- Increase in ocean boundary water level – sea level projections provide for a direct increase in tidal and storm surge water level conditions; and
- Increase in rainfall intensity – the frequency and severity of extreme rainfall events is expected to increase.

The model configuration and assumptions adopted for these potential climate change impacts are discussed in the following sections.

9.1.1 Ocean Water Level

As discussed in Section 1.3.1, the sea level rise planning benchmarks provided in the NSW Sea Level Rise Policy Statement (DECCW, 2009) have been adopted for this Flood Study.

The benchmarks are a projected rise in sea level, relative to the 1990 mean sea level, of 0.4 metres by 2050 and 0.9 metres by 2100 (DECCW, 2009). Based on these guidelines, design ocean boundary conditions were raised by 0.4 m and 0.9 m to assess the potential impact of sea level rise on flood behaviour in the City Area catchment for the year 2050 and 2100 respectively.

The sea level rise allowances provide for direct increases in these ocean water levels. Table 9-1 presents a summary of the adopted peak ocean water levels for 1% AEP design modelling for existing water level conditions and the 2050 and 2100 sea level rise benchmarks.

Table 9-1 Design peak Sydney Harbour water levels incorporating sea level rise

Existing (5% AEP Tide)	2050 (+0.4m)	2100 (+0.9m)
1.38 m AHD	1.78 m AHD	2.28 m AHD

9.1.2 Design Rainfall Intensity

Current research predicts that a likely outcome of future climatic change will be an increase in flood producing rainfall intensities. Climate Change in New South Wales (CSIRO, 2007) provides projected increases in 2.5% AEP 24h duration rainfall depths for Sydney Metropolitan catchments of up to 12% and 10%, for the years 2030 and 2070 respectively.

The NSW Government has also released a guideline (DECC, 2007) for Practical Consideration of Climate Change in the floodplain management process that advocates consideration of increased design rainfall intensities of up to 30%. In line with this guidance note, additional tests incorporating 10%, 20% and 30% increases in design rainfall have been undertaken.

9.2 Climate Change Model Conditions

A range of design event simulations have been undertaken incorporating combinations of increases in rainfall intensities and ocean water levels. A summary of the modelled scenarios for the 1% AEP design event is provided in Table 9 2.

Table 9-2 Summary of model runs for climate change consideration

Design Flood	Rainfall Intensity Increase	Sydney Harbour Peak Water Level (mAHD)
1% AEP 90 min duration	10%	1.38 (5% AEP Harbour Level)
1% AEP 90 min duration	20%	1.38 (5% AEP Harbour Level)
1% AEP 90 min duration	30%	1.38 (5% AEP Harbour Level)
1% AEP 90 min duration	0%	1.78 mAHD (+0.4m to 2050)
1% AEP 90 min duration	0%	2.28 mAHD (+0.9m to 2050)

9.3 Climate Change Results

The modelled peak flood levels for the climate change scenarios are presented in Table 9-3 for the reporting locations indicated in Figure 7-1. The impact of potential climate change scenarios on the standard design flood condition is presented in Figure A- 31 to Figure A- 35 as a series of maps showing increase in peak flood inundation extents from the baseline (existing) conditions.

The model simulation results show a general increase in peak flood levels along the major and some minor overland flow paths within the study area with increasing rainfall intensity, with increased peak flood levels particularly evident along the major overland flow paths. The 10% rainfall increase scenario which is closest to the regional estimate of future rainfall intensity increases for the Sydney region typically results in flood level increases of less than 0.05 m. Figure 9-1 shows the peak flood level profile along Pitt Street (for the profile location refer to Figure 7-1) and highlights the limited impact from the Climate Change scenarios.

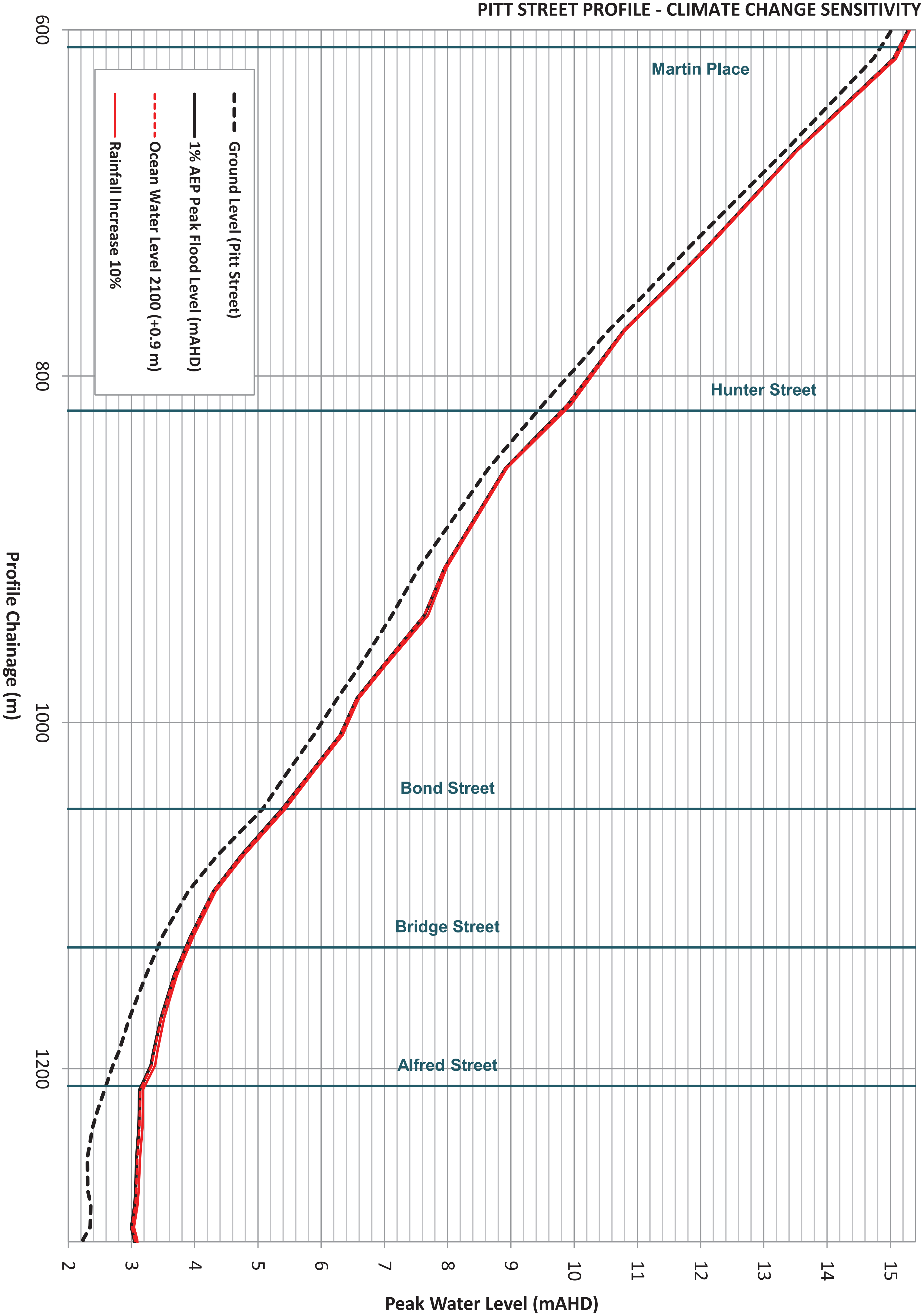
Figure A- 36 shows the tidal inundation extents due to future sea level rise. These results show that future sea level rise has minimal effect on flooding.

Table 9-3 Changes in peak flood levels (m) for climate change scenarios

Location	10% Rainfall	20% Rainfall	30% Rainfall	2050 Harbour	2100 Harbour
H01	+0.04	+0.07	+0.10	+0.00	+0.00
H02	+0.03	+0.06	+0.08	+0.00	+0.00
H03	+0.04	+0.09	+0.13	+0.00	+0.00
H04	+0.03	+0.08	+0.12	+0.00	+0.00
H05	+0.05	+0.10	+0.15	+0.00	+0.00
H06	+0.03	+0.06	+0.09	+0.00	+0.01
H07	+0.02	+0.04	+0.06	+0.00	+0.00
H08	+0.01	+0.02	+0.04	+0.00	+0.00
H09	+0.02	+0.04	+0.06	+0.02	+0.04
H10	+0.03	+0.06	+0.10	+0.00	+0.00
H11	+0.01	+0.02	+0.02	+0.00	+0.00
H12	+0.02	+0.03	+0.03	+0.02	+0.03
H13	+0.01	+0.03	+0.04	+0.00	+0.03
H14	+0.01	+0.03	+0.04	+0.00	+0.01

FIGURE 9-1

PITT STREET PROFILE - CLIMATE CHANGE SENSITIVITY



9.4 Conclusions

The potential impacts of future climate change have been considered for a range of design event scenarios as defined in Table 9-2. The impact of climate change scenarios on the standard design flood condition us presented in Appendix A as a series of maps showing the increase in peak flood inundation extents from the baseline (existing) conditions. The most significant impacts of climate change within the study area are associated with increased rainfall intensities.

The results of the climate change analysis highlight the sensitivity of the peak flood level conditions in the City Area catchment to potential impacts of climate change. Future planning and floodplain risk management in the catchment will need to take due consideration of the increasing flood risk under possible future climate conditions.

10 PROPERTY INUNDATION AND FLOOD DAMAGE ASSESSMENT

A flood damage assessment has been undertaken to identify flood affected property, to quantify the extent of damages in economic terms for existing flood conditions and to enable the future assessment of the relative merit of potential flood mitigation options by means of benefit-cost analysis. As part of the flood damage assessment a property database has been developed detailing individual buildings subject to flood inundation.

The general process for undertaking a flood damages assessment incorporates:

- Identifying properties subject to flooding;
- Determining depth of inundation above floor level for a range of design event magnitudes;
- Defining appropriate stage-damage relationships for various property types/uses;
- Estimating potential flood damage for each property; and
- Calculating the total flood damage for a range of design events.

10.1 Property Data

10.1.1 Location

Property locations have been derived from Council's cadastre information and associated detailed aerial photography of the catchment. Linked within a GIS system, this data enables rapid identification and querying of property details. A property database has been developed detailing individual properties subject to flood inundation.

10.1.2 Land Use

For the purposes of the flood damage assessment, property was considered as either residential or commercial. Commercial properties have been identified from the property survey. Public infrastructure and utility assets have been excluded from the damages assessment. Figure 10-1 shows the breakdown of residential versus commercial properties.

10.1.3 Ground and Floor Level

During the course of the flood study, a surveyor was engaged to survey the building floor levels for the cadastral parcels flagged from the preliminary PMF inundation assessment. Approximately 1400 cadastral parcels were flagged as requiring inclusion in the flood damage assessment for both the Darling Harbour and City Area studies. The floor level was surveyed for the lowest entrance level to the property. Properties with basement levels had the crest level of the basement surveyed. No internal building survey was undertaken.

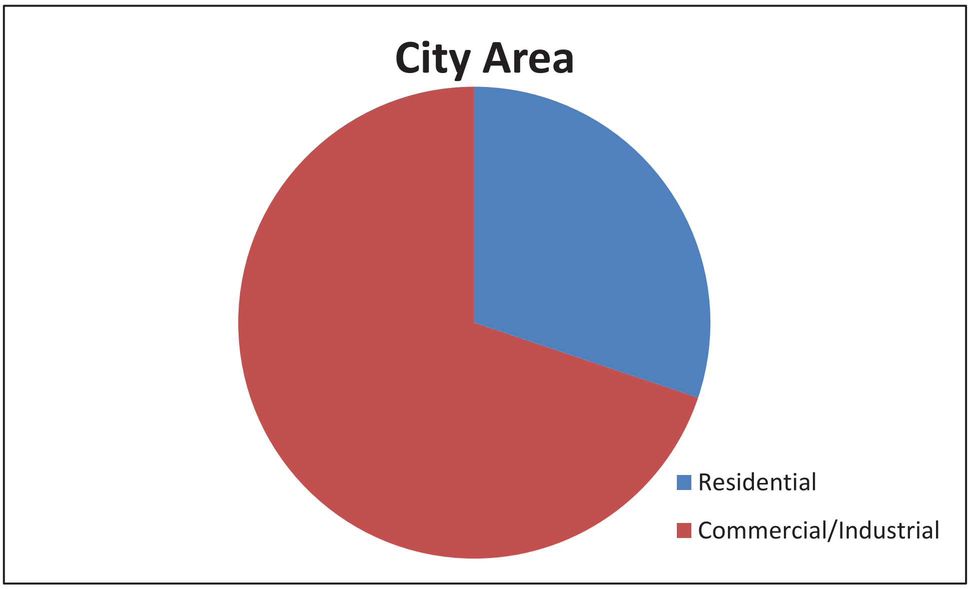


Figure 10-1 Proportion of residential and commercial properties in the City Area catchment

10.1.4 Flood Level

Design flood levels have been obtained for each property for the full range of design events modelled. Topography in the catchment can rapidly change meaning the flood level across a property may vary considerably. The flood level closest to the location of the lowest entrance was used as the critical flood level defining potential flood damages.

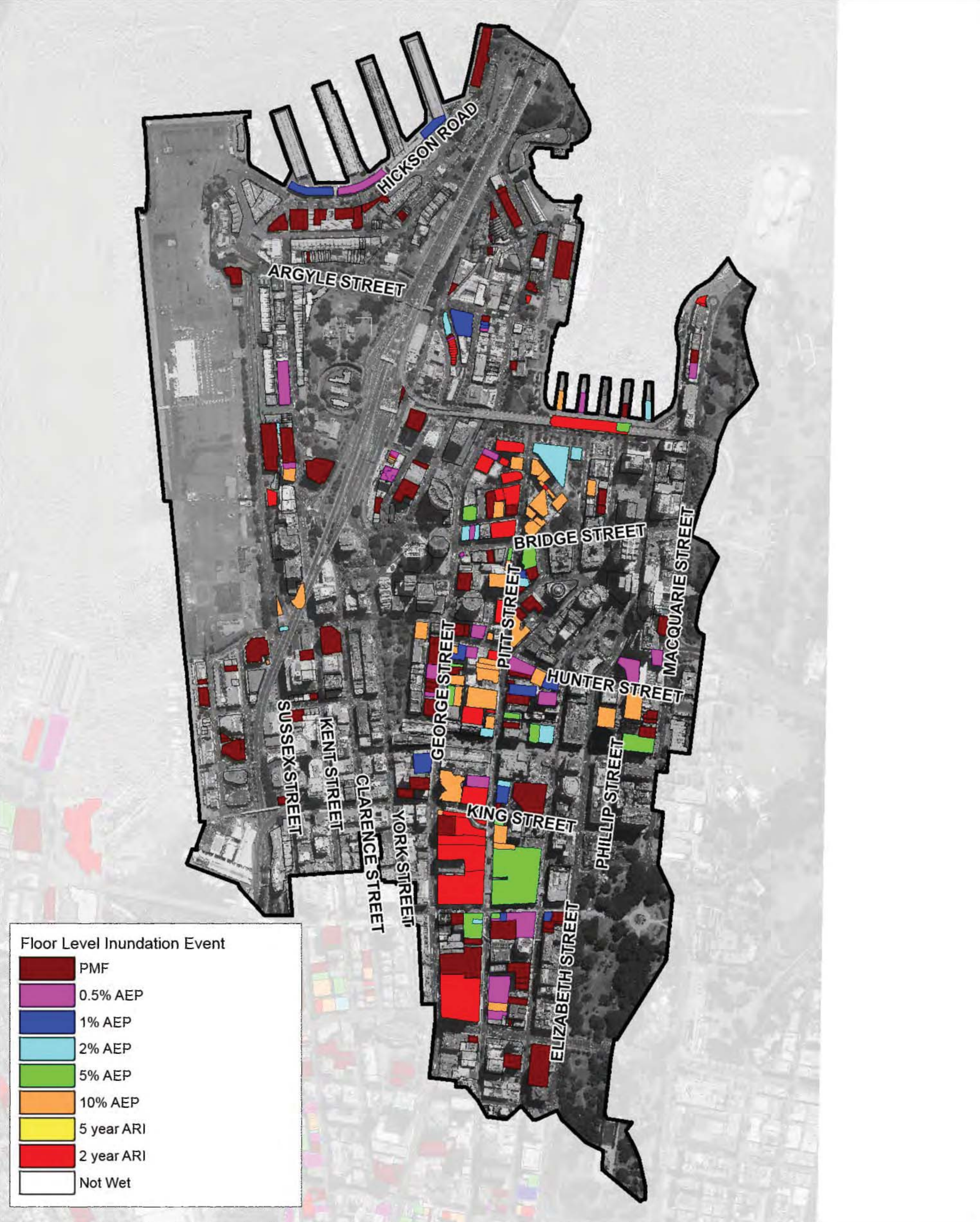
10.2 Property Inundation

A summary of the number of properties potentially affected by above floor flooding for a range of flood magnitudes is shown in Table 10-1.

Figure 10-2 shows the spatial distribution of properties potentially affected by above floor flooding and the design event which first results in above floor flooding for individual properties. The distribution of the affected properties for each design flood event is shown in Figure 10-2.

Table 10-1 Number of properties affected by above floor flooding for various design flood events.

Design Flood	Residential	Commercial	Total
2 yr ARI	9	31	40
5 yr ARI	17	51	68
10% AEP	17	72	89
5% AEP	20	85	105
2% AEP	21	96	117
1% AEP	30	107	137
0.2% AEP	35	125	160
PMF	72	206	278



Title:

Flood Damage Assessment Floor Level Inundation Event

Figure: 10-2

Rev: 1

0 250 500m

Approx. Scale

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10.3 Flood Damages Assessment

10.4 Types of Flood Damage

The definitions and methodology used in estimating flood damage are summarised in the Floodplain Development Manual. Figure 10-3 summarises the "types" of flood damages typically considered. The two main categories are 'tangible' and 'intangible' damages. Tangible flood damages are those that can be more readily evaluated in monetary terms, while intangible damages relate to the social cost of flooding and therefore are much more difficult to quantify.

Tangible flood damages are further divided into direct and indirect damages. Direct flood damages relate to the loss, or loss in value, of an object or a piece of property caused by direct contact with floodwaters. Indirect flood damages relate to loss in production or revenue, loss of wages, additional accommodation and living expenses, and any extra outlays that occur because of the flood.

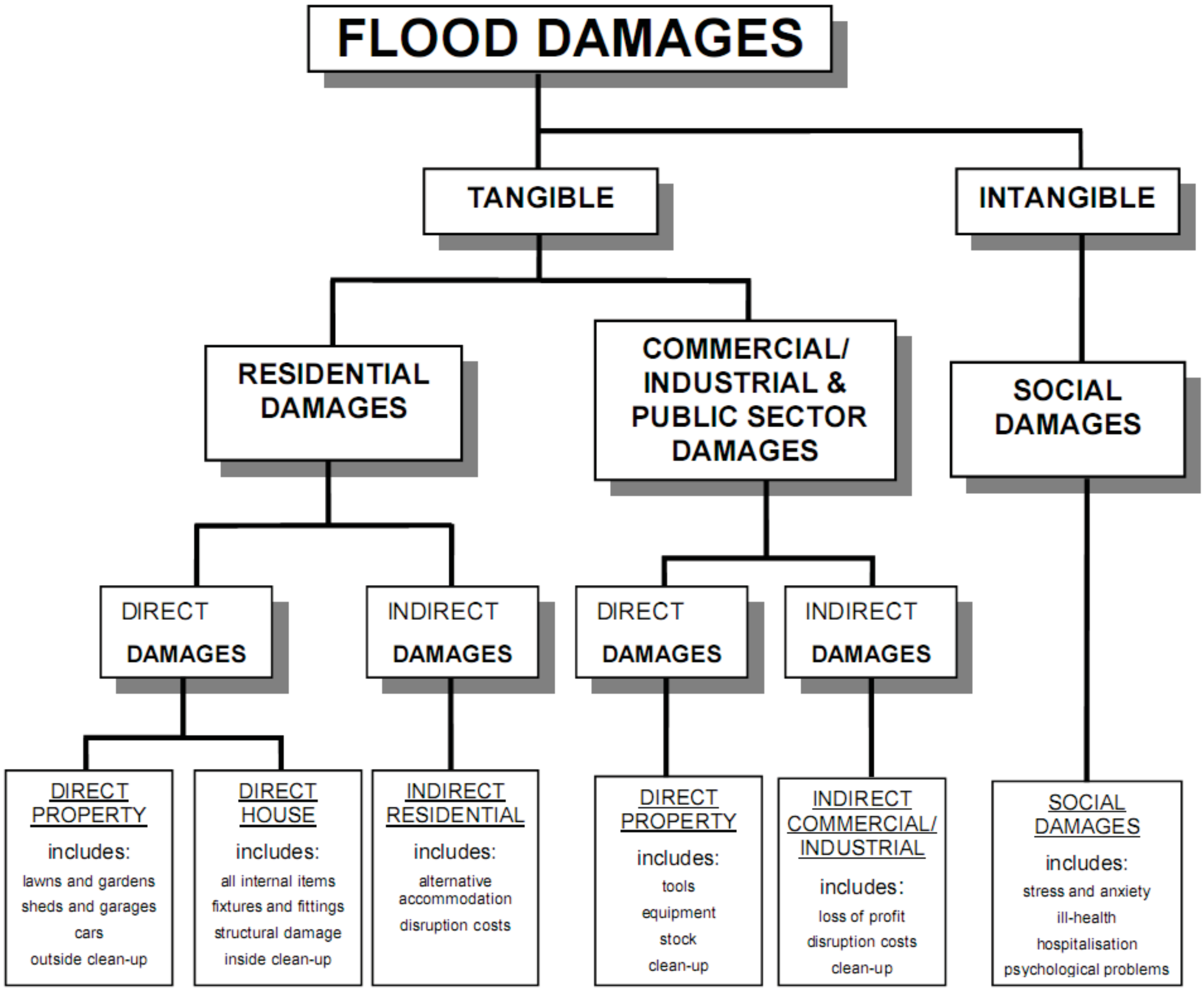

Figure 10-3 Types of Flood Damage

10.4.1 Basis of Flood Damage Calculations

Flood damages have been calculated using the data base of potentially flood affected properties and a number of stage-damage curves derived for different types of property within the catchment. These curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular property type. Residential damage curves are based on the OEH guideline stage-damage curves for residential property. Commercial damage curves are based upon Queensland Government Guidance on the Assessment of Tangible Flood Damages (DNRM, 2002)

Different stage-damage curves for direct property damage have been derived for:

- Residential dwellings (categorised into small, typical or raised categories); and
- Commercial premises (categorised by size [small, medium, large] and damage class [1-5]).

Apart from the direct damages calculated from the derived stage-damage curves for each flood affected property, other forms of flood damage include:

- Indirect residential, commercial and industrial damages, taken as a percentage of the direct damages;
- Infrastructure damage, based on a percentage of the total value of residential and business flood damage; and
- Intangible damages relate to the social impact of flooding and include:
    - inconvenience,
    - isolation,
    - disruption of family and social activities,
    - anxiety, pain and suffering, trauma,
    - physical ill-health, and
    - psychological ill-health.

The damage estimates derived in this study are for the tangible damages only. Whilst intangible losses may be significant, these effects have not been quantified due to difficulties in assigning a meaningful dollar value.

The Average Annual Damage (AAD) is the average damage in dollars per year that would occur in a designated area from flooding over a very long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events). Estimation of the AAD provides a basis for comparing the effectiveness of different floodplain management measures (i.e. the reduction in the AAD).

Table 10-2 Estimated flood damages

Design Flood	Properties	Event Damage	Contribution to AAD
2 yr ARI	40	$1,880,467	$224,388
5 yr ARI	68	$3,000,370	$517,857
10% AEP	89	$4,112,054	$306,214
5% AEP	105	$5,025,749	$211,961
2% AEP	117	$5,849,570	$157,525
1% AEP	137	$6,876,224	$62,682
0.2% AEP	160	$8,833,531	$62,463
PMF	278	$27,582,892	$36,378
		Total AAD	**$1,579,467**

The total estimated flood damage to occur in a 1% AEP local catchment flood event is $6.9 million, increasing to an estimated $28 million worth of damage for the PMF. The annual cost of flooding is estimated to be approximately $1.6 million.

The sensitivity of the damage estimate to climate change has been assessed for the 1% AEP event. Table 10-3 shows the increased number of properties affected and the increase in estimated event damage for the climate change scenarios assessed in Section 9.

Table 10-3 Flood damages sensitivity to climate change

Design Flood	Properties	Event Damage
1% AEP	137	$6,876,224
10% Rainfall	+ 7	+ 13%
20% Rainfall	+ 20	+ 25%
30% Rainfall	+ 31	+ 39%
2050 Harbour	+ 0	+ 1%
2100 Harbour	+ 2	+ 2%

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APPENDIX A: DESIGN FLOOD MAPPING

DISCLAIMER:
BUILDINGS HAVE NOT BEEN MODELLED AND RESULTS CAN'T BE USED TO DETERMINE INTERNAL BUILDING FLOODING.
INUNDATION PATTERNS FROM LOCAL OVERLAND FLOW MAY VARY SLIGHTLY TO THE MAPPED RESULTS SHOWN.
COUNCIL SHOULD BE CONSULTED TO CONFIRM FLOOD AFFECTATION AT INDIVIDUAL ALLOTMENTS.

Title:
Peak Flood Depth
2 year ARI

Figure: A-1

Rev: -

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Approx. Scale

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Title:
Peak Flood Depth
5 year ARI

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Title:

Peak Flood Depth
10% AEP (10 yr ARI)

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Title:
Peak Flood Depth
5% AEP (20 yr ARI)

Figure: A-4

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Title:
Peak Flood Depth
2% AEP (50 yr ARI)

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Title:

Peak Flood Depth
1% AEP (100 yr ARI)

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Title:
Peak Flood Depth
0.2% AEP (500 yr ARI)

Figure: A-7

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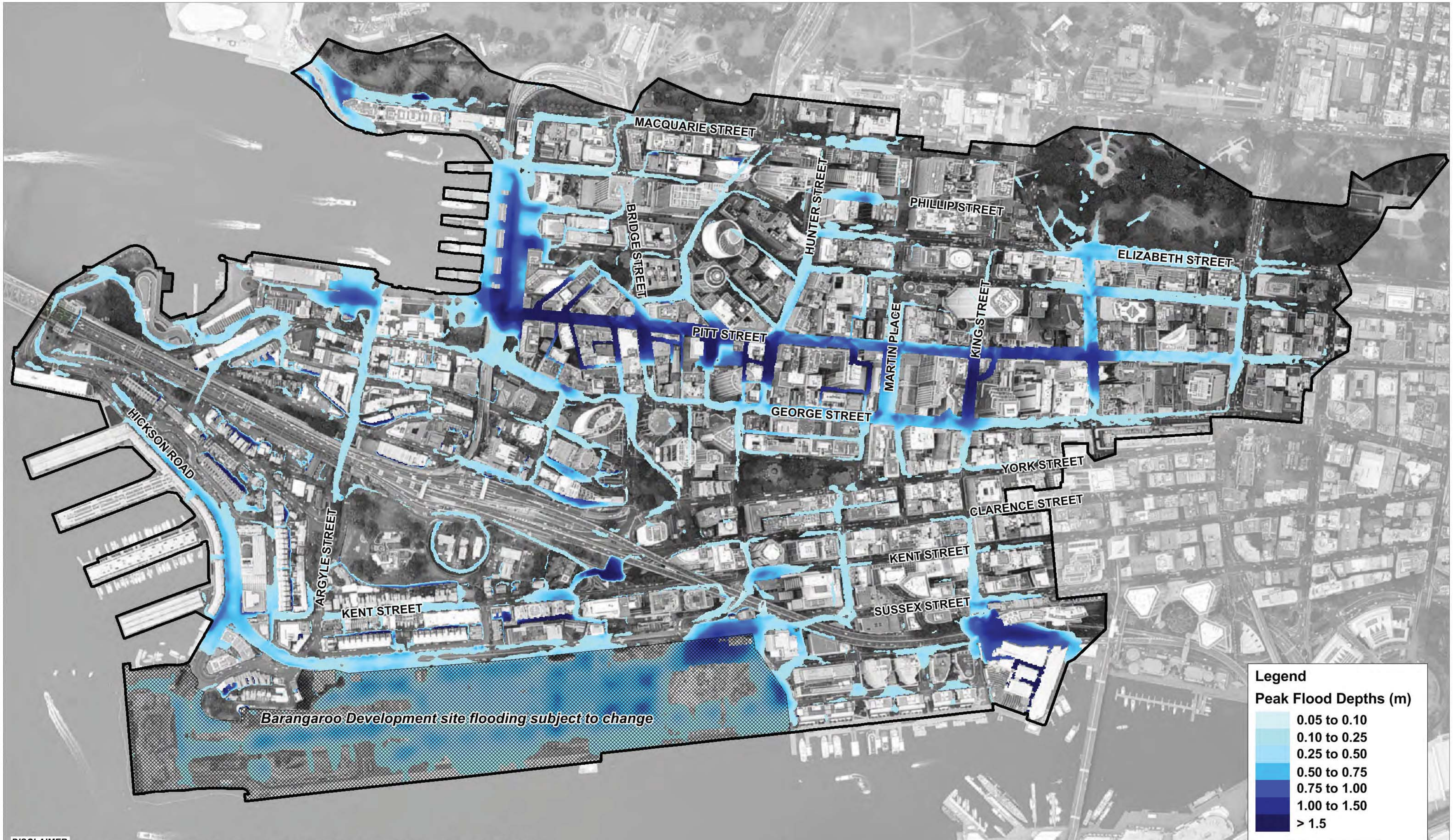

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Title:
Peak Flood Depth
Probable Maximum Flood (PMF)

Figure: **A-8**

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Title:
Peak Flood Level
2 year ARI

Figure: A-9

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Title:
Peak Flood Level
5 year ARI

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