# 8 SENSITIVITY ANALYSIS

A number of sensitivity tests have been undertaken on the modelled flood behaviour in the City Area catchment. In defining sensitivity tests, consideration has been given to the most appropriate tests taking into account catchment properties and simulated design flood behaviour. The tests undertaken have included:

- Hydraulic roughness;
- Blockage of the stormwater drainage system;
- Change in rainfall losses; and
- Changed sea level

The rationalisation for each of these sensitivity tests along with adopted model configuration/parameters and results are summarised in the following sections.

As outlined in Section 7 the critical duration varies across the catchment. For the purpose of sensitivity testing the 1% AEP, 90-minute duration, design storm event has been used as the design base case.

## 8.1 Hydraulic Roughness

Sensitivity tests on the hydraulic roughness (Manning's 'n') were undertaken separately for the 1D stormwater network and for the 2D overland flow paths. Whilst adopted design parameters are within typical ranges, the inherent variability/uncertainty in hydraulic roughness warrants consideration of the relative impact on adopted design flood conditions. The potential uncertainty in selected parameter choice is different between buried conduits which has much firmer guidance in literature versus overland flow paths which could feasible have greater variation.

Sensitivity analysis for the TUFLOW 2D overland flow path Manning's '*n*' values was assessed by applying a 50% increase and a 50% decrease in the adopted values for the baseline design conditions. Sensitivity analysis for the 1D buried pipe network was assessed by applying a 20% increase and a 20% decrease in the adopted values for the baseline design conditions.

The results of the sensitivity tests on hydraulic roughness are summarised in Table 8-1 for the reporting locations indicated in Figure 7-1 and Figure 7-2.

With regard to the TUFLOW 2D overland flow path hydraulic roughness, the model simulations show minor change (generally <0.05 m) in peak flood level for the variation in roughness values. It should be noted that the reduction in hydraulic roughness does not always reduce flood levels and conversely an increase in hydraulic roughness does not always increase peak flood levels which can be attributed to the timing of flows at the confluences of difference flow paths. Of particular interest is Pitt Street which is the main flow path for the catchment, where changes in simulated peak flood levels are less than 0.10 m.



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Variation of the hydraulic roughness of the pipe network results in changes to peak flood levels of less than or equal to 0.02 m. In the scenario where pipe roughness is increased, the pipe has a reduced capacity and more flow is conveyed via overland flow paths. In the scenario where the pipe roughness is reduced, the pipe is able to convey a higher flow reducing overland flows and overland flood levels.

**Table 8-1 Changes in Flood Levels for Manning's '*n*' Sensitivity Tests**

| Location | + 50% Manning's '*n*' (2D Domain) | - 50% Manning's '*n*' (2D Domain) | + 20% Manning's '*n*' (1D Domain) | - 20% Manning's '*n*' (1D Domain) |
|---|---|---|---|---|
| H01 | -0.02 | +0.09 | +0.01 | -0.01 |
| H02 | +0.01 | +0.01 | +0.00 | +0.00 |
| H03 | +0.02 | -0.07 | +0.01 | -0.01 |
| H04 | -0.05 | +0.12 | +0.02 | -0.02 |
| H05 | +0.03 | +0.01 | +0.01 | -0.01 |
| H06 | +0.02 | -0.03 | +0.01 | -0.01 |
| H07 | +0.03 | -0.09 | +0.00 | +0.00 |
| H08 | +0.01 | +0.00 | +0.00 | +0.00 |
| H09 | -0.01 | -0.01 | +0.01 | -0.01 |
| H10 | -0.02 | +0.02 | +0.01 | -0.01 |
| H11 | +0.01 | -0.03 | +0.00 | +0.00 |
| H12 | +0.00 | +0.00 | +0.01 | -0.02 |
| H13 | +0.01 | -0.01 | +0.00 | +0.00 |
| H14 | +0.01 | -0.02 | +0.00 | +0.00 |

## 8.2 Stormwater Drainage Blockage

Structure blockages have the potential to substantially increase the magnitude and extent of property inundation through local increases in water level, redistribution of flows on the floodplain, and activation of additional flow paths. As outlined in Section 6, different pit blockages were considered for different magnitude storms, summarised as follows:

- 5 year ARI and more frequent: Grade Blockage 20%, Sag Blockage 50%
- 10% AEP and less frequent: Grade Blockage 50%, Sag Blockage 100%

Pit inlet blockage sensitivity was therefore separately assessed for 5 year ARI design event and also the 1% AEP design event. The blockage scenarios modelled are shown below:

- 5 year ARI: Grade Blockage 50%, Sag Blockage 100%
- 1% AEP: Grade Blockage 100%, Sag Blockage 100%.

The results of the sensitivity tests on blockages are summarised in Table 8-2 for the reporting locations indicated in Figure 7-1.

For the 5 year ARI event, if the level of pit blockage was used, the modelled peak water level would increase typically by less than 0.05 m. A higher sensitivity is exhibited in isolated trapped low points which are more reliant on the drainage network.

For the 1% AEP event, blockage sensitivity analysis assumes a very extreme scenario where no water is allowed into the stormwater system via on-grade or sag pits. Peak water levels for this scenario typically increase by less than 0.1 m though increase higher in isolated locations. Given the extreme sensitivity analysis scenario and the limit of sensitivity analysis modelled confidence can be relied upon the 1% AEP design results used to derive the Flood Planning Level.

**Table 8-2 Changes in Flood Levels for Pit Inlet Blockage Sensitivity Tests**

| Location | 5yr ARI Blockage - Grade 50%, Sag 100% | 1% AEP Blockage - Grade 100%, Sag 100% |
|---|---|---|
| H01 | -0.01 | +0.10 |
| H02 | +0.06 | +0.08 |
| H03 | +0.04 | +0.13 |
| H04 | +0.00 | +0.10 |
| H05 | +0.08 | +0.15 |
| H06 | +0.04 | +0.11 |
| H07 | +0.04 | +0.05 |
| H08 | +0.00 | +0.01 |
| H09 | +0.03 | +0.09 |
| H10 | +0.00 | +0.25 |
| H11 | +0.01 | +0.04 |
| H12 | +0.00 | +0.03 |
| H13 | +0.00 | +0.16 |
| H14 | +0.03 | +0.04 |

## 8.3 Rainfall Losses

Sensitivity analysis has been undertaken for rainfall losses by assessing both a 50% increase and decrease in rainfall losses (initial loss and infiltration). The fraction impervious parameter was not adjusted. The results of the sensitivity tests on rainfall losses are summarised in Table 8-3 for the reporting locations indicated in Figure 7-1.

The change in flood levels from rainfall loss changes is typically less than 0.01 m. The limited sensitivity to rainfall losses is due to the highly impervious nature of the catchment, whereby there is little opportunity for rainfall infiltration which translates to a negligible change in the amount of rainfall lost via pervious surfaces.

**Table 8-3 Changes in Flood Levels for Rainfall Loss Sensitivity Tests**

| Location | + 50% Rainfall Losses | - 50% Rainfall Losses |
|---|---|---|
| H01 | +0.00 | +0.00 |
| H02 | +0.00 | +0.00 |
| H03 | +0.00 | +0.00 |
| H04 | +0.00 | +0.01 |
| H05 | -0.01 | +0.01 |
| H06 | -0.01 | +0.00 |
| H07 | +0.00 | +0.00 |
| H08 | +0.00 | +0.00 |
| H09 | -0.01 | +0.01 |
| H10 | +0.00 | +0.00 |
| H11 | +0.00 | +0.00 |
| H12 | +0.00 | +0.00 |
| H13 | +0.00 | +0.00 |
| H14 | +0.00 | +0.00 |

## 8.4 Conclusion

A series of sensitivity tests have been undertaken on the modelled flood behaviour of the Sydney CBD catchment. The tests provide a basis for determining the relative sensitivity of modelling results to adopted parameter values. The parameters assessed include:

- Hydraulic roughness;
- Stormwater drainage blockage; and
- Design rainfall losses.

Results were shown to be generally insensitive to the values adopted for deriving the design flood levels and extents for the hydraulic roughness and rainfall losses tests, with the magnitude changes in flood level less than 0.10m.

The stormwater drainage blockage sensitivity tests represent an extreme scenario whereby there is 100% blockage applied to the drainage network, effectively eliminating all sub-surface drainage. The 100% blockage scenario indicates that flood levels may increase by up to 0.25m in the 1% AEP design event. This could be considered to be contained within the 0.50m freeboard (if adopted) applied to the 1% AEP results to determine the Flood Planning Levels (FPL).

# 9 CLIMATE CHANGE ANALYSIS

In 2009, the NSW Government incorporated consideration of potential climate change impacts into relevant planning instruments. The NSW Sea Level Rise Policy Statement (DECCW, 2009) was prepared to support consistent adaptation to projected sea level rise impacts. The policy statement incorporates sea level rise (SLR) planning benchmarks for use in assessing potential impacts of sea level rise in coastal areas, as well as in flood risk and coastal hazard assessments. 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.

The NSW Government announced its Stage One Coastal Management Reforms in September 2012. As part of these reforms, the NSW Government no longer recommends state-wide sea level rise benchmarks for use by local councils, but instead provides councils with the flexibility to consider local conditions when determining future hazards within their LGA.

It was agreed between Council and BMT WBM that the sea level rise benchmarks from the 2009 NSW Sea level Rise Policy Statement be adopted based on the conclusion that it was the best available information at the time of preparation of this report.

Worsening coastal flooding impacts as a consequence of sea level rise are of concern for the future. Regional climate change studies (e.g. CSIRO, 2004) indicate that aside from sea level rise, there may also be an increase in the maximum intensity of extreme rainfall events. This may include increased frequency, duration and height of flooding and consequently increased number of emergency evacuations and associated property and infrastructure damage.

The NSW Floodplain Development Manual (2005) requires consideration of climate change in the preparation of Floodplain Risk Management Studies and Plans, with further guidance provided in:

- Floodplain Risk Management Guideline – Practical Consideration of Climate Change (DECC, 2007); and
- Flood Risk Management Guide - Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments (DECCW, 2010).

Key elements of future climate change (e.g. sea level rise, rainfall intensity) have been incorporated into the assessment of future flooding conditions in the City Area catchment for consideration in the ongoing floodplain risk management.

## 9.1 Potential Climate Change Impacts

The impacts of future climate change are likely to lead to a wide range of environmental responses in receiving waters such as Sydney Harbour. These are likely to manifest throughout the physical, chemical and ecological processes that drive local estuarine ecosystems.

The following changes in the physical characteristics of the City Area catchment have potential influence on the flood behaviour of the system and implications for medium and long term floodplain management:

- 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% | 1.24 (5% ARI Harbour Level) |
| 1% AEP 90 min duration | 20% | 1.24 (5% ARI Harbour Level) |
| 1% AEP 90 min duration | 30% | 1.24 (5% ARI 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. Further discussion on relative increases from existing peak flood levels is provided herein.

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.

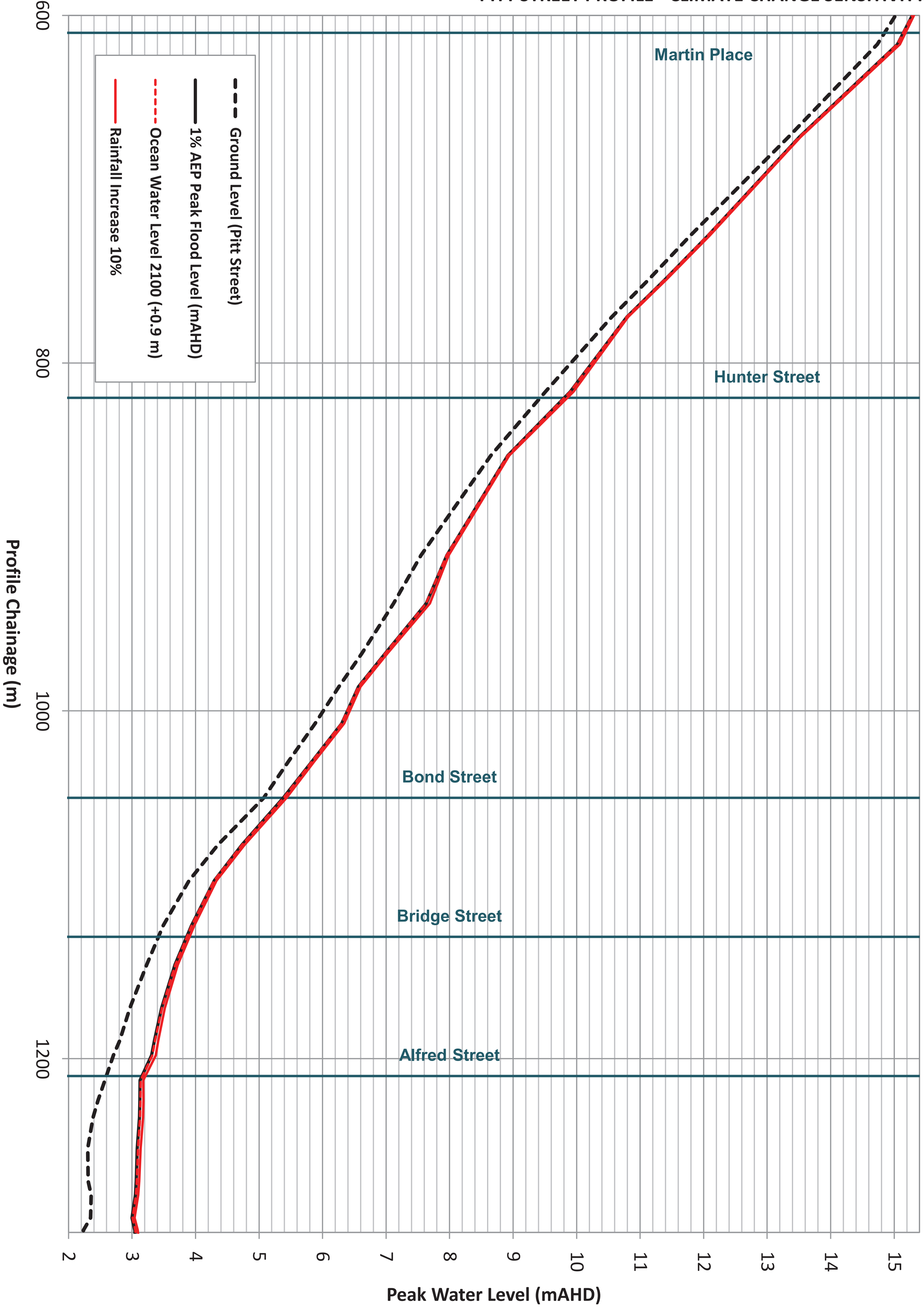
Figure A- 36 shows the tidal inundation extents due to future sea level rise. These results show that future sea level rise has minimal effect on flooding.

**Table 9-3 Changes in Flood Levels 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 FLOOD DAMAGE ASSESSMENT

To be prepared upon completion of floor level survey.

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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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N

0 125 250m
Approx. Scale

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Filepath : S20022DraftingWORAppendixA_FiguresFigureA01_002YR_Depth.wor


Title:
**Peak Flood Depth**
**5 year ARI**

Figure: A-2

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Title:
**Peak Flood Depth**
**10% AEP (10 yr ARI)**

Figure: A-3

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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)**

Figure: A-5

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***COUNCIL SHOULD BE CONSULTED TO CONFIRM FLOOD AFFECTATION AT INDIVIDUAL ALLOTMENTS.***

Title:
**Peak Flood Depth**
**1% AEP (100 yr ARI)**

Figure: A-6

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**COUNCIL SHOULD BE CONSULTED TO CONFIRM FLOOD AFFECTATION AT INDIVIDUAL ALLOTMENTS.**

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

Figure: A-7

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**COUNCIL SHOULD BE CONSULTED TO CONFIRM FLOOD AFFECTATION AT INDIVIDUAL ALLOTMENTS.**

| Title: | Figure: | Rev: |
|---|---|---|
| **Peak Flood Depth** **Probable Maximum Flood (PMF)** | A-8 | - |

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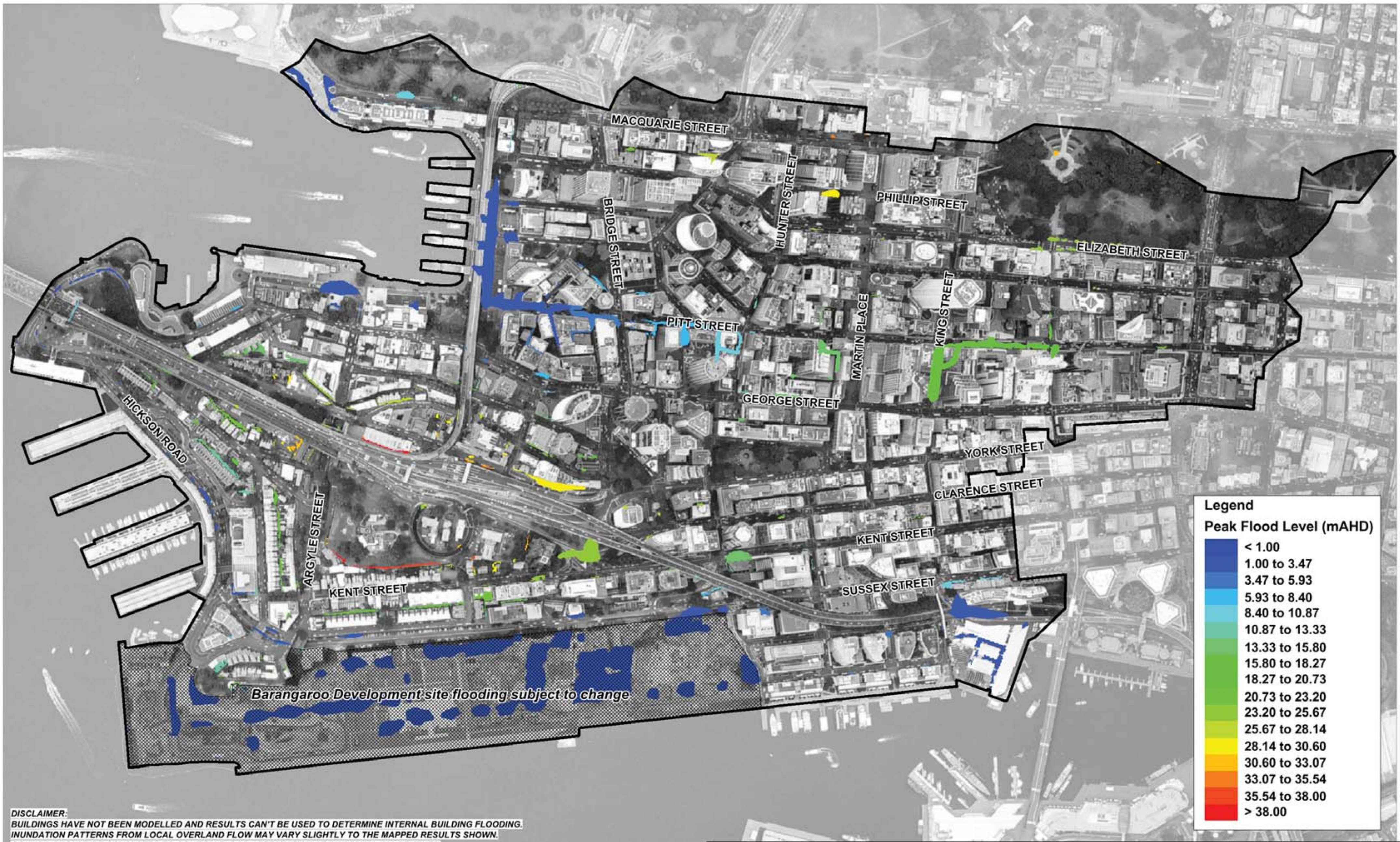
Filepath : S20022DraftingWORAppendixA_FiguresFigureA08_PMF_Depth.wor

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Title:
**Peak Flood Level**
**2 year ARI**

Figure: A-9

Rev: -

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Approx. Scale

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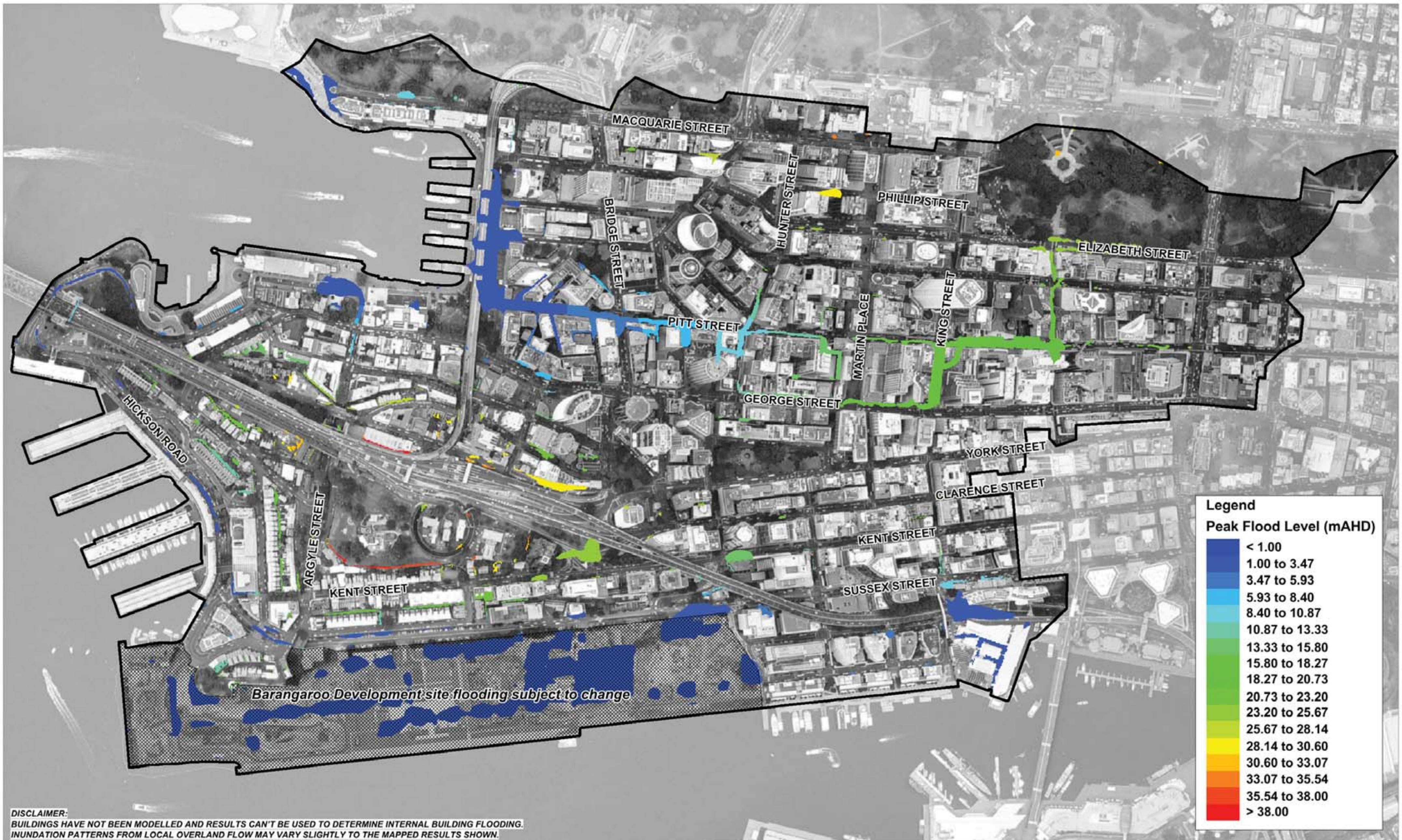
Filepath : S20022DraftingWORAppendixA_FiguresFigureA09_002YR_Level.wor

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**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 Level
## 5 year ARI

Figure: A-10

Rev: -

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Approx. Scale

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Title:
## Peak Flood Level
## 10% AEP (10 yr ARI)

Figure: A-11

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**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 Level**
**5% AEP (20 yr ARI)**

Figure: A-12

Rev: -



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**COUNCIL SHOULD BE CONSULTED TO CONFIRM FLOOD AFFECTATION AT INDIVIDUAL ALLOTMENTS.**

| Title: Peak Flood Level 2% AEP (50 yr ARI) | Figure: A-13 | Rev: - |
|---|---|---|

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0 125 250m
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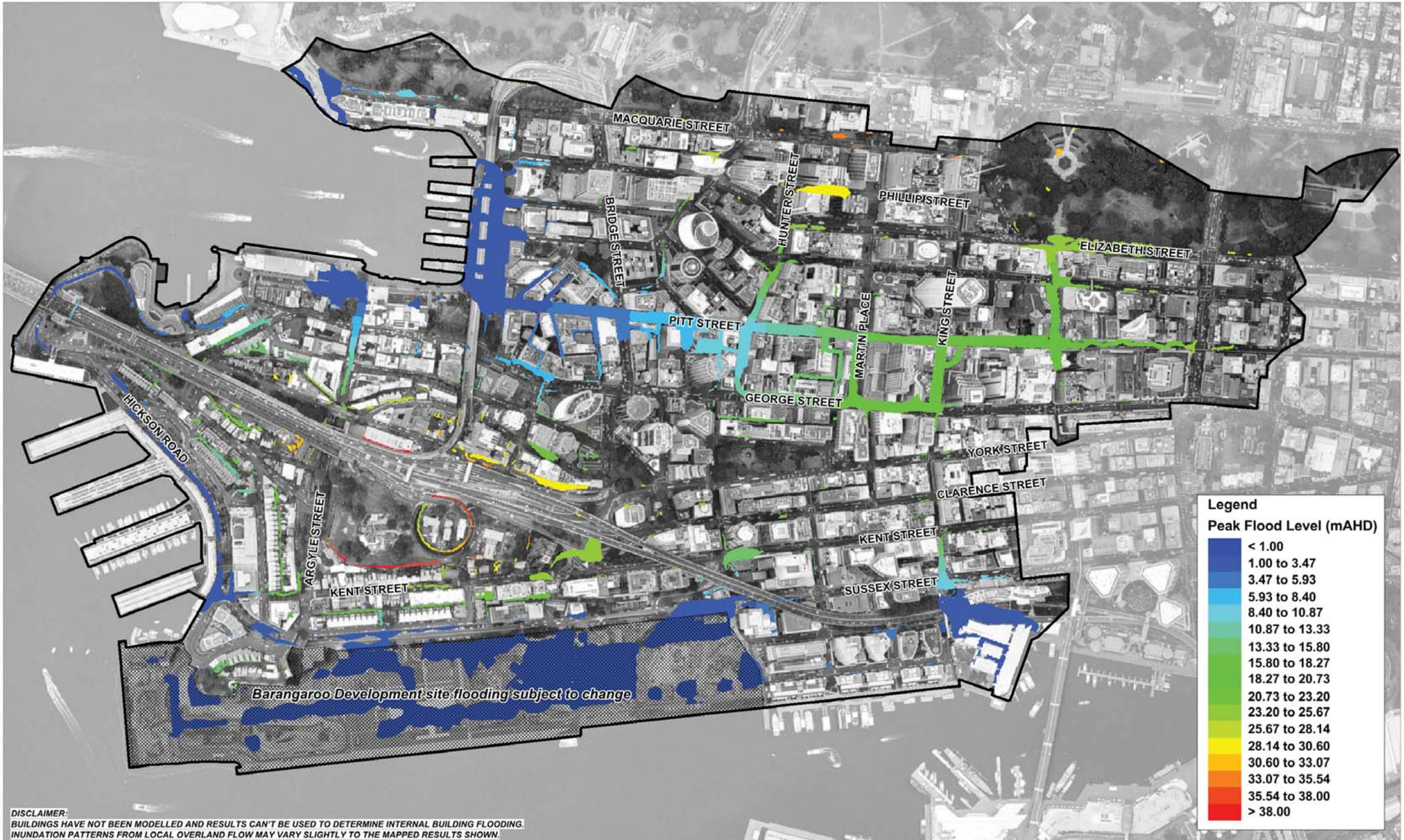


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Title:
**Peak Flood Level**
**1% AEP (100 yr ARI)**

Figure: A-14

Rev: -

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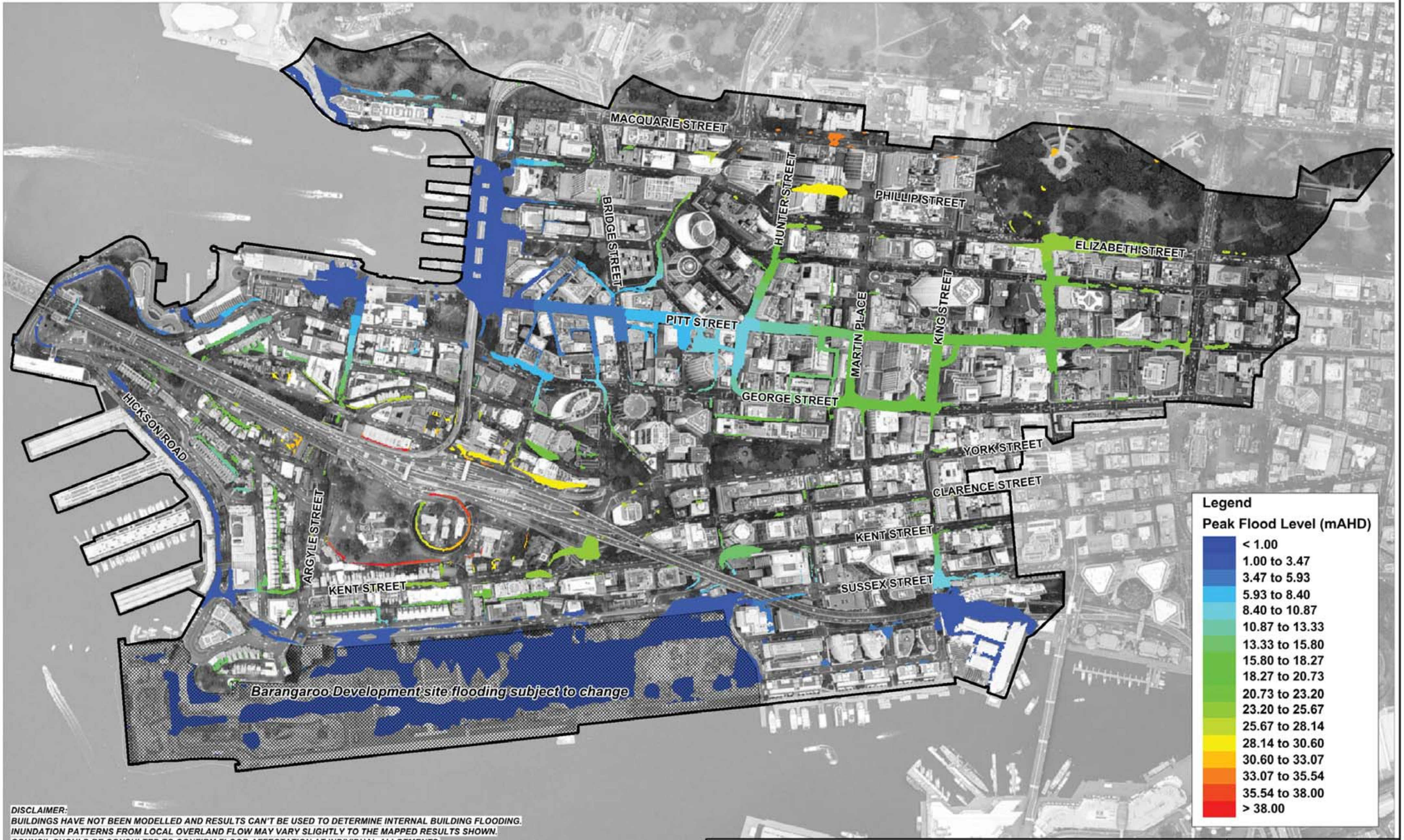


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Title:
## Peak Flood Level
## 0.2% AEP (500 yr ARI)

Figure: A-15

Rev: -



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| Title: | Figure: | Rev: |
|---|---|---|
| **Peak Flood Level**<br>**Probable Maximum Flood (PMF)** | A-16 | - |

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Title:
## Peak Flood Velocity
## 2 year ARI

Figure: A-17

Rev: -

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Title:
**Peak Flood Velocity**
**5 year ARI**

Figure: A-18

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Title:
**Peak Flood Velocity**
**10% AEP (10 yr ARI)**

Figure: A-19

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

Figure: A-20

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

Figure: A-21

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Title:
## Peak Flood Velocity 1% AEP (100 yr ARI)

Figure: A-22

Rev: -



N

0 125 250m
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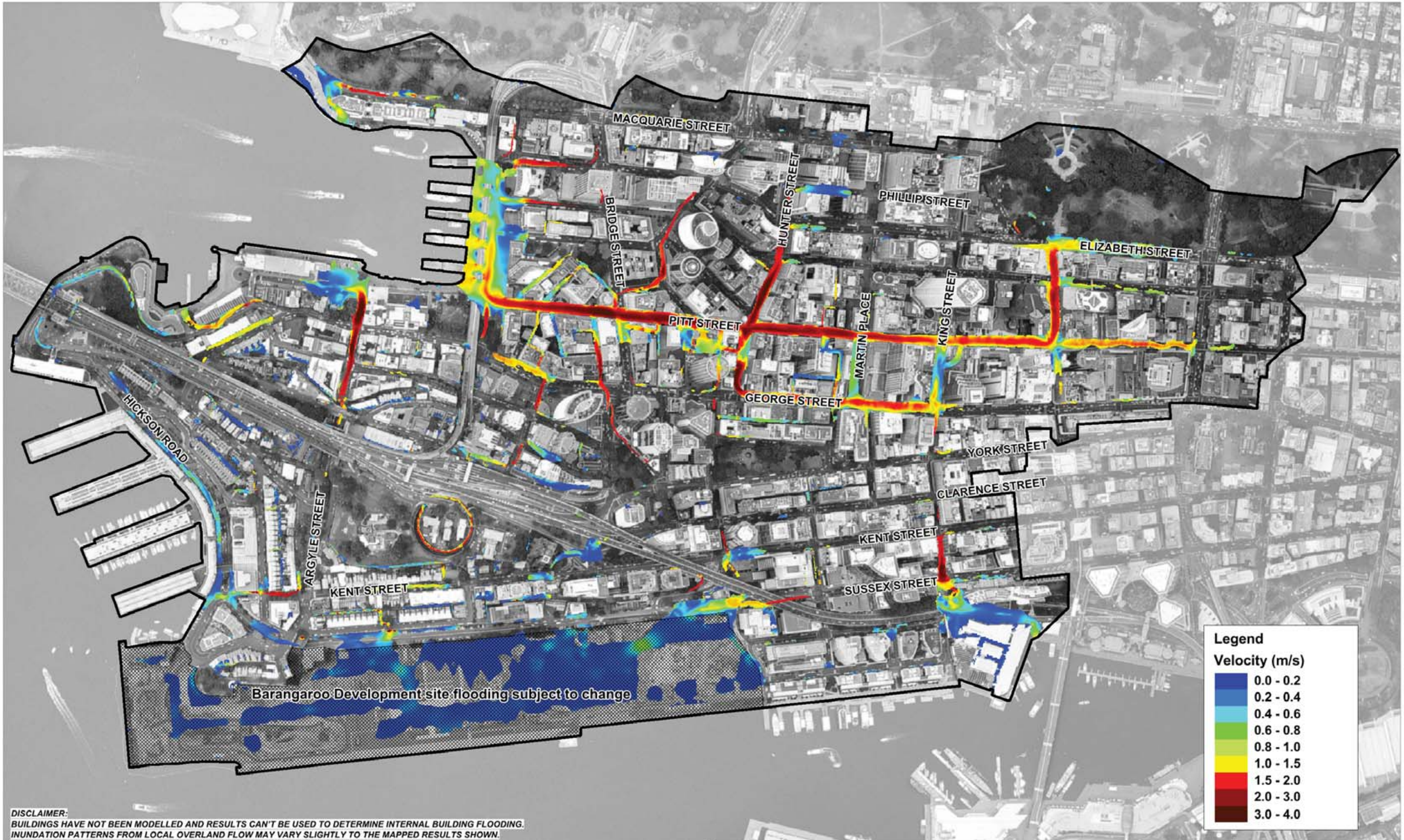
Filepath : S20022DraftingWORAppendixA_FiguresFigureA22_100YR_Velocity.wor

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

Figure: A-23 | Rev: -

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