time and other practical challenges including infrastructure cost and impact on the CBD urban landscape. Namely, the scope of this work was to:

- Prepare a feasibility analysis for each of the three potential evacuation methods: (a) horizontal evacuation at street level, (b) horizontal evacuation at high level, and (c) vertical evacuation;
- Prepare an analysis comparing evacuation capability and risks of the three evacuation methods that considered the following variables: (a) year (2016, 2036, 2056); time of flood (midday, midnight and PM peak); type of flood (20 year ARI, 100 year ARI, PMF);
- Summarise the results of the study with sufficient detail that a case can be presented to support a preferred evacuation option (which may include a combination of methods).

The study used a risk analysis framework which is technically rigorous, transparent and defensible.

1.3 STUDY AREA

The study area includes the extent of the Parramatta CBD Planning Proposal boundary, plus part of the "Western Corridor" (i.e. the blocks west of the Parramatta CBD Planning Proposal boundary, between Marsden St and Parramatta Park). Although the Western Corridor is not included in the Planning Proposal, it was considered in this study because its proximity to the CBD would result in a similar flood response strategy. The study area is shown in Figure 1.

1.4 NATURE OF FLOODING

Flooding in Parramatta CBD occurs as a joint effect of three mechanisms:

- The Parramatta River overtopping its banks and expanding laterally into the CBD;
- Overbank flooding of Brickfield Creek and Clay Cliff Creek;
- Overland flooding of streets caused by intense rainfall.

A detailed description of the flooding behaviour in Parramatta CBD is provided in Molino Stewart (2016). This section will only summarise the key-information about flood timing (e.g. rate of rise and duration) and extent, because, as indicated by NSW SES, these directly underpin the selection of the most suitable emergency response strategy.

Figure 2 shows the Probable Maximum Flood (PMF) hydrograph upstream of Charles St Weir. The figure also includes the Council's adopted flood levels for the 20 year and 100 year ARI events.

If floodwaters rose as quick as in the PMF (which is the worst case scenario), it would take 180 minutes from the beginning of the rainfall to reach the level of the 20 year ARI, 192 minutes to reach the 100 year ARI level, and 320 minutes to reach the peak of the PMF. After that, floodwaters would begin to recede, and would return to the pre-flood level in about 700 minutes (i.e. 11.6 hours) from the beginning of the rainfall.

Because the PMF would reach its peak within six hours, the flooding of Parramatta CBD is classified as "flash flooding".

Figure 3 shows the extent of the currently adopted 20 year ARI and 100 year ARI floods and the PMF. In addition to informing the peak flood extent, Figure 3 also shows indirectly which areas would flood first (i.e. those exposed to the 20 year ARI flood) and which areas would flood later during the PMF.

It should be noted that updated flood modelling of the Upper Parramatta River and its tributaries is currently being prepared for Council and the shown flood extents may be revised. However, until that work is completed and adopted by the elected Council, the existing flood modelling and mapping applies.

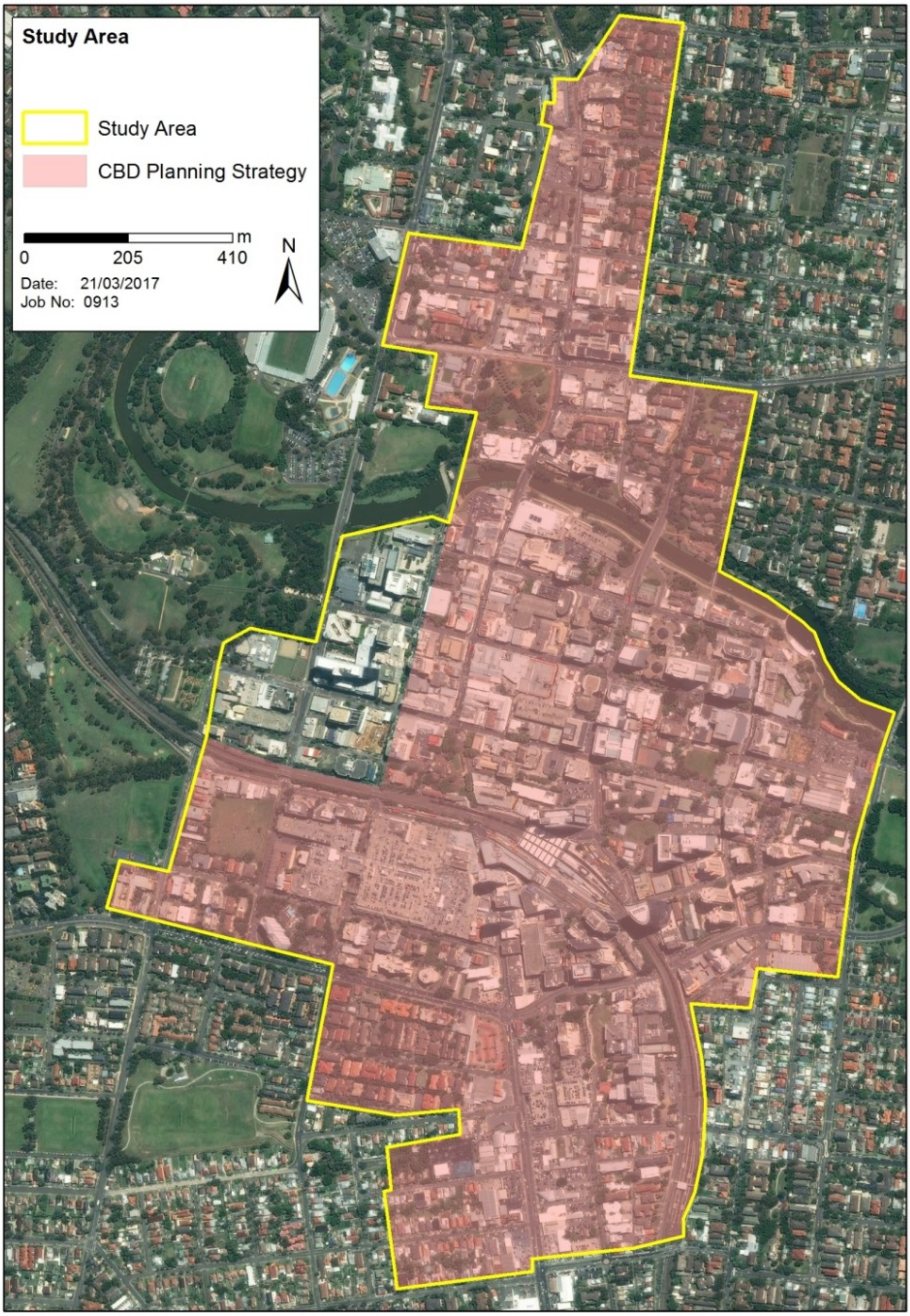

Figure 1: Study Area

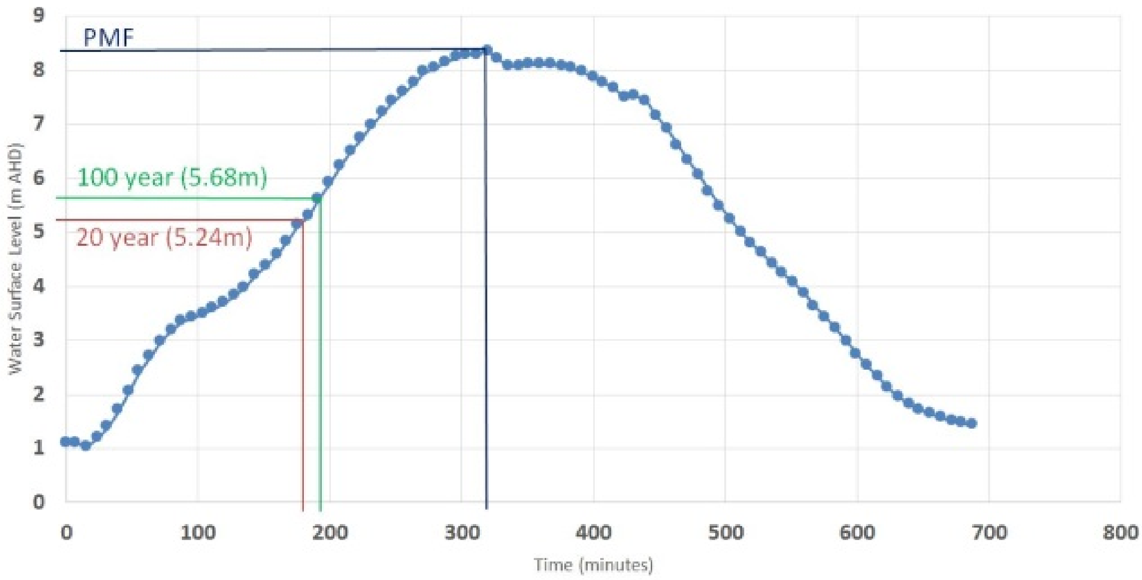

Figure 2: PMF hydrograph upstream of Charles Street Weir

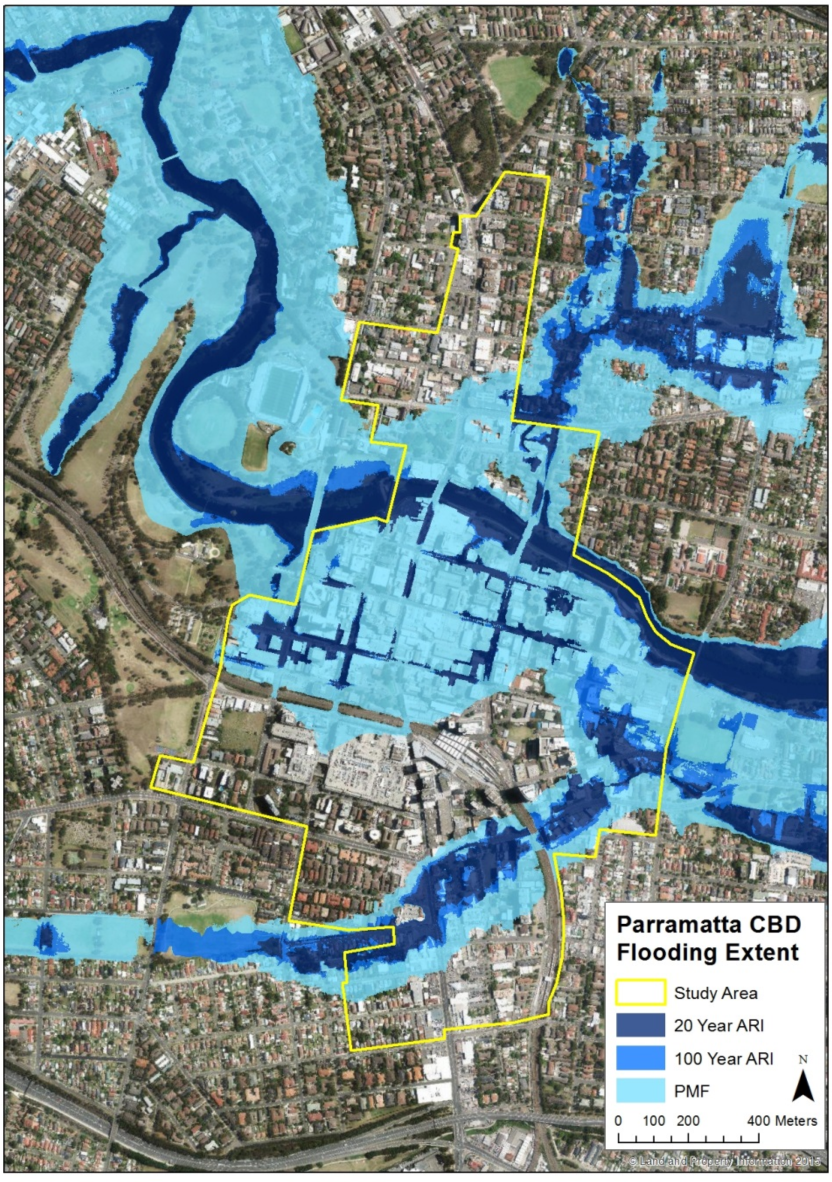

Figure 3: Flood extent in Parramatta CBD

1.5 ANALYSIS OF LOCAL EMERGENCY MANAGEMENT

The NSW SES has been involved in this project since its early stages to provide guidance on the most suitable emergency response strategy under present and future conditions. This section summarises the position of the NSW SES with regard to flood response in Parramatta CBD and vertical evacuation.

1.5.1 NSW SES Letter to the City of Parramatta Council (2016)

The brief of this project was initially submitted to the NSW SES for feedback, which was provided to the City of Parramatta Council together with a letter dated 2 December 2016 about their views on evacuation from the CBD. The letter encompasses the role of the NSW SES in flood emergency response, and points out the view of the NSW SES on some key emergency management principles. These are:

- Risk assessment should consider the full range of design flood events up to the PMF, ideally encapsulating a measure of the variability associated with the flood model results for each event.
- Flood risk assessment should also have particular regard to flood warning and evacuation demand on existing and future access/egress routes.

The NSW SES letter goes on stating that horizontal evacuation should be the primary response strategy during flooding, and should possess the following requisites:

- It should be completed before the onset of a flood;
- Evacuees should use vehicles where feasible (pedestrian evacuation is a backup option);
- It must not require people to drive or walk through floodwaters;
- It should use rising roads leading away from the flood.

With regard to the option of vertical evacuation, also referred to as Shelter In Place (SIP), the NSW SES points out that:

- SIP in isolated buildings represents a higher risk than a properly conducted evacuation and should only be used when evacuation is not possible. In these cases, the risks associated with SIP should be adequately considered and addressed. These include the instability of buildings due to pressure and velocity of floodwaters, risk of medical emergencies, and the risk of people leaving the SIP refuge before floodwaters have withdrawn.
- SIP increases the risk to emergency service personnel during search and rescue operations. If the risk of assisting someone who is taking shelter in place is deemed too high by the emergency responders, assistance may not be provided.
- SIP should only be preferred to evacuation where the risks associated with evacuation are higher than the risks of SIP. This happens, for instance, if evacuation routes are cut by floodwaters before flooding is obvious to residents. In these cases, a response based on horizontal evacuation may result in people driving through floodwaters, as discussed in Haynes et al (2009).

With regard to future development and SIP, the NSW SES letter highlights that:

- Development strategies relying on SIP are not equivalent, in risk management terms, to horizontal evacuation.
- Development strategies assuming that mass rescue of people taking SIP is possible are not acceptable to the SES.
- Future development must not conflict with NSW SES's flood response and evacuation strategy for the existing community.

The letter concludes by referencing the literature landscape around the NSW SES's view on SIP. The next sections include a summary of such literature, which appeared in the "Three Tributaries Floodplain Risk Management Study" (Molino Stewart, 2015).

a) Opper and Toniato (2008)

- NSW SES holds the position that if development is to occur on floodplains, it must be possible to evacuate people out of the floodplain in advance of floods;
- NSW SES has recognised that in an existing flash flood context, and only in that context, causing residents to attempt to evacuate at the time of flash flooding is occurring, could be a serious risk to life. Only in areas where urban redevelopment cannot be prevented under existing planning policy (e.g. already approved under the gazetted planning policy), , it has therefore been proposed that the DCP for any new or redeveloped dwelling will require an internal refuge area above the level of the PMF. (Note: the Fairfield DCP is one that allows this in parts of some floodplains);
- This concession has been seized upon to wrongly apply it to all flood contexts and to justify any new development;
- In response, NSW SES may have no choice but to adopt a harder line and to not support any redevelopment or development in flash flood areas;
- Two elements of flood isolation risk – which may arise when sheltering in place - are particularly significant: structural fire and medical emergency;
- An example of the problems that can arise due to isolation and the vagaries of human behaviour occurred during flooding in June 2007, when a nursing home at Wyong needed to be urgently evacuated due to its rapid isolation by floodwater and the threat of further inundation. This required six ambulance crews and other emergency services to deal with just this one facility. The management and residents had ignored early advice to evacuate before they were isolated and then had a change of mind once they were surrounded by floodwater;

b) Opper et al. (2011); AFAC (2013)

- The safest place to be in a flash flood is well away from the affected area. Evacuation is the most effective strategy, provided that evacuation can be safely implemented. Properly planned and executed evacuation is demonstrably the most effective strategy in terms of a reliable public safety outcome;
- Late evacuation may be worse than not evacuating at all because of the dangers inherent in moving through floodwaters, particularly fast-moving flash flood waters. If evacuation has not occurred prior to the arrival of floodwater, taking refuge inside a building may generally be safer than trying to escape by entering the floodwater;
- Remaining in buildings likely to be affected by flash flooding is not low risk and should never be a default strategy for pre-incident planning. It is not equivalent to evacuation;
- The risks of 'shelter-in-place' include:

a) Floodwater reaching the place of shelter (unless the shelter is above the PMF level);

b) Structural collapse of the building that is providing the place of shelter (unless the building is designed to withstand the forces of floodwater, buoyancy and debris in a PMF);

c) Isolation, with no known basis for determining a tolerable duration of isolation;

d) People's behaviour (drowning if they change their mind and attempt to leave after entrapment);

e) People's mobility (not being able to reach the highest part of the building);

f) People's personal safety (fire and accident); and

g) People's health (pre-existing condition or sudden onset e.g. heart attack).

- In line with EMA's Manual (2009) and Handbook (2007), NSW SES reinforces that for evacuation to be a defensible strategy, the risk associated with the evacuation must be lower than the risk people may be exposed to if they were left to take refuge within a building which could either be directly exposed to or isolated by floodwater;
- Pre-incident planning needs to include a realistic assessment of the time required to evacuate a given location via safe evacuation routes. This requires consideration of barriers to evacuation posed by available warning time, availability of safe routes and resources available;
- Successful evacuation strategies require a warning system that delivers enough lead time to accommodate the operational decisions, the mobilisation of the necessary resources, the warning and the movement of people at risk;
- Effective evacuation typically requires lead times of longer than just a couple of hours and this creates a dilemma for flash flood emergency managers. Due to the nature of flash flood catchments, flash flood warning systems based on detection of rainfall or water level generally yield short lead times (often as short as 30 minutes) and as a result provide limited prospects for using such systems to trigger planned and effective evacuation;
- Initiating evacuation of large numbers of people from areas prone to flash flooding based only on forecasts may be theoretically defensible in a purely risk-avoidance context but it is likely to be viewed as socially and economically unsustainable. Frequent evacuations in which no flooding occurs, which statistically will be the outcome of forecast-based warning and evacuation, could also lead to a situation where warnings are eventually ignored by the community.

c) NSW SES (2014)

- In the context of future development, self-evacuation of the community should be achievable in a manner consistent with the NSW SES's principles for evacuation;
- Development must not conflict with the NSW SES's flood response and evacuation strategy;
- Evacuation must not require people to drive or walk through floodwaters;
- Development strategies relying on deliberate isolation in buildings are not equivalent to evacuation;
- Development strategies relying on the assumption that mass rescue may be possible where evacuation either fails or is not implemented are not acceptable to the NSW SES;
- The NSW SES is opposed to the imposition of development consent conditions requiring private flood evacuation plans rather than the application of sound land use planning and flood risk management.

d) Summary of the NSW SES position

The NSW SES holds that horizontal evacuation is the preferred emergency response for floodplain communities, where this can safely be achieved. Late evacuation, through floodwater, may be a recipe for disaster and in that situation it might be safer to remain inside the building, though sheltering-in-place has a number of direct and indirect risks associated with it. Evacuating prior to flooding is therefore much preferred. Where current hydro-meteorological monitoring systems, communications systems, road infrastructure and expected community behaviours do not allow this, the NSW SES advocates improvements to these so that evacuation can proceed safely. However, the AFAC (2013) guide makes clear that, even with these improvements, insufficient time may be available to inform evacuation decisions with confidence. If evacuations are ordered based only on predicted rainfall, the community may eventually come to ignore warnings.

1.5.2 Subsequent SES Correspondence

In December 2017 the NSW SES wrote to the then Department of Environment and Planning regarding a site-specific planning proposal for 180 George St Parramatta. While the letter was specifically responding to that planning proposal, it stated that, *"Ideally, it is better to address flood risk in land use planning activities at a strategic or precinct scale than in the planning proposal stage."* The letter then went on to articulate generic principles which should be adhered to in development planning generally and Parramatta CBD in particular. This includes statements such as:

"Despite modifying buildings to reduce the risk, research into human behaviour during actual events has shown that in populations surrounded by a hazard there is always the chance that a person will not behave rationally and remain in place but rather place themselves at unnecessary risk. "

"…where safe evacuation is compromised by a lack of adequate infrastructure and/or warning time, the NSW SES recognises that the situation may result in it being safer for a population at risk to remain in place as long as the building in which the occupants are sheltering is structurally sound and there is sufficient accessible space available above the PMF for all occupants to shelter where adequate services are available and maintained."

"Emergency service response will likely be compromised by the hazardous nature of flash flooding in Parramatta CBD. In this area it is likely that emergency services cannot respond to assist those trapped in buildings due to the rapid onset and hazardous nature of fast flowing floodwater and limitations caused by access and transport issues."

Appendix 2 of the letter listed site specific design considerations and Parramatta CBD General Design considerations but both are listed here because the site specific considerations are relevant to many sites in the Parramatta CBD, not just 180 George St.

Site specific design considerations

The site specific design considerations should be applied to this development to assist in minimising additional risk.

1. Residential development: *The habitable floors of any residential development (including aged care) should be located above the PMF with the building structurally designed for the likely flood and debris impacts.*

2. Commercial development (including retail): *To cater for the safety of potential occupants, clients and visitors in commercial development there should be the provision of sufficient readily accessible habitable areas above the PMF.*

3. Child care facilities: *Childcare facilities must be located with floor levels above the PMF level.*

4. Car parking: *Any additional parking should be above ground level and have pedestrian access to a podium level above the PMF.*

5. Making buildings as safe as possible to occupy during flood events. *Ensuring buildings are designed for the potential flood and debris loadings of the PMF so that structural failure is avoided during a flood.*

6. Limiting exposure of people to floodwaters. *This can be aided by providing sufficient readily accessible habitable areas above the PMF to cater for potential occupants, clients, visitors and residents.*

7. Provision of public accessible space for the itinerant population in areas surrounding intensive development in Parramatta CBD. *Provision of publically accessible space or access to space above the PMF (with adequate infrastructure to enable the physically impaired to access such space) that is easily accessible 24 hours a day for seven days a week which is clearly identified for this purpose with associated directional signage.*

8. Providing adequate services so people are less likely to enter floodwaters. *This includes access to ablutions, water, power and basic first aid equipment. Consideration must be given to the availability of on-site systems* *to provide for power, water and sewage services for the likely flood duration (up to 12 hours) plus a further period of up to 48 hours to provide allowance for restoration of external services.*

9. Addressing secondary risks of fire and medical emergencies during floods. *Where there is no CBD wide strategy to address secondary risks during flooding. The proponent needs to consult with the relevant emergency service agency.*

Parramatta CBD general considerations

1. Sensitive development including child care: *All new emergency response hospitals, childcare and primary school facilities in Parramatta CBD should be located on land outside the extent of the PMF on land were service interruption is likely to be limited.*

2. Secondary schools and day hospitals: *Ideally new day hospitals and secondary school classrooms should also be located above the PMF level. However, at minimum there should be within a day hospital and high school building, the provision of access to adequate space above the PMF for patients, high school students, staff and visitors.*

3. Reducing human behaviour risks through businesses, schools and childcare centres. *Undertaking regular exercising of a building flood emergency response plan similar to a building fire evacuation drill.*

4. Increasing the flood awareness of current and future communities. *Council should have community awareness strategies that include requiring current and future building owners to participate in increasing this awareness.*

5. Parramatta CBD PA system. *There needs to be consideration given to developing a Parramatta CBD PA system like Sydney CBD to communicate evacuation directions and safety messages to the Parramatta CBD population in the lead up to and during a flood to assist in improving the safety of the community.*

6. Addressing secondary risks of fire and medical emergencies during floods. *To minimise the increased risk of fire and to reduce both the potential for adverse outcomes in the case of a medical emergency and the risks to those who may aid the patient, Council, DPE, NSW SES, Ambulance NSW and the relevant Health Functional area and fire agency servicing the area, should be consulted to determine appropriate risk management strategies during flooding.*

2 METHODOLOGY

2.1 A MULTI-SCENARIO APPROACH

This study employed a multi-scenario approach to provide a comprehensive overview of the circumstances under which flood evacuation of Parramatta CBD may be required, today and in the future.

Each scenario is the result of a combination of variables, including flood probability, year (as a proxy of the degree of development of the CBD), type of evacuation, and time of day.

For each combination of year, flood probability, and evacuation type, the worst case scenario was determined by the time of the day. These scenarios were identified and assessed.

The following sections describe in more detail the variables used to construct the evacuation scenarios.

2.1.1 Flood Probability

As advised by NSW SES, evacuation assessment should consider a wide range of flood events, up to the PMF. This study used the following design flood events:

- 20 year ARI
- 100 year ARI
- PMF

These were selected because:

- The 20 year ARI is a relatively frequent flood event that may require evacuation. More frequent events, such as the 10 year or 5 year ARI, are unlikely to require a large-scale response.
- The 100 year ARI is the design event adopted for planning and development purpose.
- The PMF represents the greatest flood extent and flood hazard and is indicative of the potential fastest rate of rise.
- Availability of flood model results.

2.1.2 Year

Evacuation was assessed in three different years: 2016, 2036 and 2056.

Year 2016 represents the existing condition in terms of development and evacuee numbers.

Year 2036 was obtained by projecting 20 years into the future the number of evacuees that would be achieved under the existing planning controls, plus some site-specific planning proposals that have at least received Council endorsement to be sent for Gateway determination.

Year 2056 was obtained by assuming that two-thirds of the additional development capacity introduced by the CBD Planning Proposal would be taken up.

2.1.3 Evacuation Type

The following three types of evacuation were considered in this study.

- Horizontal Street-Level (HSL) evacuation, entirely achieved by vehicle;
- Horizontal High–Level (HHL) evacuation, achieved on foot by means of a network of elevated walkways which would allow evacuees to walk out of the CBD even if this has already flooded;
- Vertical Evacuation (Shelter in Place). Evacuees would reach a designated refuge above the flood level within their building, or within an adjoining building which provides a shelter above the flood level.

In addition to this, a “mixed” evacuation was also considered. In “mixed” evacuation scenarios it was assumed that only buildings not isolated by the 20 year ARI flood would be able to evacuate by car, while the remainder would need to evacuate on foot. These scenarios may represent a more “realistic” situation, in which building blocks at the boundary of the CBD could evacuate by car, while the commercial core of the CBD, which would be reached by local flooding earlier than peripheral blocks, would evacuate on foot using the elevated walkways.

2.1.4 Time of Day

A large number of workers and visitors travel to and from Parramatta CBD on a daily basis. Similarly, many of the CBD residents go to work in different parts of the Sydney Metropolitan Area.

As a consequence of this, the time of day at which an evacuation order is issued would have a profound influence on the number of evacuees, the willingness of evacuees to leave and ultimately on the evacuation duration.

For instance, if the evacuation were triggered late at night, mostly residents would need to evacuate. On the other hand, if an evacuation order were issued during business hours, the majority of evacuees would be workers and visitors, while the number of residents would be much lower.

Additional challenges for emergency responders may then arise in more specific scenarios. For instance, during the PM peak hour, workers and visitors would need to evacuate, but at the same time residents would be returning to the CBD after work. This scenario would be particularly difficult to manage regardless of the selected emergency response strategy (horizontal evacuation vs SIP).

In the case of vehicular evacuation, returning residents would generate significant background road traffic, which would slow down the evacuation of workers and visitors. This would also result in additional load on emergency responders, who, in addition to facilitating evacuation, would have to prevent residents from entering the CBD.

If SIP were the preferred strategy, it would be difficult to ensure that workers would remain within their offices at the end of the day, when they are keen to leave and go home.

The following times of the day and scenarios were considered in the evacuation assessment:

- Midnight: only residents evacuate/SIP;
- Midday: only workers and visitors evacuate/SIP;
- PM peak: only workers and visitors evacuate/SIP, residents return home. This “time of the day” option constitutes in fact a variation of the Midday option, because the number of evacuees would be the same (i.e. workers and visitors). However, because the variables making the PM peak scenario slightly worse than the Midday one (i.e. background traffic, and human behaviour) cannot be modelled using the NSW Timeline Evacuation Model, the additional challenges of the PM peak scenario are only discussed qualitatively.

The AM was not considered to be as problematic as other scenarios because it would involve residents being told to evacuate when they would be leaving the CBD anyway and telling workers and visitors not to enter the CBD which is not expected to be met with a lot of resistance.

2.1.5 Simulated Scenarios

Combining all possible scenario variables would results in 81 scenarios to be modelled and/or discussed. However, for practical reasons, only the 24 “worst case” scenarios were modelled. These are listed in Table 1 and Table 2.

It should be noted that scenarios 7, 8 and 23 are different from all the others.

Scenario 8 represents a situation in which all car spaces within the CBD would evacuate at the same time. This would include residential, commercial and visitor cars. Although such a scenario is unlikely the happen in the real world, this approach is often used by the NSW SES to get a sense of the worst possible situation in terms of vehicular evacuation.

Scenarios 2 and 23 represent “mixed” evacuation types.

Table 1: Evacuation scenarios modelled for each combination of flood probability and year.

	2016	2036	2056
1 in 20	Scenario 1 Scenario 2	Scenario 9 Scenario 10	Scenario 15 Scenario 16 Scenario 17
1 in 100	Scenario 3 Scenario 4	Scenario 11 Scenario 12	Scenario 18 Scenario 19 Scenario 20
PMF	Scenario 5 Scenario 6 Scenario 7 Scenario 8	Scenario 13 Scenario 14	Scenario 21 Scenario 22 Scenario 23 Scenario 24

Table 2: Variables used to generate each evacuation scenario. (year_flood event_time of day_ evacuation type).

Scenario number	Code	Scenario number	Code
1	2016_20yr_Midday_HSL	**13**	2036_PMF_Midday_HSL
2	2016_20yr_Midday_HHL	**14**	2036_PMF_Midday_HHL
3	2016_100yr_Midday_HSL	**15**	2056_20yr_Midday_HSL
4	2016_100yr_Midday_HHL	**16**	2056_20yr_Midnight_HSL
5	2016_PMF_Midday_HSL	**17**	2056_20yr_Midday_HHL
	2016_PMF_Midday_HHL	**18**	2056_100yr_Midday_HSL
7	2016_PMF_Midday_Mixed	**19**	2056_100yr_Midnight_HSL
8	2016_PMF_AllCars_HSL	**20**	2056_100yr_Midday_HHL
9	2036_20yr_Midday_HSL	**21**	2056_PMF_Midnight_HSL
10	2036_20yr_Midday_HHL	**22**	2056_PMF_Midday_HHL
11	2036_100yr_Midday_HSL	**23**	2056_PMF_Midday_Mixed
12	2036_100yr_Midday_HHL	**24**	2056_PMF_Midday_HSL

2.2 DATA COLLECTION

Due to the spatial nature of the information required to build each scenario, a GIS (Geographic Information System) was created.

The input data needed included:

- People: maximum number of Residents, Workers and Visitors at any one time of the day;
- Vehicles: number of residential, commercial and visitor car spaces;
- Buildings: cadastre lots, current and future land zoning, Floor Surface Area (FSA) for residential and commercial development, heritage sites;
- Transport Network: road network, lane numbers, one-way roads;
- Flood model results for the selected design events;
- Flood warning lead time.

In order to be used as input in the evacuation modelling exercise, each dataset had to satisfy the following requirements:

- Possess the highest possible spatial resolution, so that it could be referred to each cadastre lot;
- Be available and evenly distributed across the whole CBD;
- Be available for year 2016, 2036 and 2056.

As only a part of the above-listed data was available, a number of assumptions were introduced to obtain the missing information. These are described in detail in Appendix A.

2.3 EVACUATION MODELLING

The scope of an evacuation modelling exercise is to calculate the time needed to complete a full evacuation and to compare this with the time available before evacuation routes are cut by floodwaters.

The time needed to complete the evacuation is generally estimated using evacuation models, while the time available depends on the lead time provided by the flood warning system.

Evacuation models range from simplified calculation spreadsheet to more sophisticated agent-based algorithms, which simulate the incoming flood, traffic conditions and the behaviour of individual evacuees.

This study employed the NSW SES Timeline Evacuation Model. This was preferred to an agent based model because it incorporates the assumptions made by the NSW SES and provides a level of accuracy that was deemed sufficient for the scope of this work.

In setting up the evacuation modelling exercise, this study introduced a number of assumptions, which are summarised in Appendix A. Each assumption is supported by the relevant literature and was assessed in consultation with the City of Parramatta Council.

At the time this study was originally undertaken, the City of Parramatta Council was developing a flood warning system for the CBD. Preliminary results suggested that a warning time of two hours should be used for the purpose of the evacuation assessment (Assumption 1 – Appendix A). Council has confirmed since commissioning of the warning system that two hours remains an appropriate lead time for evacuation assessment purposes.

This lead time is intended as the notice that would be given before a particular flood level is reached. These warnings would be issued by SMS to the NSW SES and members of the public who are registered to receive flood warnings.

It is possible that during any particular event several warnings will be given as flood forecasting predicts increasing flood levels over time as rain continues. For example, recipients may receive a warning that the 20 year ARI flood level will be reached in two hours' time but 30 minutes later might receive a warning that the 100 year ARI level will be reached in two hours from the second warning, and 30 minutes after that that an even higher level will be reached two hours after this third warning.

It should be noted that once the NSW SES receives each warning it would need to spend time to decide if an evacuation order needs to be issued, and then to disseminate such an order to the population.

The NSW SES in its standard evacuation planning modelling assumes that, after an evacuation order is communicated to the population, a minimum delay of two hours is to be expected before the evacuation begins (Assumption 2 – Appendix A).

This delay, or “lag”, is due to two factors:

- The Warning Acceptance Factor (WAF), defined as the time required by a member of the public to acknowledge the evacuation order and accept that it applies to them; and
- The Warning Lag Factor (WLF), defined as the time required by members of the public to get organised for the evacuation and leave their houses.

The NSW SES assumes that the WAF and the WLF will require one hour of time each.

For this reason, a warning time of no more than two hours would leave no time for the population of Parramatta CBD to evacuate at street level. Even if the NSW SES could instantaneously make a decision and issue an evacuation order as soon as it receives a warning, by the time the population is ready to evacuate (i.e. minimum two hours), the water level would already be at the level that the warning system forecast. If rain has continued then the flooding could already be rising above that level during the time it takes people to actually evacuate.

This means that using the standard SES evacuation assumptions, coupled with a warning time of two hours would not allow any type of street-level evacuation at all, regardless on the evacuation means (vehicles or on foot) employed. In the case of Parramatta CBD, the NSW SES will need to find ways to minimise its own decision making and dissemination time for evacuation orders and reduce the response time of evacuees if any evacuation is to be possible.

For this reason, the scope of the evacuation modelling exercise undertaken as part of this project solely estimated the evacuation time under a range of different scenarios and did not compare this with the time available before the evacuation routes would be cut.

Evacuation modelling was performed in two different ways, reflecting the two main evacuation modes (vehicular vs pedestrian). Refer to Appendix A.

2.3.1 Vehicular Evacuation (HSL)

Vehicular evacuation was considered first as this is the evacuation mode recommended by the NSW SES.

Vehicular evacuation, which is herein referred to as “Horizontal Street Level (HSL)”, was modelled under the assumption that evacuation routes would not be cut by floodwaters before the evacuation is completed. In other words, vehicular evacuation was considered an “early evacuation option” (Assumption 3 – Appendix A).

In addition to this, it was also assumed that any evacuees that do not have access to a car would be able to evacuate on foot in a time shorter than the time needed to complete the vehicular evacuation. This would therefore not affect the total evacuation time (Assumption 4 – Appendix A). This assumption is consistent with the time it would take for a pedestrian to walk from a location adjacent to the river to the nearest land above the reach of the PMF.

a) Vehicular Evacuation Model

The vehicular evacuation model used in this study is the NSW SES Timeline Evacuation Model (Opper et al., 2009). The model integrates the following recommended parameters (Assumption 5 – Appendix A):

- Lane Capacity: 600 cars per lane per hour;
- Queue length per car: 6m;
- Warning Acceptance Factor: 1 hour;
- Warning Lag Factor: 1 hour;
- Traffic Safety Factor: 1-3.5 hours depending on the duration of evacuation;

- Warning Rate per Hour per Door Knock Team (not used in this study): 12 properties.

b) Evacuation Routes

Vehicular evacuation routes leading out of the CBD were selected by inspecting the regional extent of the PMF and identifying routes that are least likely to be cut by floodwaters within (or in proximity of) the CBD. This analysis shortlisted the following evacuation routes:

- North: Pennant Hills Road;
- East: Victoria Road;
- South: Church Street and Harris Street;
- West: Great Western Highway.

However, it should be noted that the majority of these routes are likely to be cut by flooding at some point outside the CBD. Figure 4 shows the distribution of low points along the main roads around Parramatta CBD.

c) Vehicular Evacuation Precincts

The next part of this exercise allocated the flood-affected CBD cadastre to each of the five selected evacuation routes. This was achieved by:

- Locating each building's driveway;
- Assuming that, upon exiting each driveway, vehicles would move away from Parramatta River, Clay Cliff Creek or Brickfield Creek;
- Assuming that traffic would move according to normal traffic flow direction on roads including one-way roads.

Under these assumptions (Assumption 6 – Appendix A), the shortest path from each building to any of the five evacuation routes was identified and used to allocate each lot to an evacuation route. Lots evacuating to the same route were then grouped in the same vehicular evacuation precinct. The precincts obtained for each flood event are shown in Figure 5, Figure 6 and Figure 7.

A building was assumed to have to evacuate if it was "touched" or isolated by floodwaters in the model. The other buildings in the CBD were assumed not to have to evacuate (Assumption 7 – Appendix A). This may overestimate the number of vehicles which need to evacuate because the extent of flooding in some of these buildings may not be sufficient to require them to be evacuated.

While crossing the river or creeks was generally avoided, to reduce the risk of cars being trapped by traffic and then being overwhelmed by fast flowing water, there was one location where crossing the river was unavoidable. This is discussed in the next paragraph.

There are several buildings in Phillip Street on the corner of Wilde Street which have their parking areas at the rear and they share access to Wilde Street with a large multi-deck carpark adjacent to the river. This direct access to Wilde Street only allows them to turn left onto Wilde Street and cross over the river as there is a median in Wilde Street preventing a right-hand turn. If vehicles need to travel south from this location, away from the river, they need to head towards the river and go under Wilde Street. As this would take people towards more flood prone land it was deemed not to be a suitable vehicular evacuation route for this car park and adjacent buildings.

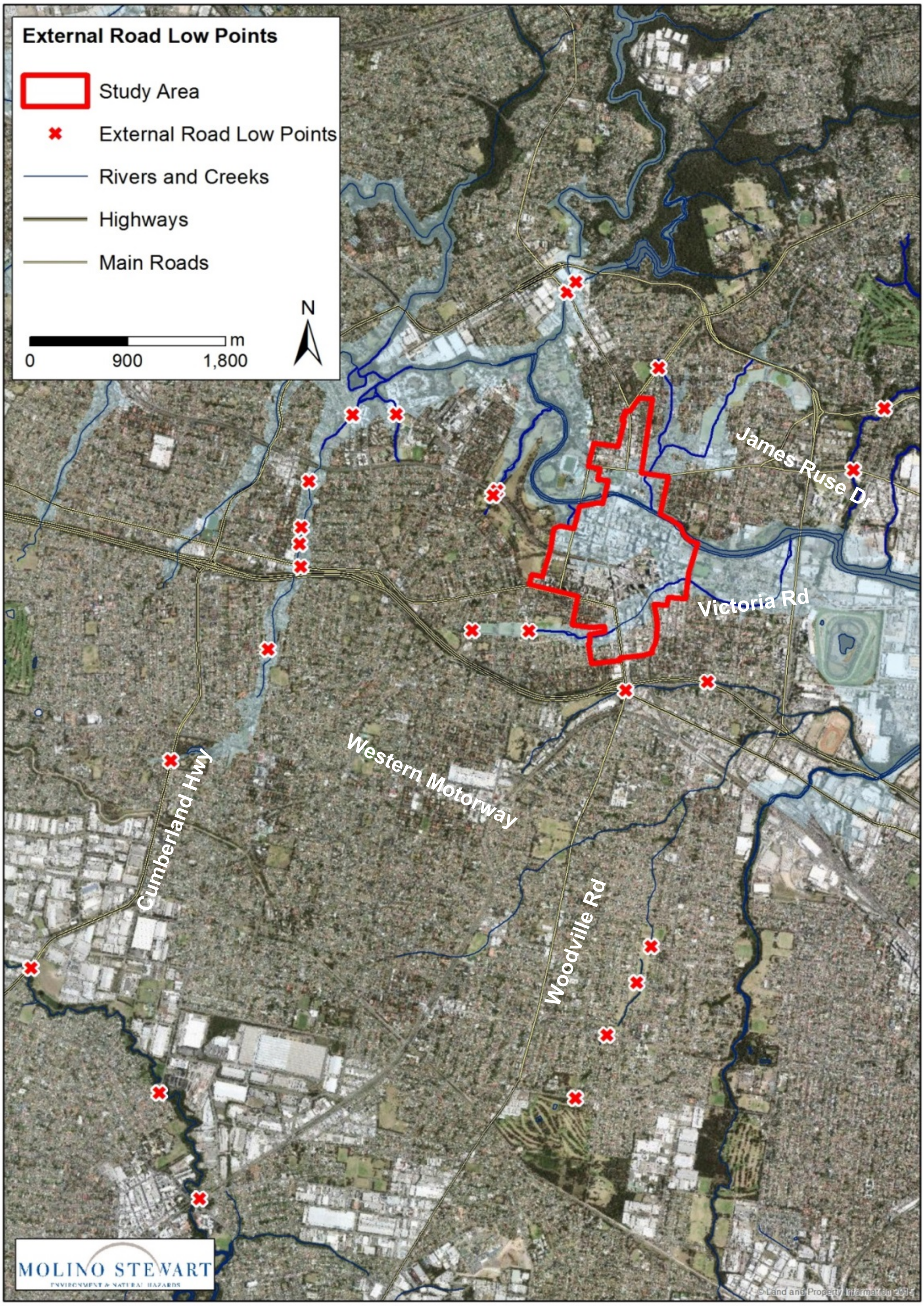

Figure 4: External road low points that may be cut by floodwaters

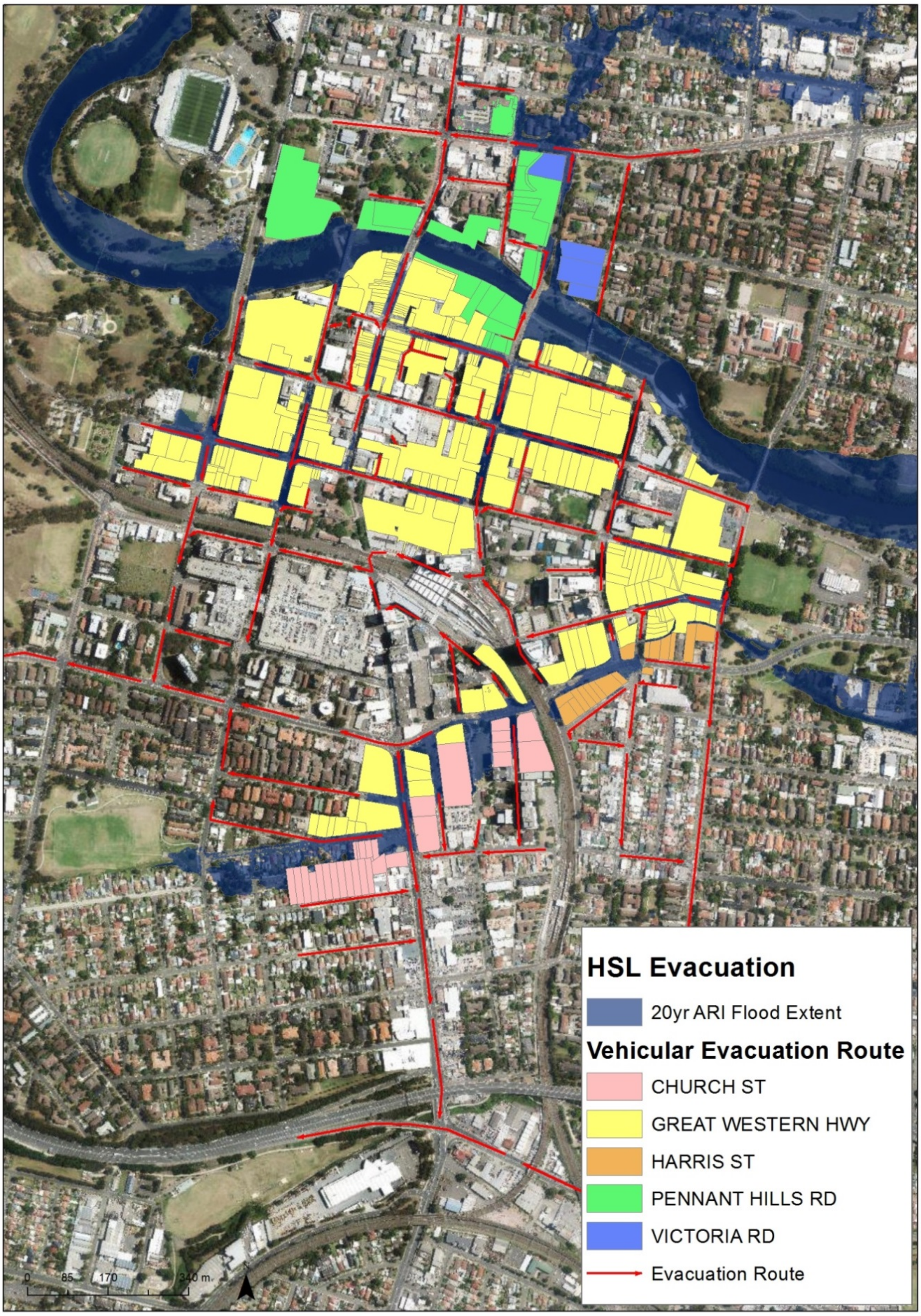

Figure 5: Allocation of buildings affected by the 20 year ARI event to five vehicular evacuation routes and precincts

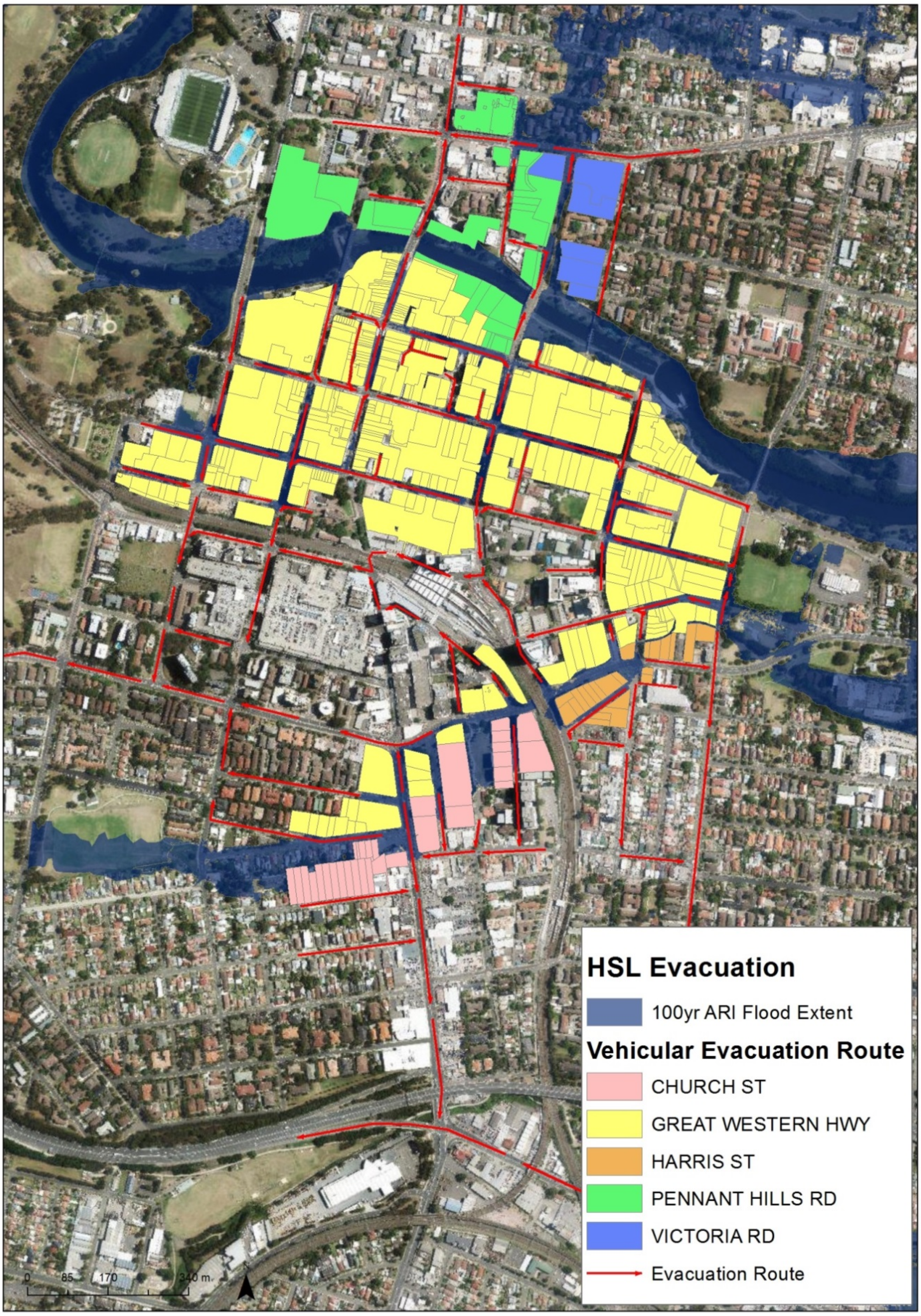

Figure 6: Allocation of buildings affected by the 100 year ARI event to five vehicular evacuation routes and precincts

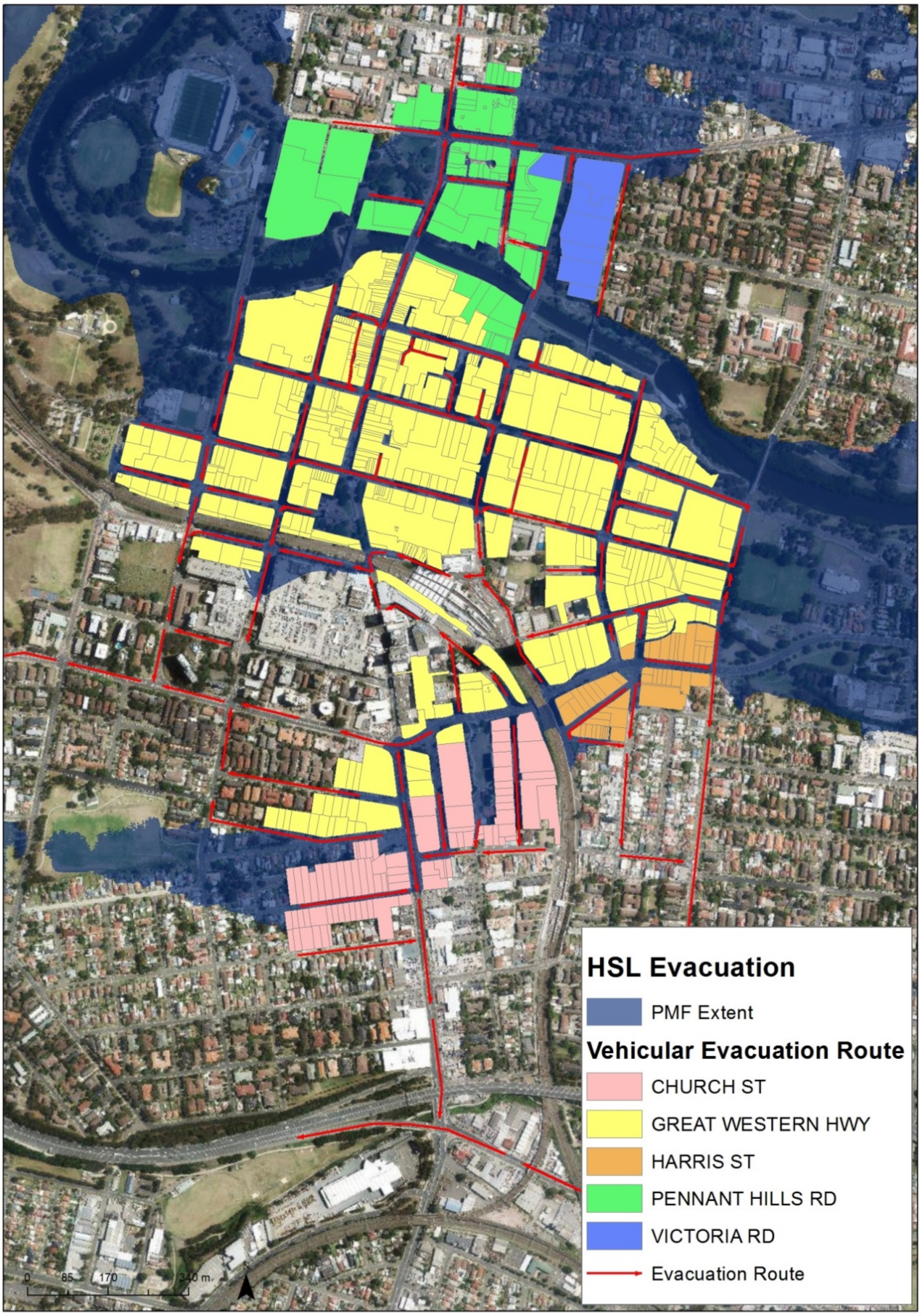

Figure 7: Allocation of buildings affected by the PMF to five vehicular evacuation routes and precincts

2.3.2 Pedestrian Evacuation (HHL)

Pedestrian evacuation, which is also referred to as "Horizontal High Level (HHL)", was considered as an alternative to vehicular evacuation because in Parramatta CBD it offers the following advantages:

- It is not constrained by one-way roads;
- People who do not have access to a car would have to evacuate on foot anyway;
- In Parramatta CBD the furthest distance to a safe flood shelter is relatively short.

a) Where to?

All evacuees between the Parramatta River and Clay Cliff Creek were assumed to head to a building of the scale and location of Westfield, which has:

- capacity to accommodate a large number of people for several hours,
- is open for most of the day.

Although dedicated arrangements would be necessary to make sure that the building designated as the refuge is accessible outside business hours, these should be fairly simple to achieve, for example making use of the 24hour security patrol service.

Evacuees north of the Parramatta River could not cross the river and would need to evacuate to a location to be determined. Similarly, evacuees south of Clay Cliff Creek would need to evacuate south. However, these are a small number compared to evacuees between the Parramatta River and Clay Cliff Creek, and would be relatively easy to accommodate in smaller buildings/refuges.

b) Elevated Walkways

Importantly, this study used pedestrian evacuation as a "late evacuation" option. This means that pedestrian evacuation would need to be a viable option regardless of the time at which people are ready to evacuate.

Because most of the roads of the CBD are within the floodplain, late evacuation on foot could only be achieved by means of a network of elevated walkways. These would need to be installed at strategic locations within the CBD to allow evacuees to safely cross flooded roads. The extent of the elevated walkways would have to be proportional to the size of the flood event up to which these can be used.

As part of this project, a concept design of the elevated walkways was completed by a team of urban planners and architects (i.e. Studio GL). Appendix C includes a report from Studio GL describing and assessing in detail the concept design's extent, dimensions, accessibility and urban planning implications (e.g. visual impact, overshadowing). It should be stressed that, while the concept design is sized to cater for events up to the 20yr ARI, the same design could be conceptually extended to larger flood events.

In events up to a 20 year ARI, it was assumed that evacuees would be able to reach the elevated walkways using communal stairs and ramps accessible from street level, while in larger events a dedicated building-by-building access would be necessary (Assumption 8 – Appendix A). This assumes that in events up to the 20 year ARI event flooding of the roads does not extend onto the adjacent footpaths to a level which would be hazardous for pedestrian to walk through to access the nearest walkway.

If the walkway network were built to cater for the 20 year ARI, then in the event of a larger flood people would not be able to access the walkways and would be trapped in their buildings.

In the case of the 100 year ARI walkway network, people within the extent of the 100 year ARI event would be able to access the walkways in any size flood because they would be accessing them from an upper floor of their building. However, should they fail to evacuate in a flood larger than the 100 year ARI event before the flood reaches the 100 year ARI level then they would not be able to safely return to street level to complete their evacuation.

The PMF walkway network on the other hand would allow people to leave their building at any time and not come in contact with floodwaters.

The extent of the elevated walkways network for each flood event is shown in Figure 8, Figure 9 and Figure 10. As with vehicular evacuation it was assumed that only those buildings which were touched by floodwaters would need to evacuate and all others could remain within their buildings.

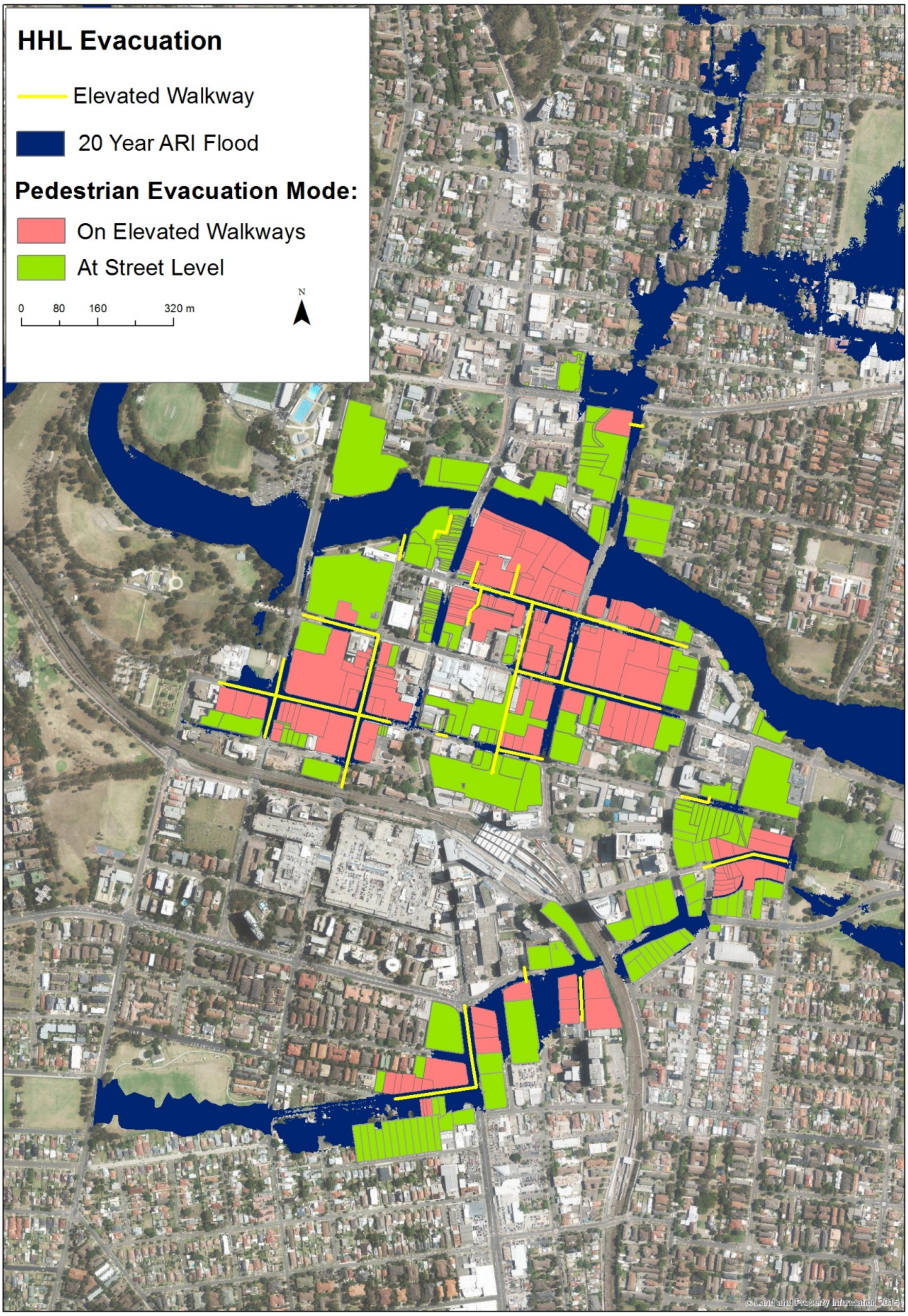

Figure 8: Extent of elevated walkways catering up to the 20 year ARI event.

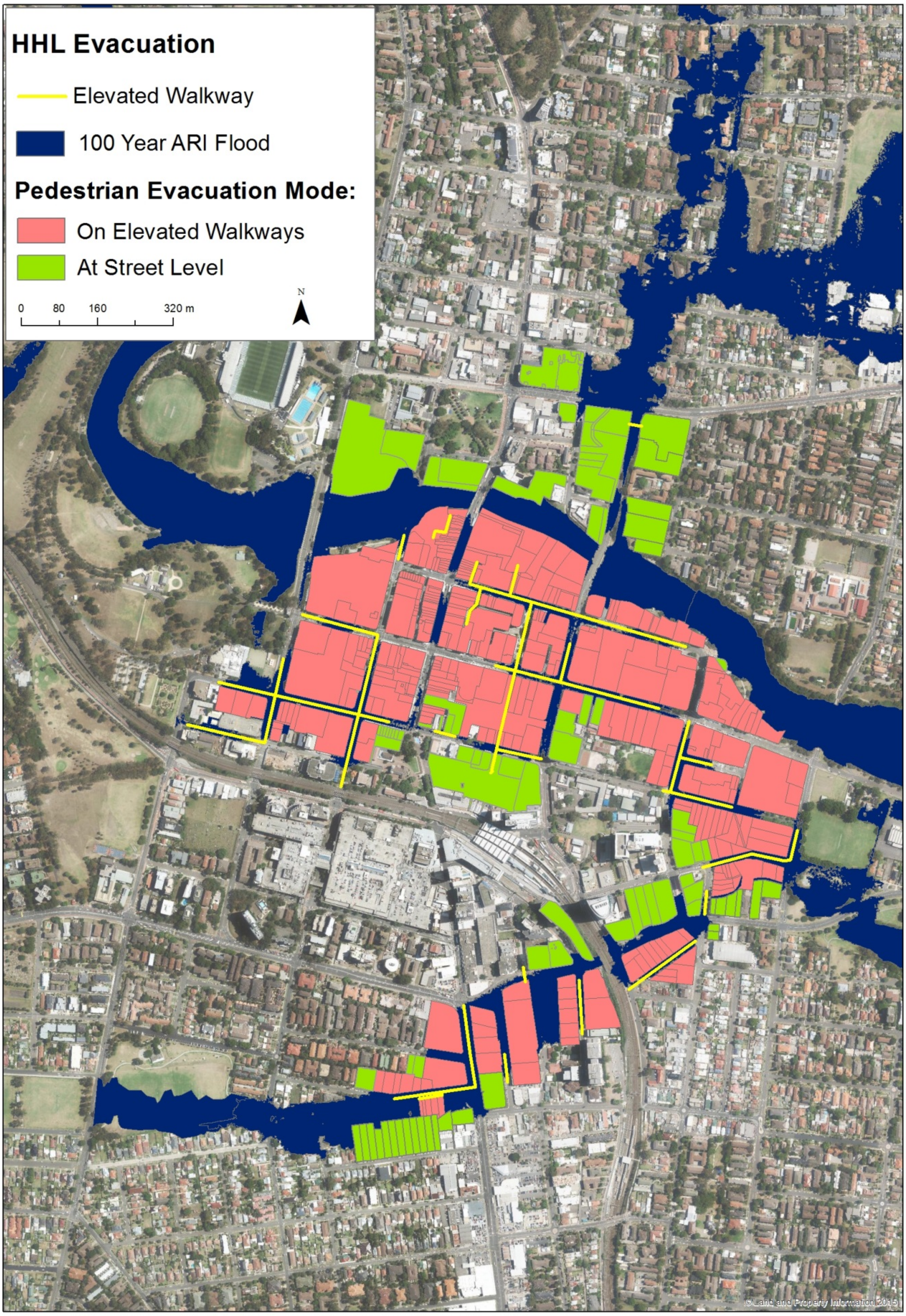

Figure 9: Extent of elevated walkways catering up to the 100 year ARI event.

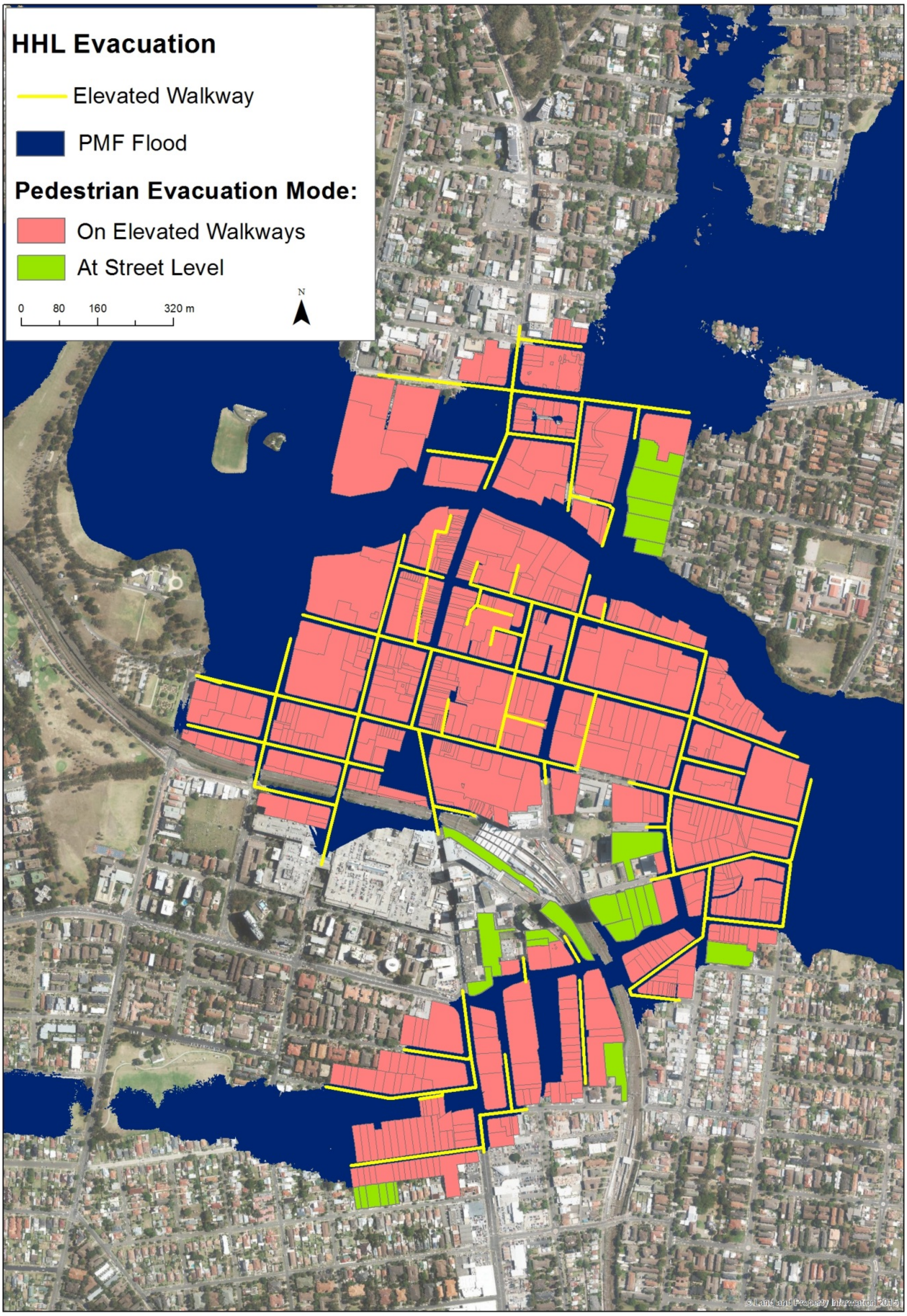

Figure 10: Extent of elevated walkways catering up to the PMF.

c) Pedestrian Evacuation Precincts

As part of the pedestrian evacuation modelling exercise, a new set of evacuation precincts was generated. Pedestrian evacuation precincts differ from vehicular evacuation precincts because:

- Pedestrians would evacuate to different locations; and
- Pedestrians would not need to abide by one-way roads.

Evacuation routes were identified for each building as the shortest “flood-free” path to the designated pedestrian refuge. For most buildings (i.e. those that are isolated by floodwaters), a flood–free path to safety could only be obtained using the elevated walkways. However, for a small number of buildings, pedestrian evacuation could be achieved without making use of the elevated walkways. This is the case of buildings that would be affected by the peak of the flood, but that would still maintain flood-free access to one of the designated pedestrian refuges. In this case, the evacuation route is entirely at street level.

Buildings were then grouped into evacuation precincts based on the narrower “bottleneck” along their designated evacuation route. Buildings sharing the same bottleneck were assigned to the same pedestrian evacuation precinct (Assumption 9 – Appendix A).

A bottleneck is defined as the point along the evacuation route with the slowest evacuation speed. Evacuation speed is inversely proportional to density of evacuees, which in turns depends on the number of evacuees and the width of the evacuation route.

For elevated walkways, which have all the same width of 2.5m, the bottleneck was identified at the walkway’s exit point, where the number of evacuees would be a maximum.

Similarly, for street-level evacuation, the bottleneck was identified along the last road before reaching the evacuation refuge.

Pedestrian evacuation precincts are shown in Figure 11, Figure 12 and Figure 13. Precincts identified by the acronym SL (i.e. Street Level) would be able to complete the evacuation remaining at street level, while the remainder would need to make use of the elevated walkways.

d) Pedestrian Evacuation Model

The model used to calculate evacuation time is based on literature findings (Seyfried et al., 2005) regarding the relationship between pedestrian walking speed and density.

The time required for a group of people to walk along a road from point A to point B depends on the walking speed, the distance between A and B, the pedestrian numbers and the path’s width.

The time required to clear all pedestrians from an elevated walkway was obtained as:

Walkway Clearance Time (WCT) = (number of pedestrians) / [(walking speed) x (effective width at bottleneck) x (pedestrian density)]

It was then assumed that pedestrians would be able to move at a speed of at least 700 metres per hour, with a density of up to two people per square metre. While elevated walkways have a fixed width of 2.5m, it was conservatively assumed that only 2m of width would be effectively used.

Where the calculated WCT resulted in a shorter time than that which a single person would take to walk the same distance at a speed of 2km/h, the latter figure was used as WCT.

The total pedestrian evacuation time for each precinct was then obtained as:

Precinct Evacuation Time = WAF + WLF + WCT

Where:

WAF = Warning Acceptance Factor (=1hr)

WLF = Warning Lag Factor (=1hr)

Finally, for each scenario, the total evacuation time was obtained as the maximum of all Precincts’ Evacuation Times.

The total number of pedestrians to be evacuated in each HHL scenario is shown in Table 3

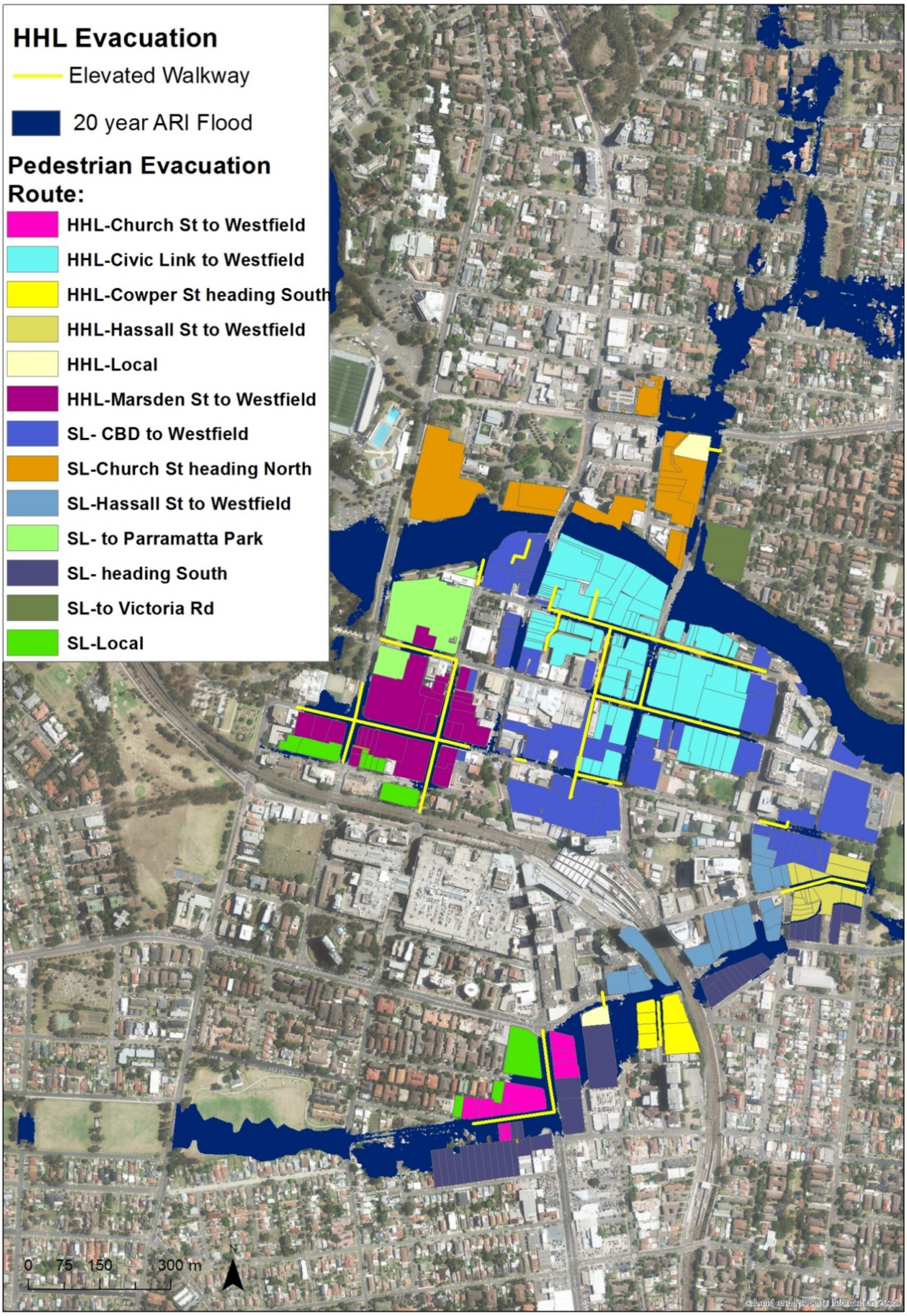

Figure 11: Pedestrian evacuation precincts evacuation routes for buildings affected by the 20 year ARI event.

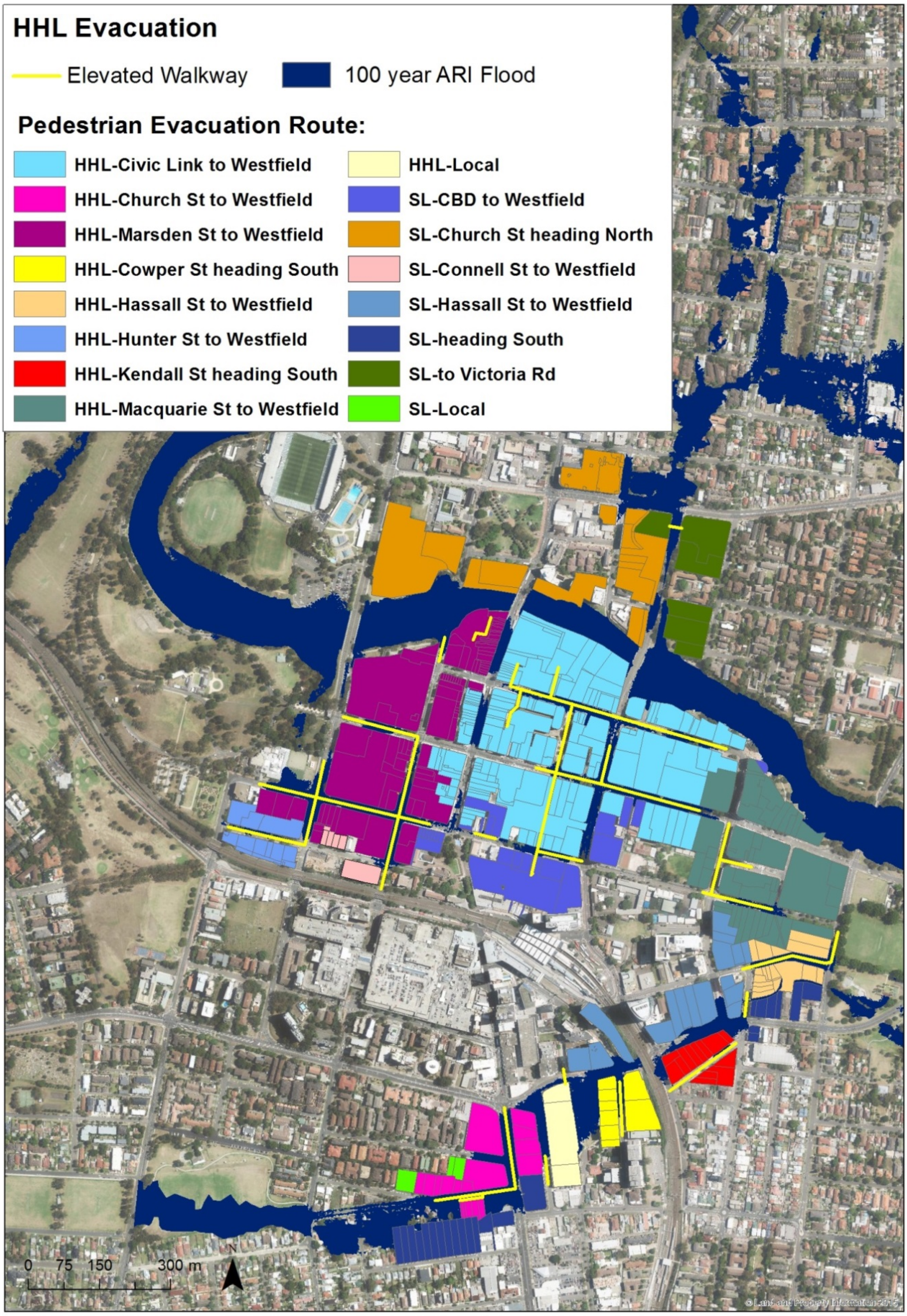

Figure 12: Pedestrian evacuation precincts evacuation routes for buildings affected by the 100 year ARI event

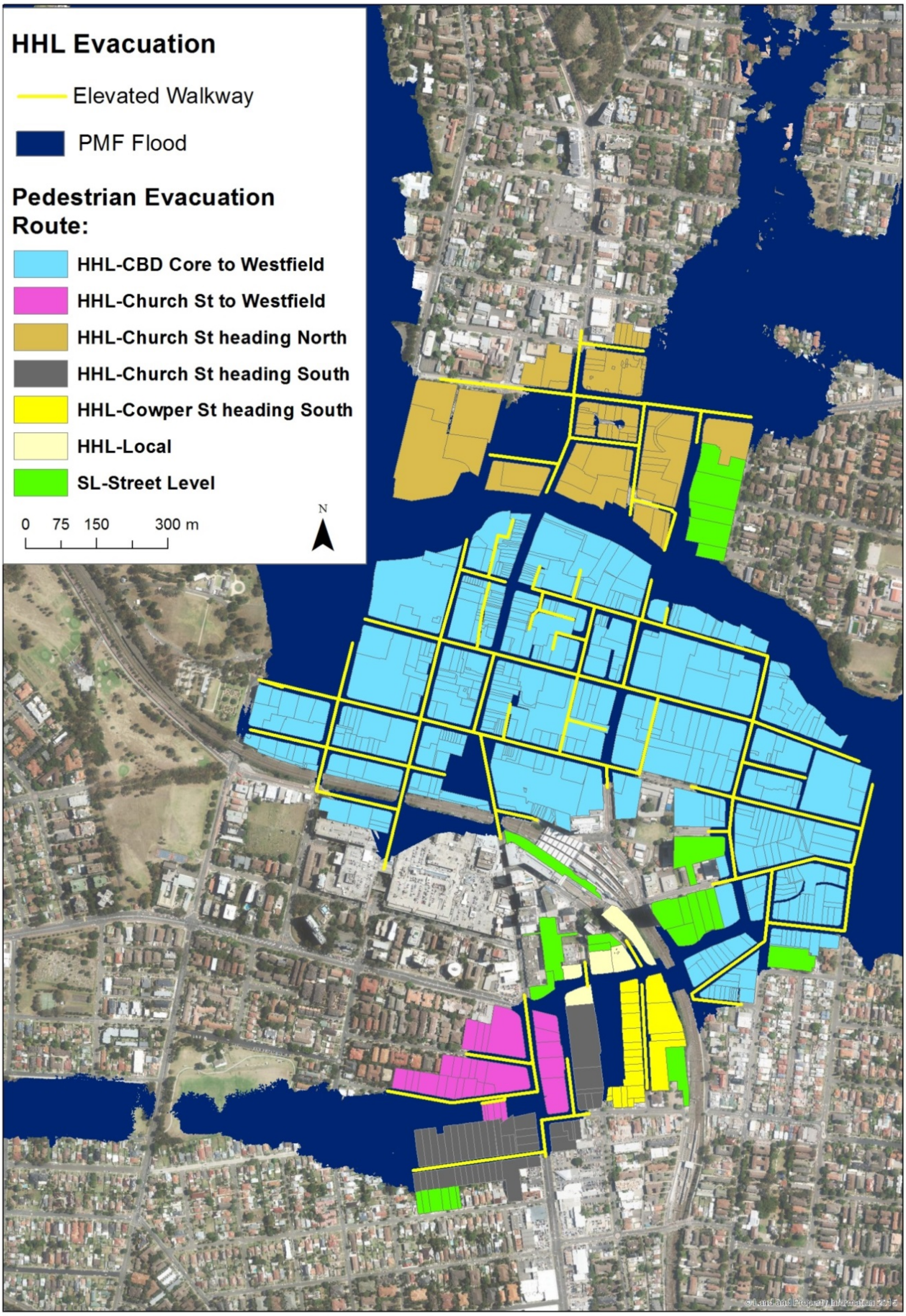

Figure 13: Pedestrian evacuation precincts evacuation routes for buildings affected by the PMF

Table 3: Pedestrians to be evacuated in HHL scenarios

Evacuation Scenario	Total Number of Pedestrians	Pedestrians on Elevated Walkways	Pedestrians at Street Level
2016 + 20yr + Midday	49,147	22,662	26,485
2016 + 100yr + Midday	53,376	44,093	9,283
2016 + PMF + Midday	73,646	68,341	5,305
2036 + 20yr + Midday	92,137	45,744	46,393
2036 + 100yr + Midday	99,324	85,096	14,228
2036 + PMF + Midday	130,245	123,524	6,721
2056 + 20yr + Midday	115,089	60,941	54,148
2056 + 100yr + Midday	123,865	110,070	13,795
2056 + PMF + Midday	167,821	158,733	9,088

3 RESULTS

Table 4 shows the total evacuation time obtained under the assumptions described in Section 2, for each of the selected scenarios. Figure 14 and Figure 15 provide a comparison of evacuation times across different years and flood probabilities, using the worst case scenario in terms of time of the day.

Evacuation times for each precinct are presented in detail in Appendix B.

Table 4: Total evacuation time for each scenario

Scenario number	Code	Total Evacuation Time (hrs)
1	2016_20yr_Midday_HSL	8.1
2	2016_20yr_Midday_HHL	4.5
3	2016_100yr_Midday_HSL	9
4	2016_100yr_Midday_HHL	5.2
5	2016_PMF_Midday_HSL	10.7
6	2016_PMF_Midday_HHL	4.4
7	*2016_PMF_Midday_Mixed*	*5.6*
8	*2016_PMF_AllCars_HSL*	*11.8*
9	2036_20yr_Midday_HSL	8.7
10	2036_20yr_Midday_HHL	7.3
11	2036_100yr_Midday_HSL	9.4
12	2036_100yr_Midday_HHL	8.9
13	2036_PMF_Midday_HSL	10.8
14	2036_PMF_Midday_HHL	6.8
15	2056_20yr_Midday_HSL	8.9
16	2056_20yr_Midnight_HSL	7.4
17	2056_20yr_Midday_HHL	9.1
18	2056_100yr_Midday_HSL	9.6
19	2056_100yr_Midnight_HSL	8.9
20	2056_100yr_Midday_HHL	11.2
21	2056_PMF_Midnight_HSL	9.7
22	2056_PMF_Midday_HHL	7.9
23	*2056_PMF_Midday_Mixed*	*9.1*
24	2056_PMF_Midday_HSL	11

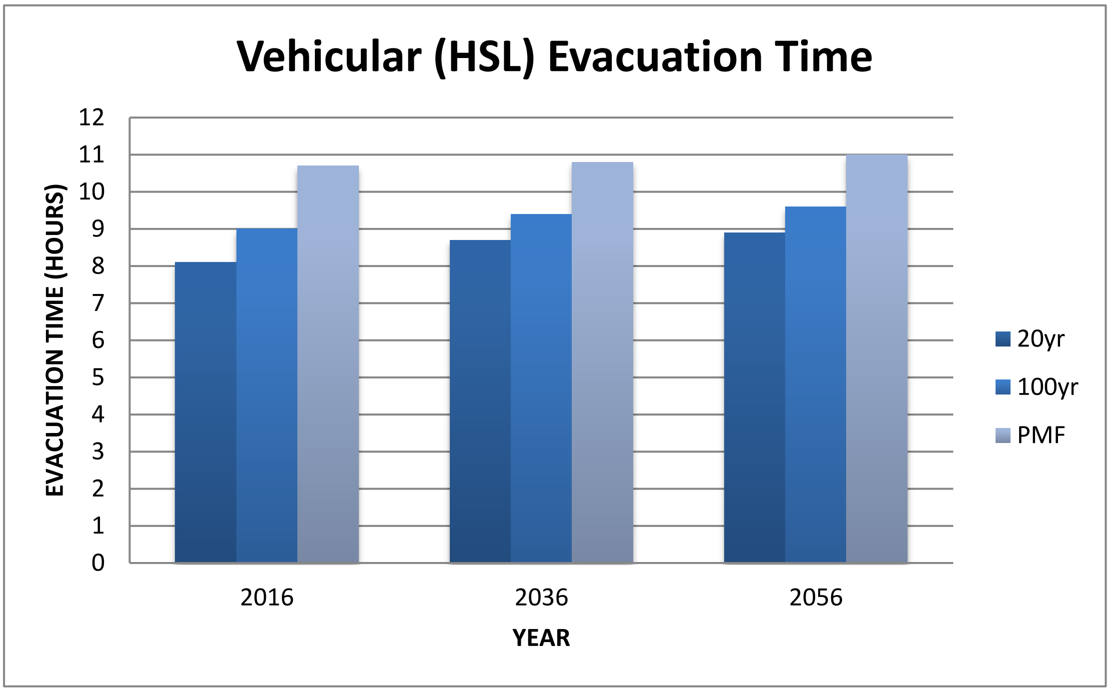

Figure 14: Comparison of vehicular evacuation times obtained for different years and flood probabilities and worst case in terms of time of the day.

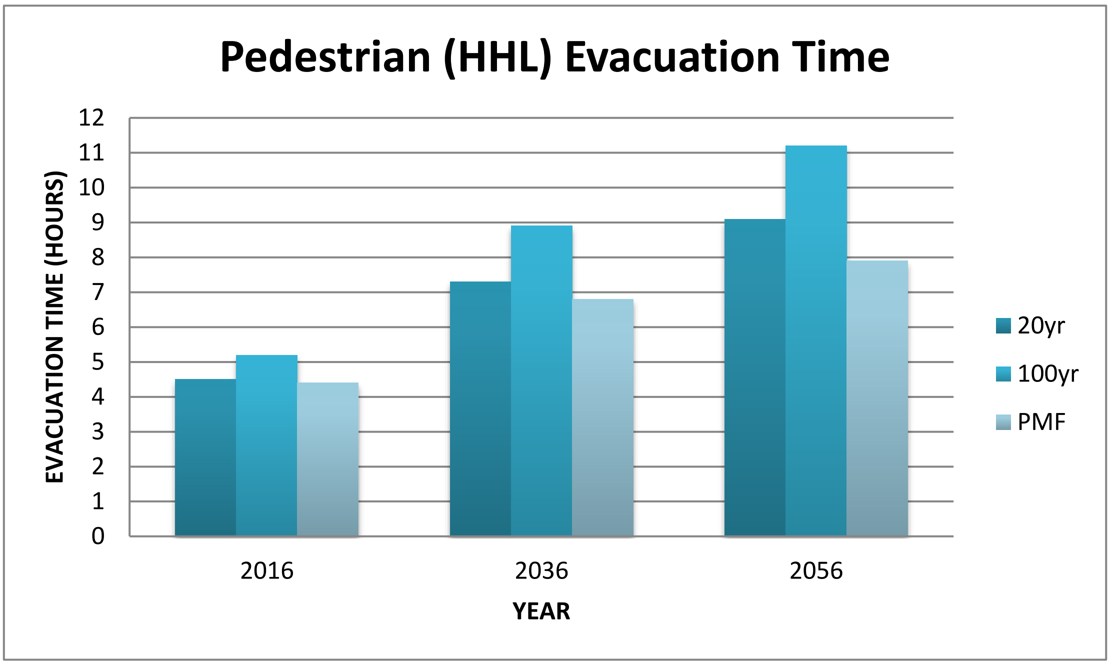

Figure 15: Comparison of pedestrian evacuation times for different years and flood probabilities and worst case in terms of time of the day

4 DISCUSSION

4.1 VEHICULAR EVACUATION (HSL)

4.1.1 Evacuation Time

Results show that, among all scenarios, vehicular evacuation time ranges between a minimum of 8 and a maximum of 11 hours. In all cases, the final evacuation time is driven by the precinct evacuating to the Great Western Highway, which includes the CBD core and, as such, contains the largest number of vehicles.

As expected, evacuation time increases consistently in future scenarios, although with relatively small increments (Figure 14). For example, the average increment from 2016 to 2036 is +4.2%, and from 2016 to 2056 the increment is +6.4%. This is due to the proposed new planning controls regulating the number of commercial and residential car spaces for new development and represents the best case scenario.

While existing controls, which are used in the 2016 scenario, require one commercial car space for every 100m^2 of effective commercial Floor Surface Area (FSA), new controls will allow only one commercial car space for every 50 m^2 of total site area. For mixed-use developments having both residential and commercial components, the new controls for commercial car parking were further adjusted by using the proportion of the commercial floor space to the total floor space of the development. The most obvious consequence of this is that multi-storey commercial buildings will undergo a significant reduction of commercial car spaces, because their site area is likely to be smaller than their commercial FSA.

However, this reduction is balanced out by the overall increase of commercial site area across the CBD. The result is a slight increase of the number of commercial car spaces from 2016 to 2056, which is reflected in the vehicular evacuation time's trend. Another consequence of the new controls on commercial car spaces is that the number of pedestrians in future scenarios will increase, which is accounted for in pedestrian evacuation scenarios.

Similarly to the increment by year, vehicular evacuation time is directly proportional to flood extent. In this case, results show an average increment of +9% from the 20 year ARI to the 100 year ARI event, and +26% from the 20year ARI event to the PMF.

In all scenarios, smaller evacuation precincts, located around the CBD core have evacuation times significantly shorter, ranging between 3 and 5 hours.

While all scenarios considered here are either based on a "midday" or "midnight" evacuation (where only a part of the available car spaces would evacuate), in Scenario 8 all the available car spaces in the CBD are assumed to evacuate at the same time. This scenario was only assessed in existing conditions (i.e. year 2016) and during a PMF event, with the intent of giving a sense of the theoretical upper limit of the evacuation time, which would be just under 12 hours.

4.1.2 Challenges of Vehicular Evacuation

There are several challenges associated with vehicular evacuation of Parramatta CBD:

a) Flood Timing

As discussed in Section 1.3.2, Parramatta CBD is affected by flash flooding. In the PMF, for example, floodwaters would reach the peak level after about 5 hours from the beginning of the rainfall, while local flooding would start affecting the road network almost immediately.

The flood warning system developed by the City of Parramatta Council is likely to be able to provide about two hours' notice of predicted flood levels being reached.

Figure 16 uses coloured arrows to show at what point on the PMF hydrograph the NSW SES would know that a given flood level is going to be reached. For instance, the NSW SES would know that a PMF is going to eventuate after about 3.5 hours from the beginning of the rainfall (this is indicated by the blue arrow in Figure 16). At that point, floodwaters would have already reached the

100 year level, most roads would be cut and vehicular evacuation from the CBD core would be impossible.

Similarly, smaller events such as the 20 year ARI and the 100 year ARI could be predicted no earlier than one hour after the beginning of the rainfall. Even though there are no flood model results for events smaller than the 20 year ARI, it is likely that at that point some degree of local flooding would have already occurred, preventing vehicular evacuation of part of the CBD.

In addition to this, even if vehicular evacuation could begin before streets are cut by local flooding, the number of cars to be directed to Great Western Highway would result in an evacuation time comparable to the flood duration, under any of the scenarios considered here.

b) Evacuation Delays

The willingness for people to evacuate by vehicle will be influenced by many factors including why they are in the building, when they were otherwise intending to leave, and whether they were travelling in the vehicle with others.

Generally, those who are visitors or workers are likely to evacuate promptly, particularly if they intended to leave soon. Those who are residents are more likely to delay evacuation or refuse to evacuate altogether if they consider their dwelling to be a safe refuge above floodwaters.

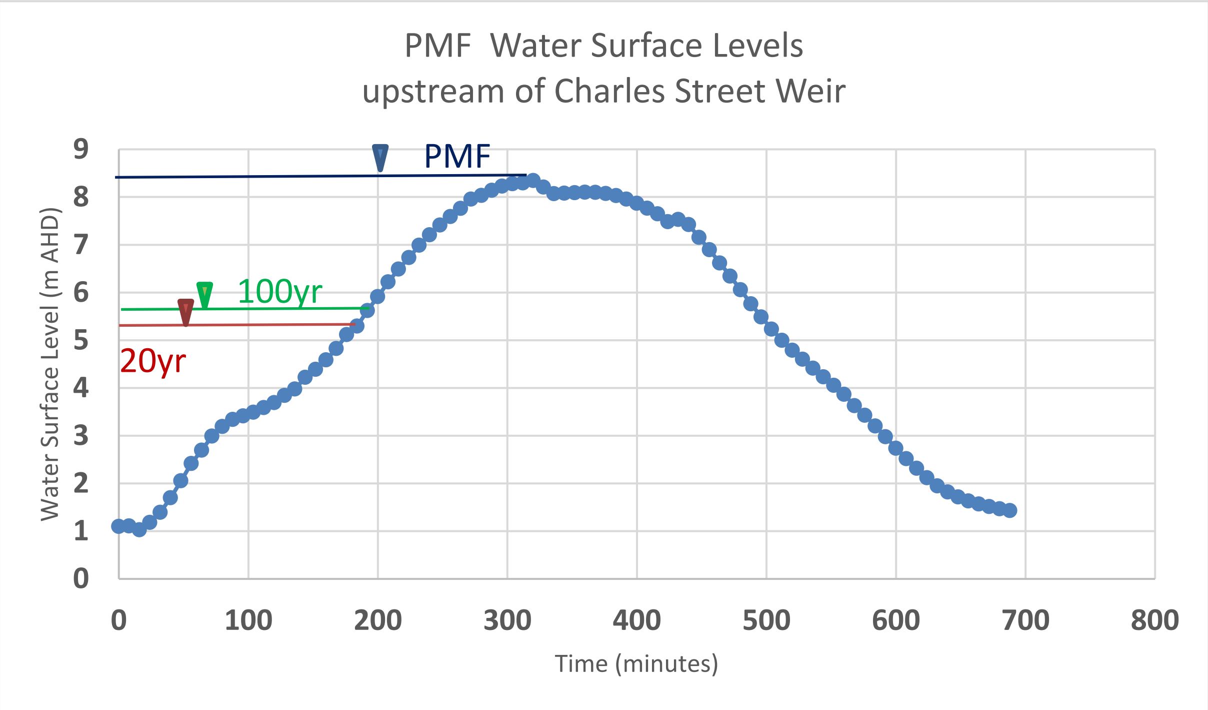

Figure 16: Flood duration and flood warning lead time

c) Regional Road Blockages

Even if evacuation could be successfully completed before roads within the CBD are cut, the extent of the regional flooding (i.e. outside the CBD) would be such that it would be difficult – if not impossible – for the large majority of vehicles to travel long distances before they reach a point on their evacuation route which is cut by flooding (Figure 4). For example, all cars evacuating to the Great Western Highway are likely to be isolated in the area between the Finlayson's Creek (west), Parramatta River (north), Clay Cliff

Creek (east) and the Motorway (south). Similarly, cars heading south on Church Street or Harris Street would most likely have their route cut by A'Becketts Creek.

d) Background Traffic

The evacuation modelling assumes that there is no other traffic on the roads when the evacuation order is given (Assumption 11 – Appendix A). This may be a reasonable assumption if the evacuation is called in the middle of the night but would not be the case during the day. On most weekdays there are considerable traffic delays during morning and afternoon peaks in Parramatta CBD and it can take 30 minutes to access the Great Western Highway or Church Street from some parts of the CBD in the evening peak in the absence of any flooding. If all vehicles are trying to leave the CBD simultaneously there is a risk of gridlocked streets as they try and merge with regional through traffic on the main roads which evacuation traffic will be directed to.

e) Traffic Queues

If cars evacuate from buildings but encounter roads blocked by regional flooding or regional traffic, then traffic will queue back into the CBD and may even prevent vehicles from leaving buildings. For example, there is only sufficient space on the Great Western Highway evacuation routes for about 1,150 cars to queue between the CBD and Finlayson Creek but there are up to 12,677 vehicles which would need to evacuate in such an event. While vehicles could go into side streets to queue above the reach of floodwaters and allow others to evacuated, most people would be reluctant to leave their place in the queue.

f) Returning traffic

In a PM peak there are likely to be many residents returning home by car and this returning traffic will need to be managed to ensure it does not enter the evacuation zone. It is unlikely that there will be sufficient emergency services resources to control this.

4.2 PEDESTRIAN EVACUATION (HHL)

4.2.1 Evacuation Time

Results show that pedestrian evacuation using elevated walkways (HHL) is generally more efficient than vehicular evacuation, particularly in existing conditions (year 2016). The only scenario in which vehicular evacuation would be faster is Scenario 20 (i.e. 2056_100yr_Midday_HHL).

Interestingly, the shortest evacuation time is always achieved in the PMF. The reason for this is that the PMF would require a larger network of elevated walkways (because the flood extent is larger), which would result in the CBD evacuees being distributed across a greater number of egress points. For example, in the PMF there would be eight egress points for evacuees heading to Westfield, while in the 20 year and 100 year ARI events there would be only 4 and 5 respectively.

It should be noted that the extent of the elevated walkways in each scenario was minimised to contain infrastructure costs and other adverse impacts (Assumption 12 – Appendix 2), however shorter evacuation times in smaller flood events could be achieved by extending the network to increase the number of egress points.

4.2.2 Challenges of Pedestrian Evacuation

Pedestrian evacuation using elevated walkways (HHL) would allow late evacuation from- access to- any flood-affected building. However, the following challenges/downsides need to be taken into consideration:

- **Cost:** Infrastructure cost would be significant and ranging from $94.5 to $324 million. A detailed breakdown of costs is provided in Appendix D.
- **Visual impact / overshadowing:** the elevated walkways would cause major visual impact on the urban landscape, particularly on heritage-listed buildings. The walkways would also increase the shadowing effect on

streets and lower levels of buildings. (Appendix C);

- **Impact on street trees:** because most walkways would be built above the footpath and/or parking lane at a height of 4.5m, any trees located along the walkway's path may need to be removed and replaced with low-level shrubs (Appendix C);
- **Compatibility with building levels:** in events larger than the 20 year ARI, the walkways would need to be directly accessible from the upper levels of each building. This would be difficult to achieve in practice, because floor levels vary between different buildings (Appendix C);
- **Limited road access for large vehicles:** where walkways traverse a road, or a crossroad, large vehicles which are taller than 4.5m (e.g. construction vehicles) would not be able to enter;
- **Evacuation Logistics:** all pedestrian evacuation scenarios were simulated under the assumption that people in buildings that are exposed to the flooding, but whose pedestrian evacuation routes are not cut by the flooding, would be able to evacuate at street level. However, this assumption implies that pedestrians would know if they are supposed to use the elevated walkways or not, which poses a challenge in terms of warning messaging. However, we note that this would only be a problem if the elevated walkways were built to cater for floods up to the 20 year ARI event, because only in this case would the walkways be accessible by anyone at street level;
- **Flood Duration:** pedestrian evacuation times range between 4 to 5 hours (in 2016) and 8 to 11 hours (in 2056). If the evacuation order is issued a few hours after the beginning of the rainfall, the evacuation process may finish after floodwaters have already receded.
- **Security:** Providing an extensive network of walkways that will not be used on a daily basis, will potentially create issues with informal use and security, and is an inefficient use of land within the CBD.
- **Road Impacts:** Providing ramps to access the walkway will impact on road layouts within the CBD.

In addition to the aforementioned challenges which are specific to using elevated walkways for pedestrian evacuation the following challenges apply to pedestrian evacuation generally:

- Those who arrived by light rail (when it is built) are unlikely to be able to leave by light rail because water across the tracks would stop its operation, many who arrived by bus will not be able to leave by bus because many bus routes will be cut by flooding, those who arrived by train may not be able to leave by train if flooding elsewhere or the inclement weather generally has disrupted rail services. All of these people may be reluctant to leave their buildings if they have no means of leaving Parramatta;
- People will be reluctant to leave a dry building to walk through torrential rain to shelter in another dry building, particularly if they perceive that their building provides shelter above the reach of floodwaters (whether that is true or not);
- Residents in particular have demonstrated an unwillingness to evacuate when orders have been given to evacuate in floods throughout Australia in recent years so it may be especially difficult to get people to leave an elevated dwelling in a high rise building on foot in torrential rain.

4.3 MIXED EVACUATION

4.3.1 Evacuation Time

Scenarios 7 and 23 incorporate mixed evacuation types, in which it is assumed that local flooding is already occurring (up to the extent of the 20 year ARI event) at the time evacuation begins, but that all buildings which could be affected by the PMF evacuate. Given that the flood warning system developed for Parramatta CBD will provide a relatively short lead time (i.e. two hours), these scenarios represent an attempt to simulate a realistic situation.

Buildings that are not isolated by events up to the 20 year ARI are assumed to evacuate by vehicle (Figure 17). These are, for the most part, located in the CBD's peripheral zones, where local flooding is a lesser issue compared to the CBD core. People in buildings from which vehicular evacuation is not possible because of local flooding in events up to the 20 year ARI are assumed to evacuate on foot.

Some of these people could complete the evacuation by remaining at street level, because even if their vehicular evacuation route is cut by local flooding, their pedestrian route is not. The remainder would need to use elevated walkways (Figure 18). Pedestrian evacuation time for these scenarios is determined by the proportion of pedestrians evacuating at high-level because the walkways are a narrower bottleneck than footpaths.

Because local flooding is assumed to have reached an extent up to the peak of the 20 year ARI event, elevated walkways are here assumed to cater up to the extent of the 20 year ARI flood.

Results of the mixed evacuation modelling show that:

- The total evacuation time would be 5.6 hours (Scenario 7) and 9.1 hours (Scenario 23);
- In both Scenario 7 and 23, the total evacuation time would be determined by vehicular evacuation to the Great Western Highway, which would take longer than pedestrian evacuation within the CBD core;
- Total evacuation times would be lower than the corresponding PMF scenarios in which evacuation is entirely achieved by car (i.e. Scenarios 5 and 24), but higher than the PMF scenarios in which evacuation is entirely done on foot (i.e. Scenarios 6 and 22).

4.3.2 Challenges of Mixed Evacuation

A large flood event with the same rate of rise as the PMF would reach and exceed the 20 year ARI extent in about 3 hours from the beginning of the rain. Because in scenarios 7 and 23 the elevated walkways would only cater up to the 20 year ARI flood extent, all evacuees would need to exit the walkways within 3 hours from the beginning of the rain. However, results of the pedestrian evacuation modelling for the CBD core (i.e. 4.5 hours for Scenario 7 and 9.1 hours Scenario 23) show that this would not be possible, unless the evacuation begins significantly earlier than the rainfall.

Extending the elevated walkways to cover the 100 year ARI flood would buy pedestrians some time (i.e. about 30 minutes), but would still not be enough for them to exit the walkways before the 100 year ARI extent is exceeded in a flood rapidly rising to a level beyond the 100 year ARI peak.

In fact, the only configuration for horizontal evacuation that would guarantee safe pedestrian evacuation of the CBD core in any event in which floodwaters rise as fast as in the PMF would be that in which the elevated walkways network covers the full extent of the flood event being considered. For example, if this event is the PMF, then the CBD core would need to be equipped with an elevated walkways network catering up to the PMF. However, in this case, a fully pedestrian evacuation like the one simulated in Scenarios 6 and 22 would be faster and more practical than a mixed type evacuation, and infrastructure cost would be only marginally higher.

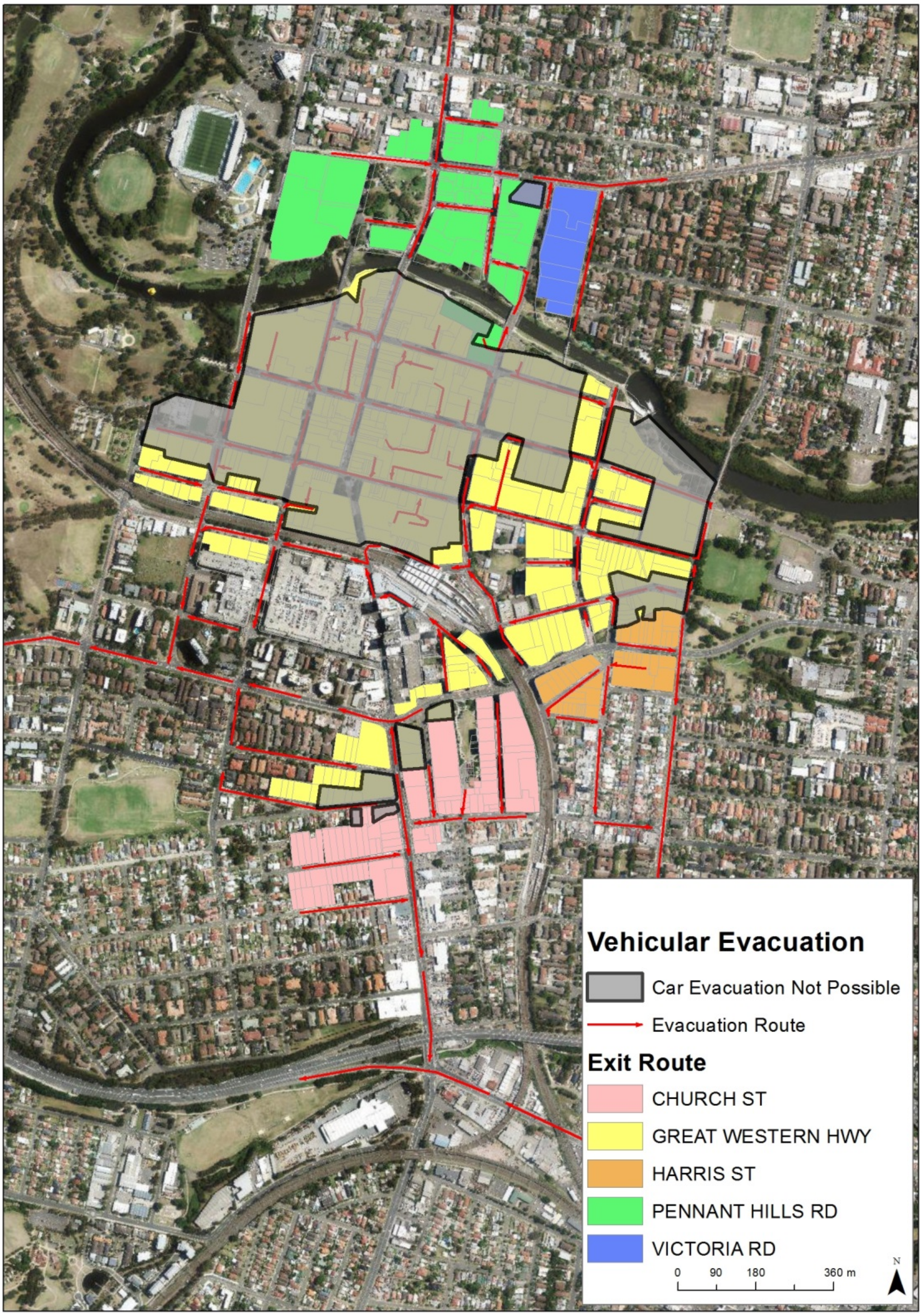

Figure 17: Mixed evacuation scenarios 7 and 23. People in greyed-out lots would not be able to evacuate by car if there was already local flooding up to the 20 year ARI event when the evacuation begins

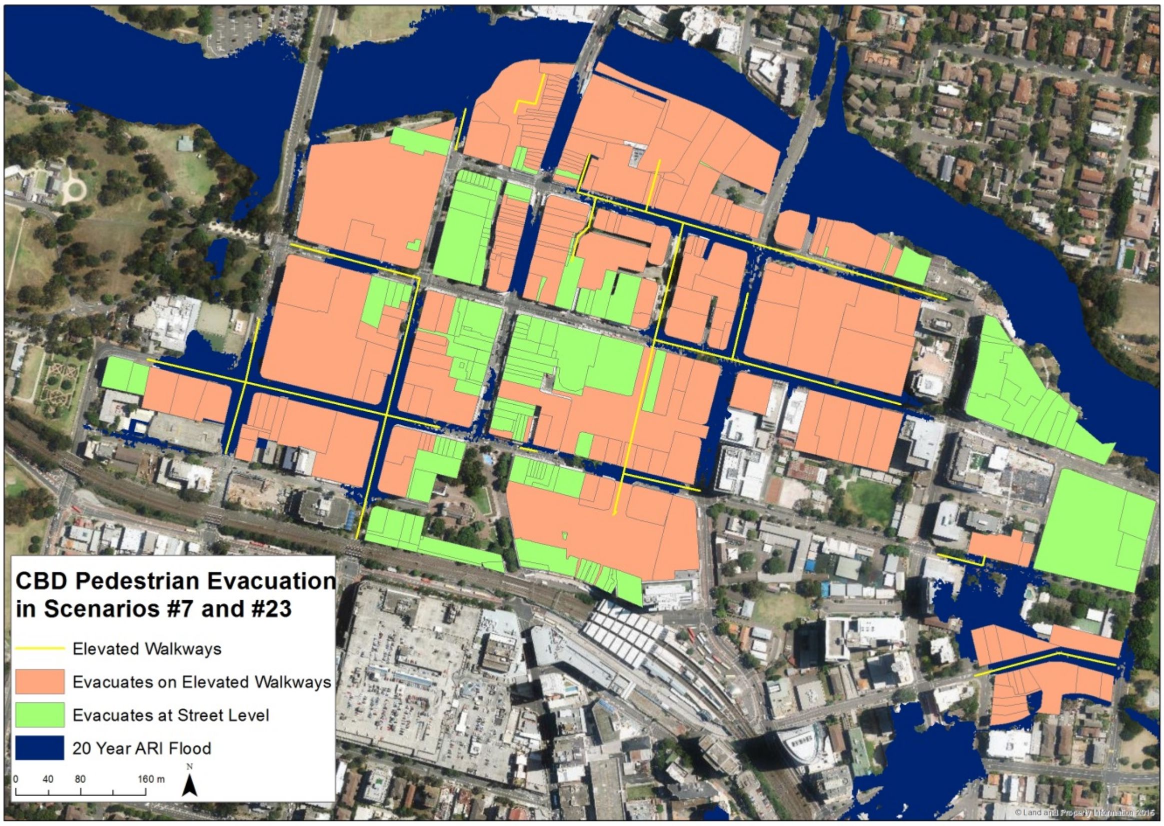

Figure 18: Pedestrian evacuation of the CBD in Scenarios 7 and 23.

4.4 SHELTER IN PLACE (SIP)

4.4.1 Risks of SIP

Shelter in Place (SIP), or vertical evacuation, is often considered a viable option in areas exposed to flash flooding, where there is not enough time for the population to evacuate safely. SIP as a possible flood emergency response strategy in Parramatta CBD is thoroughly discussed in Molino Stewart (2016). While SIP, where appropriate, is a policy requirement for new development, some existing sites may not be able to achieve this (e.g. heritage buildings). This issue is further discussed in Section 4.4.2.

The risks associated with SIP in Parramatta CBD could include:

- **No refuge above the floodwater:** the flooding reaches a peak higher than the highest accessible space in the building;
- **Structural failure:** the building used as a shelter cannot withstand the flood forces and may collapse;
- **Power supply:** the lack of power, which is likely to occur during a major flood, may make the SIP refuge unsafe or uncomfortable. People may decide to leave the building and walk though floodwaters;
- **Medical emergency:** evacuees taking shelter in place may require urgent medical assistance requiring hospital grade care, which would be difficult (and risky) to deliver because the building is isolated by floodwaters;
- **Fire emergencies:** building fires can be triggered during a flood by a short-circuit, or by human behaviour. For instance, evacuees taking shelter in place may use naked flames for improvised lighting or cooking. A building fire happening during a flood would be very difficult to manage, because the building could not be easily accessed by firefighters and it may not be safe to evacuate the building because it is surrounded by hazardous floodwaters;
- **Human behaviour:** evacuees taking shelter in place may decide to leave the building and walk through floodwaters for a number of reasons. For example, if the flood emergency occurs at the end of a working day (e.g. PM peak), workers may not like the idea of remaining in their offices. Similarly, evacuees may leave the building if they cannot communicate with their families, or if the refuge is not functional or safe enough.

Risks associated with SIP can be mitigated in a number of ways. These are summarised in Table 5. However it should be noted that SIP doesn’t directly solve the issue of where to put people in the public domain during a flood. This needs to be addressed as part of the overall response strategy by providing access to appropriate buildings.

As part of the work undertaken by Molino Stewart to support the update of Parramatta Floodplain Risk Management Plans (Molino Stewart, 2016), a zoning of the CBD was proposed based on the degree of risks associated with SIP. For each zone, Molino Stewart (2016) generated a set of development controls to reduce these risks. The risk zoning proposed by Molino Stewart is shown in Figure 19 (in which zone 4 has the highest risk, while zone 1 has the lowest). In Figure 20, each lot was allocated to the corresponding risk zone. All lots within zone 1 and 2 have street frontage which is at or above the 100 year ARI flood level. Existing buildings might not have an access currently on that frontage but the development controls would require at least emergency access to these lots at or above the 100 year ARI flood level.

Table 6 shows the proposed development controls for each risk zone, while Table 7 shows how the number of people in each risk zone is expected to change from year 2016 to year 2056 as a consequence of the implementation of the CBD Strategy.

It is noted that the majority of buildings, and therefore people, are in zones 1 and 2. The areas with highest risk (zones 3 and 4) are principally those affected by flooding from Clay Cliff Creek rather than the Parramatta River.

Table 5: Example of mitigation measures for risks associated with SIP

SIP Risks	Examples of Risk Mitigation Measure	Suggested Mechanism for Implementation
Inadequate Refuge	Habitable space above the reach of the PMF is accessible to all occupants	LEP
Structural Failure	Buildings able to withstand PMF forces	LEP
Power Supply	Backup power supply available in SIP refuge	DCP
Medical Emergencies	Managed high level evacuation or access system	DCP & DA
Fire Emergencies	Switchboards that automatically shut down when electrical circuits are in contact with water	DCP & DA
	Fire suppression equipment as required for residential high rise buildings including sprinkler systems	DCP
	Backup power supply above reach of the PMF	DCP
Human Behaviour	Safe, functional and flood-free shelter Managed high level evacuation or access system	DCP & DA

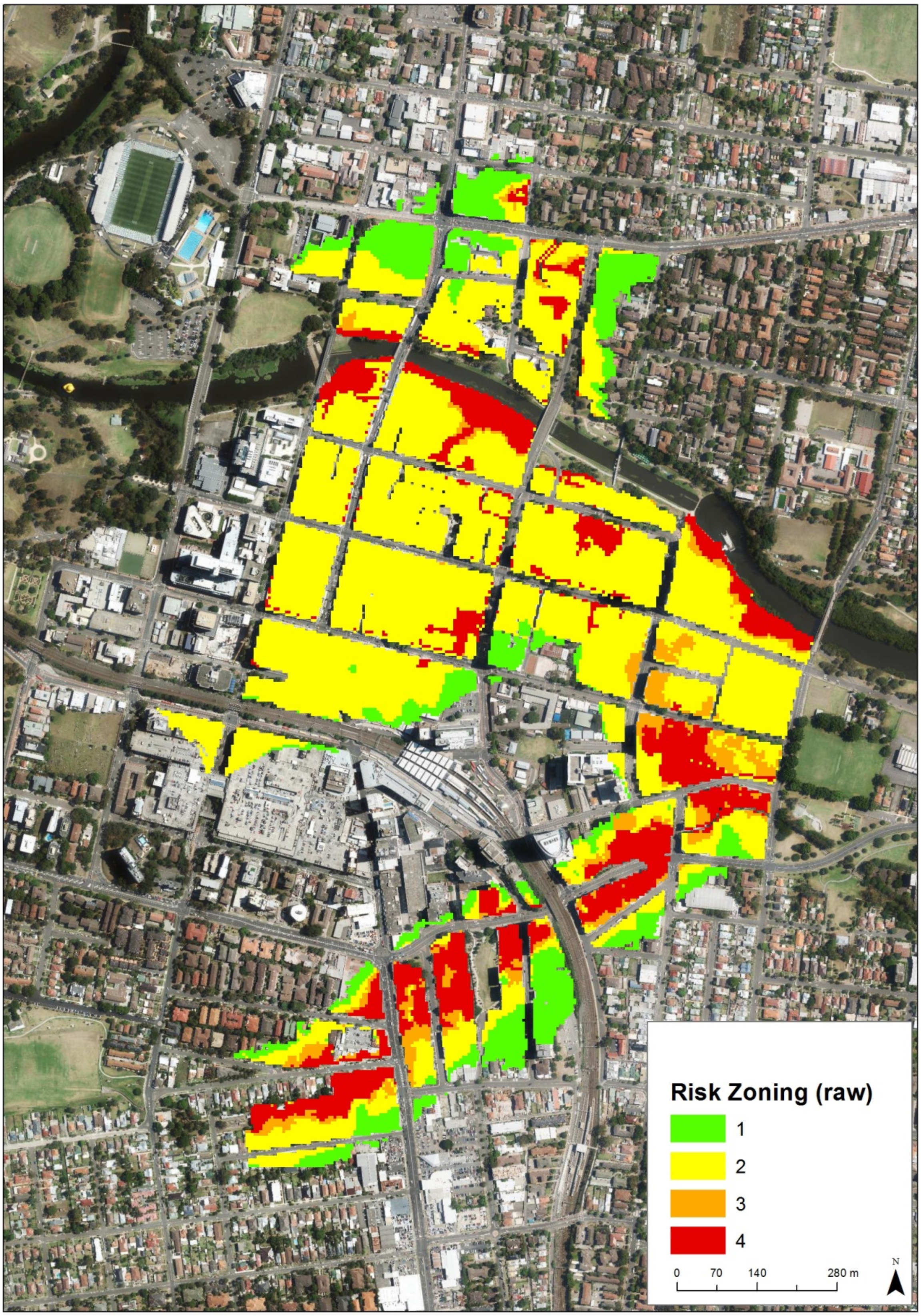

Figure 19: Risk Zoning (raw map) proposed by Molino Stewart (2016) to reduce risks of SIP through development controls. The western part of the study area is not zoned because not included in the scope of Molino Stewart (2016).

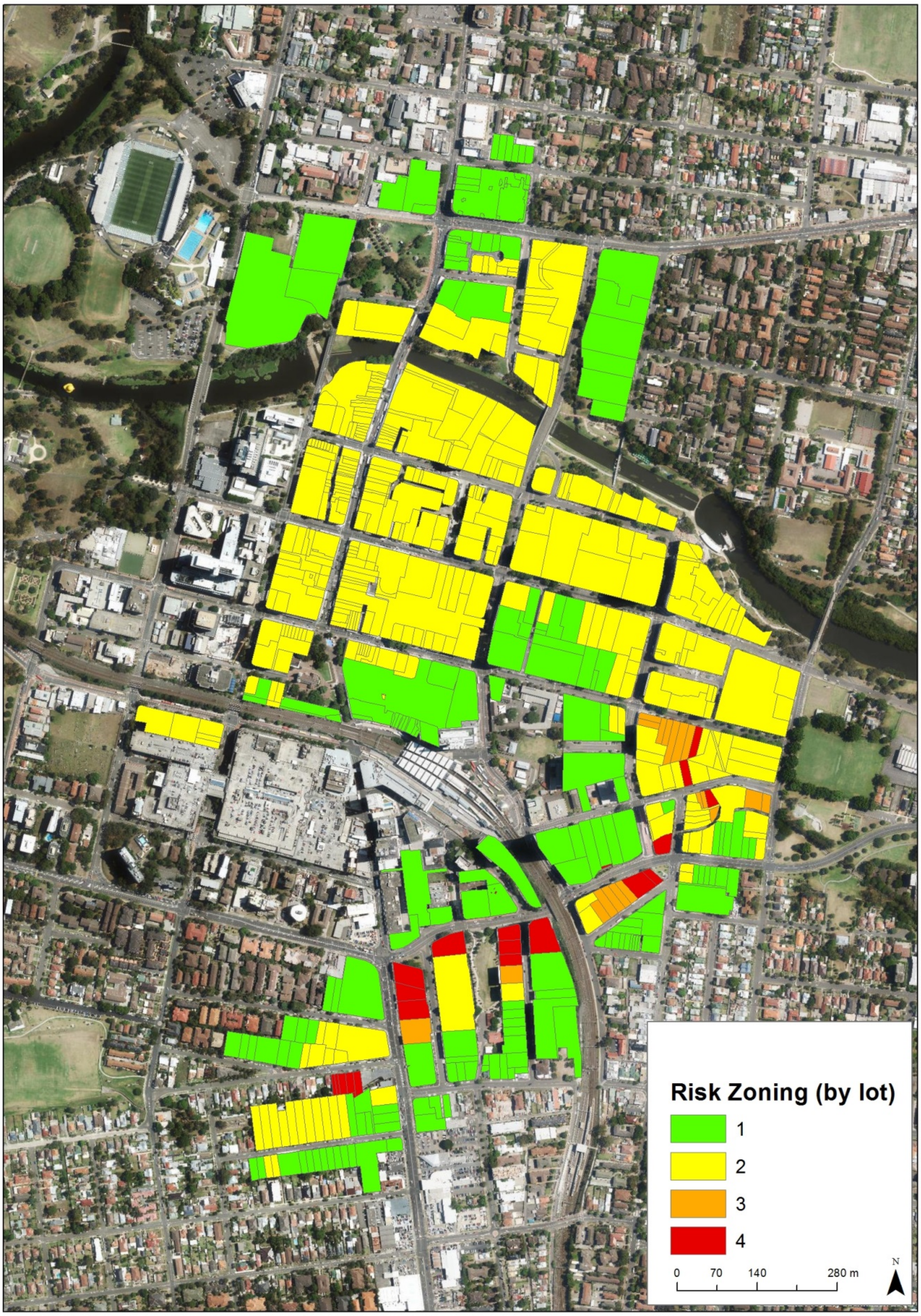

Figure 20: Risk Zoning (interpolated by lot) proposed by Molino Stewart (2016) to reduce risks of SIP through development controls. The western part of the study area is not zoned because it is not included in the scope of the Parramatta CBD Planning Proposal.

Table 6: Development controls to mitigate SIP risks proposed by Molino Stewart (2016)

Probability (AEP)	Existing Parramatta Development Control Plan 2011'		Recommended Amendments to the existing DCP	
	Existing Flood Risk Precinct	**Evacuation requirements for residential and commercial development**	**Risk Zone**	**Suggested Occupant Response**
< 1%	Low	3. 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 (residential only) 4. Applicant is to demonstrate the development is consistent with any relevant flood evacuation strategy or similar plan	1	Safe to evacuate or shelter in place. No evacuation controls required.
			2	Safe to evacuate early or shelter in place above PMF in accordance with a flood emergency response plan for the building.
< 5%	Medium	3. 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 4. Applicant is to demonstrate the development is consistent with any relevant flood evacuation strategy or similar plan 6. Adequate flood warning is available to allow safe and orderly evacuation without increased reliance upon SES and other authorised emergency services personnel	3	Evacuate early or shelter in place above PMF in accordance with a flood emergency response plan for the building providing flood free access is available to an exit through an area above the 1% flood level.
> 5%	High	As for medium flood risk precinct but only if development qualifies as concessional development	4	Evacuate early or shelter in place above PMF in accordance with a flood emergency response plan for the building providing flood free access is available to an exit through an area above the 1% flood level.

Table 7:Number of people in each risk zone.

Zone	Year	Residents	Workers	Visitors
1	**2016**	4,545 (45%)	12,947 (37%)	11,778 (45%)
	2036	9,239 (28%)	23,275 (37%)	16,670 (37%)
	2056	15,143 (30%)	26,991 (33%)	19,574 (33%)
2	**2016**	4,658 (47%)	21,468 (61%)	13,471 (51%)
	2036	21,858 (67%)	39,073 (62%)	27,985 (62%)
	2056	32,486 (64%)	51,920 (63%)	37,652 (63%)
3	**2016**	402 (4%)	244 (1%)	371 (1%)
	2036	837 (3%)	385 (1%)	275 (1%)
	2056	1,623 (3%)	1,083 (1%)	786 (1%)
4	**2016**	405 (4%)	272 (1%)	625 (2%)
	2036	859 (3%)	397 (1%)	284 (1%)
	2056	1,322 (3%)	1,832 (2%)	1,328 (2%)

4.4.2 Single-Storey Buildings

It should be noted that SIP is unsuitable in buildings that do not have a level above the PMF (e.g. single-storey buildings, or two storey buildings close to the river). All existing buildings less than 4.5m high are shown in Figure 21. These buildings are unlikely to be suitable for sheltering in place as they probably don't have a second storey and are too low to have direct access to an elevated walkway. This issue could be addressed as part of the CBD redevelopment, with single-storey buildings being redeveloped into multi storey buildings with appropriate features to manage the secondary risks of sheltering in place.

However, the problem remains for single-storey buildings that cannot be redeveloped, for example because they are heritage listed. For these buildings, a different flood response strategy needs to be put in place. These buildings are already at high risk from flooding, regardless of any future development of the CBD, because neither evacuation nor SIP are achievable.

An option for these buildings could be to Shelter In Place in neighbouring buildings that have a safe refuge above the PMF level (24h access to these buildings may need to be provided as part of the response strategy).

Figure 21 shows the location of heritage-listed buildings and buildings whose height is less than 4.5 metres. This shows that most of the single storey heritage listed buildings are in the risk zoning 1 or 2 which means they have access in the 1% AEP flood and some have flood free access. The two exceptions are a brick cottage near the corner of Wigram Street and Hassall Street which is in the Risk Zone 3 and a brick cottage in Lansdowne Street near the corner of Church Street which in is Risk Zone 4.

4.4.3 Existing Buildings Unable to Withstand the Forces of the PMF

SIP is not an option for buildings that do not have a safe refuge above the PMF levels. This includes existing buildings whose structure is not able to withstand the forces of the PMF. For these buildings, redevelopment offers a chance to reduce flood risk. However, until redevelopment can be undertaken, an alternative safe refuge above the PMF should be identified, for example in neighbouring buildings (24 hour access to these buildings may need to be provided as part of the response strategy).

4.4.4 Vulnerable Facilities

If the suggested SIP requirements are satisfied, vulnerable buildings such as hospitals, nursing homes, schools or childcare centres should put in place SIP emergency plans to ensure that all occupants are safely transferred to the refuge area before the peak of the flood is reached. The plan should also include measures to communicate with the families before, during and after the emergency to assure them that their loved ones are safe but also to discourage people trying to access the building through floodwaters.

Alternatively, some of these land uses may need to be prohibited where it is deemed any probability or duration of sheltering in place poses an unacceptable risk although this needs careful thought.

In the case of preschools it is possible to ensure that the children are not coming and going during a flood, but it is more difficult keeping parents from travelling through floodwaters to try and drop off or pick up children.

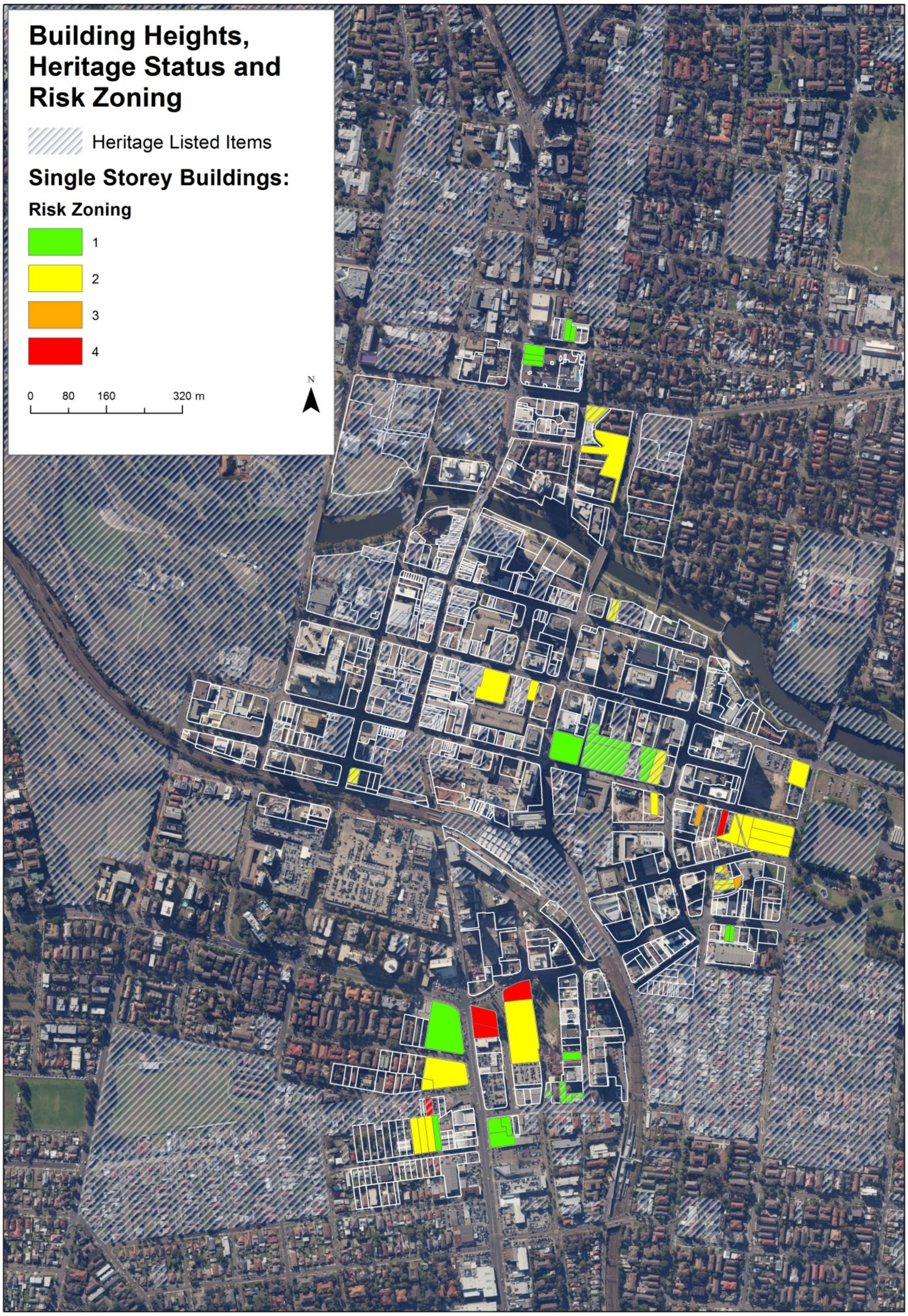

Figure 21: One-storey buildings and heritage listed buildings

4.4.5 SIP to Manage Residual Risk of Horizontal High Level Evacuation

SIP could also be used to manage residual risk in Pedestrian Evacuation Scenarios (HHL). For example, if it was decided to build a network of elevated walkways to cater for flood events up to the 20 year ARI, SIP could be used as the backup emergency response strategy for rarer floods.

4.4.6 Managed High-Level Evacuation/Access System

A substantial part of the risks of SIP, such as the risk of medical emergencies, could be addressed by implementing a "managed high-level evacuation or access system". This would entail the installation of a lightweight system of walkways with managed access to be used mainly by emergency responders. This option would also address a number of the key issues associated with HHL evacuation, namely:

- A suitable walkway width could be provided for emergency responder access, and evacuation of a limited number of people within the existing street pattern;
- Ramped access would not be required to be provided, as emergency personnel could evacuate individuals using specialist equipment/ stretchers where necessary;
- A lightweight single width (approx.1m) walkway could be provided, potentially utilising existing buildings and awnings, significantly reducing overshadowing and visual impact on the street;
- The length of proposed walkways could potentially be reduced by terminating the route at designated multi-storey car parks within the CBD suitable for helicopter access/ evacuation;
- By providing a lightweight, less visually obtrusive and secure walkway system that is only accessible by emergency responders, informal use of the walkways is minimised;
- Providing a lightweight route will enable the retention of more street trees;
- Providing a route that is managed by trained emergency responders enables temporary deployable structures, including bridges, to be utilised reducing the visual impact of the route and not permanently closing streets to high vehicles;
- Narrower and potentially shorter length of walkways, with no accessibility requirements, will keep construction and maintenance costs significantly lower.

Key issues for further investigation, should this option be progressed, include:

- Discussion of the suitability of the concept of a managed high level evacuation route with the NSW SES staff.
- Discussion of access requirements including walkway widths, steps, and ladders with the NSW SES.
- Discussion with Council and the NSW SES regarding ownership and maintenance of the system.
- Investigation of how building codes would apply to the proposal.
- More detailed design investigations of how the walkways would access buildings, the street, and be structurally supported.
- A visual impact study, once design parameters and the suitability of the proposal have been established demonstrating the effect of the proposals on views within the CBD.

5 SENSITIVITY TESTING

Since the original version of this report was prepared in 2017, there have been some changes in the study area which could potentially have some bearing on the results presented in the previous sections of this report.

This section describes those changes and provides an analysis of the extent to which these may affect the evacuation assessment results.

5.1 NEW WARNING SYSTEM

At the time of writing the original version of this report, in 2017, Council was in the process of developing a flood warning system for the Parramatta River. Since that time the system has been commissioned and used.

In Section 2.3 it was assumed that the warning system would be able to provide about two hours' notice. Council has since advised that two hours represents the maximum warning likely to be available in the extreme floods which would enter the CBD (C. Gooch pers comm).

It had also been assumed that the flood warnings would only be sent to the NSW SES and the NSW SES would then have to issue evacuation orders.

The Parramatta Floodsmart warning system, as eventually commissioned, not only sends flood warning messages to the NSW SES, but it also sends warning messages directly to members of the public who have subscribed to the service.

Floodsmart only issues flood warning information, not evacuation orders. Evacuation orders would still need to come from the NSW SES. Those who receive warnings directly from Floodsmart may choose to evacuate without receiving an order from the NSW SES. However, currently only 516 people have registered on Floodsmart which compares to the 30,000 flood affected properties across the entire catchment. Furthermore, many of the registrants are not in flood prone properties.

This means that, unless the number of Floodsmart's registrants increases significantly, it is unlikely to make a significant difference to the sequence of evacuation decisions and departures assumed in the original evacuation modelling.

5.2 DRAFT PLANNING PROPOSAL CHANGES

There have been some minor changes to the draft Parramatta CBD Planning Proposal within the areas affected by flooding.

5.2.1 Zonings

The draft zonings in the Parramatta CBD Planning Proposal, as endorsed by Council in April 2016 for the purpose of seeking a Gateway determination, and the draft zonings which are now proposed (as of June 2019) are identical (Figure 22)

However, at the time that the original version of this evacuation assessment report was being prepared, consideration was being given to a slight variation to the proposed zonings along the southern end of Church Street. These interim zonings, which were the basis of the evacuation calculations, are shown in Figure 23.

The location with the changes are circled in both figures. There are two lots which are zoned partly mixed use and partly commercial whereas during the evacuation analyses they were considered to be completely mixed use.

For the same floor surface area (FSA), commercial office space would have about 1.5 to 1.8 as many people as residential space. However, there would be a decrease in the number of vehicles in the building.

In the case of vehicles evacuating from these premises, they would evacuate onto the Great Western Highway. This is the most congested evacuation route and determines the maximum evacuation time from the CBD. The area of zoning difference is so small compared to all of the areas evacuating onto the Great Western Highway that the decrease in vehicle numbers would not make a significant difference to the evacuation time.

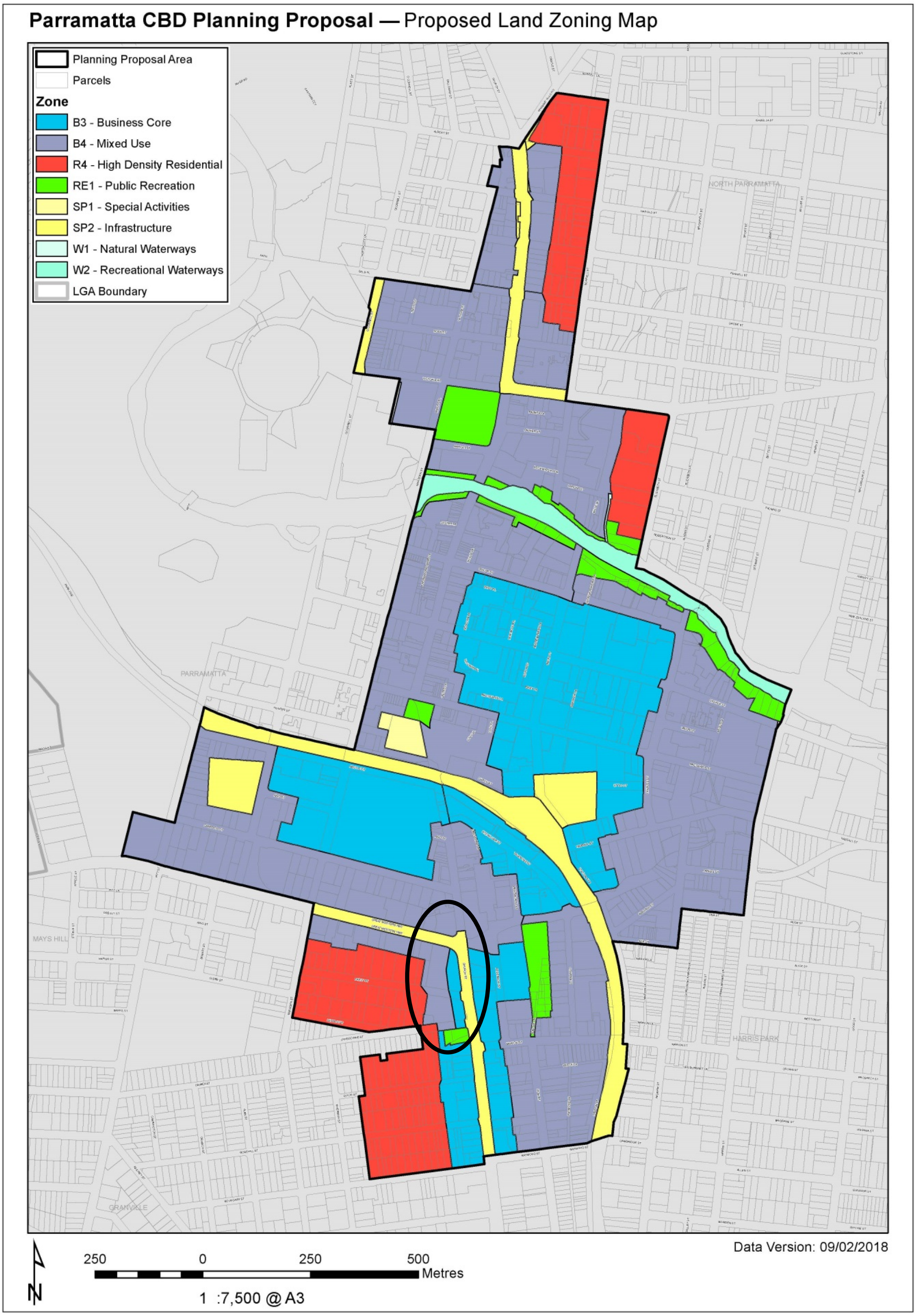

Figure 22: Current Draft Zonings

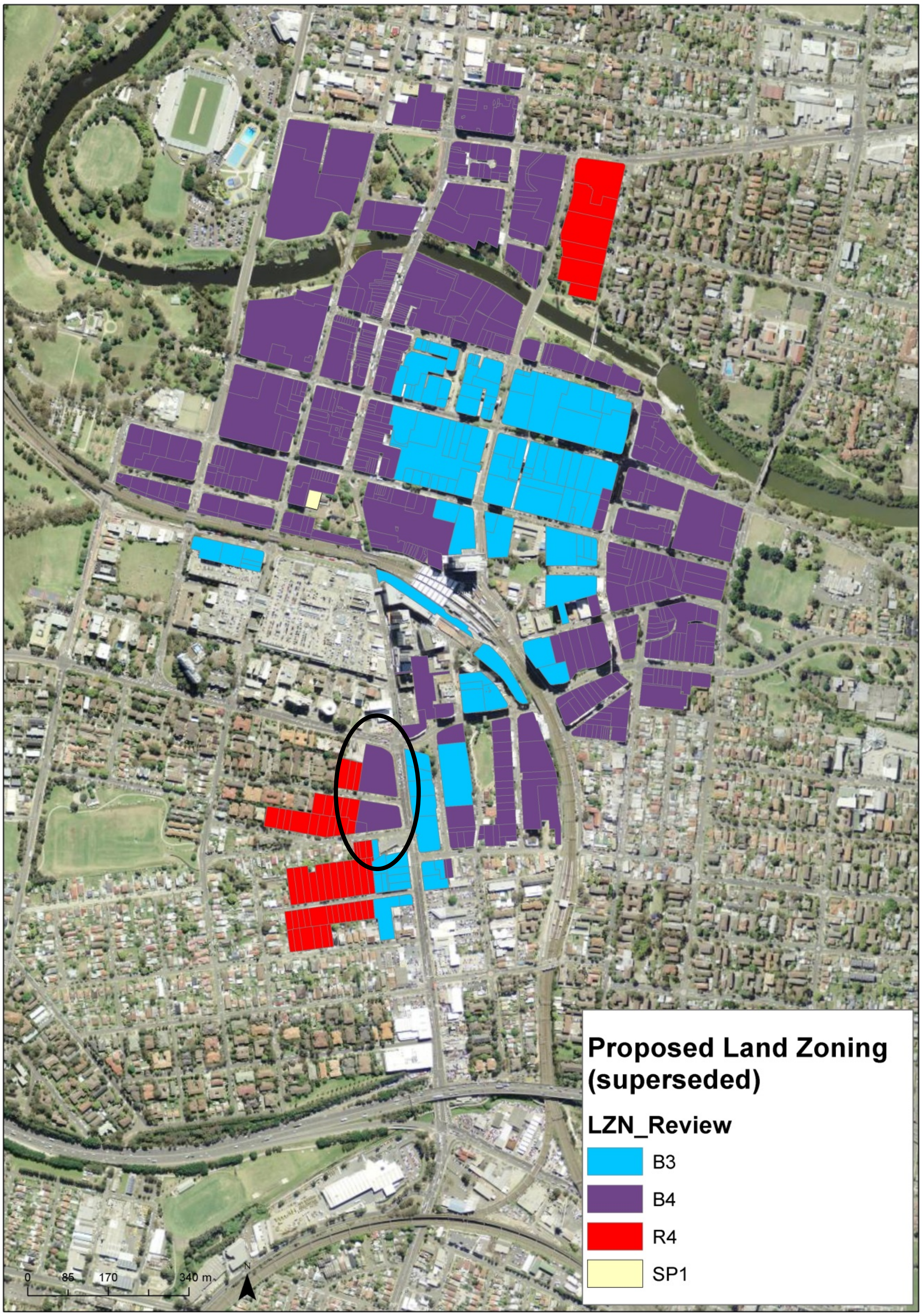

Figure 23: Interim Draft Zonings (used for evacuation calculations).

As far as pedestrian evacuation is concerned, these premises would evacuate north to seek refuge in a building of the scale and location of Westfield. There are only a few people evacuating from this area compared to those evacuating from the core of the CBD north of the railway line. It is the latter area which determines the minimum time for pedestrian evacuation. As such, a relatively small change in the number of people evacuating from Church Street will make no difference to the time needed to safely evacuate the whole of Parramatta CBD. It will have no impact on the cost of infrastructure because the same high level walkway will be required in this location irrespective of the scale of the development.

5.2.2 Floor Surface Area

There have been some substantial changes to floor space ratios (FSRs) and maximum building heights between the Parramatta CBD Planning Proposal as endorsed by Council in April 2016 and the current draft as at June 2019. These changes convert to changes in FSA, which underpinned the estimates of the number of vehicles and pedestrians who would need to evacuate in each future scenario. They have no impact on the Year 2016 evacuation estimates.

The FSRs and building heights which appeared in the April 2016 draft of the Planning Proposal were not the ones used to estimate FSAs and vehicle and pedestrian numbers for the evacuation analyses.

Firstly, all of the sites which had redevelopment approval or commencement since the draft planning proposal exhibition, were assigned actual FSAs in accordance with their planning approval or development approval on the assumption that these would not be redeveloped again within the next 40 years. For the residual properties the incentive FSRs were used because these represented the maximum development possible on each site.

Therefore to determine how changes to FSRs in the revised planning proposal affect the evacuation analyses, the redevelopable lots used in the evacuation analysis (Figure 24) need to be compared with the current planning proposal incentive FSRs (Figure 25).

The following section discusses the changes and the impact they would have on the evacuation analyses. The locations of the changes are highlighted in Figure 24.

a) Cnr Villiers St and Victoria Rd

The site on this corner would evacuate north onto Pennant Hills Road and has had its Incentive FSR reduced from 6.0 to 4.8, which equates to fewer vehicles and pedestrians evacuating from this block if fully redeveloped in the future. This is a relatively small reduction in FSR for a site which is only a small part of the area evacuating along this route.

This route is not a constraint to the vehicle evacuation analysis and is only part of the PMF pedestrian evacuation analysis.

The small changes in FSR for a minor contributor to evacuation in this area would not make a significant difference to the results and conclusions.

b) Between Lamont St and the River

This block has had its Incentive FSR reduced from 6.0 to 5.2. It is one of many blocks which evacuate to Pennant Hills Road. As with the block on the corner of Villiers Street and Victoria Road, the small change in the FSR of a block which makes a small contribution to one of the smaller evacuation flows is not going to make a significant difference to the evacuation analyses.

c) Between Argus St and Harris St

This block was assumed to have an Incentive FSR of 7.2 in the evacuation analyses but had an Incentive FSR of 10.0 in the current draft as at June 2019. This block evacuates onto the Great Western Highway, although its vehicle evacuation routes get cut early in the flooding.

It is only a small contributor to the evacuation traffic onto the Great Western Highway. However, this is the route which has the most traffic and therefore this increase in FSR would only make vehicular evacuation harder to achieve.

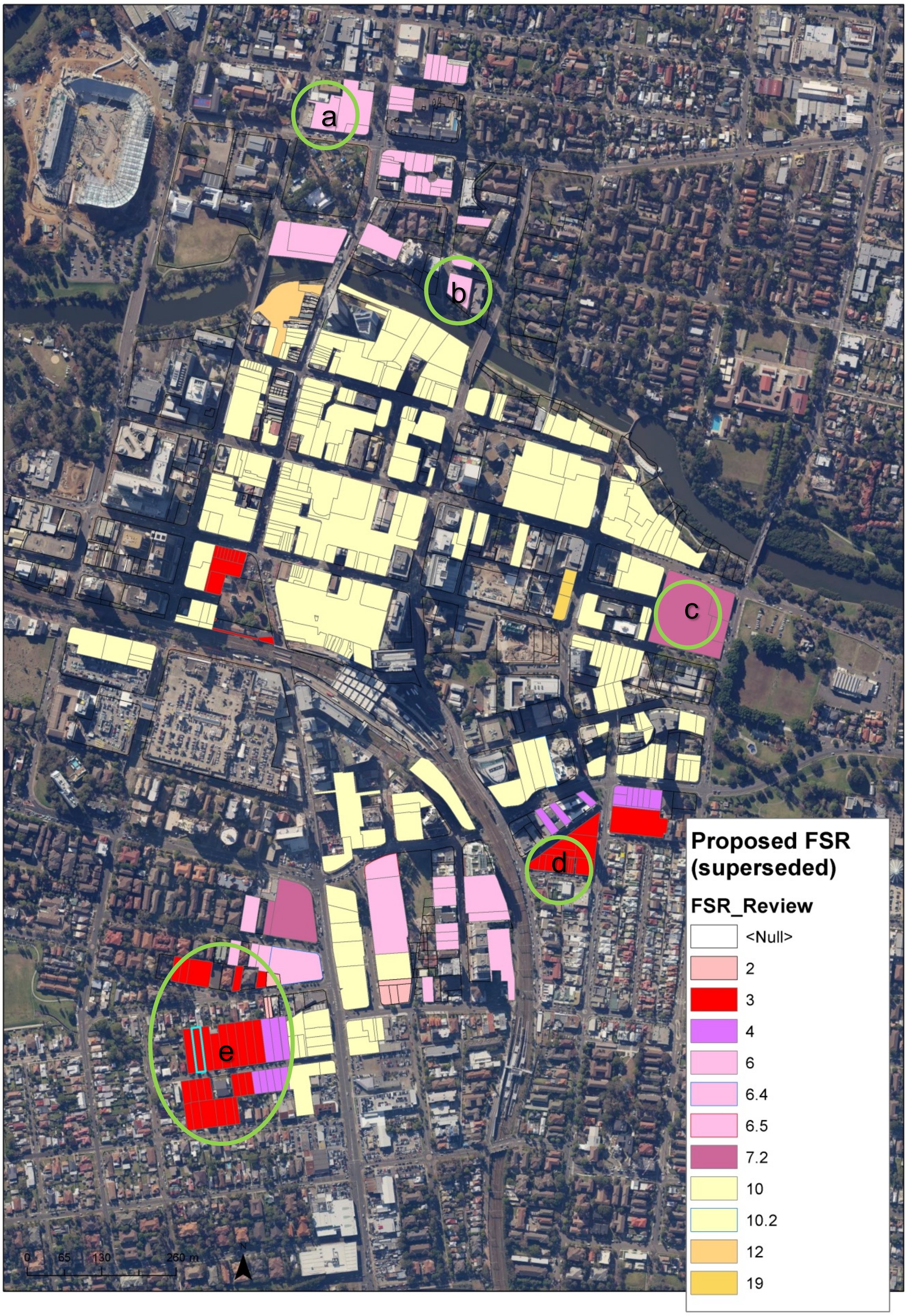

Figure 24: FSRs of Redevelopable Lots used in Evacuation Analyses

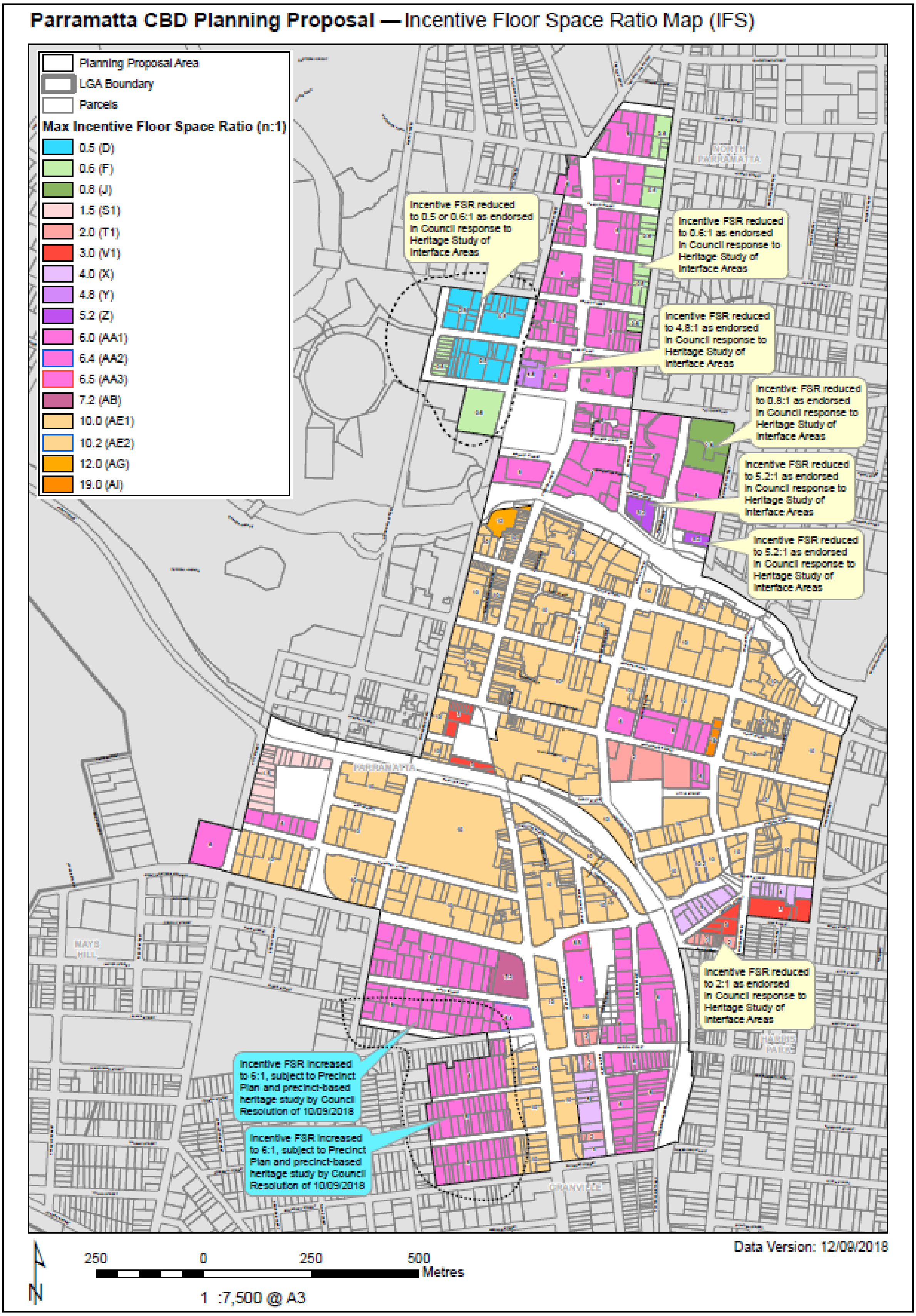

Figure 25: Incentive FSRs in 2019 Draft Planning Proposal

It would not increase the cost of elevated pedestrian infrastructure but would increase the number of people using it.

d) Ada St

There is a strip of properties along this street which have had their Incentive FSR reduced from 3 to 2. While this is a significant percentage reduction in the FSRs for these particular properties, these are a small part of the area which evacuates to Harris Street which itself is the second smallest evacuation precinct.

The changes here would not make a significant difference to the results and conclusions.

e) Lansdowne St and Dixon St

In this area the Incentive FSR is proposed to increase from 3.0 to 6.0, therefore doubling the number of vehicles and people needing to evacuate from these properties.

The few which are affected on the North of Lansdowne Street would evacuate by vehicle to the Great Western Highway and cause an extremely small increase on the route which takes the longest time to evacuate.

The rest of the properties would evacuate to Church Street and head south. Their contribution to this traffic stream would be more noticeable than that of their neighbours because Church Street would not have to accommodate as many evacuees as the Great Western Highway. Nevertheless, this traffic stream would take less than 40% of the total time that the Great Western Highway takes to evacuate so the changes in Church Street evacuation times would not make a difference to previous conclusions about the viability of vehicular evacuation.

These increases would not affect the quantum of elevated pedestrian evacuation infrastructure, just the number of people using it. The increase in the time taken would be small compared to the total time taken to evacuate the CBD core which the most critical to evacuating the viability of pedestrian evacuation as an option.

There would be a significant increase in the number of people needing to shelter in place in this street if that were the adopted response option.

5.1 SUMMARY OF SENSITIVITY ANALYSES RESULTS

Overall, the sensitivity analyses indicated that:

- The new flood warning system does not affect the assumptions of the evacuation modelling exercise
- The updated planning proposal causes only very minor differences in the numbers of people and vehicles evacuating. Where there are decreases it is in the least critical areas. The Great Western Highway, which is most critical for vehicular evacuation, will have more traffic directed to it

6 CONCLUSIONS

Based on the results produced in this work, the following conclusions can be drawn:

- Under the assumptions of the NSW SES Timeline Evacuation Model, HSL vehicular evacuation would take between 8 and 11 hours (depending on year and flood event). It should be noted that the flood warning lead time for Parramatta CBD is about two hours before the peak of any probability event is reached, and that the PMF would reach its peak level in about 5 hours from the beginning of the rainfall.
- In addition to this, the NSW SES assumes a time lag of at least two hours between when the evacuation order is communicated to the population and when the evacuation actually begins. Under this assumption, safe vehicular evacuation would not be realistically achievable under any circumstances.
- HHL pedestrian evacuation would take between 4.5 and 11 hours, and would be generally faster than HSL vehicular evacuation. Still, the pedestrian evacuation time would be of the same order of magnitude as the flood duration. This means that by the time evacuees have reached the designated refuge through the elevated walkways, most likely queuing under intense rain, floodwaters may have already receded.
- A specific urban design analysis, which was undertaken as part of this project, demonstrated that the infrastructure required to allow high-level evacuation (i.e. a network of elevated walkways) would have a cost ranging between $94.5 million and $324 million, depending on the size of the flood event these would need to cater for.
- The elevated walkways would also have very significant impacts on the urban landscape in terms of visual disturbance, overshadowing, removal of urban trees, impacts on heritage buildings, capability of large vehicles to access the CBD, maintenance costs and safety.
- A suitable alternative to evacuation would be for the population to Shelter In Place (SIP) and wait until the floodwaters have receded. SIP would be particularly appropriate in Parramatta CBD due to the type of the development (i.e. most buildings are multi-storey), and to the flashing nature of the flooding which would not allow enough time to evacuate safely.
- SIP could expose people to a number of secondary risks to life, including (but not limited to) those arising from: building structural failure, medical emergencies, building fires or people deciding to leave the shelter and walk through floodwaters These risks would need to be managed. This project, as well as the work by Molino Stewart (2016) suggested a number of achievable risk reduction measures through development controls.
- Furthermore, SIP is not an option for buildings that do not have a shelter above the PMF level (e.g. some of the one-storey buildings), and that do not possess the structural strength to withstand the PMF hydraulic forces (e.g. lightweight timber-frame buildings). However, occupants of these buildings are already exposed to the same level of flood risk, because this study has demonstrated that evacuation of Parramatta CBD is not achievable within the available time. If SIP were deemed the preferred emergency response strategy, measures would need to be put in place to allow the occupants of these buildings to access a suitable refuge in neighbouring, appropriate structures. In the future, redeveloping these buildings will provide an opportunity to reduce their flood risk.
- SIP risks could also be reduced through a “managed high-level

evacuation/access system". This would entail the installation of a network of light-weight elevated walkways to facilitate access of emergency responders to isolated buildings and/or allow evacuation of a small number of people (e.g. those requiring medical attention).

- In addition to these risks, SIP does not directly address the issue of people that are in the public domain when floodwaters begin to rise. The overall response strategy needs to address this issue, for example identifying suitable refuge above the PMF level within buildings that (a) can withstand PMF forces, and (b) can be accessed by the general public at any time of the day.

The analysis included also an assessment of the combined use of some evacuation types. Results showed that:

- Combining HSL (vehicular) and HHL (pedestrian) evacuation types would not provide significant advantages over fully pedestrian HHL evacuation types;
- If the elevated walkways network was designed to cater only for smaller events (i.e. the 20 year ARI), the residual risk associated with larger low-probability events could be managed using SIP.

Based on the results obtained, the following response options may be suitable:

- Mandatory evacuation. This option could theoretically apply to either vehicular (street-level) or pedestrian (high-level) evacuation, although safe vehicular evacuation is likely to be unachievable.
- Optional Evacuation/SIP. This option would leave the decision to evacuate or SIP to the evacuees. Because of the high risks associated with vehicular evacuation, this option is only recommended for high-level pedestrian evacuation (HHL). It should be noted that the use of elevated walkways would in fact eliminate the risk of buildings being isolated by floodwaters, because the occupants would have a safe way out at any time. As a consequence, occupants could either evacuate or remain in their buildings (if these are equipped with a refuge above the flood level and all SIP risks are managed appropriately).
- Mandatory SIP. This option would be required if no elevated pedestrian evacuation routes were available, and would require appropriate development controls to manage all risks associated with SIP.

Results of this study should be interpreted in conjunction with the assumptions made to obtain the evacuation model input data. Please refer to Appendix A for a detailed description of these assumptions.

The sensitivity analysis undertaken using new information which has become available since the completion of the original report does not alter the abovementioned conclusions. . In fact, it suggests that, overall, vehicular evacuation may be slightly more difficult to achieve than originally thought. These should be re-examined when the new Upper Parramatta Flood Study results become available.

7 RECOMMENDED STRATEGY

The identification of the most suitable flood emergency response strategy in Parramatta CBD is a complex exercise, because it depends on the assessment of each alternative's performance against multiple evaluation criteria.

These types of problems involve subjective evaluations and can be simplified using an approach based on Multi-Criteria Analysis (MCA). The main strengths of MCA are that it:

- Provides a structure for decision making while still allowing flexibility and is particularly useful for complex problems;
- Follows naturally from the way people tend to approach problems with multiple objectives;
- Has flexible data requirements;
- Allows information that is agreed upon by all parties to be distinguished from areas of contention;
- Is amenable to sensitivity analysis;
- Does not require assignment of monetary value to all quantities;

The use of MCA allowed us to rank the evacuation strategies in a way that takes account of different evaluation criteria. Each criterion was selected to evaluate the key issues to be addressed by the evacuation strategy, which are discussed throughout this report. The evaluation criteria used in the MCA exercise were:

- The strategy effectiveness, in terms of capability to reduce the risk of casualties during a flood. This is determined by the probability that evacuees have to reach a suitable flood-free area timely and safely, i.e. without any risk of contact with floodwaters. This was assessed using state of the art evacuation models (Section 2.3);
- The difficulty of implementation of the strategy, arising from setting-up the appropriate response infrastructure (e.g. elevated walkways) and from the logistics of the response. For instance, it may be difficult to communicate to the population a very complex evacuation plan in which some of the evacuees use elevated walkways, and some do not. Similarly, it may be difficult to communicate to the population that they should evacuate on elevated walkways in events smaller than the 20 year ARI event, but take shelter in place for bigger events;
- The risks associated with the strategy and the extent to which these can be reduced. This accounts for any risks associated with not being able to evacuate in a timely manner, or risks of SIP (Section 4.4);
- The impacts on the urban environment (i.e. due to the construction of elevated walkways);
- The cost of implementation and maintenance of the strategy;
- The load on emergency services, in terms of the support required from emergency services to support the strategy (e.g. communication of evacuation order, management of traffic, search and rescue).

The alternatives that were assessed against the evaluation criteria were:

- Vehicular Evacuation;
- Shelter in Place;
- Horizontal High-Level (HHL) Pedestrian Evacuation up to the PMF;
- Horizontal High-Level (HHL) Pedestrian Evacuation up to the 20 year ARI, and SIP for larger events;
- Horizontal High-Level (HHL) Pedestrian Evacuation up to the 100 year ARI, and SIP for larger events;

The multi-criteria assessment is summarised in Appendix E.

Under the assumption that all selection criteria have the same weight, results show that the preferable response option is Shelter In Place (overall score = 22/30), followed by HHL Pedestrian Evacuation up to the 20 year ARI, and SIP for larger events (overall score of 18/30).

SIP scores are relatively low under the following two selection criteria:

- Residual Risk, and
- Load on emergency services.

These scores could be improved by implementing a “managed light weight high-level access system” (Section 4.4.6), which would allow emergency managers to access dwellings requiring urgent assistance and/or to evacuate people who cannot remain in the SIP refuge (e.g. medical emergencies).

It should be noted that his type of system would have a cost of installation/maintenance and would cause a moderate impact on the CBD urban landscape. However, both these adverse effects would be smaller than in the case of a full-sized network of elevated walkways. As such, we recommend that further studies assess in detail the risks, costs and benefits associated with a lightweight managed high-level access system, paired with a SIP policy. Specifically, the issues to be addressed include: access requirements, ownership and maintenance of the system, implications for building codes, detailed structural design and management of visual impact.

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APPENDIX A - ASSUMPTIONS

Evacuation Model Assumptions

Assumption	Description	Notes
1: Warning Time	A minimum two hours lead time is provided by the flood warning system before any size event is reached	At the time this study was undertaken, the City of Parramatta Council was developing a flood warning system for the CBD. Preliminary results suggested that a warning time of two hours should be used for the purpose of the evacuation assessment
2: Time lag between warning and response	After an evacuation order is communicated to the population, a minimum delay of two hours is to be expected before the evacuation begins	This is based on the assumptions underlying the NSW Timeline Evacuation Model. This delay, or "lag", is due to two factors: • The Warning Acceptance Factor (WAF), defined as the time required by a member of the public to acknowledge the evacuation order and accept that it applies to them; and • The Warning Lag Factor (WLF), defined as the time required by members of the public to get organised for the evacuation and leave their houses. The NSW SES assumes that the WAF and the WLF will require one hour of time each.
3: Time available in vehicular evacuation scenarios	Evacuation routes are not be cut by floodwaters before vehicular evacuation is completed	Vehicular evacuation, which is herein referred to as "Horizontal Street Level (HSL)", was modelled under the assumption that evacuation routes would not be cut by floodwaters before the evacuation is completed. In other words, vehicular evacuation was considered an "early evacuation option".
4: Evacuees without access to a vehicle	In a vehicular evacuation scenario, people with no access to a car are able to evacuate on foot in a time shorter than the time needed to complete the vehicular evacuation	Evacuees that do not have access to a car would be able to evacuate on foot in a time shorter than the time needed to complete the vehicular evacuation, therefore not impacting on the total evacuation time. This assumption is consistent with the time it would take for a pedestrian to walk from a location adjacent to the river to the nearest land above the reach of the PMF.
5: Vehicular Evacuation Model	• Lane Capacity: 600 cars per lane per hour; • Queue length per car: 6m; • Warning Acceptance Factor: 1 hour; • Warning Lag Factor: 1 hour; • Traffic Safety Factor: 1-3.5 hours depending on the duration of evacuation	These are the NSW SES recommended parameters for the NSW Timeline Evacuation Model, which is the model adopted in this study to simulate vehicular evacuation.
6: Vehicular Evacuation Precincts	Vehicles move away from rivers and creeks; Vehicles would move according to one-way roads	Each building was allocated to an evacuation route by: • Locating each building's driveway; • Assuming that, upon exiting each driveway, vehicles would move away from Parramatta River, Clay Cliff Creek or Brickfield Creek;

		• Assuming that traffic would move according to normal traffic flow direction on roads including one-way roads.
7: Buildings that need to evacuate	Buildings that are "touched" or isolated by floodwaters will need to be evacuated	This may overestimate the number of vehicles or pedestrians who need to evacuate because the extent of flooding in some of these buildings may not be sufficient to require them to be evacuated.
8: Elevated Walkways	In events up to a 20 year ARI, evacuees would be able to reach the elevated walkways using communal stairs and ramps accessible from street level, while in larger events a dedicated building-by-building access would be necessary	In a 20 year ARI flood there would be a relatively small amount of water ponding in the streets when the evacuation begins. This would allow evacuees t reach the access to the elevated walkways (stairs and ramps) from street level. In larger events, the local flooding would have a larger extent and direct access to the elevated walkways would be necessary
9: Pedestrian Evacuation Precincts	Defined based on the narrower bottleneck along the designated evacuation route	Buildings sharing the same bottleneck are assigned to the same pedestrian evacuation precinct. For elevated walkways, the bottleneck is at the end of the walkway. For on street pedestrian evacuation, the bottleneck is the last road before reaching the evacuation refuge.
10: Pedestrian Evacuation Dynamics	Walking speed: 700metres per hours Density: two people per square metre Effective width of elevated walkways: 2m only are used by evacuees	Assumption based on literature (Seyfried et al., 2005)
11: Background Traffic	Vehicular evacuation is modelled under the assumption that there is no background traffic	In a real world day evacuation scenario, vehicular evacuation time would be significantly longer than the one obtained using the NSW Timeline Evacuation Model.
12: Extent of Elevated Walkways	Minimised to contain infrastructure cost and adverse impacts on the urban landscape	This results in the system of elevated walkways catering for the PMF having a larger number of egress points, and an overall smaller evacuation time. Shorter evacuation times in smaller flood events could be achieved by extending the network to increase the number of egress points.

Input data needed to calculate vehicular and pedestrian evacuation time and relevant codes. Each code is described in the following table.

Exit Road	2016	2036	2056
Number of Residents	A1	A2	A3
Number of Workers	B1	B2	B3
Number of Visitors	C1	C2	C3
Residential Car Spaces	D1	D2	D3
Commercial Car Spaces	E1	E2	E3
Visitor Car Spaces	F1	F2	F3

Description of the assumptions made to obtain the input data

Code	Description
A1	**Number of Residents, 2016.** It was agreed with Council that the existing number of residents in each lot could not be obtained by applying current development controls, because these are based on the existing residential FSA, whose exact value is not known to Council (although an approximate estimate is available). Instead, the existing number of residents in each Travel Zone within the study area was extracted from the NSW Bureau of Transport Statistics website. This figure was then allocated to individual lots according the ratio between the lot's estimated existing residential FSA and the total estimated existing residential FSA in the Travel Zone.
A2	**Number of Residents, 2036.** The number of residents in 2036 was obtained by summing the 2016 number of residents and the additional number of residents expected from 2016 to 2036. The number of residents in 2016 was adjusted to account for any change of land zoning from 2016 to 2036. The additional number of residents (from 2016 to 2036) was obtained by applying the development controls to the additional residential FSA for year 2036. Namely: Additional residents = 2.31 per dwelling Number of additional dwellings = [(2/3)*(additional residential FSA)]/100

Code	Description
	Finally, the number obtained was reduced by a factor of 0.75 to account for the expected residential take-up rate from 2016 to 2036.
A3	**Number of Residents, 2056.** The number of residents in 2056 was obtained by summing the 2016 number of residents and the additional number of residents expected from 2016 to 2056. The number of residents in 2016 was adjusted to account for any change of land zoning from 2016 to 2056. The additional number of residents (from 2016 to 2056) was obtained by applying the CBD Strategy development controls to the additional residential FSA for year 2056. Namely: Additional residents = 2.31 per dwelling Number of additional dwellings = [(2/3)*(additional residential FSA)]/100
B1	**Number of Workers, 2016.** It was agreed with Council that the existing number of workers in each lot could not be obtained by using current development controls, because these are based on the existing commercial FSA in each lot, whose exact value is not known to Council (although an approximate estimate is available). Instead, the existing number of workers in each Travel Zone within the study area was extracted from the NSW Bureau of Transport Statistics website. This figure was then allocated to individual lots according to the ratio between the lot's estimated existing commercial FSA and the total commercial FSA in the Travel Zone.
B2	**Number of Workers, 2036.** The number of workers in 2036 was obtained by summing the 2016 number of workers and the additional number of workers expected from 2016 to 2036. The number of workers in 2016 was adjusted to account for any change of land zoning from 2016 to 2036. The additional number of workers (from 2016 to 2036) was obtained by applying the CBD Strategy development controls to the additional commercial FSA for year 2036. Namely: Number of additional workers = [(2/3)*(additional commercial FSA)]/24 Finally, the number obtained was reduced by a factor of 0.65 to account for the expected commercial take-up rate from 2016 to 2036.
B3	**Number of Workers, 2056.** The number of workers in 2056 was obtained by summing the 2016 number of workers and the additional number of workers expected from 2016 to 2056. The number of workers in 2016 was adjusted to account for any change of land zoning from 2016 to 2056. The additional number of workers (from 2016 to 2056) was obtained by applying the CBD Strategy development controls to the additional commercial FSA for year 2056. Namely:

Code	Description
	Number of additional workers = [(2/3)*(additional commercial FSA)]/24
C1	**Number of Visitors, 2016.** The number of visitors in 2016 was deducted from the number of daily Opal tap offs at Parramatta CBD train and bus stations. Namely, it was assumed that the average number of Opal tap offs between 5am and 12pm includes part of the daily visitors and all workers travelling to the CBD by public transport. The number of workers was then calculated by taking 37% of the total number of workers (obtained as described at point B1), based on the mode share estimate provided by the City of Parramatta CBD Strategic Transport Study (AECOM, 2016). The number of visitors arriving between 9am and 12am was then obtained by subtracting 37% of the total workers from the number of Opal tap offs between 5am and 12pm, under the assumptions that visitors would start arriving at 9am. This was divided by 3 (i.e. the number of hours between 9am and 12pm) to obtain the number of visitors arriving every hour. The result was then multiplied by 6 to obtain the number of visitors arriving (by public transport) over a 9 hour-long day, assuming that visitors would remain in the CBD on average for 3 hours, and that no visitors would be arriving after the 6th hour. The figure obtained was then assumed to correspond to 11% of the total number of visitors travelling daily to the CBD, based on the mode share for household trips in the West Central Region proposed by the 2012/2013 Household Travel Survey Report (BTS, 2014). The maximum number of visitors in the CBD <u>at any one time</u> was finally obtained by dividing the daily total number of visitors by 3, based on the assumption that each visitor would remain in the CBD for 3 hours, over a 9-hour long day. Based on guidance provided by the City of Parramatta Council, it was then assumed that 45% of these visitors would be within the Westfield building. The remaining 55% was allocated to each lot according to the lot's commercial FSA. This was based on the assumption that most visitors travel to Parramatta CBD for shopping/commercial/business purpose.
C2 and C3	**Number of Visitors, 2036 and 2056.** The number of visitors in 2036 (and 2056) was obtained from the number of visitors in 2016, assuming that these would increase at the same rate of workers from 2016 to 2036 (and 2056). This was based on the assumption that most visitors travel to Parramatta CBD for shopping/commercial/business purpose. The number obtained was then adjusted to account for the additional number of visitors (i.e. 1 million extra visitors per year) that from year 2022 are expected to travel to the CBD to visit the new Museum of Applied Arts and Sciences (MAAS), as estimated by PWC (2016), in "Parramatta 2021: Unlocking the potential of a new economy".
D1 and E1	**Number of Residential and Commercial Car Spaces, 2016** <u>Private Residential and Commercial Car Spaces</u> A reliable count of the number of existing private car spaces in the CBD is provided by AECOM (2017), in "Technical Paper 03: Parking Review". This number was obtained on

Code	Description
	a block-by-block basis via a survey recently undertaken by the City of Parramatta Council. The document however does not differentiate between commercial and residential car spaces, and does not go down to the scale of individual lots. The figures provided by AECOM (2017) were therefore modified as follows: • Allocated to each cadastre lot within the relevant block, and • Split between residential and commercial car spaces. This was achieved by: 1. Calculating the <u>estimated</u> number of residential and commercial car spaces in each lot based on current development controls. These are: a. For residential car spaces: one space per dwelling. The City of Parramatta Council assumes an average of 2.38 residents per dwelling (in 2016). The estimated number of residential car spaces per lot was then calculated as = (number of residents in the lot)/2.38. b. For commercial car spaces: 1 space every 100 sq.m. of commercial FSA. Commercial FSA values for 2016 were available for each lot, however it was agreed with Council that this value was not reliable for year 2016. A reliable value of commercial FSA was then obtained from the number of workers in each lot, using the assumption that there is 1 worker every 24 sq.m. of "effective" commercial FSA. Council assumes that the "effective" portion of commercial FSA is 2/3. This resulted in the following equation: (Estimated commercial car spaces in 2016) = 0.36 * (number of workers in 2016) 2. It was then observed that the estimated number of car spaces (residential and commercial) obtained as described at point 1 exceeded the availability of car spaces in each block surveyed by AECOM (2017). Council advised that this is due to previous development controls that would have applied to the older buildings of the CBD when these were originally constructed. To overcome this discrepancy, the number of residential and commercial car spaces in each lot calculated at point 1 was "scaled down" using to the ratio between the estimated number of car spaces within each block (obtained as described at point 1) and the actual number of car spaces within each block (obtained from AECOM, 2017). <u>Public Commercial Car Spaces</u> The City of Parramatta Council provided an estimate of the average number of car spaces used by workers in each of the publicly accessible car parks within the CBD. These are: • Wentworth Street (1,163 car spaces): 80% allocated to commercial use • Horwood Place (558 car spaces):40% allocated to commercial use • Riverside (805 car spaces): 40% allocated to commercial use It should be noted that Westfield is omitted on purpose because not significantly affected by flooding.

Code	Description
D2 and D3	**Number of Residential Car Spaces, 2036 and 2056** Based on guidance from the City of Parramatta Council, it was assumed that in 2036 (and 2056) there will be 0.28 additional residential car spaces per additional resident. The number of residents in each lot was adjusted to account for any change of land zoning from 2016 to 2036 (and to 2056).
E2 and E3	**Number of Commercial Car Spaces, 2036 and 2056** The total number of commercial car spaces in 2036 (and 2056) was obtained by applying the new development controls. These allow one commercial car space every 50 sq.m. of commercial site area. The new controls were applied to the whole CBD but in the Western Corridor, which is not included in the Planning Proposal. For this area the existing development controls were used (i.e. 1 commercial car space every 100 sq.m. of commercial FSA). It was also assumed that the number of commercial car spaces in publicly accessible car parks within the CBD would not change in future scenarios.
F1	**Number of Visitors Car Spaces, 2016.** Based on guidance from the City of Parramatta Council, it was assumed that the car spaces available to visitors would include: • All on-street car spaces • The remainder of the car spaces in the publicly-accessible car parks within the CBD, namely: ○ Wentworth Street (1,163 car spaces): 20% allocated to commercial use ○ Horwood Place (558 car spaces):60% allocated to commercial use ○ Riverside (805 car spaces): 60% allocated to commercial use It should be noted that Westfield is omitted on purpose because not significantly affected by flooding.
F2 and F3	**Number of Visitors Car Spaces, 2036 and 2056** Based on guidance from the City of Parramatta Council, this was assumed to be the same as in 2016.

APPENDIX B – EVACUATION MODELLING RESULTS

Scenario 1 – 2016_20yr_Midday_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	215	3	1	1	0.1	1	**3.1**
Great Western Hwy	8222	3	1	1	4.6	1.5	**8.1**
Harris St	132	1	1	1	0.2	1	**3.2**
Pennant Hills Rd	978	2	1	1	0.8	1	**3.8**
Victoria Rd	14	3	1	1	0	1	**3**

Scenario 2 - 2016_20yr_Midday_HHL

Exit Road	No. of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
Marsden St	6383	1	1	1	2.3	**4.3**
Civic Link	13814	2	1	1	2.5	**4.5**

Scenario 3 – 2016_100yr_Midday_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	258	3	1	1	0.1	1	**3.1**
Great Western Hwy	9932	3	1	1	5.5	1.5	**9.0**
Harris St	156	1	1	1	0.3	1	**3.3**
Pennant Hills Rd	1003	2	1	1	0.8	1	**3.8**
Victoria Rd	14	3	1	1	0	1	**3**

Scenario 4 - 2016_100yr_ Midday_HHL

Exit Road	No. of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
Marsden St	10236	2	1	1	1.8	**3.8**
Macquarie St	6241	1	1	1	2.2	**4.2**
Civic Link	18142	2	1	1	3.2	**5.2**

Scenario 5 – 2016_PMF_Midday_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	501	3	1	1	0.3	1	**3.3**
Great Western Hwy	12023	3	1	1	6.7	2	**10.7**
Harris St	217	1	1	1	0.4	1	**3.4**
Pennant Hills Rd	1520	2	1	1	1.3	1	**4.3**
Victoria Rd	25	3	1	1	0	1	**3**

Scenario 6 - 2016_PMF_Midday_HHL

Exit Road	No. of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
CBD Core to Westfield	53699	8	1	1	2.4	**4.4**
Church Street heading North	5697	2	1	1	1	**3**

Scenario 7 - 2016_PMF_Midday_Mixed Evacuation (Vehicular Part)

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	624	3	1	1	0.3	1	**3.3**
Great Western Hwy	4704	3	1	1	2.6	1	**5.6**
Harris St	214	1	1	1	0.4	1	**3.4**
Pennant Hills Rd	903	2	1	1	0.8	1	**3.8**
Victoria Rd	82	3	1	1	0	1	**3**

Scenario 7 - 2016_PMF_Midday_HHL (Pedestrian Part)

Elevated Walkway	Workers + Visitors	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
Marsden St	6692	1	1	2.39	**4.39**
Civic Link	14205	1	1	2.5	**4.5**
Hassal St	453	1	1	0.25	**2.25**
Church St	597	1	1	0.53	**2.53**

Scenario 8 – 2016_PMF_AllCars_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	1463	3	1	1	0.8	1	**3.8**
Great Western Hwy	14048	3	1	1	7.8	2	**11.8**
Harris St	627	1	1	1	1	1	**4**
Pennant Hills Rd	2606	2	1	1	2.2	1	**5.2**
Victoria Rd	255	3	1	1	0.1	1	**3.1**

Scenario 9 – 2036_20yr_Midday_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	558	3	1	1	0.3	1	**3.3**
Great Western Hwy	9407	3	1	1	5.2	1.5	**8.7**
Harris St	65	1	1	1	0.1	1	**3.1**
Pennant Hills Rd	1044	2	1	1	0.9	1	**3.9**
Victoria Rd	17	3	1	1	0	1	**3**

Scenario 10 - 2036_ 20yr_ Midday_HHL

Exit Road	No. of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
Marsden St	11335	1	1	1	4	**6**
Civic Link	29751	2	1	1	5.3	**7.3**

Scenario 11 – 2036_100yr_Midday_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	601	3	1	1	0.3	1	**3.3**
Great Western Hwy	10698	3	1	1	5.9	1.5	**9.4**
Harris St	124	1	1	1	0.2	1	**3.2**
Pennant Hills Rd	1086	2	1	1	0.9	1	**3.9**
Victoria Rd	17	3	1	1	0	1	**3**

Scenario 12 - 2036_100yr_Midday_HHL

Exit Road	No. of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
Marsden St	18384	2	1	1	3.3	**5.3**
Macquarie St	10302	1	1	1	3.7	**5.7**
Civic Link	38813	2	1	1	6.9	**8.9**

Scenario 13 – 2036_PMF_Midday_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	1053	3	1	1	0.6	1	**3.6**
Great Western Hwy	12292	3	1	1	6.8	2	**10.8**
Harris St	307	1	1	1	0.5	1	**3.5**
Pennant Hills Rd	1722	2	1	1	1.4	1	**4.4**
Victoria Rd	28	3	1	1	0	1	**3**

Scenario 14 - 2036_PMF_Midday_HHL

Exit Road	No.of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
CBD Core to Westfield	108368	8	1	1	4.8	**6.8**
Church Street heading North	4361	2	1	1	0.8	**2.8**

Scenario 15 – 2056_20yr_Midday_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	388	3	1	1	0.2	1	**3.2**
Great Western Hwy	9667	3	1	1	5.4	1.5	**8.9**
Harris St	69	1	1	1	0	1	**3**
Pennant Hills Rd	937	2	1	1	0.5	1	**3.5**
Victoria Rd	17	3	1	1	0	1	**3**

Scenario 16 – 2056_20yr_Midnight_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	600	3	1	1	0.3	1	**3.3**
Great Western Hwy	6950	3	1	1	3.9	1.5	**7.4**
Harris St	562	1	1	1	0.3	1	**3.3**
Pennant Hills Rd	1373	2	1	1	0.8	1	**3.8**
Victoria Rd	191	3	1	1	0.1	1	**3.1**

Scenario 17 - 2056_20yr_ Midday_HHL

Exit Road	No. of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
Marsden St	12959	1	1	1	4.7	**6.7**
Civic Link	39759	2	1	1	7.1	**9.1**

Scenario 18 – 2056_100yr_Midday_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	404	3	1	1	0.2	1	**3.2**
Great Western Hwy	10218	3	1	1	6.1	1.5	**9.6**
Harris St	93	1	1	1	0.1	1	**3.1**
Pennant Hills Rd	980	2	1	1	0.5	1	**3.5**
Victoria Rd	17	3	1	1	0	1	**3**

Scenario 19 – 2056_100yr_Midnight_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	778	3	1	1	0.4	1	**3.4**
Great Western Hwy	9751	3	1	1	5.4	1.5	**8.9**
Harris St	618	1	1	1	0.3	1	**3.3**
Pennant Hills Rd	1400	2	1	1	0.8	1	**3.8**
Victoria Rd	226	3	1	1	0.1	1	**3.1**

Scenario 20 - 2056_100yr_Midday_HHL

Exit Road	No. of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
Marsden St	21810	2	1	1	3.9	**5.9**
Macquarie St	11669	1	1	1	4.2	**6.2**
Civic Link	51342	2	1	1	9.2	**11.2**

Scenario 21 – 2056_PMF_Midnight_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	1444	3	1	1	0.8	1	**3.8**
Great Western Hwy	11246	3	1	1	6.2	1.5	**9.7**
Harris St	944	1	1	1	0.5	1	**3.5**
Pennant Hills Rd	2213	2	1	1	1.2	1	**4.2**
Victoria Rd	276	3	1	1	0.2	1	**3.2**

Scenario 22 - 2056_PMF_Midday_HHL

Exit Road	No. of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
CBD Core to Westfield	131071	8	1	1	5.9	**7.9**
Church Street heading North	5393	2	1	1	1	**3**

Scenario 23 - 2056_PMF_Midday_Mixed Evacuation (Vehicular Part)

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	712	3	1	1	0.4	1	**3.4**
Great Western Hwy	3626	3	1	1	2	1	**5**
Harris St	184	1	1	1	0.1	1	**3.1**
Pennant Hills Rd	894	2	1	1	0.5	1	**3.5**
Victoria Rd	82	3	1	1	0	1	**3**

Scenario 23 - 2056_20Yr_Midday_HHL (Pedestrian Part)

Exit Road	No. of Workers + Visitors	No. of Lanes	WAF	WLF	Walkway Clearance Time (Travel Time)	Evac Time
Marsden St	12959	1	1	1	4.6	**6.6**
Civic Link	39759	2	1	1	7.1	**9.1**

Scenario 24 – 2056_PMF_Midday_HSL

Exit Road	Cars	Lanes	WAF	WLF	Travel Time	TSF	Evac Time
Church St	790	3	1	1	0.4	1	**3.4**
Great Western Hwy	12677	3	1	1	7	2	**11**
Harris St	189	1	1	1	0.1	1	**3.1**
Pennant Hills Rd	1509	2	1	1	0.8	1	**3.8**
Victoria Rd	28	3	1	1	0	1	**3**

APPENDIX C – HIGH LEVEL EVACUATION ROUTE CONCEPT DESIGN

Flood Evacuation Assessment for the Parramatta CBD

HIGH LEVEL EVACUATION ROUTE
CONCEPT DESIGN

Final Report

Issued 06 September 2017

Prepared for Molino Stewart and City of Parramatta Council

by Studio GL

Document Information

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Client	Molino Stewart
Job number	1704
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Revision	Date	Prepared by	Approved by
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Final 3	22/05/2017	RE	FL
Final 4	06/09/2017	RE	FL

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01 INTRODUCTION

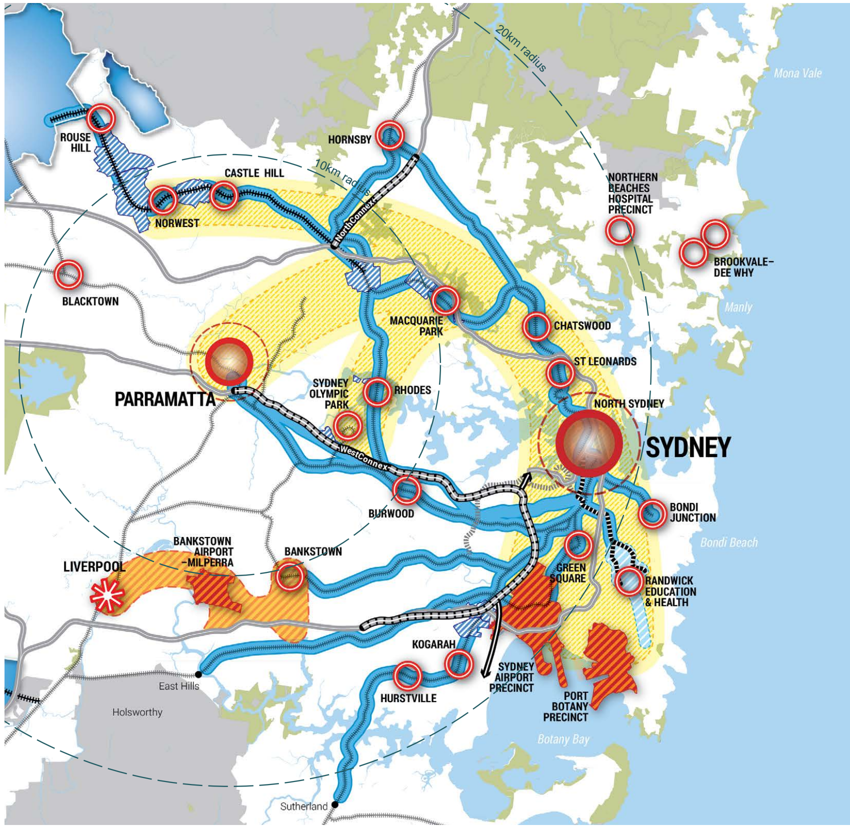


Figure 1 Metropolitan context diagram
(Source: A Plan For Growing Sydney, 2014)

1-1 Background

Parramatta CBD is of metropolitan importance, and in recognition of it's growing role council commissioned a number of studies to identify how the City of Parramatta can develop.

The result of these studies informed a planning proposal to allow additional employment opportunities supported by high density residential development.

As part of this process a draft update of the Parramatta Floodplain Risk Management Plans (2016) was produced by Molino Stewart. The report described how large parts of the Parramatta CBD would be affected by overbank flooding of the Parramatta River, and by flooding due to local overland flows.

One of the key findings of the report is that there is not sufficient advance warning of a major flood to enable evacuation of large parts of the CBD, and therefore for these areas, 'shelter in place' or 'flood free evacuation routes' need to be considered.

Adopting some or all of the recommendations within the Molino Stewart Report would require the imposition of some controls above the flood planning level. This is currently prohibited by state government for residential properties unless 'exceptional circumstances' can be demonstrated.

01 INTRODUCTION

1-2 Flood Evacuation Feasibility Assessment

Council has commissioned a team of consultants lead by Molino Stewart to undertake a Flood Evacuation Feasibility Assessment. The aim of the assessment is to estimate the ability of people within the Parramatta CBD to safely evacuate during a flood event, both now and in the future, when it is predicted there will be higher resident, employee and visitor populations.

The project will assess the benefits and risks of three approaches to evacuation to flood free areas:

- Street Level Evacuation
- Vertical Evacuation (shelter in place)
- Horizontal Evacuation (high level)

The overall purpose of the study is to:

- Help the council identify and understand the long term implications of preferred evacuation strategies.
- To inform a potential application for ‘exceptional circumstances’
- To inform further discussions with the NSW State Emergency Services (SES) and Office of Environment and Heritage (OEH).

1-3 Scope of this Document

The scope of this document is

- to provide strategic analysis of potential urban design implications of a high level horizontal evacuation system, and
- to provide a preliminary concept design for a high level evacuation route.

Figure 2 Study Area, Aerial Map

02 KEY ASSUMPTIONS

2-1 Scope of Concept Design

The proposed concept route design is based on the assumption of providing flood free evacuation routes during a 20 year ARI flood event. The proposed design and concept elements have the potential to be scaled to provide flood free evacuation routes during a 100 year ARI flood event and during a probable maximum flood (PMF)

2-2 Access Points

Further to discussions with Molino Stewart, no direct connection between the high level evacuation route and the upper levels of existing buildings has been assumed for the 20 year ARI concept design. Direct connection between the evacuation route and the upper levels of existing buildings would be required if the concept design were scaled for 100 year ARI and PMF events. A high level building access concept design is shown in section 9-1.

To provide a fully accessible system, ramps and stairs have been proposed to access the walkway, and it is assumed these will be accessed when the road is not yet in flood. Lifts have not been proposed due to the potential interruption of power supply during a flood event.

The location of ramps and stairs is based on the assumption of providing access at key intersections, and at regular intervals between these points. These locations are indicative only as detailed design would be required to determine an accurate location.

2-3 Walkway Width

The width of the high level walkway is proposed to be 2.5m. No modelling of evacuation numbers has been undertaken, and the suitability of this width to provide a safe evacuation route has not been assessed.

2-3 Fixed System

A fixed system of walkways has been proposed. To accommodate vehicle traffic within the CBD, and avoid level changes to the walkway when crossing roads, a height to the underside of the walkway has been established at 4.5m.

2-4 Cover to Walkways

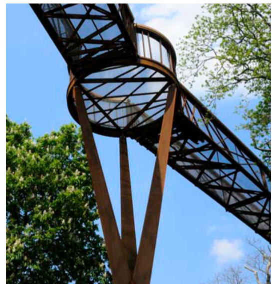
No cover has been proposed to the walkways. Covered walkways would provide protection from adverse weather and could encourage use of the system in a flood event, however they would have a significant detrimental effect on visual impact and overshadowing.

2-5 Flood Doors

No internal routes between buildings have been considered as part of this concept design. It is noted that internal flood escape routes could be feasible if redeveloping a number of adjacent buildings simultaneously, however providing internal escape routes via adjoining properties presents a number of issues, including differing internal floor levels, differing uses and floor layouts (e.g office to residential) , building management, fire evacuation and protection measures, and security.

2-3 Street Width

Typical street widths within the CBD have been measured from a cadastre to provide a number of typical street typologies. Footpath and carriageway widths were estimated from street photographs.



Examples of high level walkways

3-1 Public Use

It is proposed that the elevated walkway is accessed by ramp and stair from street level, prior to the road becoming flooded. We would question whether members of the public would walk to the nearest stair/ ramp access point, and use an elevated escape route if their street is yet to flood.

3-2 Walkway Width

It is our understanding that the proposed high level walkway will be unmanaged, and open to public access. Figures have not yet been provided for the number of people (current and potential) required to be evacuated via the route, however the proposed routes detailed in section 4 show that the walkways will encompass a number of city blocks, and it is likely thousands of people will be concentrated on routes crossing Macquarie St, and Hunter St.

3-3 Location of Ramps

Stairs and ramps need to be located at regular intervals to provide access to the high level walkway. A large length of ramp is required to ascend 4.8m (4.5m + structural allowance). A 1.5m wide ramp produces a footprint of 21x3m, which has a significant impact on the street layout. Where side streets without walkways cannot be used to locate ramps, the ramp may result in the loss of parking and/or a traffic lane, as well as resulting in a narrower footpath. (fig 3+4).

3-4 Visual Impact

Providing an elevated walkway will significantly affect the character of the CBD, as the supporting columns, walkway deck, stairs and ramps will be prominent features within the street scene. Whilst attractive design and detailing can help create a feature of the infrastructure, its impact will still be significant.

3-5 Daily Use

Roads within the CBD accommodate 2-4 lanes of traffic and there are pedestrian crossings at frequent intersections, therefore it is unlikely that any future walkway will be used to cross the road when it requires ascending 4.8m. This may lead to issues with how the walkways are used on a day to day basis, and whether they become appropriated for inappropriate uses: e.g graffiti/ rough sleeping/ drug use.

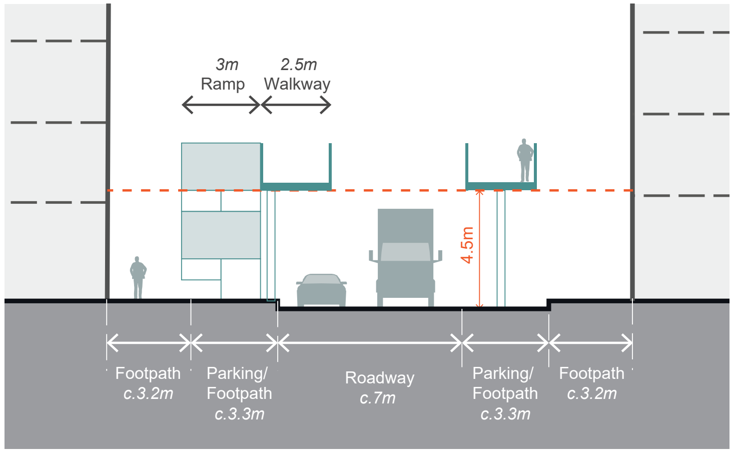


Figure 3 Typical ramp location section

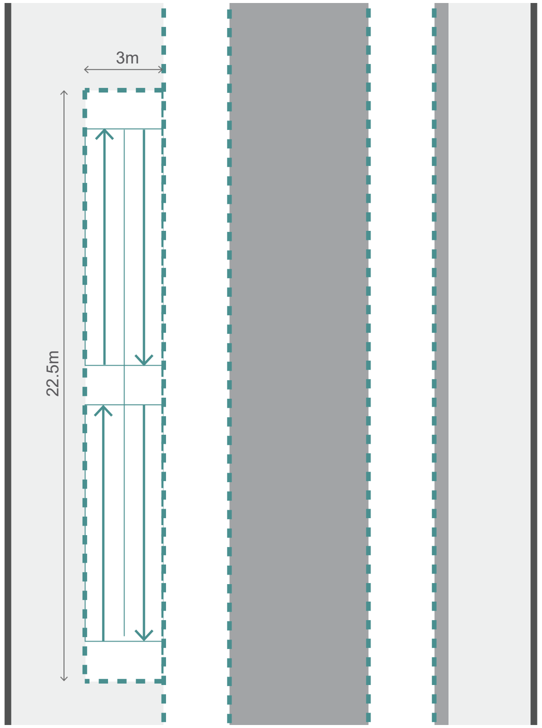


Figure 4 Typical ramp location plan

3-6 Overshadowing

Providing an elevated walkway will result in significant overshadowing of the public realm, and ground floor units (fig 5+6). Where taller buildings already shade the street, walkways will still reduce light-levels due to blocking ambient and reflected light. The level of overshadowing is dependant on the walkways width and height, the design of the balustrades also impacts overshadowing.

3-7 Street Trees

There are a large number of street trees within the CBD. In order to accommodate an independent high level walkway a number of these would have to be removed, especially on roads with walkways on both sides. Whilst lower level planting could be introduced beneath or adjacent to the walkways, the loss of mature street trees results in a harsher urban environment.

3-8 Building Levels

If buildings directly connect to the high level walkway in the future ramped access may be required. The proposed walkway height is at approx. 4.8m above road level, which will be significantly above 1st floor level for most buildings. The height of the walkway would compromise windows at the upper levels.

3-9 Deployable Bridges

Proposing a lower height of walkway with temporary deployable bridges to span roads could make it impossible to accommodate fixed walkways over parking bays and traffic lanes. Temporary deployable bridges could also result in a higher risk due to the time and management required in deploying temporary structures.

3-10 Maintenance

The walkways, support structures, ramps, and stairs will require maintenance to ensure they remain safe do not visually deteriorate. This maintenance cost may be significant, especially when it is considered that the structures are unlikely to be in use for decades.

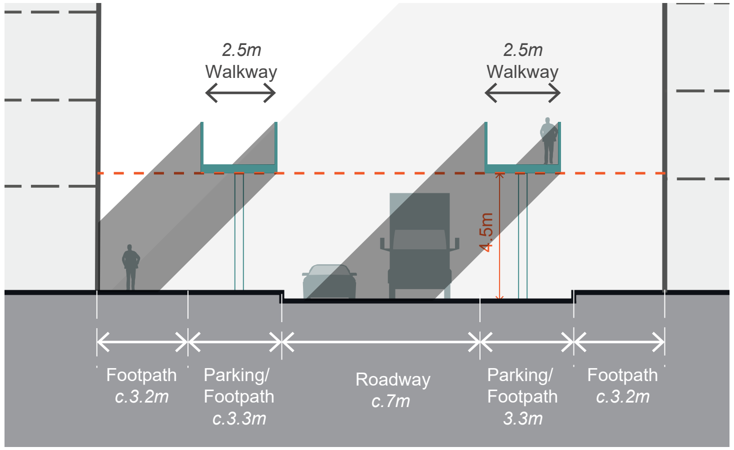


Figure 5 Overshadowing Section Diagram

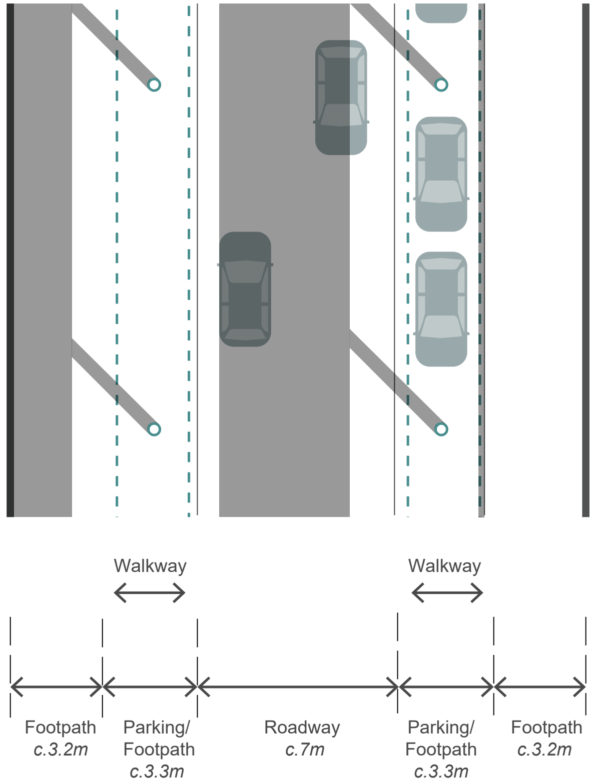


Figure 6 Overshadowing Plan Diagram

04 EVACUATION

4-1 Overview

Note: Evacuation r
on information prov
Molino Stewart.

Figure 7 Propose

4-2 Evacuation Route Area A

Area A	
Walkway Typology 1 *(walkway both sides of street)*	1,550m
Walkway Typology 2 *(walkway one side of street)*	800m
Walkway Typology 3 *(walkway one side of street cantilevered)*	300m
Walkway Typology 4 *(access street, walkway bridges street)*	45m
Walkway Typology 5 *(8m height walkway above light rail)*	70m
Total Walkway Length	**2,765m**

Stairs	S	29
Ramps	R	36

Key

- Buildings requiring high level evacuation in a 20 year ARI flood event.
- Heritage items
- (C) Junction Type *(detailed in section 6-1)*
- Preferred Light Rail route

Note: Evacuation routes based on information provided by Molino Stewart. Location of ramps and stairs is indicative only. Provided for pricing.

* For walkway options relating to the proposed civic link see work undertaken by other consultants.

Figure 8 Proposed evacuation route map Area A

4-3 Evacuation Route Area B

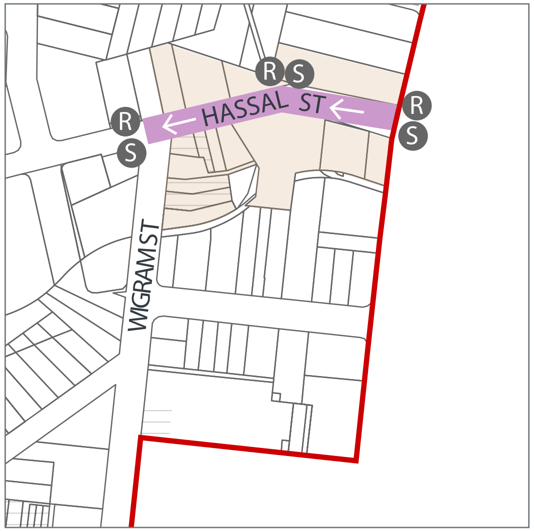


Figure 9 Proposed evacuation route map

Area B		
Walkway Typology 2 *(walkway one side of street)*		170m
Total Walkway Length		170m

Stairs	S	3
Ramps	R	3

4-4 Evacuation Route Area C

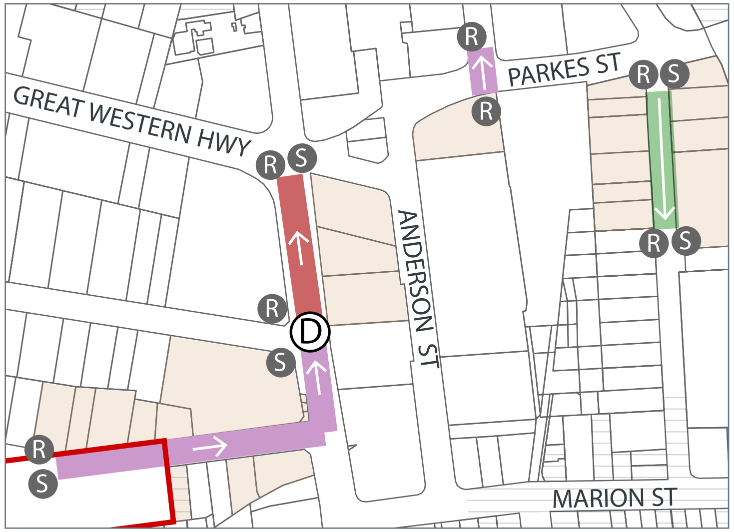


Figure 10 Proposed evacuation route map

Area C		
Walkway Typology 1 *(walkway both sides of street)*		100m
Walkway Typology 2 *(walkway one side of street)*		290m
Walkway Typology 3 *(walkway one side of street cantilevered)*		90m
Total Walkway Length		**480m**

Stairs	S	5
Ramps	R	7

4-5 Evacuation Route Area D

Figure 11 Proposed evacuation route map

Area D		
Walkway Typology 2 *(walkway one side of street)*		25m
Total Walkway Length		25m

Stairs	S	0
Ramps	R	2

Note: Evacuation routes based on information provided by Molino Stewart. Location of ramps and stairs is indicative only. Provided for pricing.

4-6 Evacuation Walkway Schedule

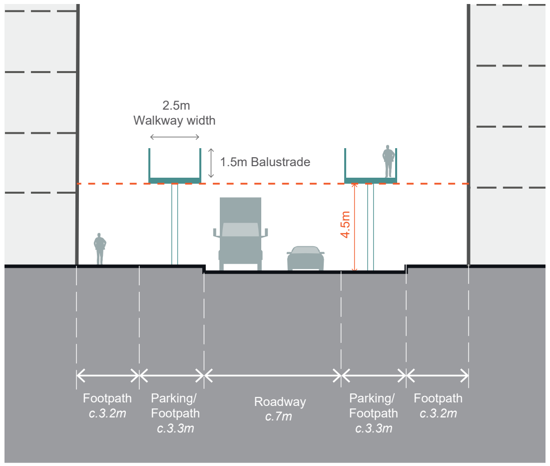
The table below summarises the total lengths of different walkway typologies, and stair and ramp units, proposed in the concept design for providing flood free evacuation routes during a 20 year ARI flood event.

Totals		
Walkway Typology 1 *(walkway both sides of street)*		1,650m
Walkway Typology 2 *(walkway one side of street)*		1,285m
Walkway Typology 3 *(walkway one side of street cantilevered)*		390m
Walkway Typology 4 *(access street, walkway bridges street)*		45m
Walkway Typology 5 *(8m height walkway above light rail)*		70m
Total Walkway Length		3,440m

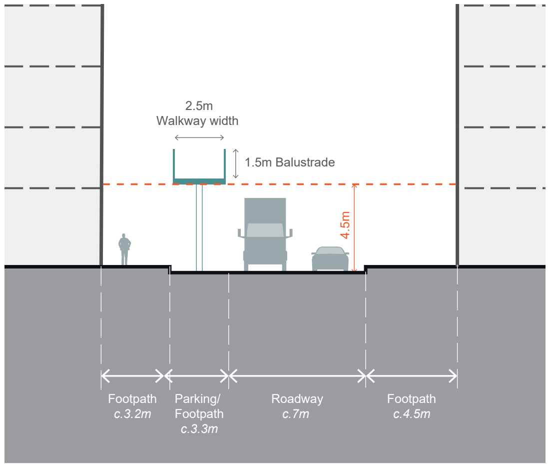
Stairs	S	37
Ramps	R	48

Note: Approximate length of walkway, only provided for costing.

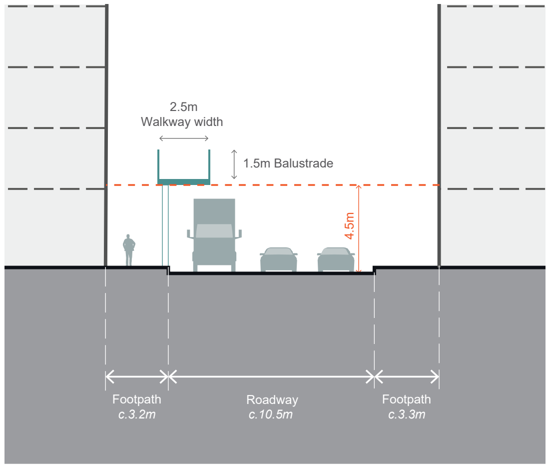
5-1 Walkway typology 1



5-2 Walkway typology 2



5-3 Walkway typology 3



Walkway typology 1
(walkways both sides of street)

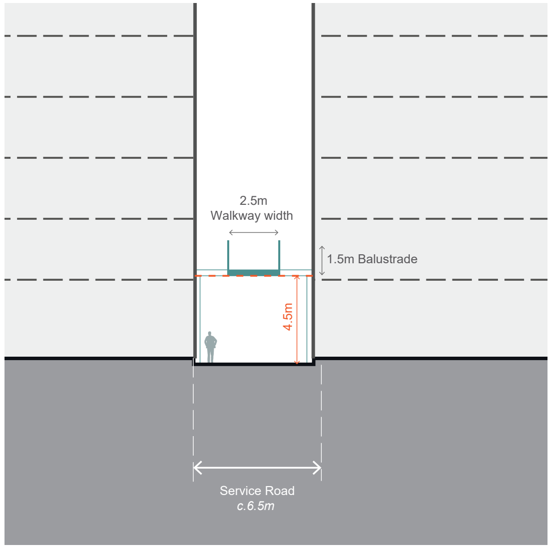
Walkway typology 2
(walkways one side of street)

Walkway typology 3
(walkways one side of street, cantilevered)

Note: This information is provided for pricing only.

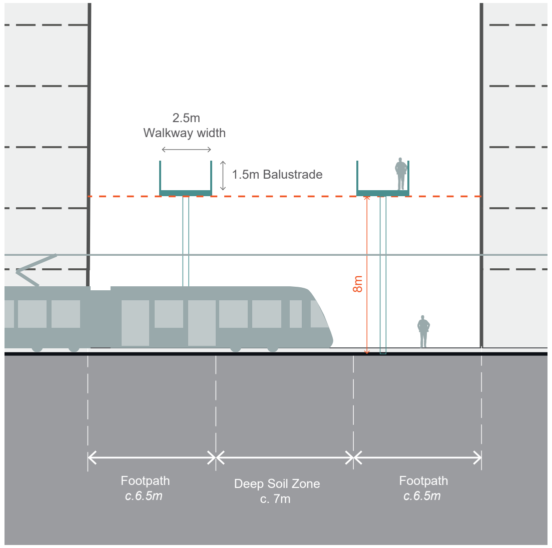
05 ELEVATED WALKWAY TYPOLOGIES

5-4 Walkway typology 4



Walkway typology 4
(Access street, walkway bridges street)

5-5 Walkway typology 5

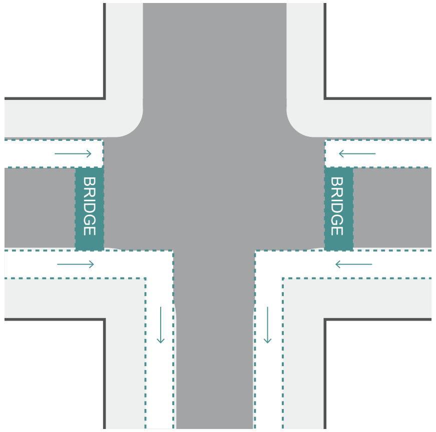


Walkway typology 5
(8m height walkway above light rail)

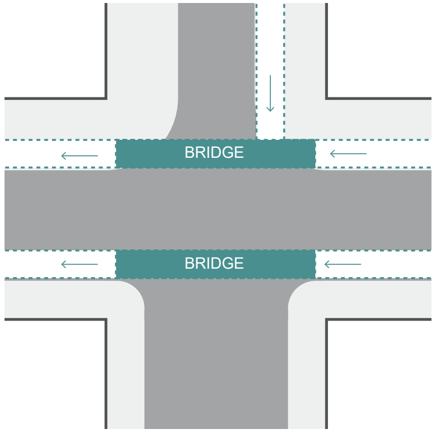
Note: This information is provided
for pricing only.

06 ELEVATED WALKWAY JUNCTION TYPES

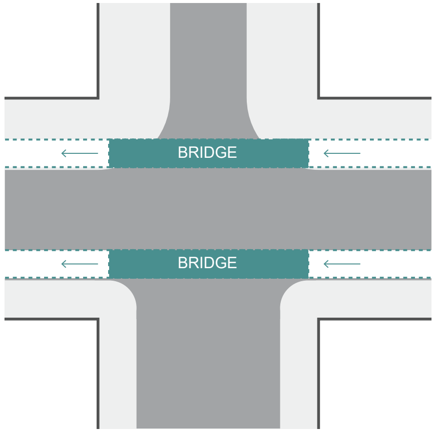
6-1 Junction types



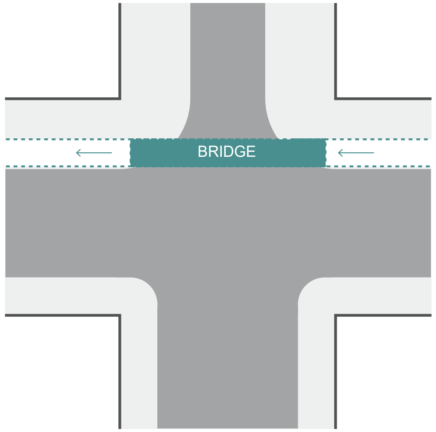
Junction Type A



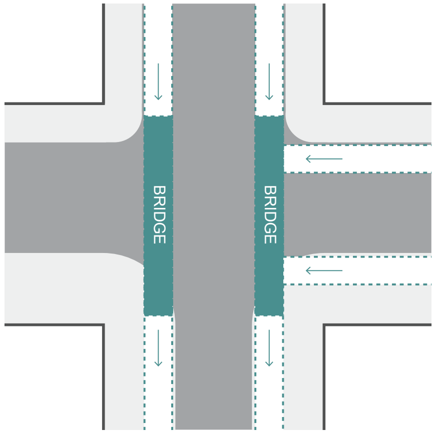
Junction Type B



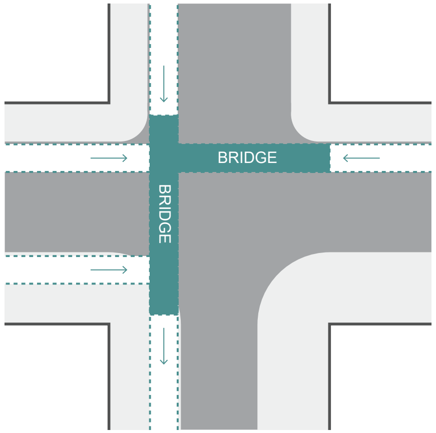
Junction Type C



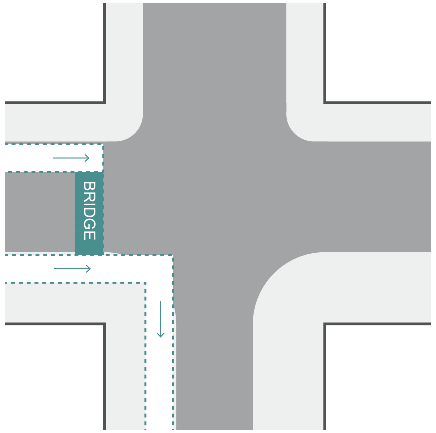
Junction Type D



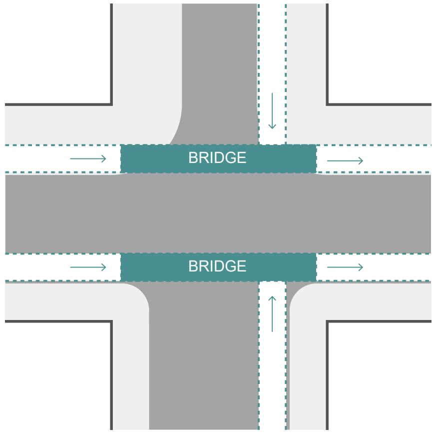
Junction Type E



Junction Type F



Junction Type G



Junction Type H

Note: This information is provided for pricing only.

7-1 Typical design

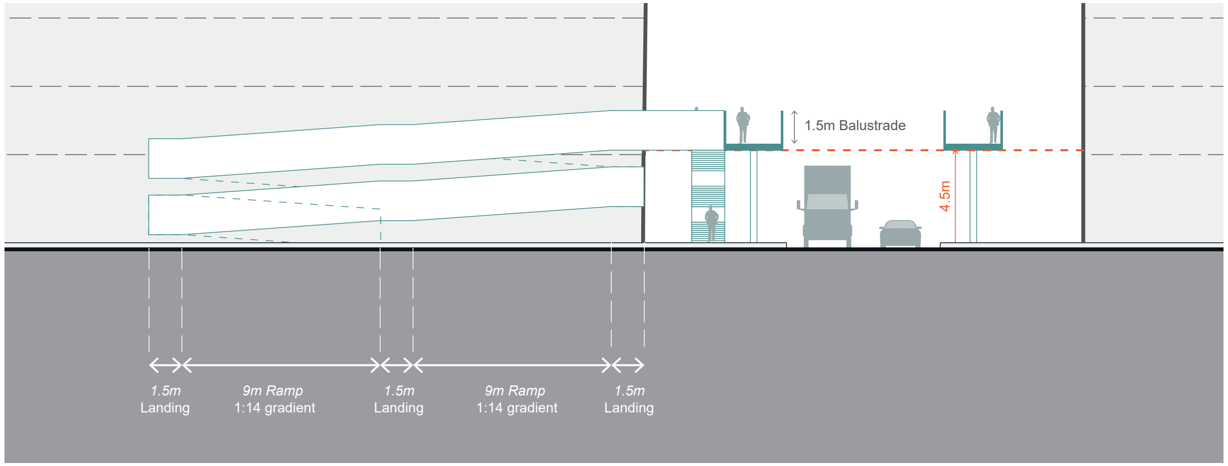


Figure 12 Typical ramp elevation

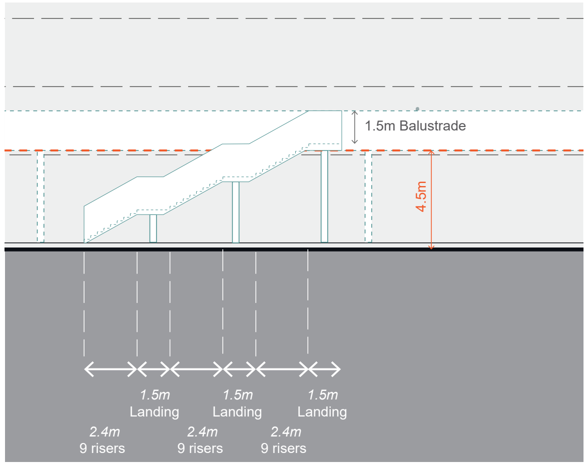


Figure 13 Typical stair elevation

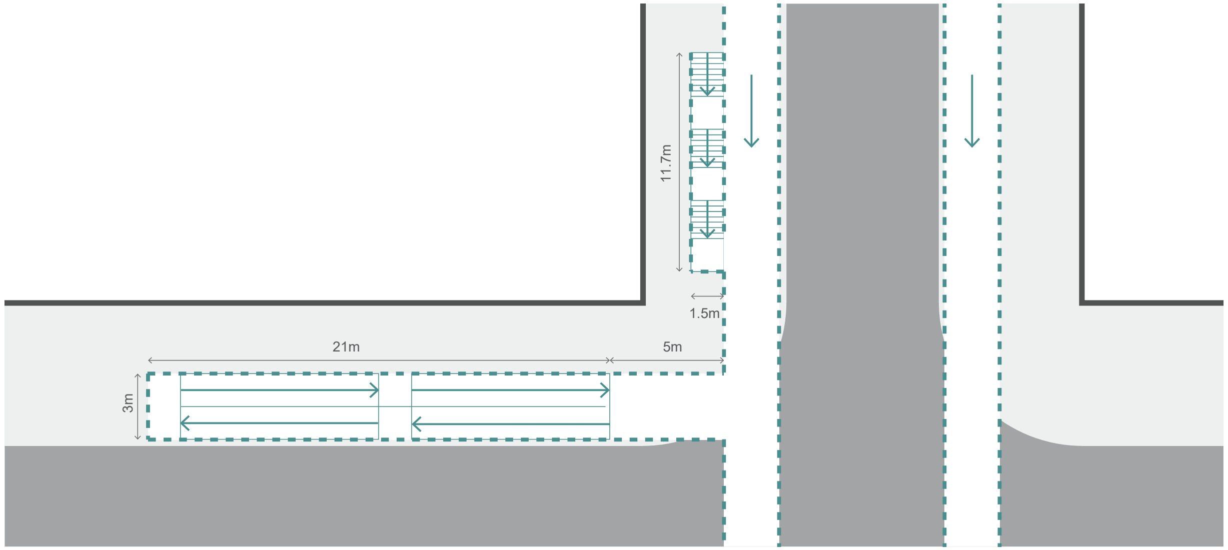


Figure 14 Typical plan

Note: This information is provided for pricing only.

08 CONCEPT WALKWAY CONSTRUCTION

8-1 Concept drawings

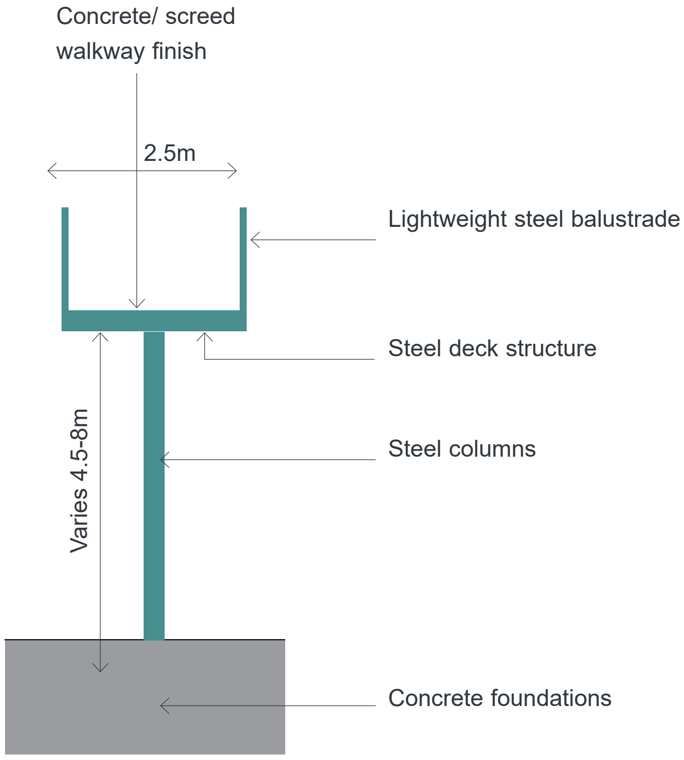


Figure 15 Typical walkway section

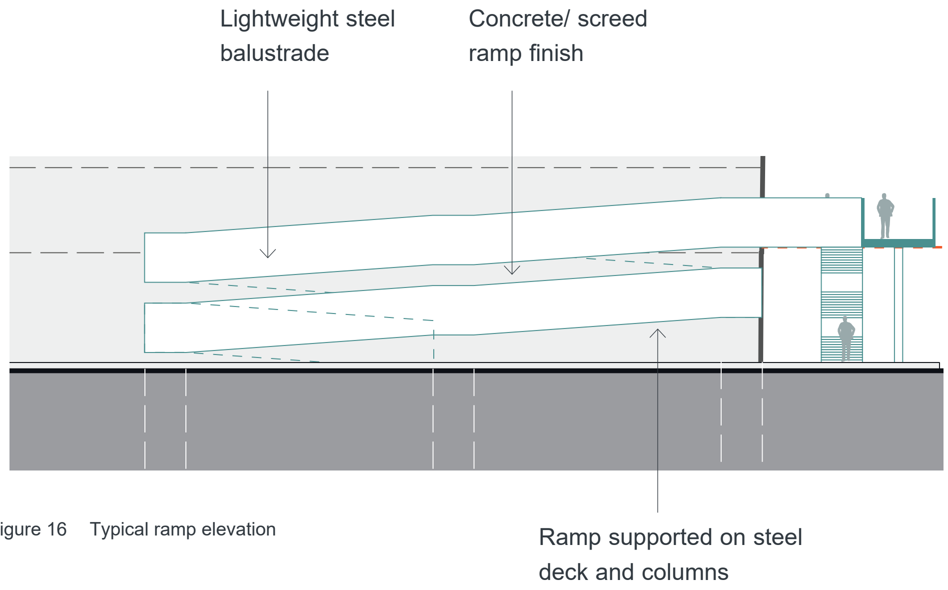


Figure 16 Typical ramp elevation

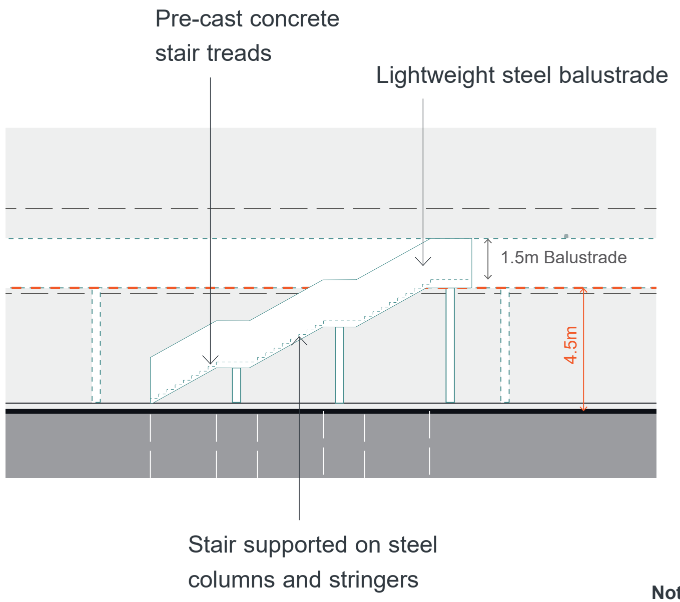


Figure 17 Typical stair elevation

Note: This information is provided for pricing only.

9-1 Concept Design Elements

During a 100 year ARI or PMF event Molino Stewart have advised that direct access may be required from the upper levels of buildings to the high level walkway. Additionally the flood depths in a limited number of locations near the Parramatta River may exceed the 4.5m height of the proposed walkway system, during a PMF event. Concept designs for high level building access, and higher level walkway infrastructure are provided opposite and on the following page.

Providing direct access from buildings to the walkway at high level, in addition to increasing the size of the walkway network, will significantly increase many of the impacts discussed in section 3. Specifically the negative visual impact, and overshadowing created by the system will be increased through the enlarged network affecting the character and amenity of a wider area. These impacts will also be intensified by the increase in structure required for direct building access.

9-2 High Level Building Access Concept Design

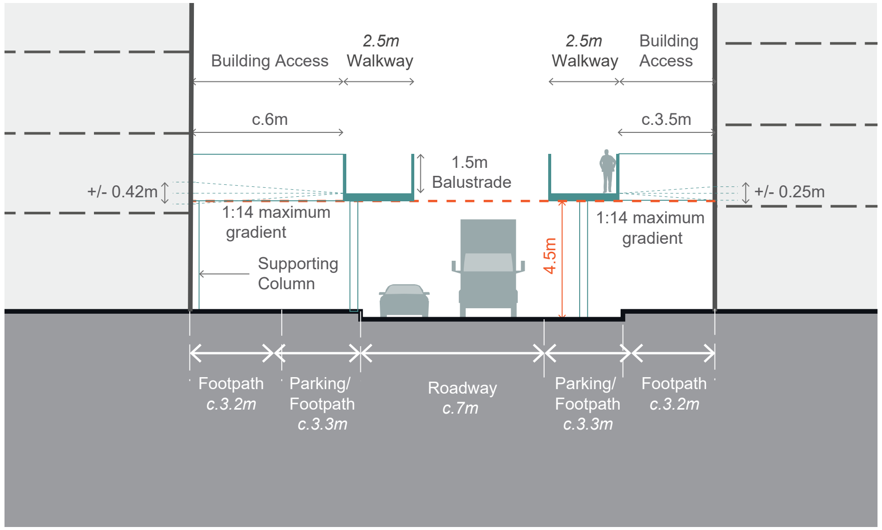


Figure 18 Typical High Level Building Access Arrangement

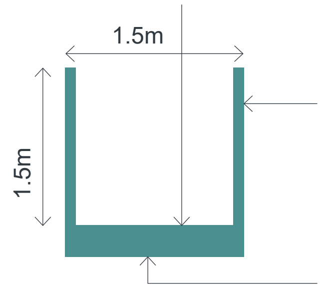


Figure 19 Typical Building Access Section

9-3 Higher Level Walkway Concept Design

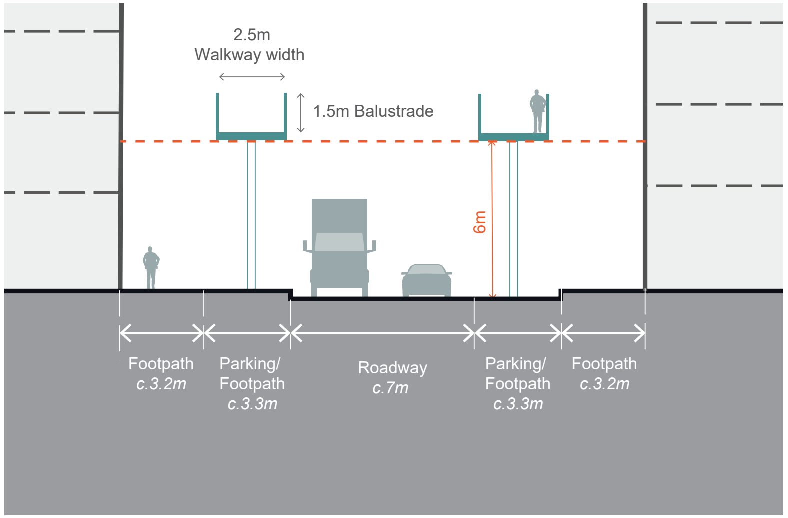


Figure 20 Walkway Typology 6 (6m height walkway)

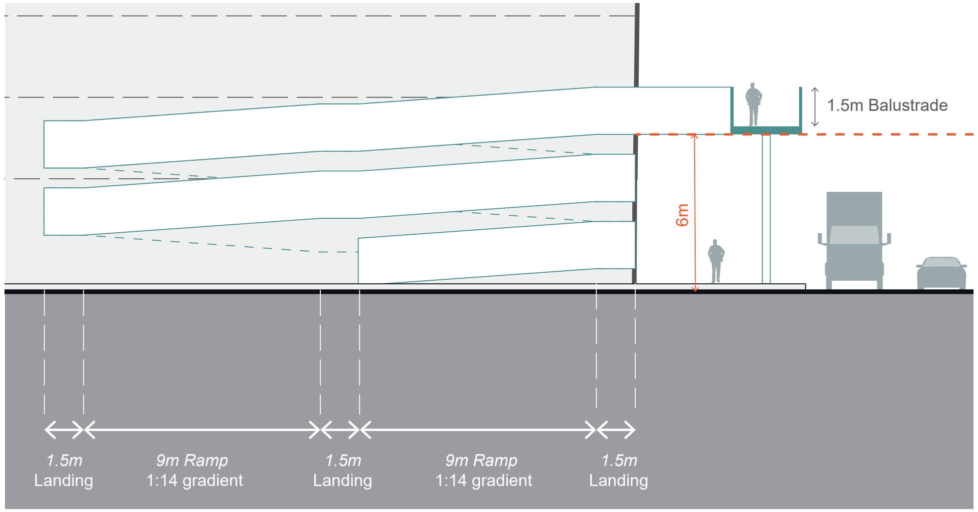


Figure 21 6m Height Ramp, Elevation (typical plan see section 7-1 fig.14)

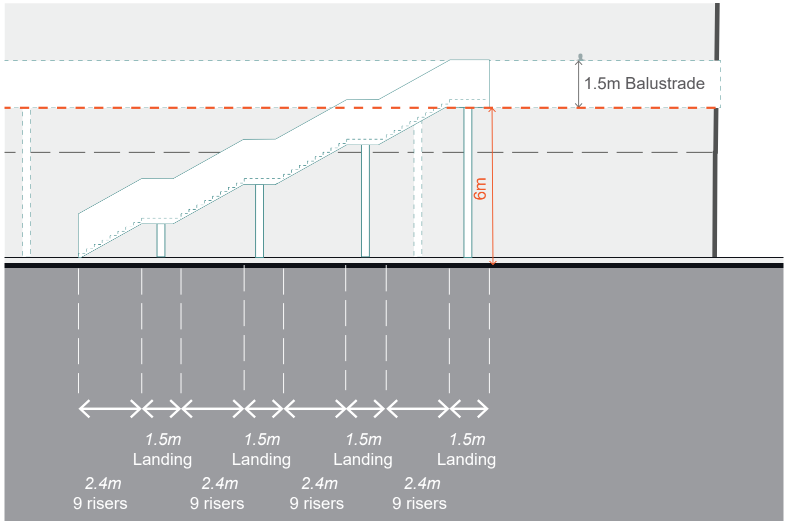


Figure 22 6m Height Stair, Elevation (typical plan see section 7-1 fig.14)

10 HERITAGE IMPACT

Key

- Heritage Listed Buildings
- Heritage Listed Buildings opposite walkway
- Heritage Listed Buildings adjacent to walkway

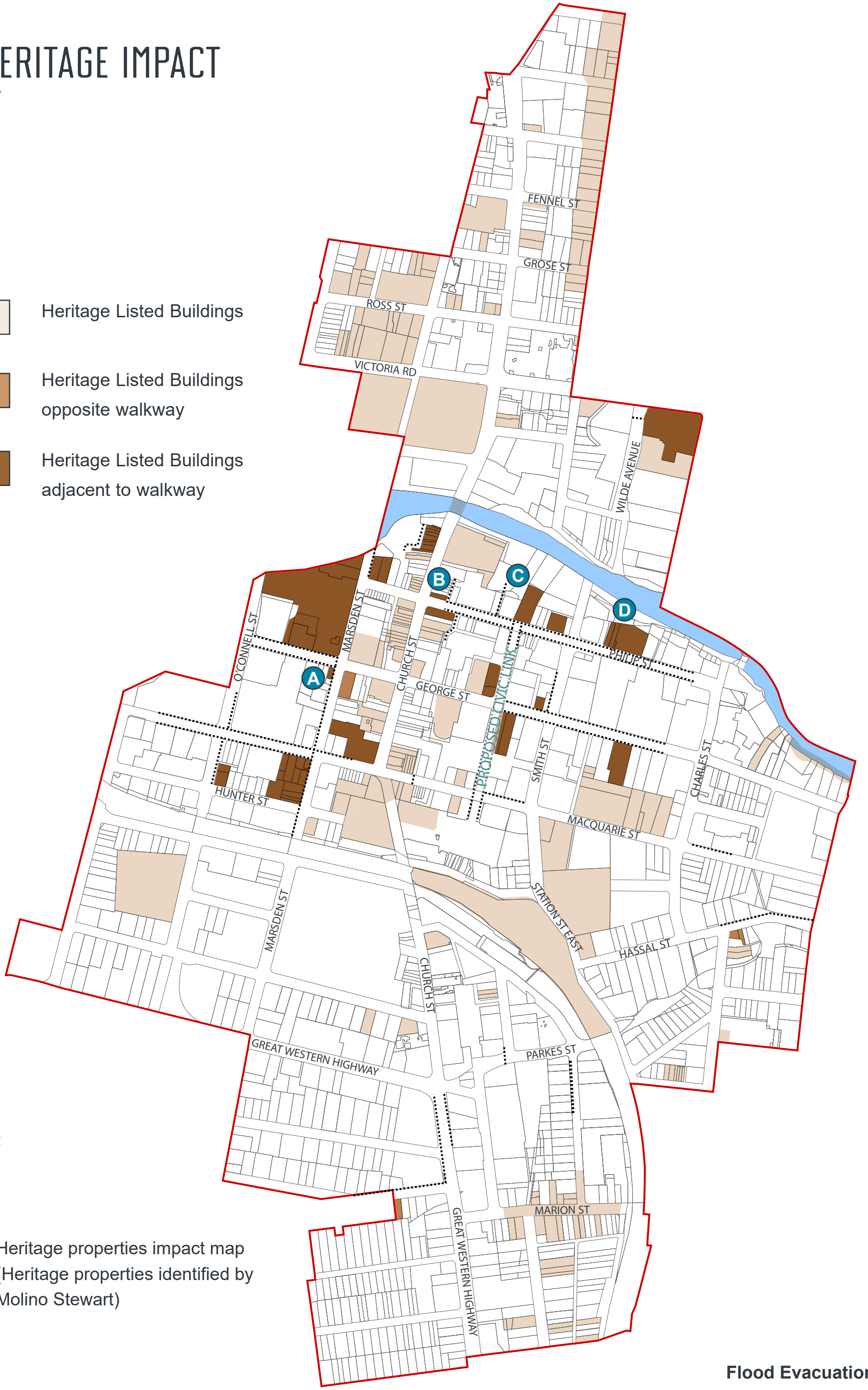


Figure 23 Heritage properties impact map (Heritage properties identified by Molino Stewart)

10-1 Impact on heritage buildings

Locating an extensive network of elevated walkways within the Paramatta CBD will affect a large number of heritage listed buildings.

The concept design proposes locating the walkways approximately 3m off the building property line. The walkways will be elevated approximately 4m above the footpath level.

The visual impact of a 2m wide walkway surface, with upstand balustrades, and associated support structures, will be significant when viewed against generally one and two storey heritage buildings.

The walkway will cut across and obscure key features of the facades of these buildings, including windows and colonnades, and may obscure the upper levels of buildings entirely when viewed from across the street, especially when this occurs from beneath another walkway.

Long views down the street are likely to be severely impacted as the walkways will potentially obscure rooflines and upper level façade details, and be the dominant element in the streetscape.

It is recommended that a detailed visual impact assessment be carried out by a heritage architect to fully understand and document the likely impacts on the range of high value heritage buildings within the Parramatta CBD.

Ⓐ 164 Marsden Street

Ⓑ 306 Church Street

Ⓒ 34 Philip Street

Ⓓ 70 Philip Street

11-1 Managed high level evacuation route

An alternative to creating a high level unmanaged evacuation route is to provide a managed high level access for emergency responders (e.g SES) to reach members of the public who have sheltered in place and may require assistance. This option addresses a number of the key issues raised in Section 3:

- A suitable walkway width can be provided for SES staff access, and evacuation of a limited number of people within the existing street pattern.
- Ramped access would not be required to be provided, as SES staff could evacuate individuals using specialist equipment/ stretchers where necessary.
- A lightweight single width (approx.1m) walkway could be provided, potentially utilising existing buildings and awnings, significantly reducing overshadowing and visual impact on the street.
- The length of proposed walkways could potentially be reduced by terminating the route at designated multi-storey car parks within the CBD suitable for helicopter access/ evacuation.
- By providing a lightweight, less visually obtrusive and secure walkway system that is only accessible by the SES, the potential for unwanted informal uses of the walkways is minimised.
- Providing a lightweight route will enable the retention of more street trees.
- Providing a route that is managed by trained SES staff enables temporary deployable structures, including bridges, to be utilised reducing the visual impact of the route.
- Narrower and potentially shorter length of walkways, with no accessibility requirements, will reduce maintenance costs.

Key issues for further investigation should this option be progressed include:

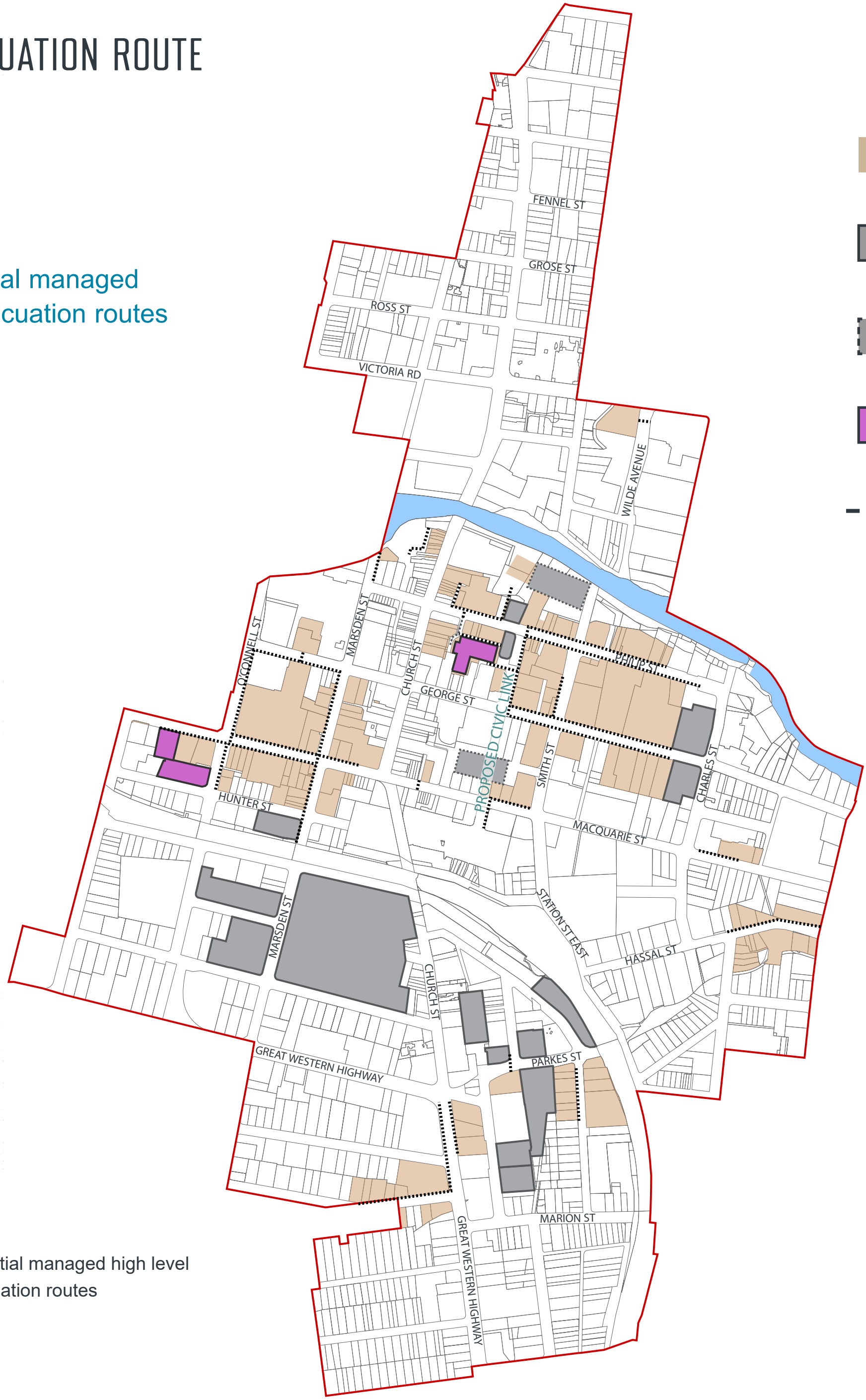
- Discussion of the suitability of the concept of a managed high level evacuation route with SES staff.
- Discussion of access requirements including walkway widths, steps, and ladders with the SES.
- Discussion with Council and SES regarding ownership and maintenance of the system.
- Investigation of how building codes would apply to the proposal.
- More detailed design investigations of how the walkways would access buildings, the street, and be structurally supported.
- A visual impact study, once design parameters and the suitability of the proposal have been established, demonstrating the effect of the proposals on views within the CBD.

Examples of lightweight high level access/escape solutions.

STUDIO GL

11 MANAGED EVACUATION ROUTE

11-2 Map of potential managed high level evacuation routes



Buildings requiring high level evacuation in a 20 year ARI flood event.

Existing Car Parking with floor levels above 4m (potential for shelter in place)

Existing Car Parking potentially to be demolished

Relevant car parks with potential for helicopter evacuation

Potential walkway routes

Figure 24 Potential managed high level evacuation routes

12 CONCLUSIONS

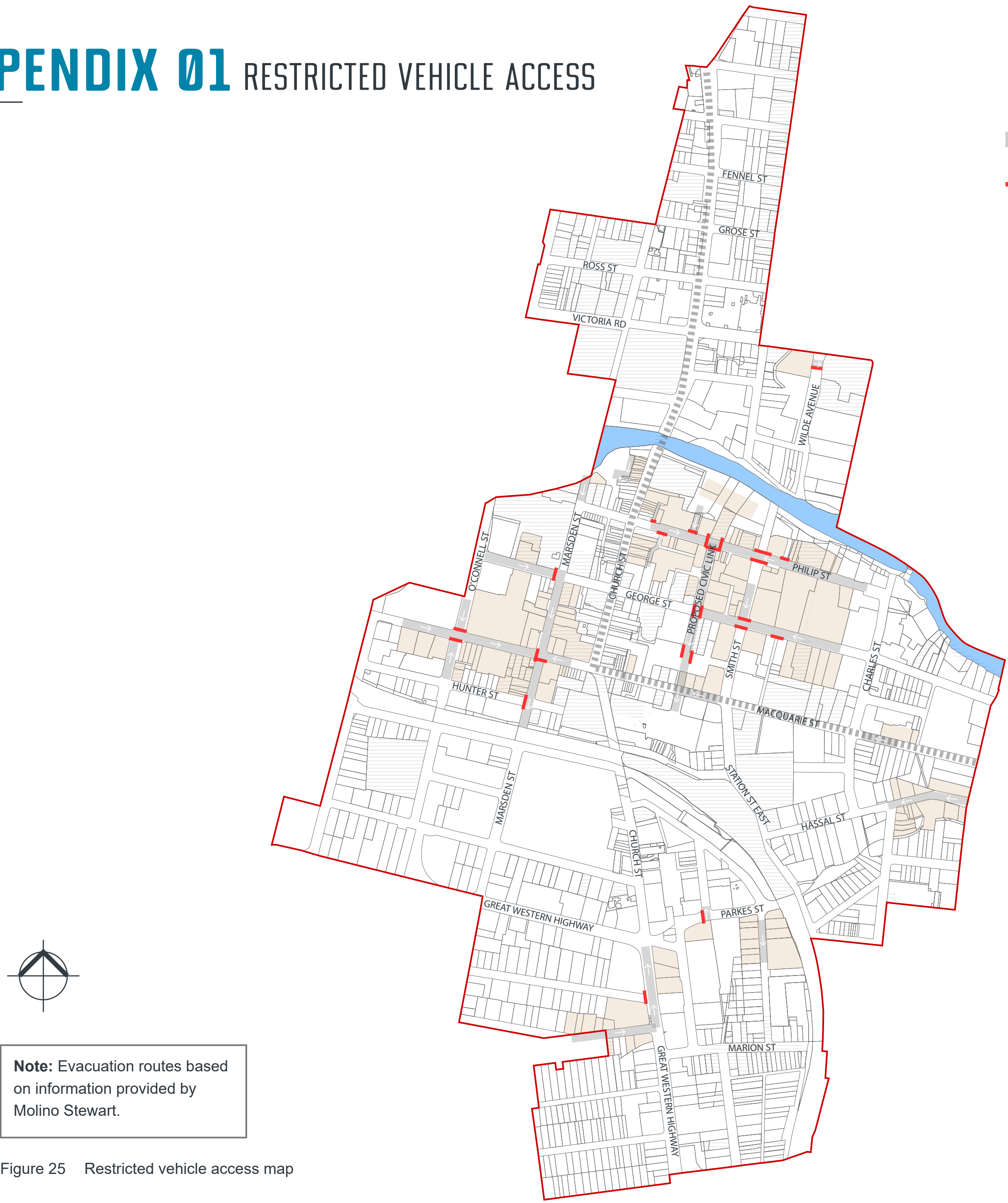
The proposed concept route design is based on the assumption of providing flood free evacuation routes during a 20 year ARI flood event. The proposed design and concept elements have the potential to be scaled to provide flood free evacuation routes during a 100 year ARI flood event and during a probable maximum flood (PMF)

Good design and detailing has the potential to make a feature of the proposed infrastructure, however given the significant detrimental impact on the urban character and heritage of the CBD we do not recommend an unmanaged high level horizontal evacuation route. Key concerns include:

- Providing a high level horizontal evacuation route will significantly impact on the character and amenity of the CBD.
- High level walkways will result in significant overshadowing of the street and ground floor units.
- High level walkways will result in the loss of street trees.
- Providing an extensive network of walkways that will not be used on a daily basis, will potentially create issues with informal use and security, and is an inefficient use of land within the CBD.
- Modelling of likely pedestrian numbers will be required to determine the requirements for the actual width of the walkway to ensure the safety of those evacuating.
- Providing ramps to access the walkway will impact on road layouts within the CBD.

A high level managed evacuation route, as described in section 11, could provide safer access for the SES to members of the public requiring assistance in a flood event, whilst reducing the visual impact and associated costs of the walkway infrastructure.

APPENDIX 01 RESTRICTED VEHICLE ACCESS



Proposed elevated walkway routes

Restricted vehicle access (excludes vehicles over 4.3m)

Buildings requiring high level evacuation in a 20 year ARI flood event.

Heritage Items

Preferred Light rail route

Note: Evacuation routes based on information provided by Molino Stewart.

Figure 25 Restricted vehicle access map

APPENDIX D - UNIT COSTS OF ELEVATED WALKWAYS

NORTH

Flood Evacuation - Parramatta CBD
Strategic Estimate

ITEM	DESCRIPTION				RATE	Unit	Qty		AMOUNT	Note
1	**Walkway (Type 1 -3) for 15m (L) span/ Segment *2.5m (W)**									
	1.7t Steelwork/15m									
1.1	Foundation- 1.5*1.5*0.6m- 2*no per segment	Demo	4.00	m3	$ 50	/ m3	2		$ 400	
	2. no columns per segment	Excavation & Disposal	4.00	m3	$ 200	/ m3	2		$ 1,600	
		Blinding- 50mm thick	2.00	m3	$ 50	/ m3	2		$ 200	
		FRP+ supply concrete	1.35	m3	$ 3,000	/ m3	2		$ 8,100	
		Backfill	2.65	m3	$ 50	/ m3	2		$ 265	
1.2	Walkway Steel framework - Tonnage rate	Fabricate, Supply and Install	1.70	T/ 15LM	$ 10,000	/T	1		$ 17,000	Based on 250*8SHS steel column and 200PFC Beam, EA75*5 bracing
1.3										
1.4	Walkway Concrete Deck	15 lm (L)*2.5m (W)	37.50	m2	$ 250	/m2	1		$ 9,375	Assumed 200 thick - Bondek, Precast in the yard
1.5	Handrails (stainless steel)	Supply & Install	15.00	LM	$ 500	/LM	2		$ 15,000	
		Kick rails (stainless steel)	15.00	LM	$ 200	/LM	2		$ 6,000	
		Allowance for seals/fittings	15.00	LM	$ 30	/LM	2		$ 900	No Allowance for Escalation or GST
1.6	Temp. works		1.00	Unit	$ 10,000		1		$ 10,000	Assume free standing
1.7	Traffic Control/ Permits							15%	$ 10,326	Assume pad foundations are sufficient, no allowance for piled foundations
										No Allowance for contaminated material
1.8	Site Survey- 2% of Construction cost							2%	$ 1,583	No allowance to demolish/alter existing building for connection to building access walkway
	Direct Works Total								**$ 80,749**	No allowance for reconfiguration of the existing pavements roads drainage or street furniture
1.9	**Night shift- installation work & Permitt- 30% over**							**30%**	**$ 24,224.80**	Exposed Steelwork assumed to be painted
1.10	**Overhead/Admin/ Margin**							**35%**	**$ 36,740.94**	No allowance for Property Acquisitions
1.11	**Design and Investigation Costs 10% of DC**							**10%**	**$ 8,075**	No Allowance for CCTV
1.12	**Project Management cost - 5.5% on DC**							**5%**	**$ 4,037**	No allowance for relocation of services
1.13	**Contingency based on minimal info. 40-70%**							**55%**	**$ 77,943**	No allowance for Lighting (assumed existing street lighting is sufficient)
	Total								**$ 231,771**	**+GST / 15m segment walkway**
									$ 15,452	**per m**

ITEM	DESCRIPTION				RATE	Unit	Qty		AMOUNT	Note
2	**Walkway (Type 4) for 15m (L) span/ Segment *2.5m (W)**									
	2.6t Steelwork/15m									
2.1	Foundation- 1.5*1.5*0.6m- 4*no per segment	Demo	4.00	m3	$ 50	/ m3	4		$ 800	
	4. no columns per segment	Excavation & Disposal	4.00	m3	$ 200	/ m3	4		$ 3,200	
		Blinding- 50mm thick	2.00	m3	$ 50	/ m3	4		$ 400	
		FRP+ supply concrete	1.35	m3	$ 3,000	/ m3	4		$ 16,200	
		Backfill	2.65	m3	$ 50	/ m3	4		$ 530	
2.2	Walkway Steel framework - Tonnage rate	Fabricate, Supply and Install	2.60	T/ 15LM	$ 10,000	/T	1		$ 26,000	Based on 250*8SHS steel column and 200PFC Beam, EA75*5 bracing
2.3										
2.4	Walkway Concrete Deck	15 lm (L)*2.5m (W)	37.50	m2	$ 250	/m2	1		$ 9,375	Assumed 200 thick - Bondek, Precast in the yard
2.5	Handrails (stainless steel)	Supply & Install	15.00	LM	$ 500	/LM	2		$ 15,000	
		Kick rails (stainless steel)	15.00	LM	$ 200	/LM	2		$ 6,000	
		Allowance for seals/fittings	15.00	LM	$ 30	/LM	2		$ 900	No Allowance for Escalation or GST
2.6	Temp. works		1.00	Unit	$ 10,000		1		$ 10,000	Assume free standing
2.7	Traffic Control/ Permits							15%	$ 13,261	Assume pad foundations are sufficient, no allowance for piled foundations
										No Allowance for contaminated material
2.8	Site Survey- 2% of Construction cost							2%	$ 2,033.32	No allowance to demolish/alter existing building for connection to building access walkway
	Direct Works Total								**$ 103,699**	No allowance for reconfiguration of the existing pavements roads drainage or street furniture
2.9	**Night shift- installation work & Permitt- 30% over**							**30%**	**$ 31,110**	Exposed Steelwork assumed to be painted
2.10	**Overhead/Admin/ Margin**							**35%**	**$ 47,183**	No allowance for Property Acquisitions
2.11	**Design and Investigation Costs 10% of DC**							**10%**	**$ 10,370**	No Allowance for CCTV
2.12	**Project Management cost - 5.5% on DC**							**5%**	**$ 5,185**	No allowance for relocation of services
2.13	**Contingency based on minimal info. 40-70%**							**55%**	**$ 100,096**	No allowance for Lighting (assumed existing street lighting is sufficient)
	Total								**$ 297,642**	**+GST / 15m segment walkway**
									$ 19,843	**per m**

ITEM	DESCRIPTION				RATE	Unit	Qty		AMOUNT	Note
3	**Walkway (Type 5) for 15m (L) span/ Segment *2.5m (W)**									
	2.2t Steelwork/15m									
3.1	Foundation- 1.5*1.5*0.6m- 2*no per segment	Demo	4.00	m3	$ 50	/ m3	2		$ 400	
	2. no columns per segment	Excavation & Disposal	4.00	m3	$ 200	/ m3	2		$ 1,600	
		Blinding- 50mm thick	2.00	m3	$ 50	/ m3	2		$ 200	
		FRP+ supply concrete	1.35	m3	$ 3,000	/ m3	2		$ 8,100	
		Backfill	2.65	m3	$ 50	/ m3	2		$ 265	
3.2	Walkway Steel framework - Tonnage rate	Fabricate, Supply and Install	2.20	T/ 15LM	$ 10,000	/T	1		$ 22,000	Based on 250*8SHS steel column and 200PFC Beam, EA75*5 bracing
3.3										
3.4	Walkway Concrete Deck	15 lm (L)*2.5m (W)	37.50	m2	$ 250	/m2	1		$ 9,375	Assumed 200 thick - Bondek, Precast in the yard
3.5	Handrails (stainless steel)	Supply & Install	15.00	LM	$ 500	/LM	2		$ 15,000	
		Kick rails (stainless steel)	15.00	LM	$ 200	/LM	2		$ 6,000	
		Allowance for seals/fittings	15.00	LM	$ 30	/LM	2		$ 900	No Allowance for Escalation or GST
3.6	Temp. works		1.00	Unit	$ 10,000		1		$ 10,000	Assume free standing
3.7	Traffic Control/ Permits							15%	$ 11,076	Assume pad foundations are sufficient, no allowance for piled foundations
										No Allowance for contaminated material
3.8	Site Survey- 2% of Construction cost							2%	$ 1,698.32	No allowance to demolish/alter existing building for connection to building access walkway
	Direct Works Total								**$ 86,614**	No allowance for reconfiguration of the existing pavements roads drainage or street furniture
3.9	**Night shift- installation work & Permitt- 30% over**							**30%**	**$ 25,984**	Exposed Steelwork assumed to be painted
3.10	**Overhead/Admin/ Margin**							**35%**	**$ 39,409.52**	No allowance for Property Acquisitions
3.11	**Design and Investigation Costs 10% of DC**							**10%**	**$ 8,661**	No Allowance for CCTV
3.12	**Project Management cost - 5.5% on DC**							**5%**	**$ 4,331**	No allowance for relocation of services
3.13	**Contingency based on minimal info. 40-70%**							**55%**	**$ 83,604**	No allowance for Lighting (assumed existing street lighting is sufficient)
	Total								**$ 248,605**	**+GST / 15m segment walkway**
									$ 16,574	**per m**

ITEM	DESCRIPTION				RATE	Unit	Qty		AMOUNT	Note
4	**Staircase & Landing**									
4.1	Foundation- 1.5*1.5*0.6m	Demo	4.00	m3	$ 50	/ m3	3		$ 600	
	3*no per staircase	Excavation & Disposal	4.00	m3	$ 110	/ m3	3		$ 1,320	
		Blinding- 50mm thick	2.00	m3	$ 50	/ m3	3		$ 300	
		FRP+ supply concrete	1.35	m3	$ 3,000	/ m3	3		$ 12,150	
		Backfill	1.75	m3	$ 50	/ m3	3		$ 263	
4.2	Walkway Steel framework - Tonnage rate		1.10	T/ Stair case	$ 10,000	/T	1		$ 11,000	Based on 250*8SHS column and 150PFC stringer
4.3	Precase concrete stair treads- Supply & Install		1.00		$ 110	each	27		$ 2,970	
4.4	Precase concrete landing		2.25	m2	$ 200	/m2	3		$ 1,350	Assumed 100 thick - Bondek
4.5	Handrails (stainless steel)	Supply & Install	12.00	LM	$ 500	/LM	2		$ 12,000	
		Kick rails (stainless steel)	12.00	LM	$ 200	/LM	2		$ 4,800	
		Allowance for seals/fittings	12.00	LM	$ 30	/LM	2		$ 720	No Allowance for Escalation or GST
										Assume free standing
4.6	Traffic Control/ Permits							15%	$ 7,121	Assume pad foundations are sufficient, no allowance for piled foundations
										No Allowance for contaminated material
4.7	Site Survey- 2% of Construction cost							2%	$ 1,092	No allowance to demolish/alter existing building for connection to building access walkway
	Direct Works Total								**$ 55,685**	No allowance for reconfiguration of the existing pavements roads drainage or street furniture
4.8	**Night shift- installation work & Permitt- 30% over**							**30%**	**$ 16,706**	Exposed Steelwork assumed to be painted
4.9	**Overhead/Admin/ Margin**							**35%**	**$ 25,337**	No allowance for Property Acquisitions
4.10	**Design and Investigation Costs 10% of DC**							**10%**	**$ 5,569**	No Allowance for CCTV
4.11	**Project Management cost - 5.5% on DC**							**5%**	**$ 2,784**	No allowance for relocation of services
4.12	**Contingency based on minimal info. 40-70%**							**55%**	**$ 53,750**	No allowance for Lighting (assumed existing street lighting is sufficient)
	Total								**$ 159,831**	**+GST / staircase**
									$ 160,000	**per staircase**

ITEM	DESCRIPTION				RATE	Unit	Qty		AMOUNT	Note
5	**Access Ramp**									
	Structural steel frame & Columns									
5.1	Foundation- 1.5*1.5*0.6m	Demo	4.00	m3	$ 50	/ m3	4		$ 800	
	4* no.	Excavation & Disposal	4.00	m3	$ 110	/ m3	4		$ 1,760	
		Blinding- 50mm thick	2.00	m3	$ 50	/ m3	4		$ 400	
		FRP+ supply concrete	1.35	m3	$ 3,000	/ m3	4		$ 16,200	
		Backfill	1.75	m3	$ 50	/ m3	4		$ 350	
5.2	Structural Steel framework - Tonnage rate	Fabricate, Supply and Install	6.80	T/ each	$ 10,000	/T	1		$ 68,000	Assume 4.no columns 250*8SHS, under the landings- 250PFC stringer- EA75*5 angle bracing
5.3	Concrete Deck (71 LM inclusive landing)	15 lm (L)*2.5m (W)	106.50	m2	$ 250	/m2	1		$ 26,625	Assumed 100 thick - Bondek
5.4	Handrails (stainless steel)	Supply & Install	71.00	LM	$ 500	/LM	2		$ 71,000	
		Kick rails (stainless steel)	71.00	LM	$ 200	/LM	2		$ 28,400	
		Allowance for seals/fittings	71.00	LM	$ 30	/LM	2		$ 4,260	No Allowance for Escalation or GST
									$ -	Assume free standing
5.5	Traffic Control/ Permits							15%	$ 32,669	Assume pad foundations are sufficient, no allowance for piled foundations
										No Allowance for contaminated material
5.6	Site Survey- 2% of Construction cost							2%	$ 5,009	No allowance to demolish/alter existing building for connection to building access walkway
	Direct Works Total								**$ 255,474**	No allowance for reconfiguration of the existing pavements roads drainage or street furniture
5.7	**Night shift- installation work & Permitt- 30% over**							**30%**	**$ 76,642**	Exposed Steelwork assumed to be painted
5.8	**Overhead/Admin/ Margin**							**35%**	**$ 116,240**	No allowance for Property Acquisitions
5.9	**Design and Investigation Costs 10% of DC**							**10%**	**$ 25,547**	No Allowance for CCTV
5.10	**Project Management cost - 5.5% on DC**							**5%**	**$ 12,774**	No allowance for relocation of services
5.11	**Contingency based on minimal info. 40-70%**							**55%**	**$ 246,596**	No allowance for Lighting (assumed existing street lighting is sufficient)
	Total								**$ 733,273**	**+GST / 71m access ramp**
									$ 10,328	**per m**

ITEM	DESCRIPTION				RATE	Unit	Qty		AMOUNT		Note
6	**Building Access Walkway (Cantilevered walkway)**										
	Cantilevered building access walkway	Height	4.50	m							
	4.5m high, 6m span, 1.5m width	Span	6.00	m							Assume negligible gradient in building access walkway
		Width	1.50	m							
6.1	**Support**										
	Pad footing foundation (1.5x1.5x0.6m)	Length	1.50	m							Assume pad foundations are sufficient, no allowance for piled foundations
		Width	1.50	m							
		Depth	0.60	m							
		Supply Concrete	1.35	m3	$ 350	/m3	1		$ 473		
		Supply reinforcement	0.27	tonnes	$ 1,300	/tonne	1		$ 351		
		Install reinforcement	0.27	tonnes	$ 800	/tonne	1		$ 216		
		Pump concrete	1.35	m3	$ 450	/m3	1		$ 608		
		Formwork	2.25	m2	$ 200	/m2	1		$ 450		
		Saw Cut 150thk	10.00	m	$ 14	/m	1		$ 140		
		Demo	3.75	m3	$ 50	/m3	1		$ 188		
		Excavation & Disposal	3.75	m3	$ 200	/m3	1		$ 750		
		Backfill	2.40	m3	$ 50	/m3	1		$ 120		
		Labour	16.00	hours	$ 84	/hr	2		$ 2,688		Rate allowance includes for nightworks
		Excavator	8.00	hours	$ 100	/hr	1		$ 800		
		Truck	8.00	hours	$ 100	/hr	3		$ 2,400		
	Column (Assume 2 250x9SHS with EA75x5 Bracing)										
	250x9 SHS	Weight	65.90	kg/m							
		Supply	296.55	kg	$ 8,000	/tonne	2		$ 4,745		
	Bracing - Assume EA75*5 - 5.27kg/m	Length	2.80	m							
		Weight	5.27	kg/m							
		Supply	14.76	kg	$ 8,000	/tonne	4		$ 472		
		Allowance for bolts/connections (5%)						5%	$ 261		
		Labour	5.00	hours	$ 84	/hr	2		$ 840		Rate allowance includes for nightworks
		Franna Crane	5.00	hours	$ 200	/hr	1		$ 1,000		
6.2	**Walkway**										
	Concrete walkway (1.5m x 6m)	Area	9.00	m2							
		Supply concrete	1.80	m3	$ 350	/m3	1		$ 630		Assume 0.2m depth
		Pump concrete	1.80	m3	$ 35	/m3	1		$ 63		
		Finish	9.00	m2	$ 4	/m2	1		$ 36		
		Cure	9.00	m2	$ 4	/m2	1		$ 36		
	Steel deck (Assume 200PFC Beam - 25.4kg/m)	Area	9.00	m2							
		Weight	25.40	kg/m							
		Supply (8PFC to make the deck)	152.40	kg	$ 8,000	/tonne	8		$ 9,754		
		Allowance for bolts/connections (5%)						5%	$ 488		
		Labour	11.00	hours	$ 84	/hr	2		$ 1,848		Rate allowance includes for nightworks
		Franna Crane	8.00	hours	$ 200	/hr	1		$ 1,600		
6.3	**Handrails (stainless steel)**	Supply & install	6.00	m	$ 500	/m	2		$ 6,000		
		Kick rails	6.00	m	$ 200	/m	2		$ 2,400		
		Allowance for seals/fittings	6.00	m	$ 30	/m	1		$ 180		Assume supported by to-be-constructed walkway
											No allowance to demolish/alter existing building for connection to building access walkway
		Labour	8.00	hours	$ 60	hr	2		$ 960		No Allowance for Escalation or GST
											No Allowance for contaminated material
6.4	**Traffic Management**	Pedestrian Traffic Management						15%	$ 5,930		No allowance for reconfiguration of the existing pavements roads drainage or street furniture
											Exposed Steelwork assumed to be painted
	Direct costs total								**$ 46,425**		No allowance for Property Acquisitions
6.5	**Overhead/Margin/Admin**							**35%**	**$ 16,249**		No Allowance for CCTV
6.6	**Project management**							**10%**	**$ 4,642**		No allowance for relocation of services
6.7	**Contingency**							**50%**	**$ 33,658**		No allowance for Lighting (assumed existing street lighting is sufficient)
	Total								**$ 100,974**	**+GST**	**/ 6m cantilevered building access walkway (4.5m high, 6m span, 1.5m width)**
									$ 16,829	**per m**	

ITEM	DESCRIPTION				RATE	Unit	Qty		AMOUNT		Note
7	**Building Access Walkway (Standard walkway)**										
	Standard building access walkway	Height	4.50	m							
	4.5m high, 3.5m span, 1.5m width	Span	3.50	m							Assume negligible gradient in building access walkway
		Width	1.50	m							
7.1	**Support**										
	Pad footing foundation (1.5x1.5x0.6m)	Length	1.50	m							Assume pad foundations are sufficient, no allowance for piled foundations
		Width	1.50	m							
		Depth	0.60	m							
		Supply Concrete	1.35	m3	$ 350	/m3	1		$ 473		
		Supply reinforcement	0.27	tonnes	$ 1,300	/tonne	1		$ 351		
		Install reinforcement	0.27	tonnes	$ 800	/tonne	1		$ 216		
		Pump concrete	1.35	m3	$ 450	/m3	1		$ 608		
		Formwork	2.25	m2	$ 200	/m2	1		$ 450		
		Saw Cut 150thk	10.00	m	$ 14	/m	1		$ 140		
		Demo	3.75	m3	$ 50	/m3	1		$ 188		
		Excavation & Disposal	3.75	m3	$ 200	/m3	1		$ 750		
		Backfill	2.40	m3	$ 50	/m3	1		$ 120		
		Labour	16.00	hours	$ 84	/hr	2		$ 2,688		Rate allowance includes for nightworks
		Excavator	8.00	hours	$ 100	/hr	1		$ 800		
		Truck	8.00	hours	$ 100	/hr	3		$ 2,400		
	Column (Assume 2 250x9SHS with EA75x5 Bracing)										
	250x9 SHS	Weight	65.90	kg/m							
		Supply	296.55	kg	$ 8,000	/tonne	2		$ 4,745		
	Bracing - Assume EA75*5 - 5.27kg/m	Length	2.80	m							
		Weight	5.27	kg/m							
		Supply	14.76	kg	$ 8,000	/tonne	4		$ 472		
		Allowance for bolts/connections (5%)						5%	$ 261		
		Labour	5.00	hours	$ 84	/hr	2		$ 840		Rate allowance includes for nightworks
		Franna Crane	5.00	hours	$ 200	/hr	1		$ 1,000		
7.2	**Walkway**										
	Concrete walkway (1.5m x 3.5m)	Area	5.25	m2							
		Supply concrete	1.05	m3	$ 350	/m3	1		$ 368		Assume 0.2m depth
		Pump concrete	1.05	m3	$ 35	/m3	1		$ 37		
		Finish	5.25	m2	$ 4	/m2	1		$ 21		
		Cure	5.25	m2	$ 4	/m2	1		$ 21		
	Steel deck (Assume 200PFC Beam - 25.4kg/m)	Area	5.25	m2							
		Weight	25.40	kg/m							
		Supply (8PFC to make the deck)	152.40	kg	$ 8,000	/tonne	8		$ 9,754		
		Allowance for bolts/connections (5%)						5%	$ 488		
		Labour	9.00	hours	$ 84	/hr	2		$ 1,512		Rate allowance includes for nightworks
		Franna Crane	6.00	hours	$ 200	/hr	1		$ 1,200		
7.3	**Handrails (stainless steel)**	Supply & install	3.50	m	$ 500	/m	2		$ 3,500		
		Kick rails	3.50	m	$ 200	/m	2		$ 1,400		
		Allowance for seals/fittings	3.50	m	$ 30	/m	1		$ 105		Assume supported by to-be-constructed walkway
											No allowance to demolish/alter existing building for connection to building access walkway
		Labour	4.00	hours	$ 60	hr	2		$ 480		No Allowance for Escalation or GST
											No Allowance for contaminated material
7.4	**Traffic Management**	Pedestrian Traffic Management						15%	$ 5,236		No allowance for reconfiguration of the existing pavements roads drainage or street furniture
											Exposed Steelwork assumed to be painted
	Direct costs total								**$ 40,621**		No allowance for Property Acquisitions
7.5	**Overhead/Margin/Admin**							**35%**	**$ 14,217**		No Allowance for CCTV
7.6	**Project management**							**10%**	**$ 4,062**		No allowance for relocation of services
7.8	**Contingency**							**50%**	**$ 29,450**		No allowance for Lighting (assumed existing street lighting is sufficient)
	Total								**$ 88,350**	**+GST**	**/ 3.5m standard building walkway (4.5m high, 3.5m span, 1.5m width)**
									$ 25,243	**per m**	Rate skewed due to short span and high setup costs

ITEM	DESCRIPTION				RATE	Unit	Qty		AMOUNT		Note
8	**Building Access Walkway (Elevated standard walkway - type 5)**										
	Elevated standard building access walkway	Height	8.00	m							
	8m high, 3.5m span, 1.5m width	Span	3.50	m							Assume negligible gradient in building access walkway
		Width	1.50	m							
8.1	**Support**										
	Pad footing foundation (1.75x1.75x0.8m)	Length	1.75	m							Assume pad foundations are sufficient, no allowance for piled foundations
		Width	1.75	m							
		Depth	0.80	m							
		Supply Concrete	2.45	m3	$ 350	/m3	1		$ 858		
		Supply reinforcement	0.49	tonnes	$ 1,300	/tonne	1		$ 637		
		Install reinforcement	0.49	tonnes	$ 800	/tonne	1		$ 392		
		Pump concrete	2.45	m3	$ 450	/m3	1		$ 1,103		
		Formwork	3.06	m2	$ 200	/m2	1		$ 613		
		Saw Cut 150thk	11.00	m	$ 14	/m	1		$ 154		
		Demo	6.05	m3	$ 50	/m3	1		$ 303		
		Excavation & Disposal	6.05	m3	$ 200	/m3	1		$ 1,210		
		Backfill	3.60	m3	$ 50	/m3	1		$ 180		
		Labour	16.00	hours	$ 84	/hr	2		$ 2,688		Rate allowance includes for nightworks
		Excavator	8.00	hours	$ 100	/hr	1		$ 800		
		Truck	8.00	hours	$ 100	/hr	3		$ 2,400		
	Column (Assume 2 250x9SHS with EA75x5 Bracing)										
	250x9 SHS	Weight	65.90	kg/m							
		Supply	527.20	kg	$ 8,000	/tonne	2		$ 8,435		
	Bracing - Assume EA75*5 - 5.27kg/m	Length	2.80	m							
		Weight	5.27	kg/m							
		Supply	14.76	kg	$ 8,000	/tonne	8		$ 944		
		Allowance for bolts/connections (5%)						5%	$ 469		
		Labour	8.00	hours	$ 84	/hr	2		$ 1,344		Rate allowance includes for nightworks
		Franna Crane	8.00	hours	$ 200	/hr	1		$ 1,600		
8.2	**Walkway**										
	Concrete walkway (1.5m x 3.5m)	Area	5.25	m2							
		Supply concrete	1.05	m3	$ 350	/m3	1		$ 368		Assume 0.2m depth
		Pump concrete	1.05	m3	$ 35	/m3	1		$ 37		
		Finish	5.25	m2	$ 4	/m2	1		$ 21		
		Cure	5.25	m2	$ 4	/m2	1		$ 21		
	Steel deck (Assume 200PFC Beam - 25.4kg/m)	Area	5.25	m2							
		Weight	25.40	kg/m							
		Supply (8PFC to make the deck)	152.40	kg	$ 8,000	/tonne	8		$ 9,754		
		Allowance for bolts/connections (5%)						5%	$ 488		
		Labour	12.00	hours	$ 84	/hr	2		$ 2,016		Rate allowance includes for nightworks
		Franna Crane	4.00	hours	$ 200	/hr	1		$ 800		
8.3	**Handrails (stainless steel)**	Supply & install	3.50	m	$ 500	/m	2		$ 3,500		
		Kick rails	3.50	m	$ 200	/m	2		$ 1,400		
		Allowance for seals/fittings	3.50	m	$ 30	/m	1		$ 105		Assume supported by to-be-constructed walkway
											No allowance to demolish/alter existing building for connection to building access walkway
		Labour	4.00	hours	$ 60	hr	2		$ 480		No Allowance for Escalation or GST
											No Allowance for contaminated material
8.4	**Traffic Management**	Pedestrian Traffic Management						15%	$ 6,396		No allowance for reconfiguration of the existing pavements roads drainage or street furniture
											Exposed Steelwork assumed to be painted
	Direct costs total								**$ 49,513**		No allowance for Property Acquisitions
8.5	**Overhead/Margin/Admin**							**35%**	**$ 17,329**		No Allowance for CCTV
8.6	**Project management**							**10%**	**$ 4,951**		No allowance for relocation of services
8.7	**Contingency**							**50%**	**$ 35,897**		No allowance for Lighting (assumed existing street lighting is sufficient)
	Total								**$ 107,690**	**+GST**	**/ 3.5m elevated standard building walkway (8m high, 3.5m span, 1.5m width)**
									$ 30,769	**per m**	Rate skewed due to high walkway elevation (based off walkway typology 5)

APPENDIX E – MULTI-CRITERIA ANALYSIS

ALTERNATIVES	CRITERIA (scores range between zero and 5)					
	A. Effectiveness in Reducing Risk to Life	**B.** Difficulty of Implementation	**C.** Residual Risks after Mitigation Measures are Implemented	**D.** Impacts on Urban Landscape	**E.** Cost of implementation	**F.** Load on emergency services
1. **Vehicular Evacuation** **Overall Score: 11**	Score = 0	Score = 1	Score = 0	Score = 5	Score = 5	Score = 1
2. Shelter In Place **Overall Score: 22 (best score)**	Score = 4	Score = 4	Score = 2	Score = 5	Score = 5	Score = 2
3. HHL PMF **Overall Score:16**	Score = 5	Score = 1	Score = 5	Score = 1	Score = 1	Score = 4
4. HHL 20 year ARI + SIP **Overall Score: 18**	Score = 4	Score = 3	Score = 3	Score = 2	Score = 3	Score = 3
5. HHL 100 year ARI + SIP **Overall Score: 16**	Score = 4	Score = 2	Score = 4	Score = 2	Score = 2	Score = 3

Notes

Alternative 1 – Vehicular Evacuation

1A: Under the assumptions of the NSW SES Timeline Evacuation Model, vehicular evacuation cannot be completed before evacuation routes are cut by floodwaters. This poses a very high risk to life.

1B: Implementation would be possible, but very difficult. Drivers in different precincts would need to know where to evacuate. Regional flooding would cut most of the main roads out of Parramatta CBD. Cars evacuating to Great Western Highway would most likely cue back to the CBD preventing more cars to leave their building. Background traffic would need to be managed in day scenarios, particularly in a PM peak scenario (residents returning to the CBD).

1C. This strategy would not reduce risk to life because evacuation cannot be completed before the arrival of floodwaters. In fact, this strategy may even increase risk to life because evacuees would experience inundation while they are blocked in their cars.

1D. There would be no alteration of the urban landscape

1E. There would be no significant implementation costs involved

1F. Emergency Managers would need to deal with the very high residual risks. This would require a complex warning communication strategy to ensure evacuees would know where to drive to, managing evacuating and background traffic, and most importantly rescuing a large number of people from their cars.

Alternative 2 – Shelter In Place up to the PMF

2A. In most instances, people would be able to take shelter in a refuge above the PMF within their own building. People in the public domain as well as people in buildings unsuitable to be used as shelters would need to have access to neighbouring buildings with a refuge above the PMF level.

2B. Ad-hoc communication strategy and risk awareness activities may be required to ensure that evacuees know what to do. A focus should be put on reducing the risk of people leaving the refuge before the emergency has passed.

2C. If risks of SIP are addressed as recommended in Molino Stewart (2016) and in this report, residual risk would be moderate.

2D. There would be no alteration of the urban landscape

2E. There would be no significant implementation costs involved

2F. Emergency responders may need to intervene in case the mitigation measures in place to address SIP risks fail.

Alternative 3: HHL up to the PMF

3A. Each building would have direct access to a flood free area up to the PMF. Risk to life would be minimum.

3B. It is expected that the construction of such a large system of elevated walkways would be very difficult to achieve. Some of the main challenges include the compatibility with existing and future development, maintenance, informal use of the structure causing safety issues and acceptance of the general public

3C. The main risk would be in case occupants of one-storey buildings refuse to evacuate on the elevated walkways.

3D. The impacts on urban landscape would be extremely high. These would include visual impact (particularly on heritage sites), overshadowing, loss of urban trees, inefficient use of land, limited accessibility to the CBD.

3E. Costs would be extremely high (estimated total construction cost of $ 324 Million. Note that this does not include maintenance costs)

3F. With such a system in place, virtually no dwellings would be isolated by floodwaters in any event up to the PMF. This would greatly simplify the role of emergency responders.

Alternatives 4 (and 5): HHL up to the 20 (100) year ARI and SIP in greater events

4(5)A. Risk to life would be significantly reduced

4(5)B. It is expected that the construction of such a large system of elevated walkways would be very difficult to achieve. Some of the main challenges include the compatibility with existing and future development, maintenance, informal use of the structure causing safety issues and acceptance of the general public.

4(5)C. Residual risk would be similar to the SIP only alternative, but SIP would only be required in large flood events

4(5)D. The impacts on urban landscape would be very high. These would include visual impact (particularly on heritage sites), overshadowing, loss of urban trees, inefficient use of land, limited accessibility to the CBD. Because of the smaller size of the elevated walkways network, impacts would be smaller than in Alternative 3 (HHL up to the PMF). Because the 100 year ARI event would require a network of elevated walkways only slightly larger than the 20 year ARI event, impacts would be similar.

4(5)E. The estimated total construction cost would be $ 94.5 Million (20 year ARI) and of $ 111 Million (100 year ARI). Note that this does not include maintenance costs)

4(5)F. Isolation would be avoided up to the 20 (100) year ARI event, so it is expected that the burden on emergency responders would be lower than in a SIP only scenario (Alternative 3)