10. Flood modification measures

A detailed review was undertaken on the existing flood behaviour, flood hazard, flood function, flood damages, emergency classification of communities, potential impacts of climate change and sea level rise to identify potential flood modification measures for the study area. In particular, floor levels of buildings and location of buildings subject to flooding during major flood events have been assessed to identify potential flood modification measures. Refer to Section 7.1 for discussion.

Flood modification measures for the study area need to be identified based on opportunities for both short term and long term works. In the long term, a broad drainage strategy could be considered with the aim to have all drainage infrastructure with a higher (say 5% AEP) design capacity, which would help to reduce flooding in most parts of the study area, although drainage of low-lying areas may remain constrained by high tailwater levels. The key challenge with this strategy is the overall scope of works, funding and a long time frame required to implement the strategy. Furthermore, many of the upstream areas which are currently impacted during frequent flooding would be upgraded last. Upgrading upstream sections first would mean that drainage system constraints remain within the system and hence the upgrades may not function to their full capacity or the flooding problems transferred to downstream areas. Hence short to medium term flood modification measures which could be implemented more readily to broadscale infrastructure upgrades have been identified and assessed, and are discussed in Section 10.1. The long-term strategies are discussed in Section 10.2 and have also been assessed to determine their performance for comparison with the shorter term strategies.

A list of potential options which could be implemented in a short-term strategy were identified from a review of existing flooding and drainage conditions and the potential options were presented to the FRMC. The options were refined in their nature and number in consultation with Council and the FRMC with consideration of the main problem areas for flooding, likely hydraulic effectiveness and feasibility, site and engineering constraints, land ownership issues and environmental and heritage considerations. The refined list of options includes mainly localised drainage improvement options which could be more readily implemented than a wide-scale drainage upgrade strategy. The options have been analysed in the TUFLOW model and are discussed in Section 10.1.

10.1 Short term strategies

A description on the selected short-term strategies is provided in this section and includes discussion of likely constraints and the hydraulic performance (changes in flood levels and changes in number of properties affected by above-floor flooding) as identified from the TUFLOW modelling. Based on the hydraulic performance, in particular, the improvements to properties affected by flooding, an initial evaluation of options was undertaken to those options which perform well and which are considered further in costings, economic and multi-criteria analysis, and those which do not perform well and are excluded from further consideration. The economic and multi-criteria evaluation of the options is provided in Section 10.5. Options have been simulated for the 20%, 5% and 1% AEP events.

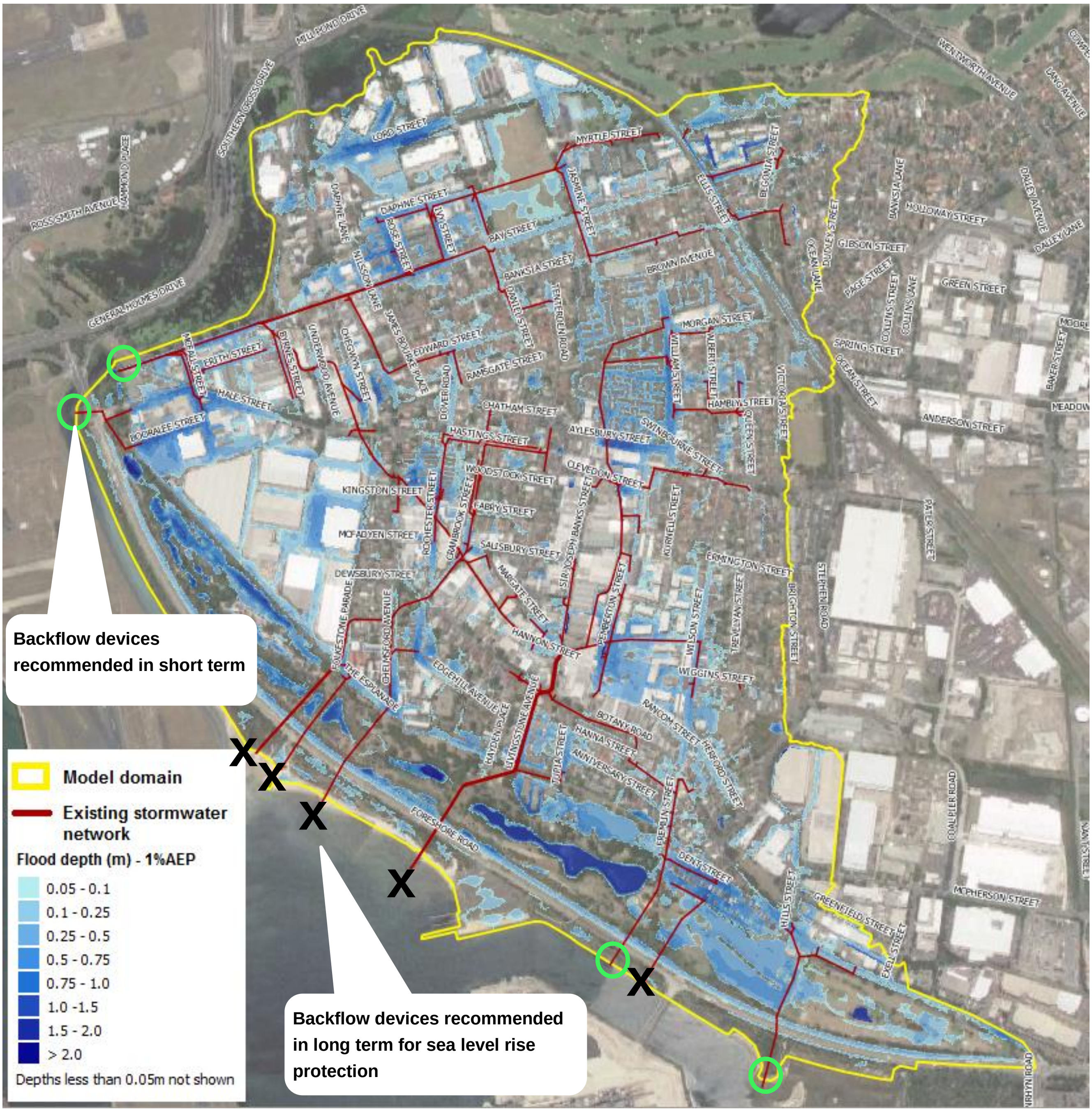
10.1.1 Backflow devices on trunk drainage outlets

10.1.1.1 Option 1 – Backflow device on drainage outlets

One-way valves or gates on the trunk drainage lines would prevent backflow of water from Botany Bay during times of elevated tailwater levels, which would protect roads and property from ocean inundation. Assessment of the improvements to flooding conditions was undertaken for catchment flooding events coinciding with high tailwater. There may be improvements due to lower flood volumes on the floodplain at the start of the catchment storm event. Refer to Figure 10.1 for illustration. Outlets with proposed backflow devices are circled. A total of four (4) outlets are recommended in the FRMP for backflow valve installation to protect against storm surge under existing climate and mean sea level conditions.

Backflow prevention devices are not proposed in the short term where the upstream invert levels of the outlet pipe are in high ground i.e. above current king tide levels. These outlets are marked with crosses on Figure 10.1. In the long term, all outlets (additional 5 locations, some with multiple pipe outlets) will require backflow devices to provide protection from tidal and storm surge inundation in future climate change and sea level rise scenarios.

Figure 10.1 Option 1 – Backflow device on drainage outlets



Constraints assessment

Sediment movements in the bay at the trunk drainage outlets are dynamic, which limits the ability to place the backflow devices (flaps, gates) directly on the outlets. The flaps/gates are at risk of being chocked open by deposited sediment or debris, with the malfunction allowing backflow to occur. Conversely, the device could be blocked up by sediments, preventing outflows and proper operation of the drainage system. The devices would need to be designed and installed to manage these sediment movement impacts. Appropriate proprietary devices are currently available.

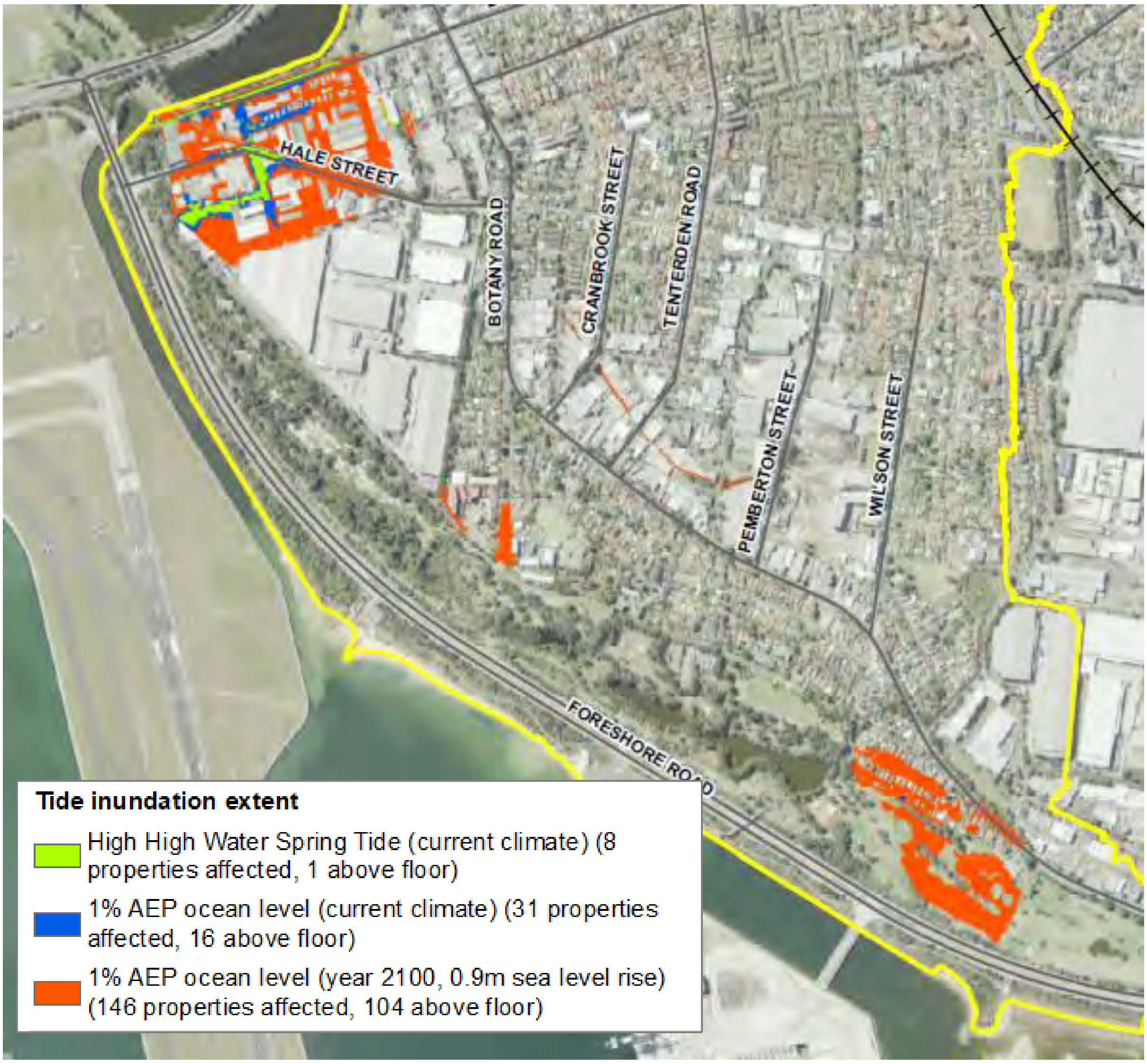
Hydraulic performance

Backflow devices were tested in the TUFLOW model but were found to provide only a minor improvement (less than 0.02m) in 1% AEP flood levels during existing climate conditions and sea levels. This is attributed to the backflow volume through the drainage system and onto the floodplain before the storm being small compared to the catchment inflow volume.

Preliminary evaluation

As mentioned above, the Option 1 backflow devices would provide negligible improvements to peak flood levels during catchment flood events. However, the benefits of this option are expected during dry weather, king tide events in the current climate, with increased benefits in future climate change conditions with sea level rise. The benefits are not quantified based on the flood modelling since the benefits would be realised during dry weather, and installation of these devices is considered justified. Figure 10.2 shows the tidal inundation extents for king tide (current climate) and 1% AEP ocean level (storm surge) conditions for current and year 2100 climate, demonstrating the benefits of the backflow devices particularly for the future climate change scenario.

Figure 10.2 Tidal inundation in king tide and 1% AEP ocean event for current sea level and with year 2100 sea level rise



10.1.2 Construction of detention basins

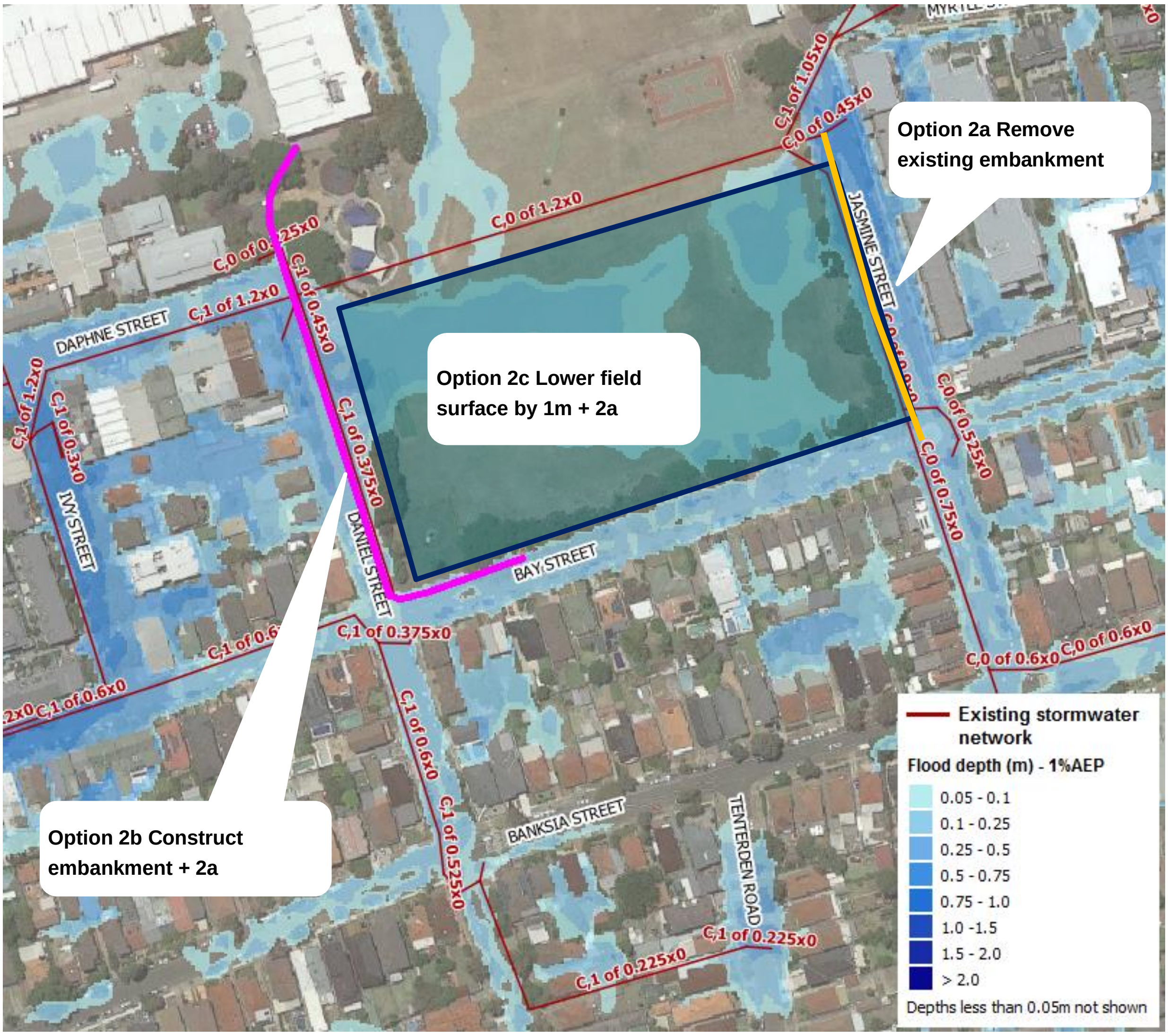
10.1.2.1 Option 2 - Detention basin at Booralee Park

About 10 properties located on the western side of the Daniel Street are impacted in the 5% AEP flood event. It is proposed to utilise Booralee Park as a detention basin by a range of modifications including diversion of flows to the park, construction of embankments and lowering of the park surface, refer to Figure 10.3. A detention basin would be expected to hold flood waters originating from eastern and southern sides of the park resulting in improved flooding to downstream properties.

Three separate sub-options were assessed. The nature of works are described below:

- Option 2a: Removal of informal embankment along western side of Jasmine Street, to increase overland flows onto the park.
- Option 2b: As per Option 2a plus construction of a 2m high embankment along the western and southern sides of the park.
- Option 2c: As per Option 2a plus lowering the base of the park by 1m to form a detention basin, with a 300mm low flow pipe outlet connection to the existing drainage network.

Figure 10.3 Option 2 – Detention basin options at Booralee Park



Constraints assessment

The park would be subject to more frequent and long duration flooding which may not be acceptable to the community. The proposed embankment may have visual and environmental impacts.

There may be issues with excavation for lowering of the park surface due contamination. Available information on soil contamination testing was limited to a small section of the park near the amenities block, which indicated contaminated material was not detected. However, site-specific testing around the basin site needs to be undertaken. Acid sulphate soil and high groundwater table may also pose constraints and need to be assessed.

The south-western portion of Booralee Park is cited as being “probable” locations for unrecorded Aboriginal heritage sites (Gondwana Consulting, 2011).

Hydraulic performance

The hydraulic performance (reduction in flood level) are described below:

- Option 2a: This resulted in a change in flow distribution, leading to increases in 1% AEP flood levels of 0.05m in Daphne Street and Daniel Street and adjacent properties. Reductions in flood levels occur on Jasmine Street and Bay Street, in the roadway and property yards. There is a reduction of one property being affected by above-floor flooding in the 1% AEP event. There is no net change in floodplain storage, hence only minimal benefits along with some resultant flood impacts. The change in flood levels in the 1% AEP event are mapped on Figure E.1 in Appendix E.
- Option 2b: This option provides reductions in flood levels of up to 0.3m in the 1% AEP event in areas adjacent to the park and downstream areas. There is a reduction of 28 residential properties being affected by above-floor flooding in the 1% AEP event. The change in flood levels in the 1% AEP event are mapped on Figure E.2 in Appendix E.
- Option 2c: This option provides reductions to flood levels of up to 0.14m in the 5% AEP and 20% AEP event and 0.3m in the 1% AEP event in areas adjacent to the park and downstream areas. Refer to Figure 10.4 and Figure 10.5 for mapping of changes to flood levels. There is a reduction of 28 residential properties being affected by above-floor flooding in the 1% AEP event and 5 commercial and residential properties in the 5% AEP event, although one residential property becomes above-floor flooded in the 5% AEP event.

Preliminary evaluation

- Option 2c provides flooding improvements to a significant number of properties, and has been selected for further evaluation including costings and multi-criteria analysis. As this option involves the lowering of the basin bed (rather than a 2m embankment a per Option 2b), it is a preferred configuration based on urban design and visual aesthetic factors. Additionally, a lowered basin may have reduced requirements from a dam safety perspective compared to a basin formed with raised embankments. Its first-preference status is dependent on the findings of site contamination investigations, to be undertaken during future feasibility study for the basin option.
- Option 2b provides flooding improvements, however, its use of an embankment to form a basin is not favourable to Council and stakeholders from an urban design and landscaping perspective, and hence is not a preferred option and is not considered further in this study. Its ranking as the preferred option may change pending the findings of site contamination investigations, to be undertaken during future feasibility study for the basin option. The presence of soil contamination may render the currently preferred Option 2c unfeasible or unfavourable and elevate the preference of Option 2b
- Option 2a provides minimal improvement in above-floor flooding and flood damages, and hence is excluded from further consideration.

In summary, Option 2c is currently the preferred basin option at Booralee Park and it is recommended that a subsequent feasibility study be undertaken, including site contamination investigations, to confirm the feasibility of Option 2c. Consultation with Dam Safety NSW needs to be undertaken during the design of the basin to confirm dam safety design requirements and address basin failure risks and flooding impacts.

Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- Embankment removal
- Detention basin
- Low flow pipe

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:4,000		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	Option 2c - Detention Basin - 5% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.4	REV 1 VER 1
CHECK AH	DATE 23/06/2020		

Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- Embankment removal
- Detention basin
- Low flow pipe

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

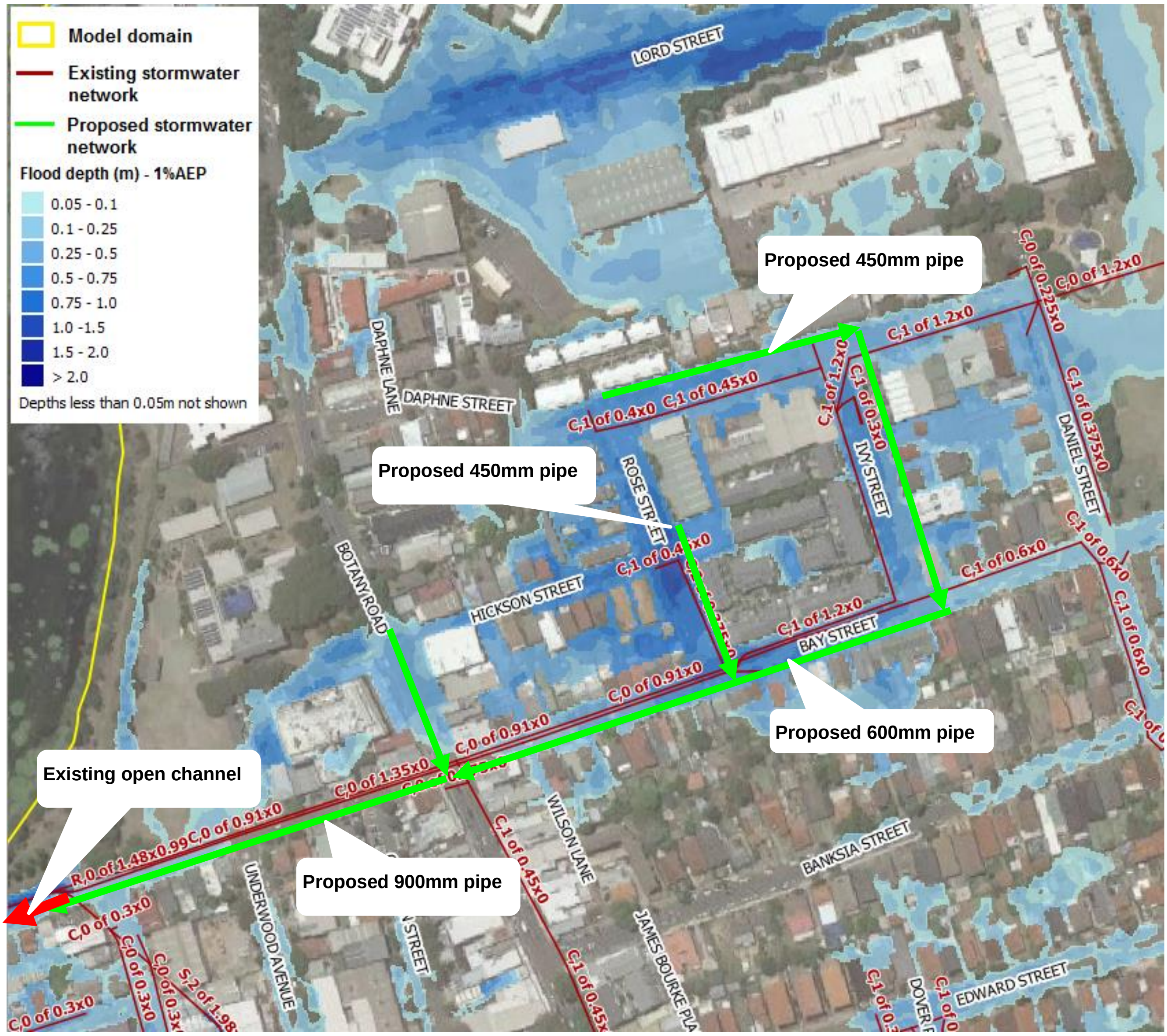
SCALE	1:4,000			A3
SHEET	1 of 1			GDA 1994 MGA Zone 56
TITLE	Option 2c - Detention Basin - 1% AEP Change in Flood Level			
PROJECT	Botany Bay Foreshore Beach FRMS			
CLIENT	Bayside Council			
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.5	REV 1	VER 1
CHECK AH	DATE 23/06/2020			

10.1.3 Improvement of localised drainage networks

10.1.3.1 Option 4a – Augmented drainage line along Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road

The existing drainage network at along Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road does not have sufficient capacity to drain floodwaters from the area and consequently, a number of properties are impacted. New stormwater pipes are proposed along the roads (refer to Figure 10.6). Size of the proposed pipes will vary between 450mm and 900mm. The proposed network would to convey more flows and provide additional drainage capacity to the existing network, thus reducing flood impacts to properties on Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road.

Figure 10.6 Option 4a – Augmented drainage line along Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road



Constraints assessment

Availability of space for proposed pipes, including potential clashes with existing utilities, may be a potential issue. Increased discharge into the open channel may impact on drainage capacity in other areas.

Discharging directly into Mill Pond instead of the existing open channel is not feasible due to the elevated normal water levels in Mill Pond. As such, there would be no resulting impacts to Mill Pond and Botany Wetlands.

Hydraulic performance

Option 4 provides the following changes:

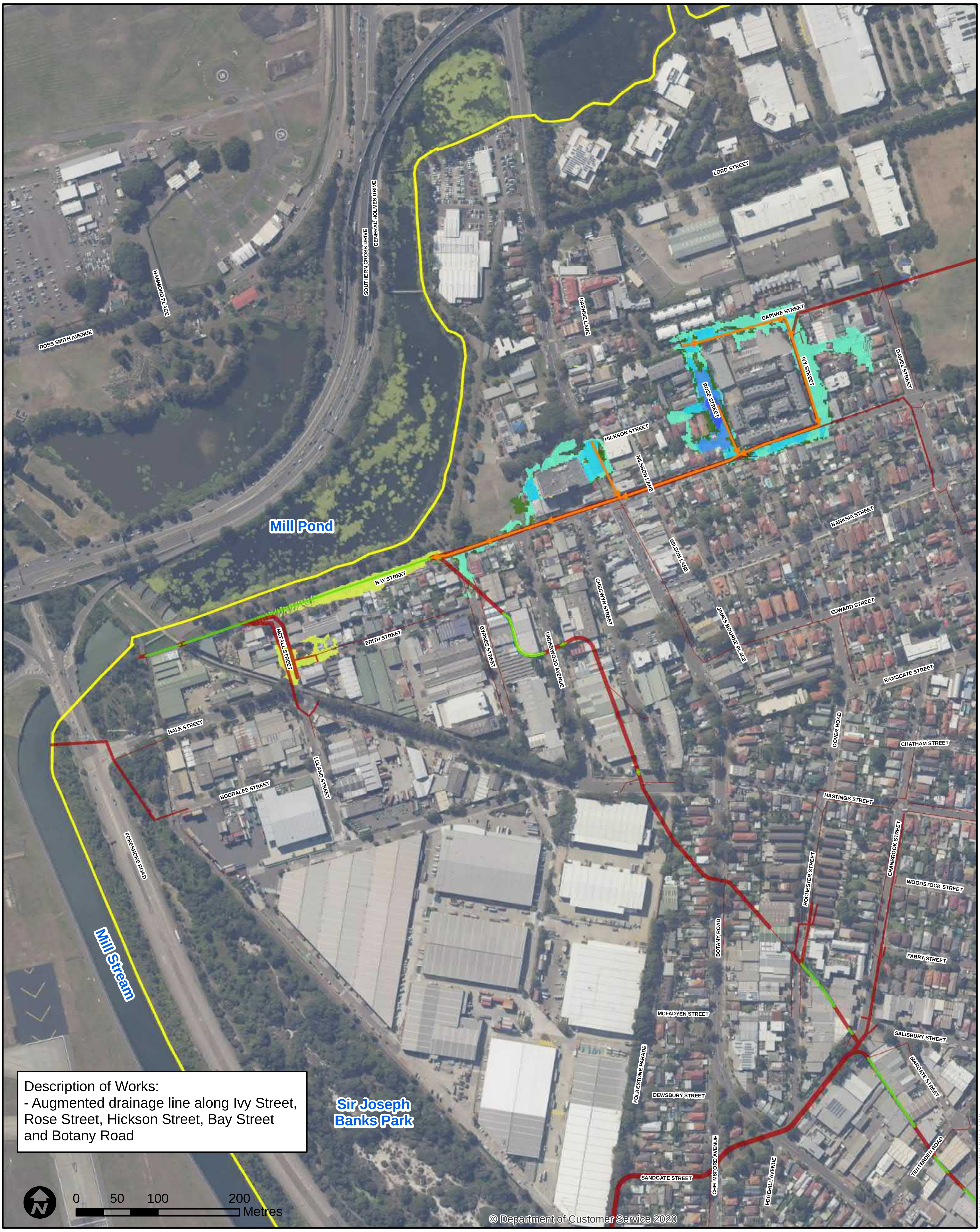
- Reductions in flood levels of up to 0.27m in the 20% AEP event, 0.32m in the 5% AEP event, and up to 0.4m in the 1% AEP event in Hickson Street, Rose Street and Daphne Street and adjacent properties.
- Discharge of the increased flows into the trunk drainage channel along Bay Street reduces the drainage capacity of other stormwater branches which results in minor localised increases in the Bay Street and Hale Street industrial area of 0.02m in the 5% AEP event in roads and trunk drainage channels.
- The resultant localised flood impacts in the 1% AEP event include increases in flood levels of 0.02m to 0.08m.

Refer to Figure 10.7 and Figure 10.8 for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

This option reduces the number of properties with above-floor flooding by 26 residences in the 1% AEP event and 5 residential and commercial properties in the 5% AEP event. However, the option also causes two new commercial and residential properties to experience above-floor flooding in both the 1% and 5% AEP events.

Preliminary evaluation

Option 4 provides flooding improvements to flooding on a significant number of properties, and has been selected for further evaluation including costings and multi-criteria analysis.



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes

Change in Flood Levels (m)

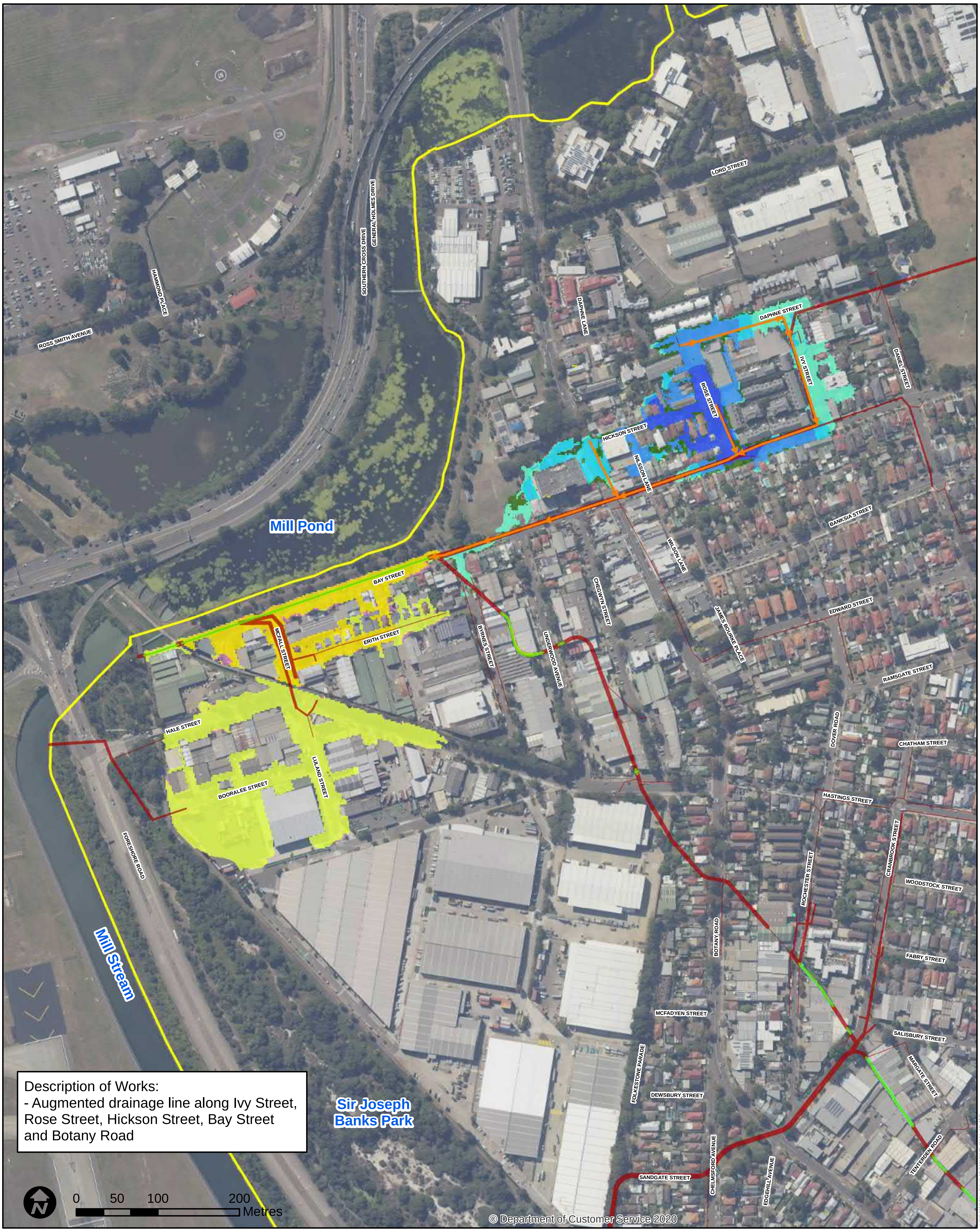
- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:4,500		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	Option 4a - Drainage Augmentation - 5% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.7	REV 1 VER 1
CHECK AH	DATE 22/06/2020		



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New storm water pipes

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

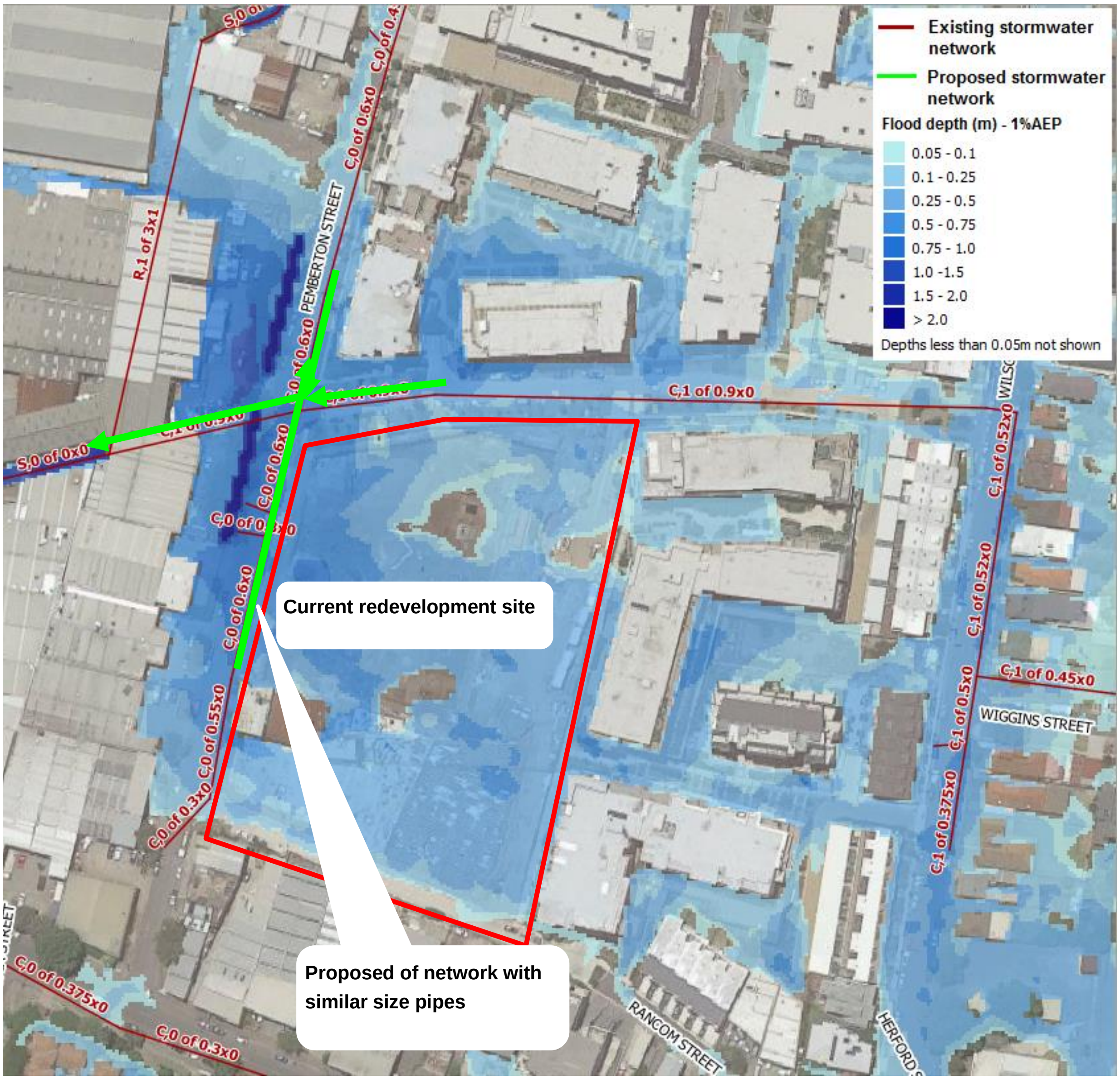
SCALE	1:4,500		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	Option 4a - Drainage Augmentation - 1% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.8	REV 1 VER 1
CHECK AH	DATE 22/06/2020		

10.1.3.2 Option 7a – Addition of pipes near junction of Pemberton Street and Mahroot Street

Additional pipes are proposed as shown in Figure 10.9 to improve the drainage of this flood ponding area. The existing pipes run at full capacities and discharge into an open channel. The additional pipes may reduce flooding impacts to properties located on Pemberton Street and Mahroot Street.

A property in the vicinity of the site, on the eastern side of Pemberton Street and between Mahroot Street and Rancom Street is currently being redeveloped and will consist of a residential apartment complex. The development was not included in the design flood estimation, and its large footprint may affect the flooding behaviour and the performance of the proposed drainage upgrades. The development has been included in a baseline case (without mitigation) and with mitigation case, for the flood mitigation options assessment. While the development included installation of on-site stormwater detention and absorption systems, these only cater for the site’s runoff and not for external catchment flood flows.

Figure 10.9 Option 7a – Additional pipes near junction of Pemberton Street and Mahroot Street



Constraints assessment

The proposed pipes are expected to discharge into an open channel which may cause it to overtop and impact on adjoining properties.

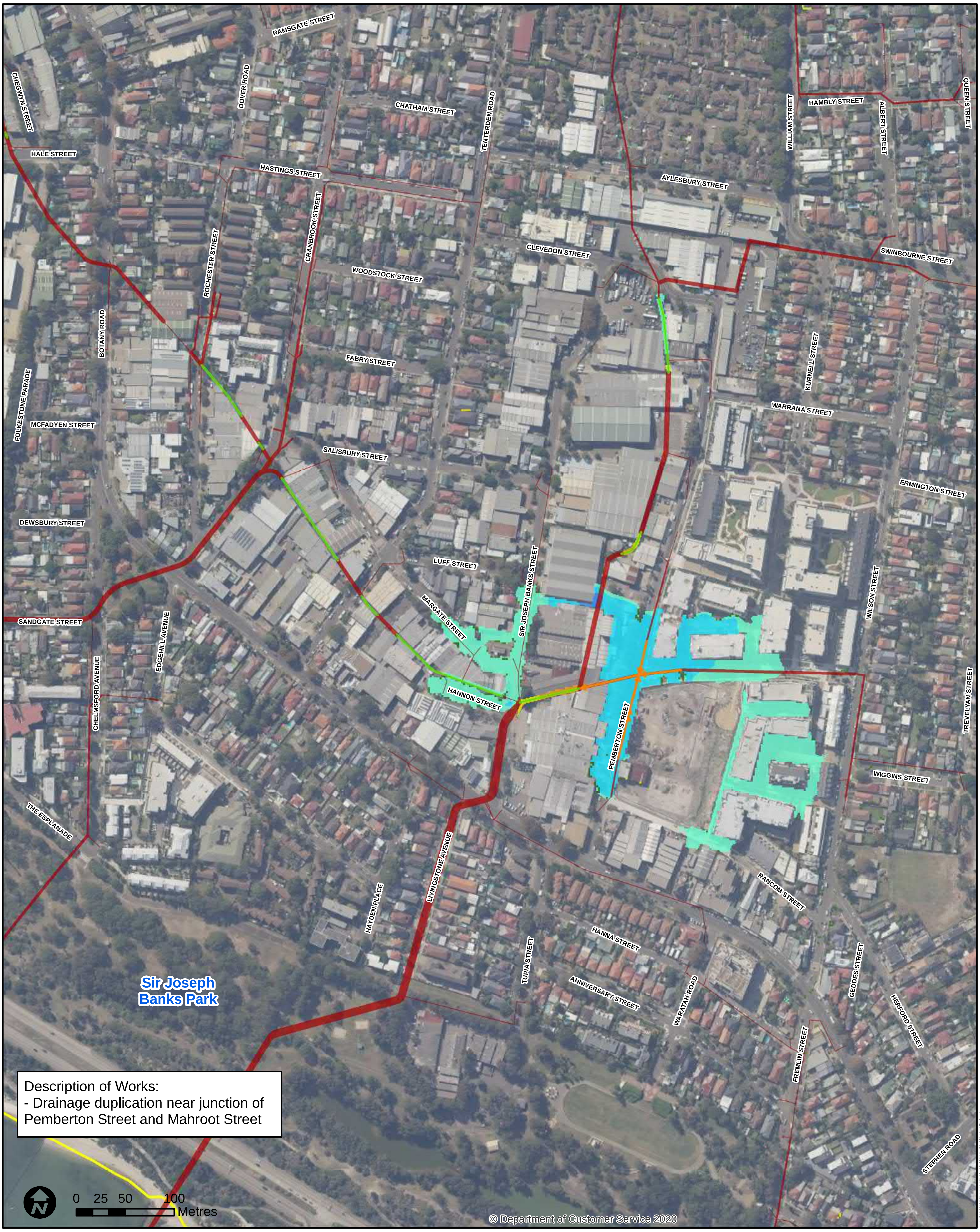
Hydraulic performance

Option 7a results in reductions in flood levels up to 0.18m in the 20% AEP, 0.08m in the 5% AEP and 0.09m in the 1% AEP events on the adjacent roads. The option also results in increases in flood levels of up to 0.15m in the 5% and 1% AEP events in the trunk drainage channel which runs between industrial warehouse-type buildings. The actual impact to these buildings may be negligible as these sides of the buildings are not open to the flood flows. Refer to Figure 10.10 and Figure 10.11 for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

Above-floor flooding at buildings is reduced by two residential properties in the 1% AEP event and six residential properties in the 5% AEP event. Two commercial properties experience new above-floor flooding in the 1% AEP event, as a result of this option.

Preliminary evaluation

Option 7a provides some improvement in above-floor flooding and flood damages, and hence is included for further consideration.



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes

Change in Flood Levels (m)

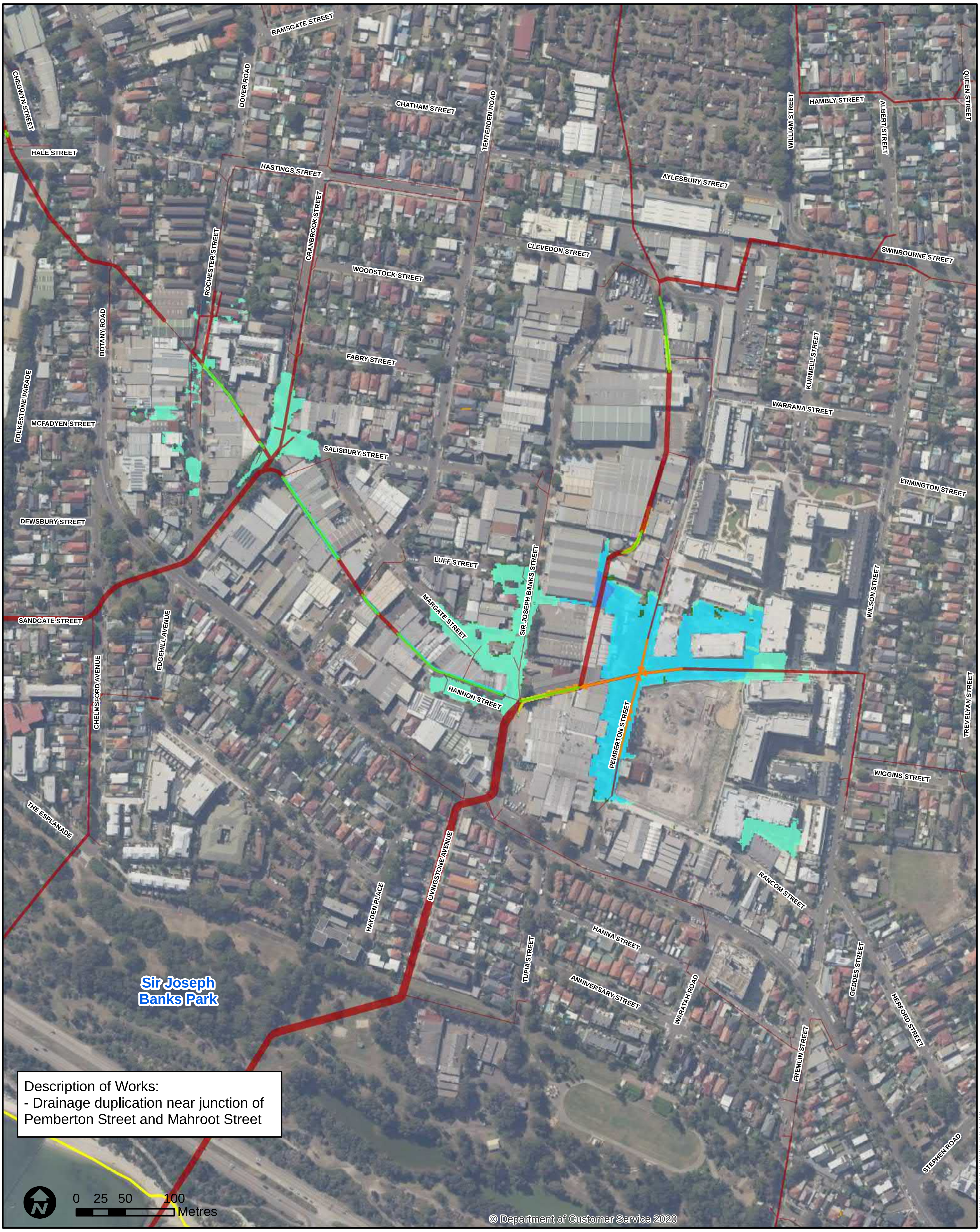
- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:3,750			A3
SHEET	1 of 1		GDA 1994 MGA Zone 56	
TITLE	Option 7a - Drainage Augmentation - 5% AEP Change in Flood Level			
PROJECT	Botany Bay Foreshore Beach FRMS			
CLIENT	Bayside Council			
DRAWN PK	PROJECT # IA190100	MAP #	Figure 10.10	REV 1 VER 1
CHECK AH	DATE 22/06/2020			



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

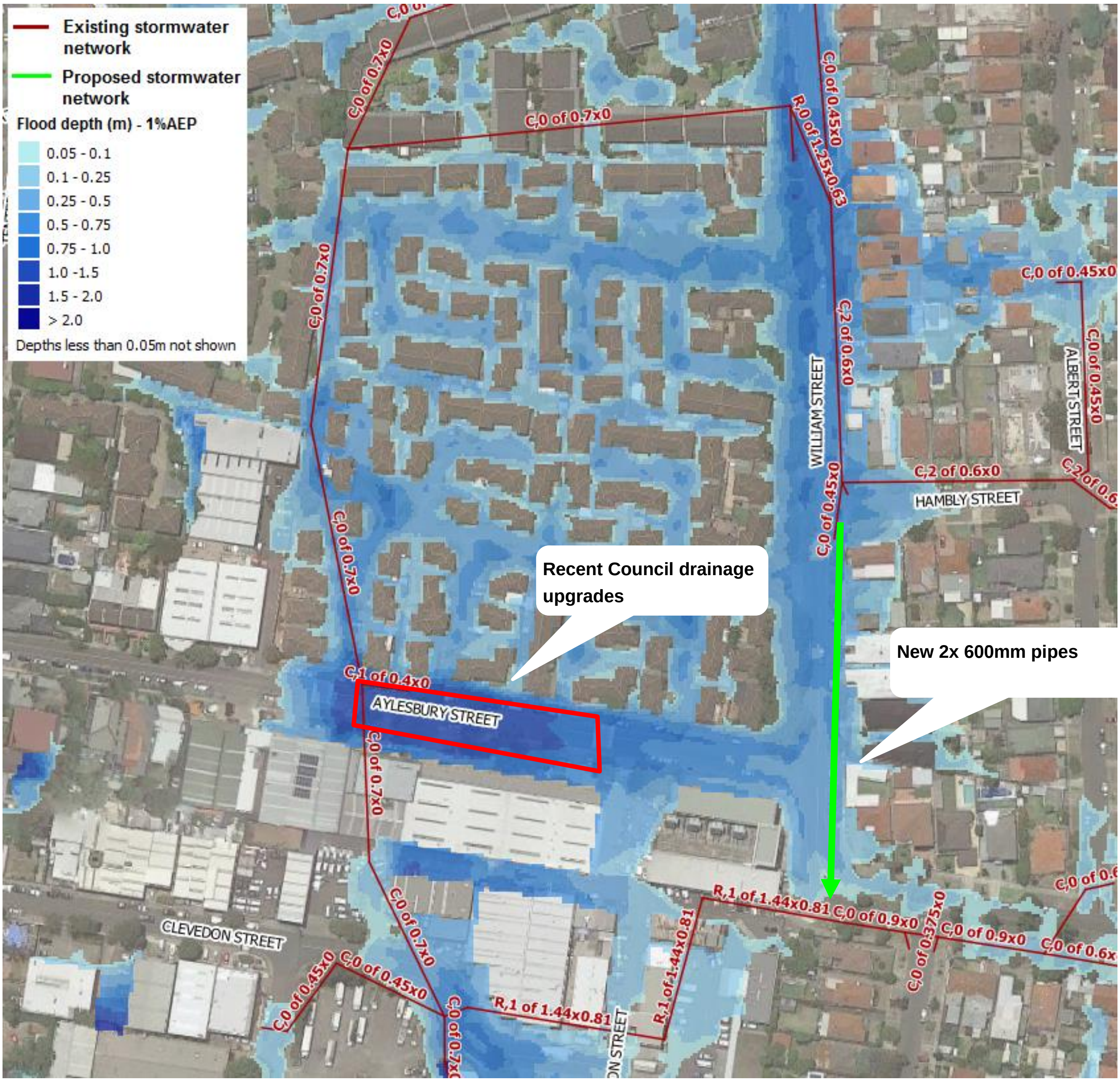
LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:3,750			A3
SHEET	1 of 1			GDA 1994 MGA Zone 56
TITLE	Option 7a - Drainage Augmentation - 1% AEP Change in Flood Level			
PROJECT	Botany Bay Foreshore Beach FRMS			
CLIENT	Bayside Council			
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.11	REV 1	VER 1
CHECK AH	DATE 22/06/2020			

10.1.3.3 Option 8 – Upgrade of stormwater system in William Street

The existing stormwater network is inefficient and impacts on several properties located between Tenterden Road and William Street during frequent storm events. The existing stormwater network could be improved by including additional stormwater pipes which would effectively reduce the distance to the outlet of the network at the open channel. It is proposed to include additional 2x 600mm diameter along the William Street to alleviate the existing flooding conditions. The proposed pipes will be connected to the downstream existing pipes as shown in the Figure 10.12.

Figure 10.12 Option 8 – Drainage upgrade at William Street



Constraints assessment

The availability of the space for the proposed pipes is a potential issue. Also, there is a risk in increase in flood level in areas downstream of the new pipe.

Hydraulic performance

Option 8 results in reductions in flood levels of up to 0.25m in the 20% AEP, 0.14m in the 5% AEP and 0.07m in the 1% AEP events on the floodplain.

Refer to Figure 10.13 and Figure 10.14 for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

Above-floor flooding at buildings is reduced by 29 residential properties in the 1% event and 25 commercial and residential properties in the 5% AEP event. One residential property experiences new above-floor flooding in the 1% AEP event and one residential property in the 5% AEP event, as a result of this option.

Preliminary evaluation

Option 8 provides flooding improvements to a significant number of properties, and has been selected for further evaluation including costings and multi-criteria analysis.

Note that an as-built drawing of 27 -31 William Street culvert was received at the end of this present study. The drawing shows that the size of the culvert at 27-31 William street is much larger than the modelled size, as discussed in Section 3.2.3. Therefore, it is recommended to undertake a sensitivity analysis before adopting Option 8.

Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes
- Council's pipes

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:2,500		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	**Option 8 - Drainage Augmentation - 5% AEP Change in Flood Level**		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # **Figure 10.13**	REV 1 VER 1
CHECK AH	DATE 22/06/2020		

Legend

- Study area
- Existing stormwater networks
- Open channels
- Council's new pipes

Proposed Mitigation

- New stormwater pipes

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

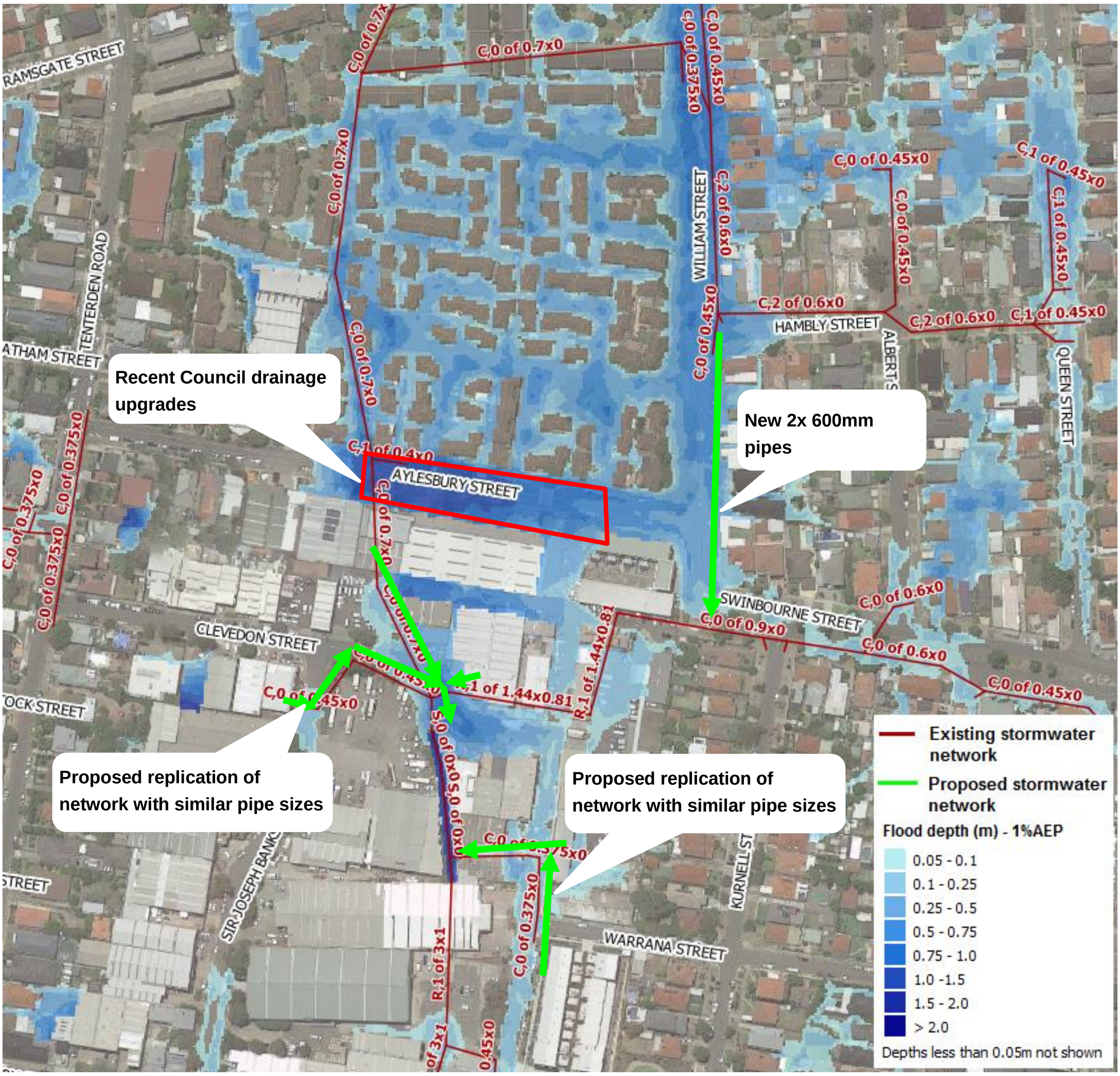
LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:2,500		A3
SHEET	1 of 1	GDA 1994 MGA Zone 56	
TITLE	Option 8 - Drainage Augmentation - 1% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.14	REV 1 VER 1
CHECK AH	DATE 22/06/2020		

10.1.3.4 Option 11 – Additional pipes near Pemberton Street and Clevedon Street + Option 8

In order to improve flooding on properties in the area of Clevedon Street and Pemberton Street, duplication of stormwater pipes are proposed as shown in Figure 10.15. Pipes will be similar of similar sizes to the existing ones, varying between 375mm and 700mm diameter. The new pipes will discharge into the existing open channel.

Figure 10.15 Option 11 – Additional pipes near Pemberton Street and Clevedon Street



Constraints assessment

Additional flows conveyed by the proposed drainage upgrades may increase flows within the open channel, potentially reducing drainage capacity for other areas. Additionally, the downstream rectangular culvert (3m x 1m) may surcharge and may impact properties adjoining to the open channel.

There may be inadequate space for additional pipes, especially for the pipes from Pemberton Street as the pipes run through private properties. Consultation with landowners would be required.

Hydraulic performance

Option 11 results in reductions in flood levels of 0.4m in the 20% AEP, 0.18m in the 5% AEP and 0.09m in the 1% AEP events around William Street and Aylesbury Street. However, the option also results in increases in flood levels of up to 0.04m in Mahroot Street, 0.01m in the 5% AEP event around Margate Street, and 0.08m in the 1% AEP event in Clevedon Street. Refer to Figure 10.16 and Figure 10.17 for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

Above-floor flooding at buildings is reduced by 33 residential properties in the 1% AEP event and 30 residential, commercial and industrial properties in the 5% AEP event. Two residential properties experience new above-floor flooding in the 5% AEP event, as a result of this option.

Preliminary evaluation

Option 11 provides flooding improvements to a significant number of properties, and has been selected for further evaluation including costings and multi-criteria analysis.

Legend

- Study area
- Open channels
- Existing stormwater networks
- Council's new pipes

Proposed Mitigation

- New stormwater pipes

Change in Flood Levels (m)

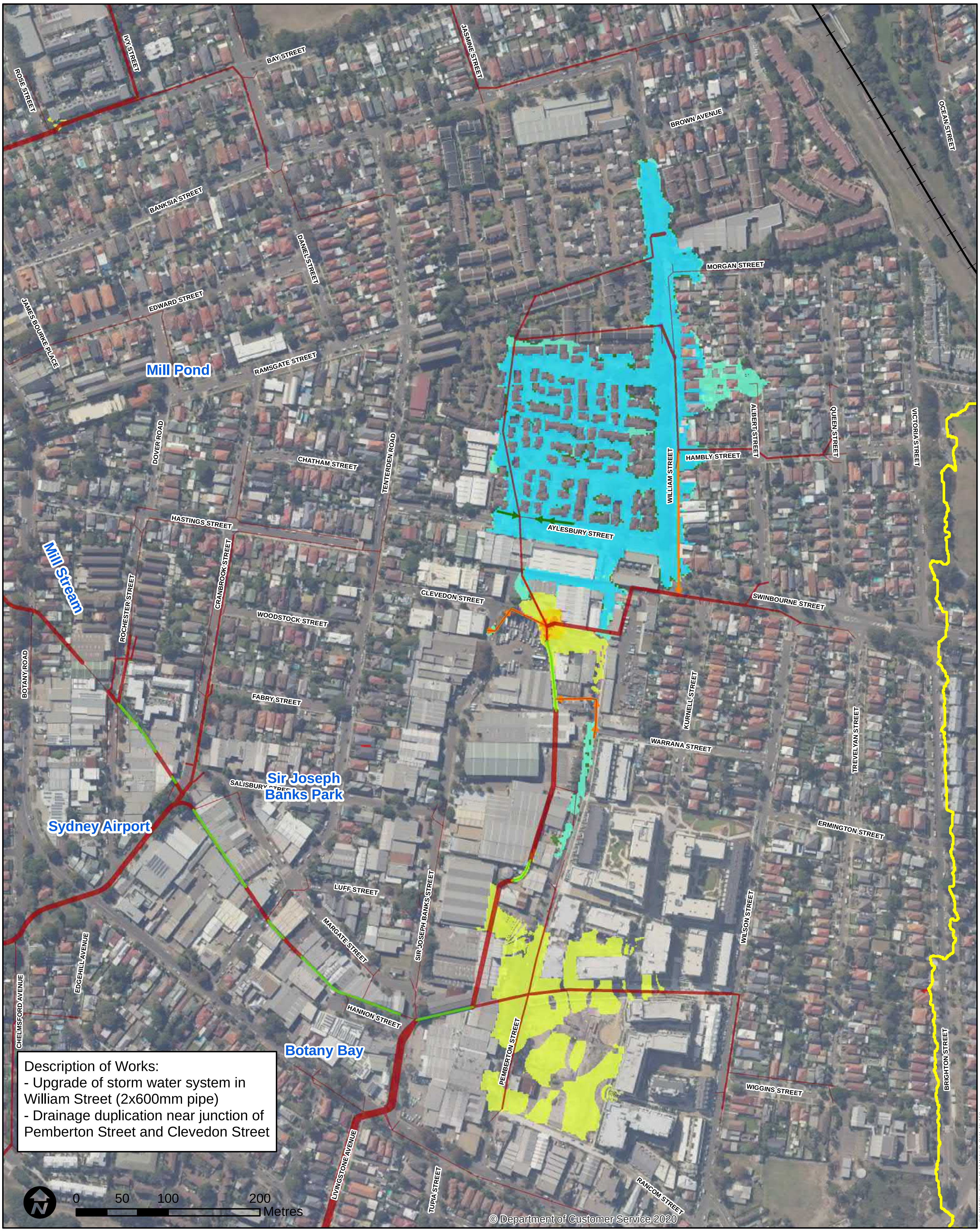
- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:4,000		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	Option 11 - Drainage Augmentation - 5% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.16	REV 1 VER 1
CHECK AH	DATE 23/06/2020		



Legend

- Study area
- Open channels
- Existing stormwater networks

Proposed Mitigation

- New stormwater pipes
- Council's new pipes

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- \> 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:4,000		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	**Option 11 - Drainage Augmentation - 1% AEP Change in Flood Level**		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # **Figure 10.17**	REV 1 VER 1
CHECK AH	DATE 23/06/2020		

10.1.3.5 Option 13a – New culvert drainage for Dent Street low point

A new culvert outlet is proposed to drain the Dent Street trapped drainage low point to the nearby large pond in Sir Joseph Banks Park. The existing pipes draining the low point to Botany Bay are running at full capacities and unable to cater for flood flows and volumes effectively. Duplicating these pipes to discharge into open space in the adjacent Botany Golf Course is not possible due to the relatively high ground elevations in the golf course.

The normal water level in the pond is around 1m AHD, while minimum ground levels in the Dent Street low point are around 1.5 – 1.8m AHD. The proposed culvert of 2 x 2.4m x 0.9m (Width x height) would start at the south-eastern corner of the low point and pass at shallow depth under Fremlins Lane and discharge into the pond. The ground levels behind the properties between Dent Street and the golf course would be regraded to remove bumps in the terrain and form a swale to more freely drain surface waters to the culvert inlet. The proposed culvert would only operate during overland flood events and is not expected to convey flows during normal rainfall events when there is no surface ponding in Dent Street low point.

A proposed 2 x 2.4m x 0.9m (Width x height) culvert was assumed to be required at the western end of the pipe connecting to the existing Livingstone Avenue trunk drainage line, and this was represented in the TUFLOW model. New advice from Sydney Water indicates an existing 450mm pipe outlet is present at the western end of the pond, connected to the existing trunk drainage which drains to Botany Bay. The outlet pipe would allow storm runoff to the pond from Dent Street to drain out rather than be retained in the pond, although future modelling is required to confirm if 450mm diameter outlet has sufficient capacity. For the purposes of modelling and costing this option, 2 x 2.4m x 0.9m culvert is assumed to be required.

A one-way valve would be installed between the trunk drainage and the pond to prevent backflow from the trunk drainage line during high bay water levels (if a separate valve is not installed on the trunk line) and during high flows and water levels in the trunk line. Sydney Water reports that backflows from Botany Bay have been observed in the past.

Constraints assessment

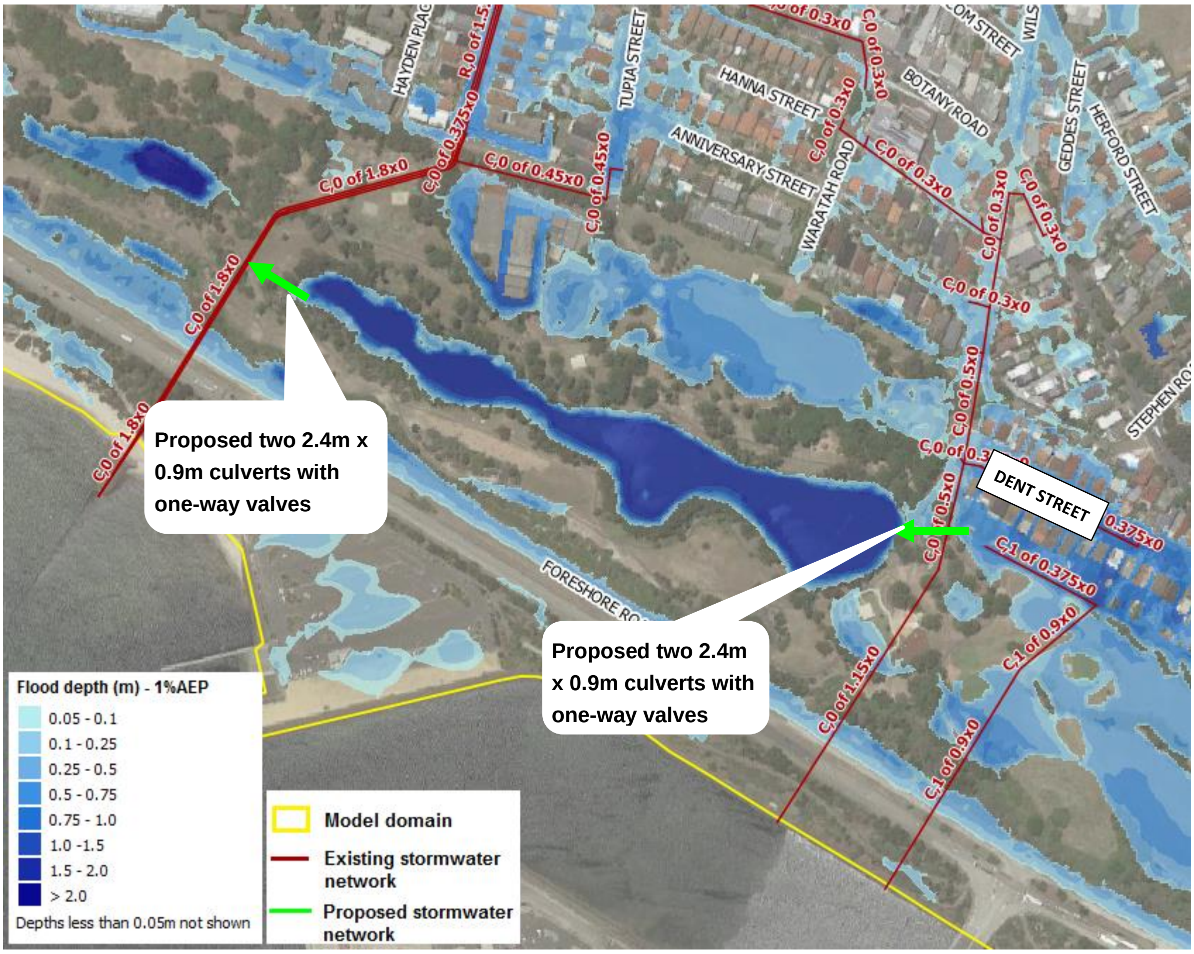
There is minimal fall in ground elevation of less than 1m between Dent Street low point and the permanent water level in the pond. Minimal culvert grade and shallow or no cover over the culvert are likely. The culvert top would need to be trafficable under Fremlins Lane crossing.

Outlet treatments in the pond may be required to reduce risk of scouring. There may be an impact of flood runoff to water quality in the pond, although Council reports that the current water quality is generally poor due to minimal flushing or circulation.

The existing drainage pipe which connects the western end of Dent Street to Botany Bay may need the be crossed by the new culvert. Available data indicates that the proposed culvert could be constructed above the existing pipe, with supports and reinforcement potentially required.

An existing Jemena gas main is also in the vicinity of the culvert inlet and crossing. The depth of the gas main needs to be located in order to confirm constructability. If the gas main is shallow, the proposed culvert inlet should be placed to the west of the gas main. Regrading of the ground surface to drain to the culvert inlet would be required. Potential modifications to existing road and footpath and disturbance of trees.

Figure 10.18 Option 13a – New culvert drainage outlet at Dent Street low point



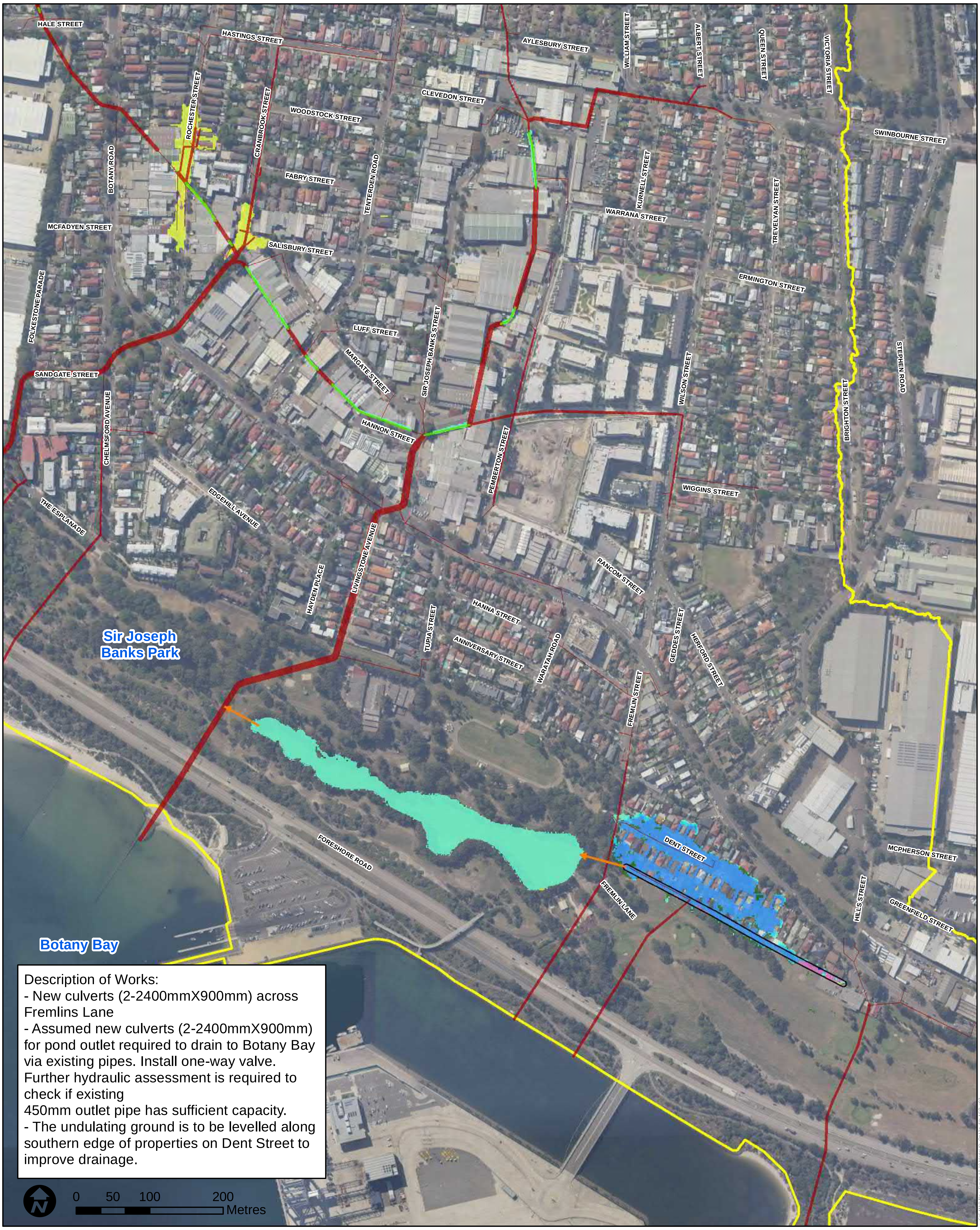
Hydraulic performance

Option 13a results in reductions in flood levels of 0.2m in the 5% AEP and in the 20% AEP, and 0.23m in the 1% AEP events on the floodplain in Dent Street. There are minor increases of 0.02m in 1% AEP flood levels in Rochester Street, attributed to increased flows into the Livingstone Avenue trunk drainage line from the pond which reduces drainage inflow capacity further upstream (including Rochester Street). Refer to Figure 10.19 and Figure 10.20 for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

Above-floor flooding at buildings is reduced by 11 residential and commercial properties in the 1% AEP event and 16 residential properties in the 5% AEP event.

Preliminary evaluation

Option 13a provides flooding improvements to a significant number of properties, and has been selected for further evaluation including costings and multi-criteria analysis.



Legend

Study area	
Existing stormwater networks	
Open channels	
Proposed Mitigation	
New stormwater culverts	
Ground leveling	

Change in Flood Levels (m)

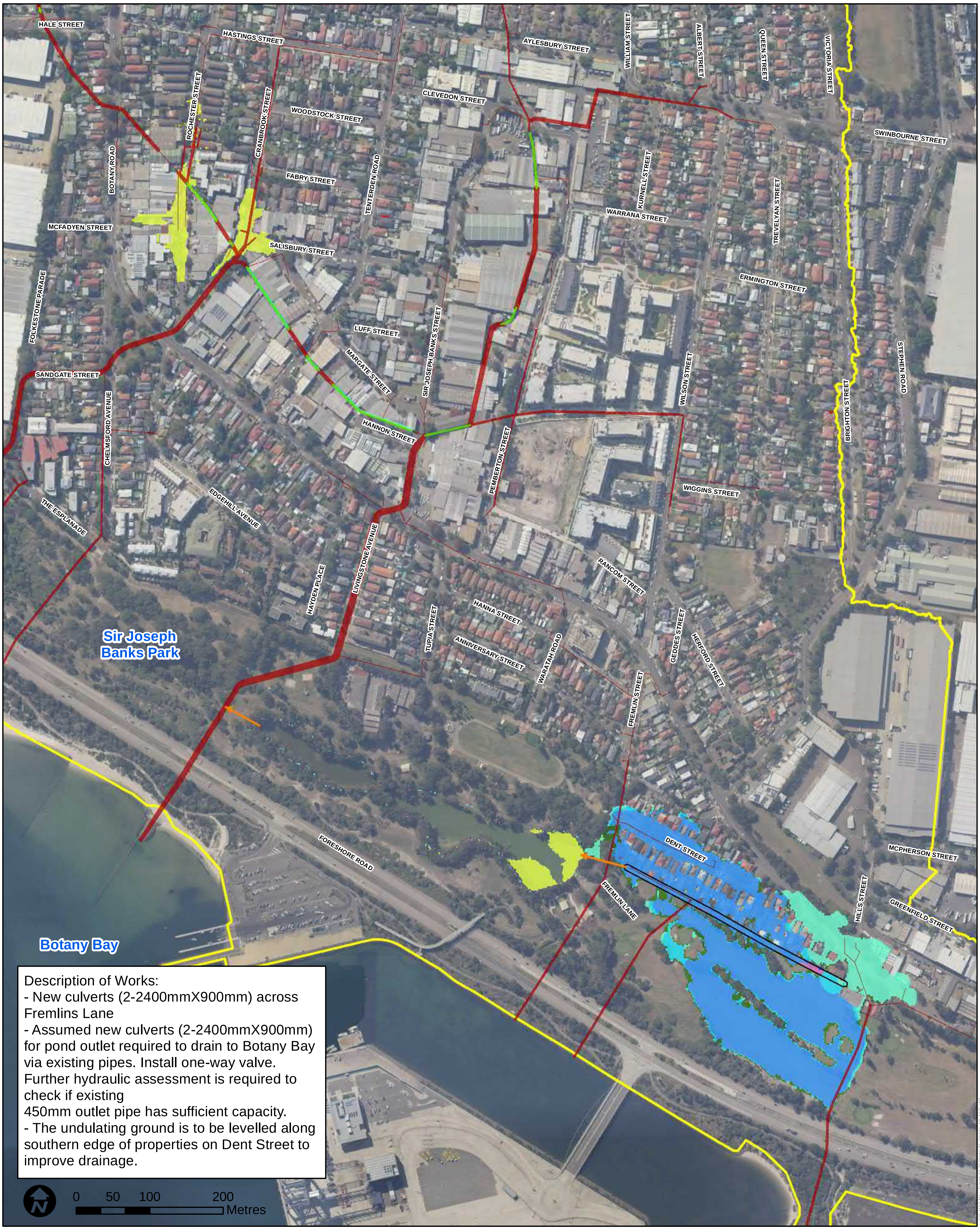
Was wet now dry	-0.1 to -0.05	0.05 to 0.1
< -0.5	-0.05 to -0.01	0.1 to 0.3
-0.5 to -0.3	-0.01 to 0.01	0.3 to 0.5
-0.3 to -0.1	0.01 to 0.05	> 0.5
		Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:5,000		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	Option 13a - Drainage Augmentation - 5% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.19	REV 1 VER 1
CHECK AH	DATE 29/06/2020		



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater culverts
- Ground leveling

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:5,000			A3
SHEET	1 of 1		GDA 1994 MGA Zone 56	
TITLE	Option 13a - Drainage Augmentation - 1% AEP Change in Flood Level			
PROJECT	Botany Bay Foreshore Beach FRMS			
CLIENT	Bayside Council			
DRAWN PK	PROJECT # IA190100	MAP # **Figure 10.20**	REV 1	VER 1
CHECK AH	DATE 29/06/2020			

10.1.4 Combination of preferred options

A number of combinations of options have been selected in consultation with Council. These are discussed below.

10.1.4.1 Option 16: combination of Option 1 and Option 13a

This option is a combination of Option 1 and Option 13a as summarised in Table 10-1.

Table 10-1: Summary of combined options for Option 16

Individual option	Location	Description
Option 1	Selected drainage outlets	Backflow devices on selected drainage outlets (refer Section 10.1.1.1)
Option 13a	Dent Street	New culvert draining Dent Street low point to adjacent pond (refer Section 10.1.3.1). Additional regrading of swale around the low point to avoid backflow from the golf course to Dent Street especially in frequent flood events (20% AEP).

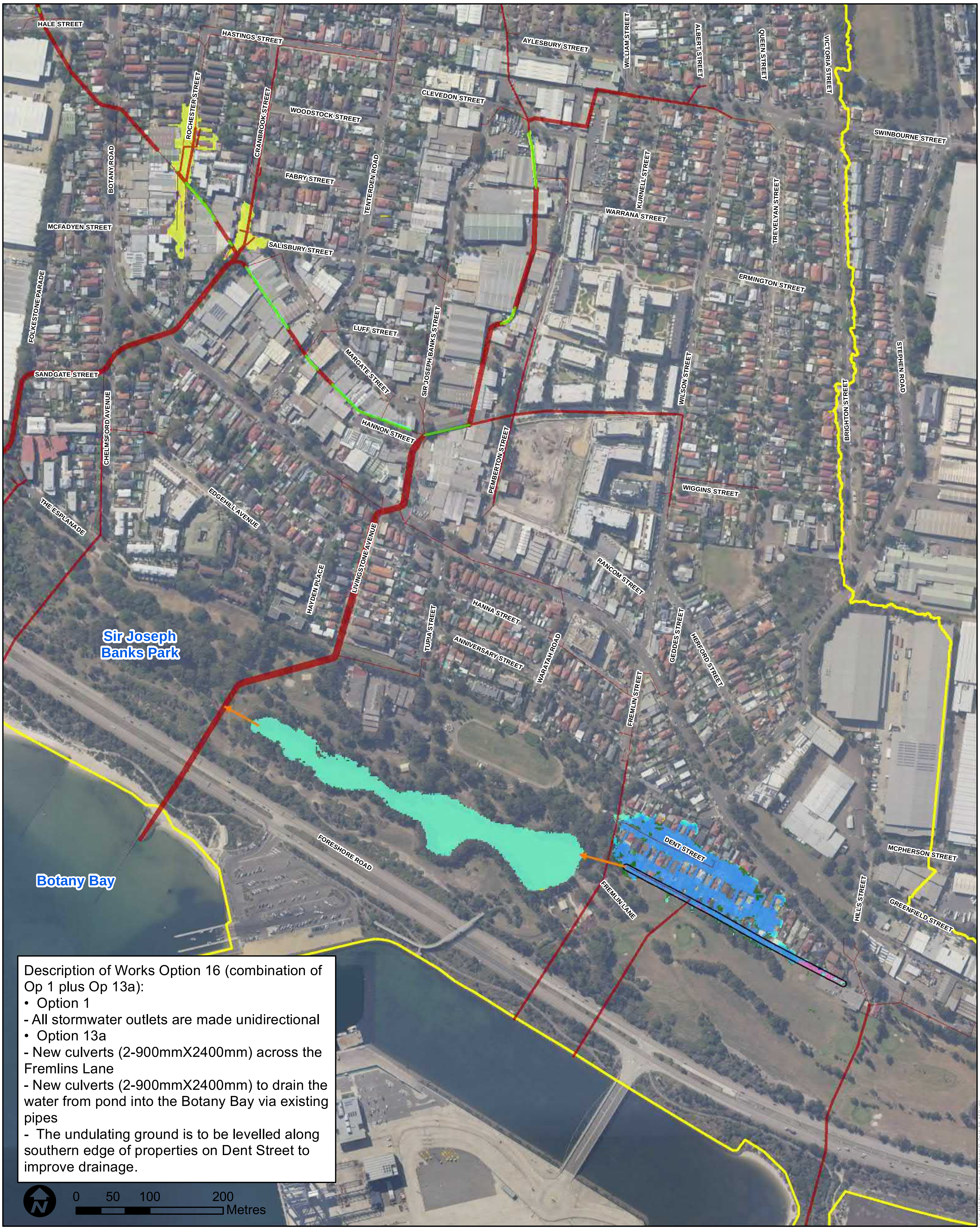
Hydraulic performance

Option 16 results in reductions in flood levels of 0.2m in the 5% AEP and in the 20% AEP, and 0.23m in the 1% AEP events on the floodplain in Dent Street. There are minor increases of 0.02m in 5% AEP flood levels in the Rochester Street. Refer to Figure 10.21 and Figure 10.22 for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

Above-floor flooding at buildings is reduced by 12 residential and commercial properties in the 1% AEP event and 16 residential properties in the 5% AEP event.

Preliminary evaluation

Option 16 provides flooding improvements to a significant number of properties, and has been selected for further evaluation including costings and multi-criteria analysis.



Description of Works Option 16 (combination of Op 1 plus Op 13a):

- Option 1

- All stormwater outlets are made unidirectional

- Option 13a

- New culverts (2-900mmX2400mm) across the Fremlins Lane
- New culverts (2-900mmX2400mm) to drain the water from pond into the Botany Bay via existing pipes
- The undulating ground is to be levelled along southern edge of properties on Dent Street to improve drainage.

Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater culverts
- Ground leveling

Change in Flood Levels (m)

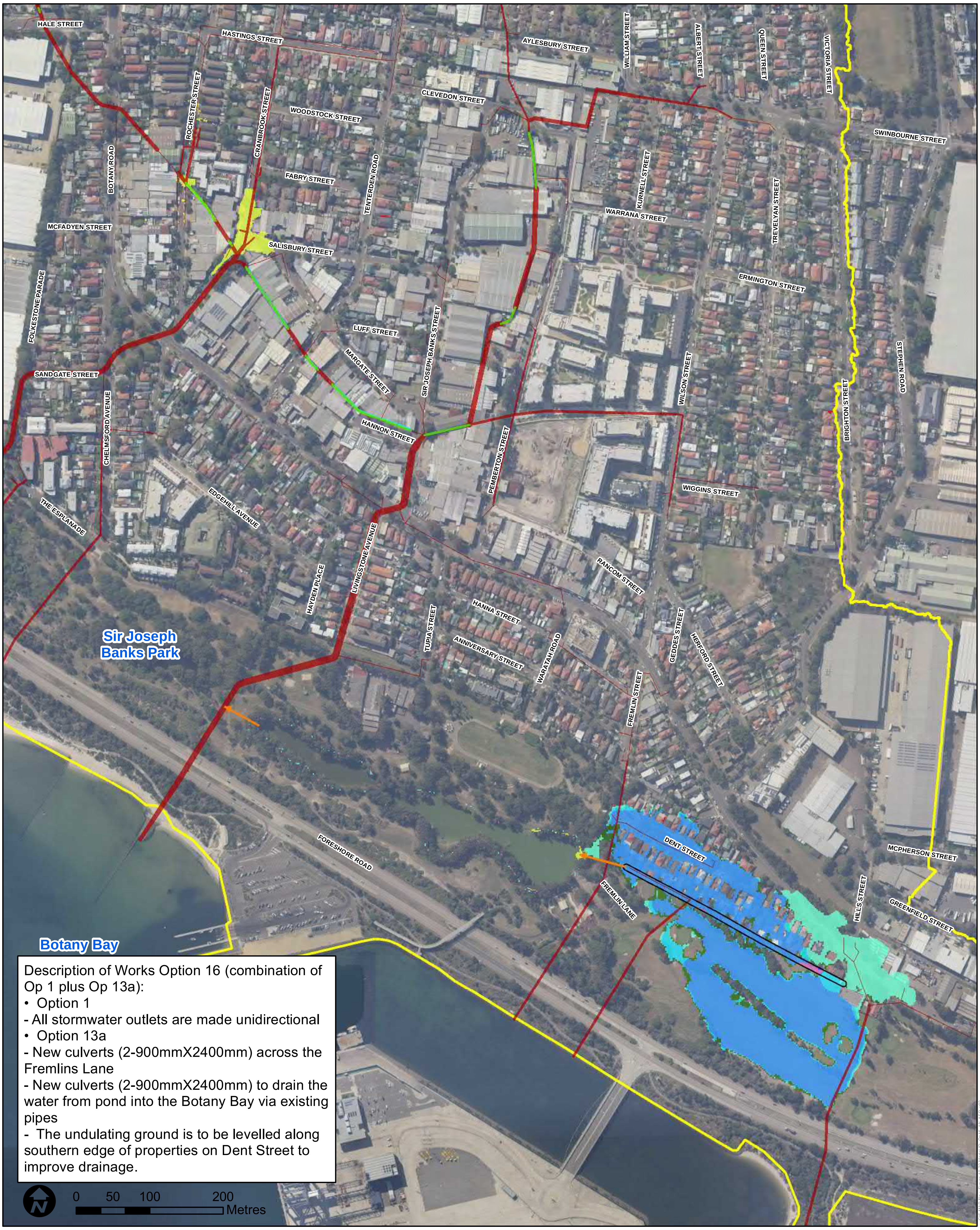
- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:5,000			A3
SHEET	1 of 1			GDA 1994 MGA Zone 56
TITLE	Option 16 - Combined Option - 5% AEP Change in Flood Level			
PROJECT	Botany Bay Foreshore Beach FRMS			
CLIENT	Bayside Council			
DRAWN PK	PROJECT # IA190100	MAP #	Figure 10.21	REV 1 VER 1
CHECK AH	DATE 29/06/2020			



Description of Works Option 16 (combination of Op 1 plus Op 13a):

- Option 1

- All stormwater outlets are made unidirectional

- Option 13a

- New culverts (2-900mmX2400mm) across the Fremlins Lane
- New culverts (2-900mmX2400mm) to drain the water from pond into the Botany Bay via existing pipes
- The undulating ground is to be levelled along southern edge of properties on Dent Street to improve drainage.

Legend

Study area
Existing stormwater network
Open channels

Proposed Mitigation

New stormwater culverts
Ground leveling

Change in Flood Levels (m)

Was wet now dry
< -0.5
-0.5 to -0.3
-0.3 to -0.1
-0.1 to -0.05
-0.05 to -0.01
-0.01 to 0.01
0.01 to 0.05
0.05 to 0.1
0.1 to 0.3
0.3 to 0.5
> 0.5
Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:5,000		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	**Option 16 - Combined Option - 1% AEP Change in Flood Level**		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # **Figure 10.22**	REV 1 VER 1
CHECK AH	DATE 29/06/2020		

10.1.4.2 Option 17: combination of Option 1, Option 4a and Option 12

To improve flooding condition in the northern part of the study area Option 17 is investigated, consisting of a combination of options as summarised in Table 10-2.

Table 10-2: Summary of combined options for Option 17

Individual option	Location	Description
Option 1	Selected drainage outlets	Backflow devices on selected drainage outlets (refer Section 10.1.1.1)
Option 4a	Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road	Augmented drainage lines (refer Section 10.1.3.1)
Option 12	Hale Street and Booralee Street	Augmented drainage lines (refer Section E.6 in Appendix E)

Option 17 targets the north-western section of the study area. This part of the study area is affected by tide. The proposed option would to convey more flows, provide additional drainage capacity to the existing network and prevent backflow prevention due to tide or sea level rise, thus reducing flood impacts to properties on Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road and adjacent area to Hale Street.

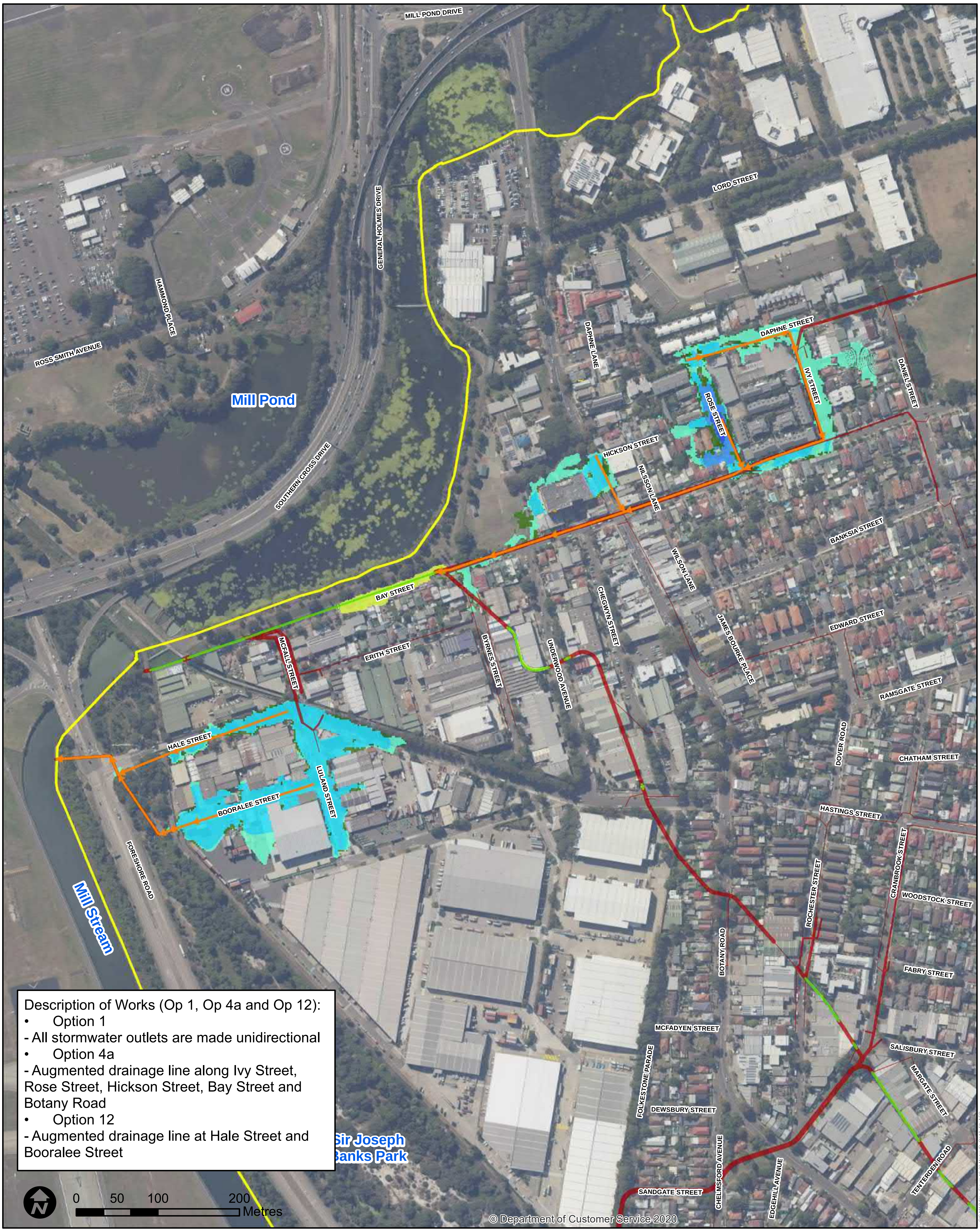
Hydraulic performance

Option 17 provides reductions in flood levels of up to 0.27m in the 20% AEP event, up to 0.32m in the 5% AEP event, and up to 0.4m in the 1% AEP event around Hickson Street, Rose Street and Daphne Street and adjacent properties. Also, there are reductions in flood levels of 0.08m in the 5% AEP and 0.02m in the 20% AEP and 1% AEP events around Hale Street, Booralee Street and Luland Street. Discharge of the increased flows into the trunk drainage channel along Bay Street reduces the drainage capacity of other stormwater branches which results in minor localised increases in the Bay Street and Hale Street industrial area of 0.02m in the 5% AEP and 20% AEP events in roads and trunk drainage channels. The flood impacts increase in increment and extent in the 1% AEP event with increases in flood levels of 0.02m to 0.07m. Refer to Figure 10.23 and Figure 10.24 for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

This option reduces the number of properties with above-floor flooding by 26 residences in the 1% AEP event, and 7 residential and commercial properties in the 5% AEP event. However, the option also causes two new commercial and residential properties to experience above-floor flooding in both the 1% and 5% AEP events.

Preliminary evaluation

Option 17 provides flooding improvements to a significant number of properties, and has been selected for further evaluation including costings and multi-criteria analysis.



Description of Works (Op 1, Op 4a and Op 12):
- Option 1
  - All stormwater outlets are made unidirectional
- Option 4a
  - Augmented drainage line along Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road
- Option 12
  - Augmented drainage line at Hale Street and Booralee Street

Legend

Study area
Existing stormwater networks
Open channels
Proposed Mitigation
New stormwater pipes

Change in Flood Levels (m)

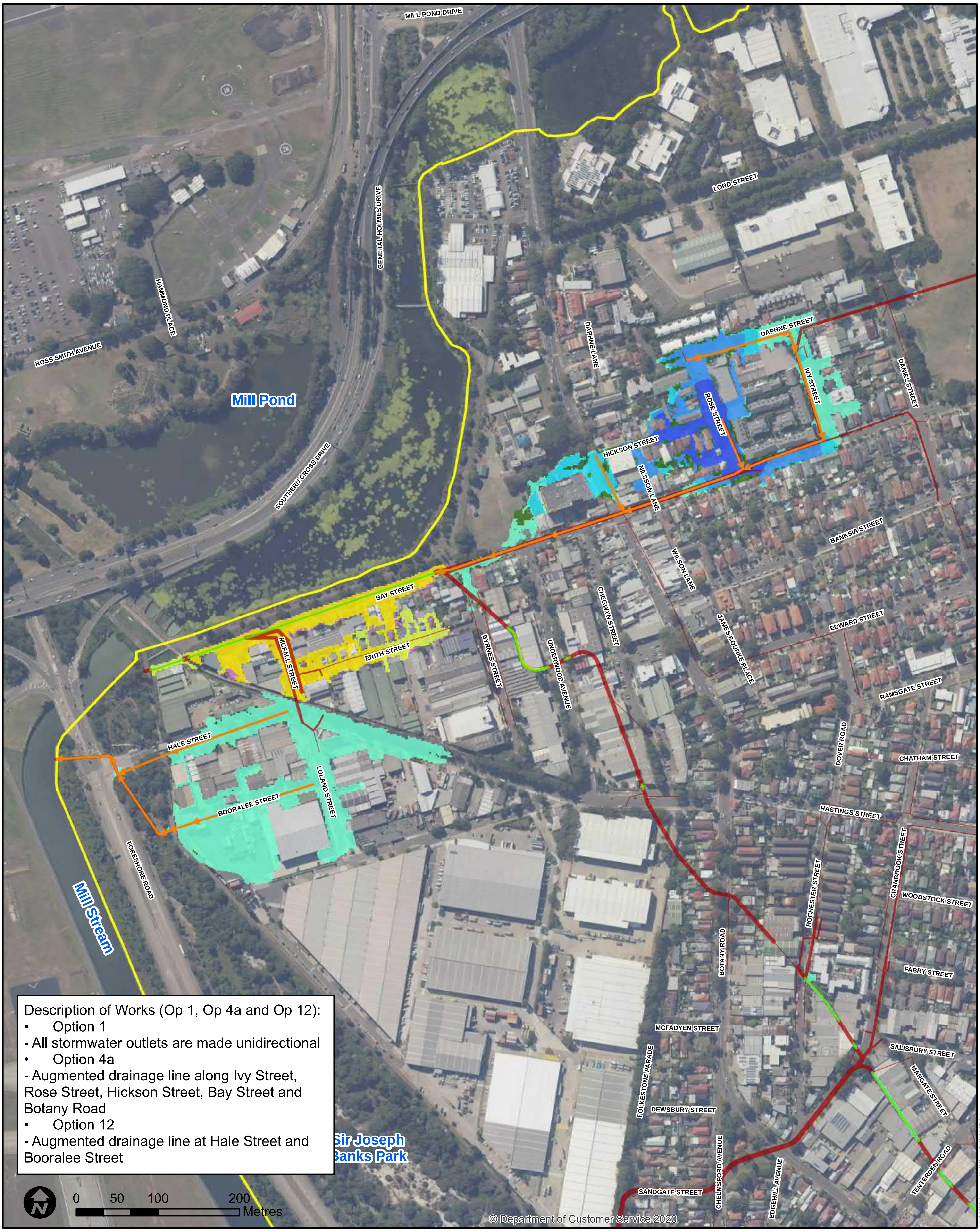
Was wet now dry	-0.1 to -0.05	0.05 to 0.1
< -0.5	-0.05 to -0.01	0.1 to 0.3
-0.5 to -0.3	-0.01 to 0.01	0.3 to 0.5
-0.3 to -0.1	0.01 to 0.05	> 0.5
		Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:4,500		A3
SHEET	1 of 1	GDA 1994 MGA Zone 56	
TITLE	Option 17 - Combined Option - 5% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.23	REV 1 VER 1
CHECK AH	DATE 23/06/2020		



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:4,500		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	Option 17 - Combined Option - 1% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.24	REV 1 VER 1
CHECK AH	DATE 23/06/2020		

10.1.4.3 Option 18: combination of Option 4a and Option 12

Option 18 is investigated to improve flooding condition in the northern part of the study area as Option 17, however, this option does not include backflow prevention device to the existing outlets. It consists of a combination of options as summarised in Table 10-3.

Table 10-3: Summary of combined options for Option 18

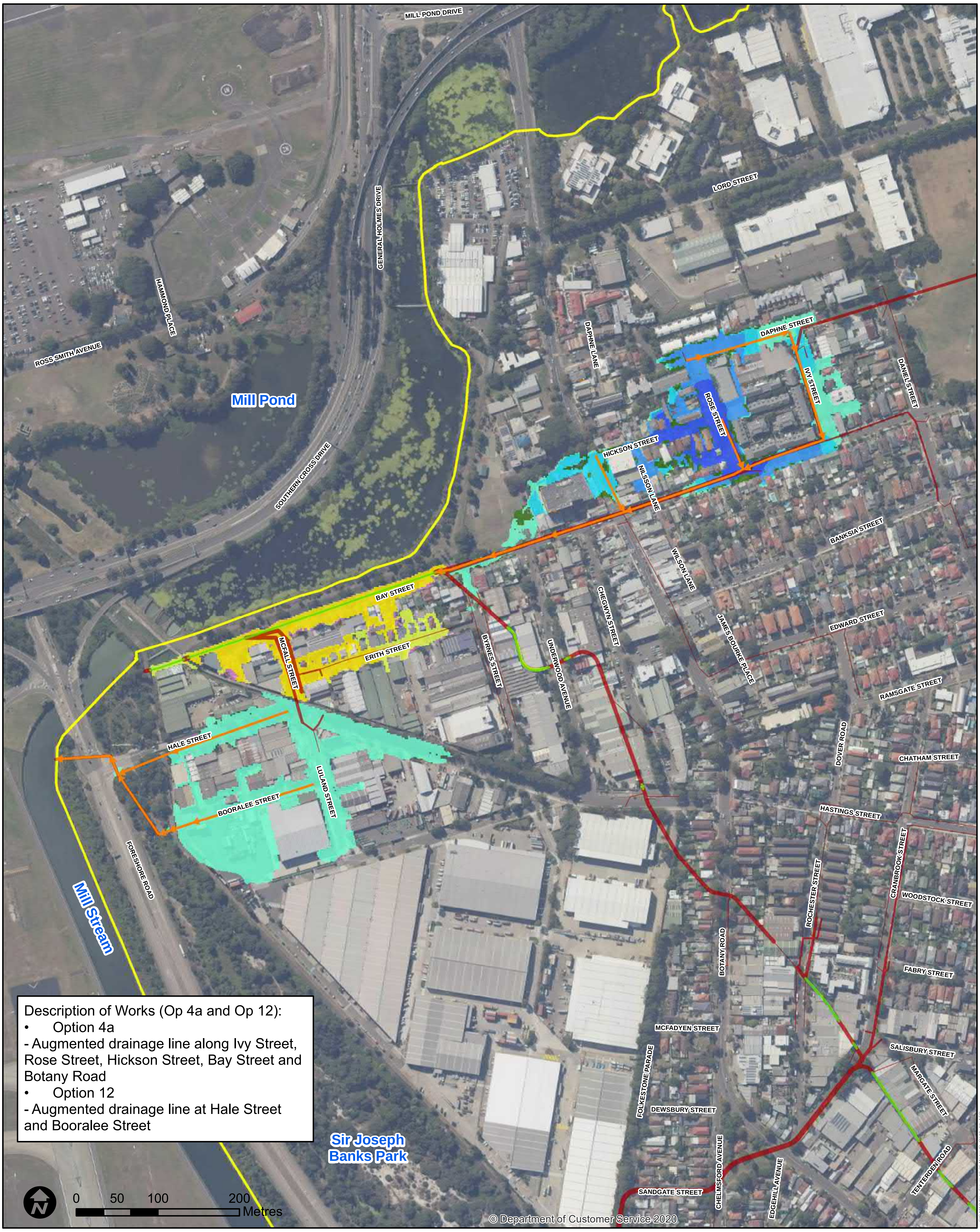
Individual option	Location	Description
Option 4a	Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road	Augmented drainage lines (refer Section 10.1.3.1)
Option 12	Hale Street and Booralee Street	Augmented drainage lines (refer Section E.6 in Appendix E)

Hydraulic performance

There is no significant change in flood behaviour between Option 17 and Option 18. Option 18 provides reductions in flood levels of up to 0.27m in the 20% AEP event, up to 0.32m in the 5% AEP event, and up to 0.4m in the 1% AEP event around Hickson Street, Rose Street and Daphne Street and adjacent properties. Also, there are reductions in flood levels of 0.08m in the 5% AEP and 0.02m in the 20% AEP and 1% AEP events around Hale Street, Booralee Street and Luland Street. Discharge of the increased flows into the trunk drainage channel along Bay Street reduces the drainage capacity of other stormwater branches which results in minor localised increases in the Bay Street and Hale Street industrial area of 0.02m in the 5% AEP and 20% AEP events in roads and trunk drainage channels. The flood impacts increase in increment and extent in the 1% AEP event with increases in flood levels of 0.02m to 0.07m. Refer to Figure 10.25 and Figure 10.26 for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

Preliminary evaluation

Option 18 provides flooding improvements to a significant number of properties, and has been selected for further evaluation including costings and multi-criteria analysis.



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes

Change in Flood Levels (m)

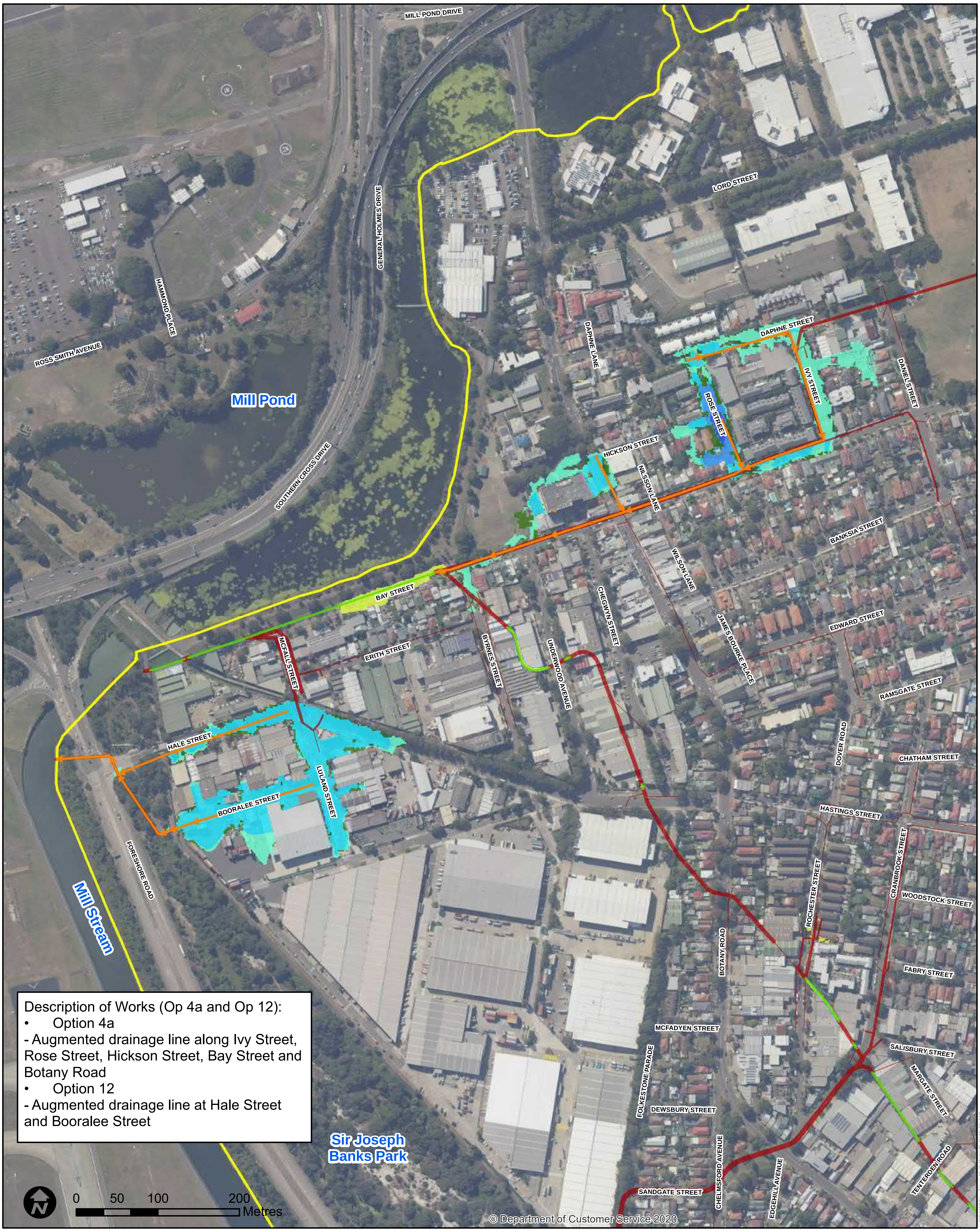
- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:4,500 — A3
SHEET	1 of 1 — GDA 1994 MGA Zone 56
TITLE	Option 18 - Combined Option - 1% AEP Change in Flood Level
PROJECT	Botany Bay Foreshore Beach FRMS
CLIENT	Bayside Council
DRAWN	PK
PROJECT #	IA190100
MAP #	Figure 10.25
REV	1
VER	1
CHECK	AH
DATE	23/06/2020



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:4,500		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	Option 18 - Combined Option - 5% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.26	REV 1 VER 1
CHECK AH	DATE 23/06/2020		

10.1.4.4 Option 19: combination of Option 2c, Option 4a and Option 12

Option 19 is a combined option which is proposed to improve flooding condition in the central and northern part of the study area, consisting of a combination of options as summarised in Table 10-4.

Table 10-4: Summary of combined options for Option 19

Individual option	Location	Description
Option 2c	Booralee Park	Preferred detention basin configuration consisting of lowering of basin bed (refer Section 10.1.2.1)
Option 4a	Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road	Augmented drainage lines (refer Section 10.1.3.1)
Option 12	Hale Street and Booralee Street	Augmented drainage lines (refer Section E.6 in Appendix E)

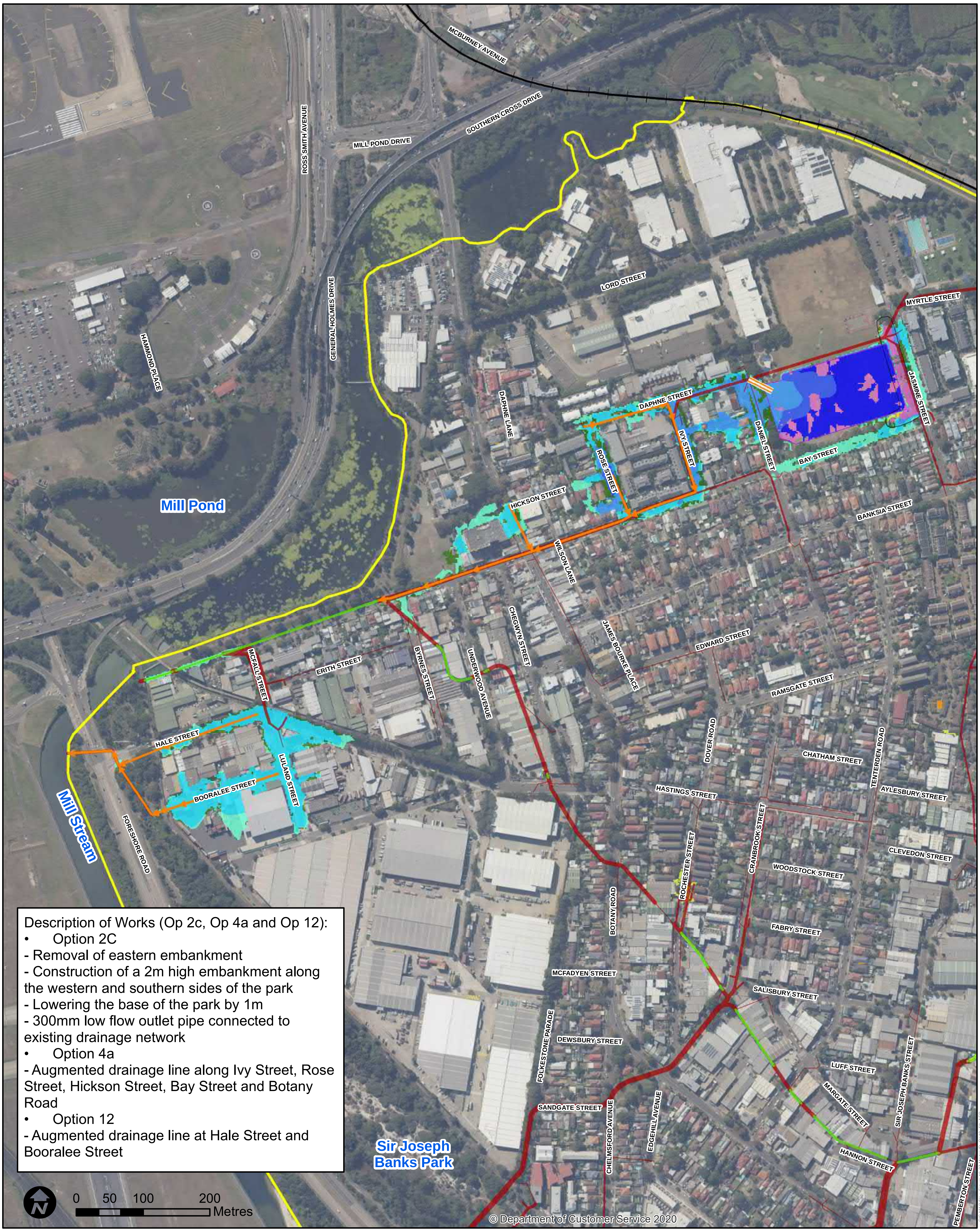
Hydraulic performance

This option provides reductions in flood levels of up to 0.16m in the 5% AEP event and 0.3m in the 1% AEP event in areas adjacent to the Booralee park and downstream areas. Option 19 also provides reductions in flood levels of up to 0.27m in the 20% AEP event, up to 0.32m in the 5% AEP event, and up to 0.58m in the 1% AEP event around Hickson Street, Rose Street and Daphne Street and adjacent properties. In addition, there are reductions in flood levels of 0.02m in the 20% AEP, 0.08m in the 5% AEP and 0.05m in the 1% AEP events around Hale Street, Booralee Street and Luland Street. Discharge of the increased flows into the trunk drainage channel along Bay Street reduces the drainage capacity of other stormwater branches which results in minor localised increases in the Bay Street and Hale Street industrial area of 0.03m in the 1% AEP event. Refer to Figure 10.27 and Figure 10.28 for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

This option reduces the number of properties with above-floor flooding by 36 residences commercial properties in the 1% AEP event, and 11 residential and commercial properties in the 5% AEP event. However, the option also causes two new commercial to experience above-floor flooding in the 1% AEP event and one residential property to experience above-floor flooding in 5% AEP event.

Preliminary evaluation

Option 19 provides flooding improvements to a significant number of properties, and has been selected for further evaluation including costings and multi-criteria analysis.



Legend

- Study area
- Existing stormwater
- Open channels

Proposed Mitigation

- New stormwater pipes
- Low flow pipe
- Detention basin
- Embankment removal

Change in Flood Levels (m)

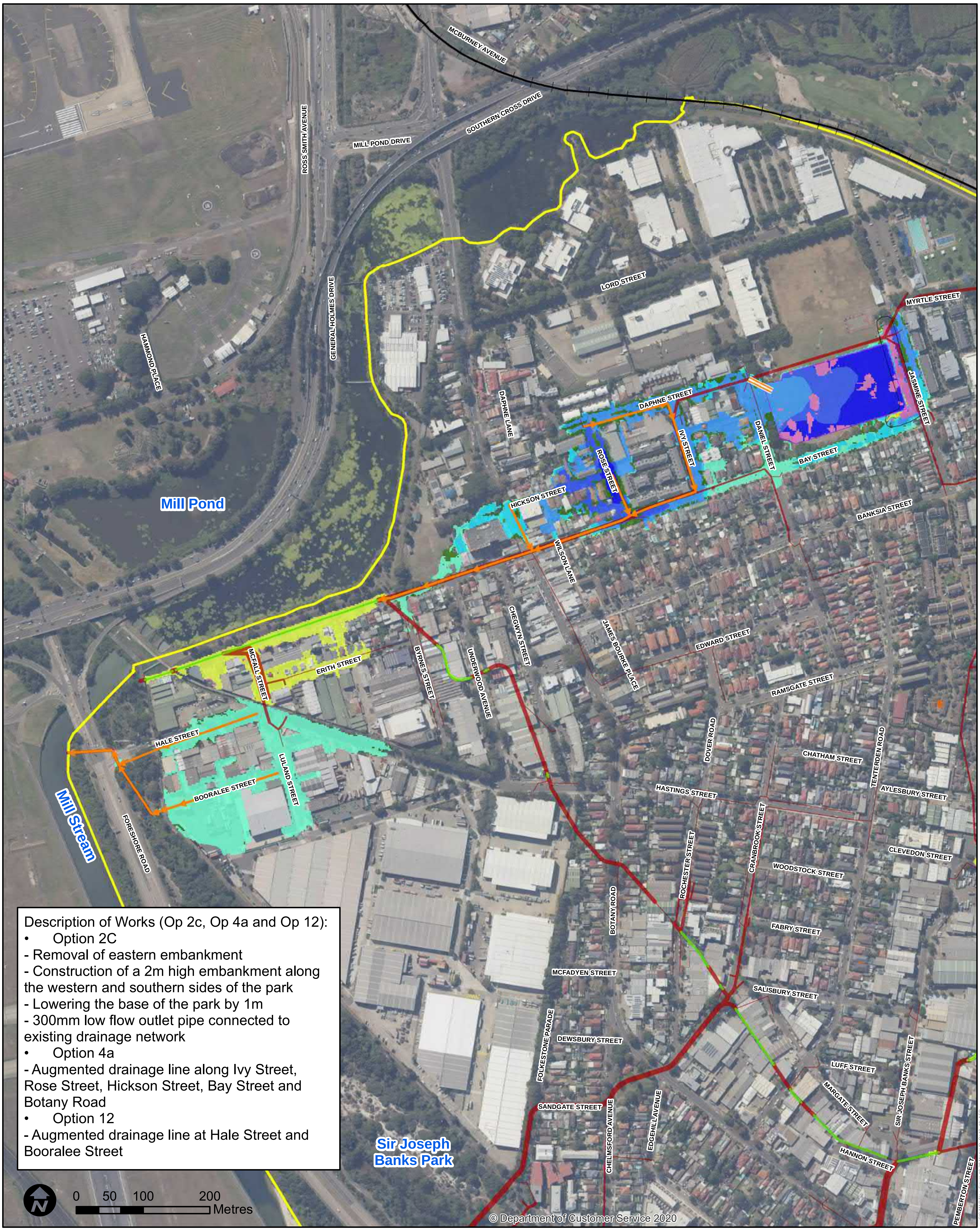
- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:5,500	A3
SHEET	1 of 1	GDA 1994 MGA Zone 56
TITLE	Option 19 - Combined Option - 5% AEP Change in Flood Level	
PROJECT	Botany Bay Foreshore Beach FRMS	
CLIENT	Bayside Council	
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.27 — REV 1, VER 1
CHECK AH	DATE 23/06/2020	



Description of Works (Op 2c, Op 4a and Op 12):

- Option 2C

- Removal of eastern embankment
- Construction of a 2m high embankment along the western and southern sides of the park
- Lowering the base of the park by 1m
- 300mm low flow outlet pipe connected to existing drainage network

- Option 4a

- Augmented drainage line along Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road

- Option 12

- Augmented drainage line at Hale Street and Booralee Street

Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes
- Low flow pipe
- Detention basin
- Embankment removal

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:5,500		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	**Option 19 - Combined Option - 1% AEP Change in Flood Level**		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # **Figure 10.28**	REV 1 VER 1
CHECK AH	DATE 23/06/2020		

10.2 Long term strategies

10.2.1 Sub-catchment prioritization

The stormwater catchments defined in the 2015 Flood Study have been further sub-divided into smaller parts based on the distribution of impacted properties in 5% AEP, alignment of stormwater networks, location of outlets and overland flow paths. The study area is therefore divided in 12 number of stormwater sub-catchment. Each sub-catchment is allocated with a priority rank number which may be used to guide implementation of flood risk management measures. The ranking is determined based on the number of impacted properties, complexity of networks and location of discharge point/outlet. The sub-catchment which includes William Street (sub-catchment I1) can be defined as priority one and sub-catchment at Dent Street (sub-catchment K) can be defined as priority 2.

Table 10-5 Stormwater sub-catchments in the study area

Sub-catchment ID	Impacted properties in 5% AEP	Discharge towards?	Sub-catchment Priority
I1	93	Sub-cat I2 and/or Sub-cat I3	1
K	62	Outside of study area	2
I2	64	Sub-cat I3	3
G4	60	Sub-cat G5 and/or Sub-cat H	4
G2	65	Sub-cat G5	5
G5	51	Outside of study area	6
H	26	Outside of study area	7
I3	19	Outside of study area	8
G1	16	Outside of study area	9
G3	11	Sub-cat G5	10
N	9	Outside of study area/ to Sub-cat F	11
F	6	Outside of study area	12

10.2.2 Pipe capacity assessment

The existing pipe capacity is indicated on Figure 10.30 in terms of the flood event AEP at which the pipes reach capacity. The figure indicates that there are sections of the trunk drainage system which may have spare capacity, as indicated by sections denoted with 1% AEP capacity or higher. Several of these sections are aligned with high priority sub-catchments including I1 and I2. It should be note however that some of these sections are close to flowing full and hence do not have significantly more capacity. Other sections are constrained by upstream and downstream sections which are flowing full, and it is not feasible to upgrade these constrained sections. For example, pipe and channel sections between Pemberton Street and Livingstone Avenue run under existing and between industrial buildings and it would not be possible to upgrade this constrained section without demolition of these buildings. Where possible, long-term upgrades have been investigated.

Legend

- Existing stormwater networks
- Rail
- Stormwater catchments
- Study area
- Subcatchments-prority

Impact Properties (above-floor)-5% AEP
- Commercial
- Industrial
- Residential

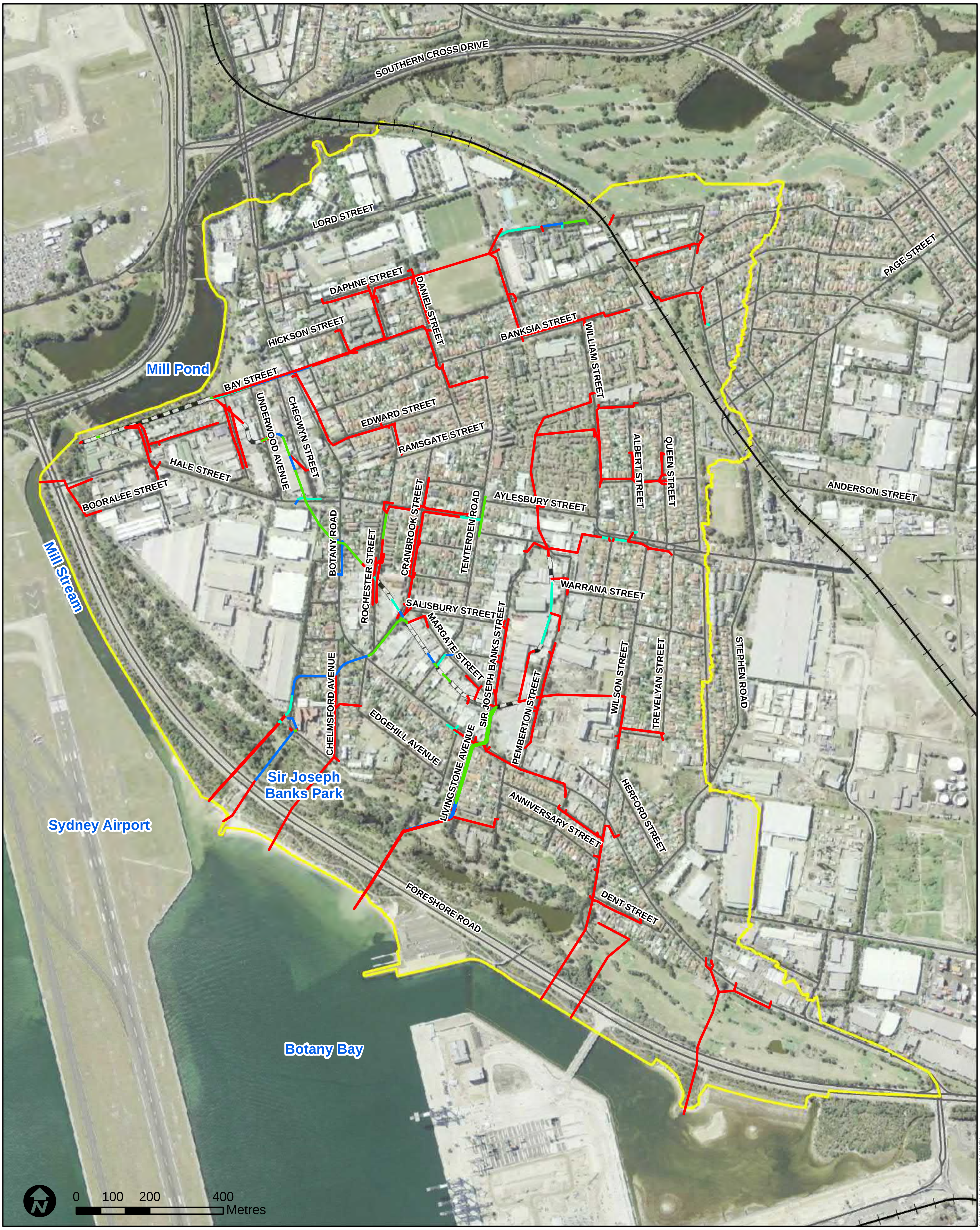
Flood depth (m) - 1% AEP
- 0.05 to 0.1
- 0.1 to 0.25
- 0.25 to 0.5
- 0.5 to 0.75
- 0.75 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- >2.0

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:10,000			A3
SHEET	1 of 1			GDA 1994 MGA Zone 56
TITLE	Sub-catchment Prioritisation			
PROJECT	Botany Bay Foreshore Beach FRMS			
CLIENT	Bayside Council			
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.29	REV 2	VER 1
CHECK AH	DATE 22/06/2020			



Legend

- Study area
- Existing open channels

Pipe Capacity

- Capacity exceeded in 20% AEP event
- Capacity exceeded in 5% AEP event
- Capacity exceeded in 1% AEP event
- Capacity exceeded in > 1% AEP event

JACOBS®

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:10,000		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	**Existing Capacity of Pipes**		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN AI	PROJECT # IA190100	MAP # **Figure 10.30**	REV 2 VER 1
CHECK LC	DATE 6/08/2020		

10.2.3 Upgrade of drainage infrastructure

The existing drainage infrastructure has limited capacity to drain the study area. In the 20% AEP event, 214 residential buildings and 134 commercial/industrial buildings are impacted by above floor flooding, while in the 5% AEP flood event, 320 residential buildings and 159 commercial/industrial buildings are impacted by above floor flooding. Significant number of properties on Queen Street, Wilson Street, Bay Street, Livingstone Avenue and Dent Street are impacted due to inadequate capacity of the drainage infrastructure.

One long term strategy is to upgrade the capacity of the drainage structure, including inlets, to approximately the 5% AEP flood event. Figure 10.30 indicates the pipes (coloured red) which have a 20% AEP capacity which would need to be upgraded to 5% AEP capacity under such a program. Upgrade of drainage infrastructure could be undertaken as part of a long-term planning and can be implemented in stages. However, due to the high level of constraints posed by full level of urban development in the study area the full upgrade of the trunk drainage system is expected to be high cost and may be difficult to justify from a purely financial and flood damages improvement standpoint. Figure 10.30 indicates that it would involve upgrade to over 80% of the existing network.

A sensitivity scenario consisting of implementation of all shortlisted mitigation options was tested and is discussed in Section 10.2.3.1. A sensitive scenario consisting of targeted upgrade in the drainage in addition to implementation of all shortlisted mitigation options was also assessed and is discussed in Section 10.2.3.2.

10.2.3.1 Long term strategy scenario-01

This is a combination of all shortlisted mitigation measures i.e. Option 2c, Option 4a, Option 7a, Option 8, Option 11, and Option 16.

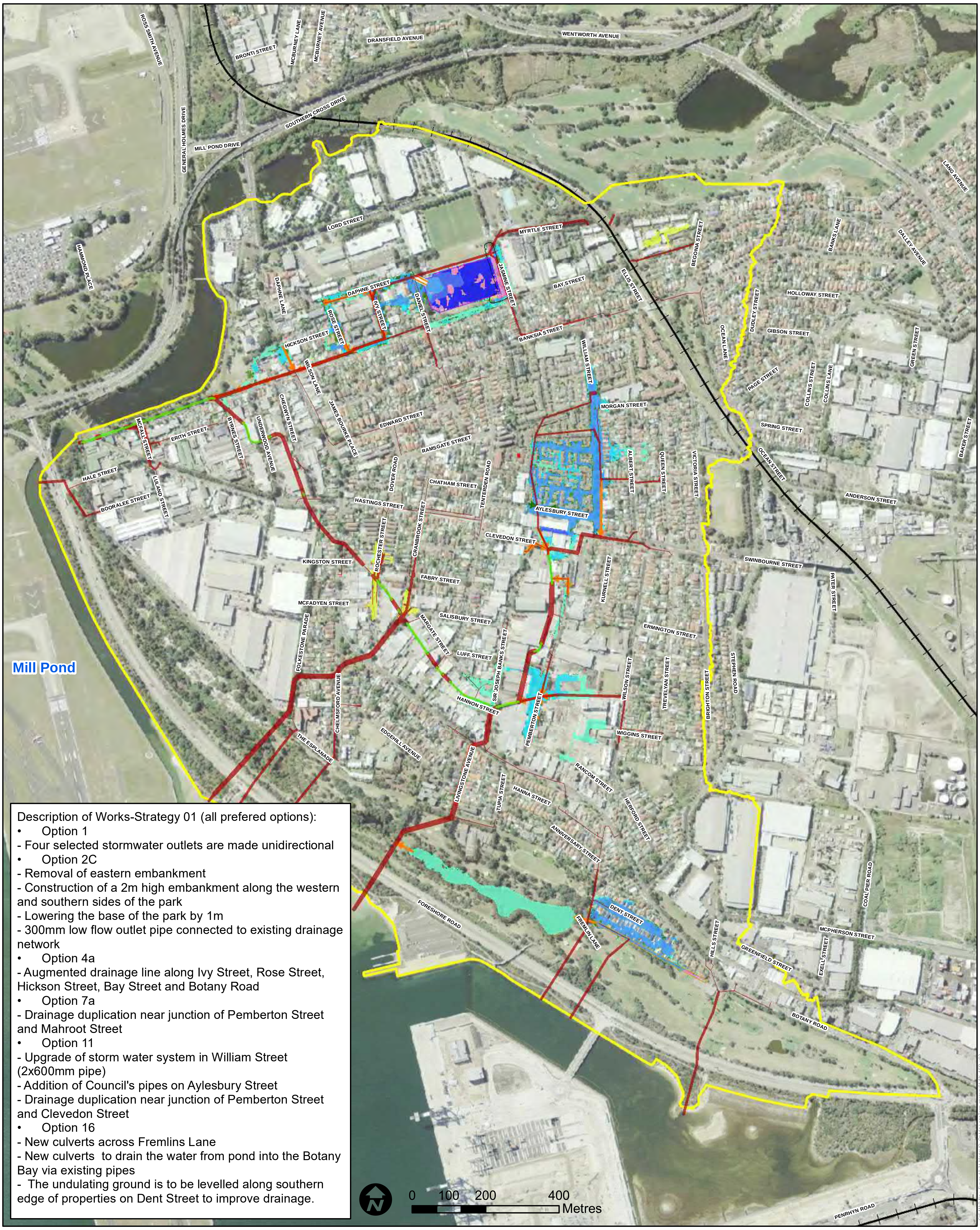
Option ID	Description
Option 2c	Detention basin at Booralee Park
Option 4a	Augmented drainage line along Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road
Option 7a	Addition of pipes near junction of Pemberton Street and Mahroot Street
Option 8	Upgrade of stormwater system in William Street
Option 11	Additional pipes near Pemberton Street and Clevedon Street + Option 8
Option 16	New culvert drainage for Dent Street low point + Backflow device on drainage outlets

Hydraulic performance

This option provides improvements to flood levels of up to 0.2m in the 5% AEP and 0.3m in the 1% AEP event in areas adjacent to Booralee park. The option reductions in flood levels of up to 0.32m in the 5% AEP event, and up to 0.58m in the 1% AEP event around Hickson Street, Rose Street and Daphne Street and adjacent properties. In addition, there are reductions in flood levels of 0.2m and 0.09m in the 5% AEP around Hale Street and William Street respectively. There are reductions in flood levels of 0.2m in the 1% AEP both in Hale Street and William Street.

This option will result in increases in Bay Street and Rochester Street of 0.03m in the 1% AEP event. Refer to and for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

This option reduces the number of properties with above-floor flooding by 79 residences commercial properties in the 1% AEP event, and 57 residential and commercial properties in the 5% AEP event. However, the option also causes seven new properties to experience above-floor flooding in the 1% AEP event and four properties to experience above-floor flooding in 5% AEP event.



Description of Works-Strategy 01 (all prefered options):

- Option 1

- Four selected stormwater outlets are made unidirectional

- Option 2C

- Removal of eastern embankment
- Construction of a 2m high embankment along the western and southern sides of the park
- Lowering the base of the park by 1m
- 300mm low flow outlet pipe connected to existing drainage network

- Option 4a

- Augmented drainage line along Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road

- Option 7a

- Drainage duplication near junction of Pemberton Street and Mahroot Street

- Option 11

- Upgrade of storm water system in William Street (2x600mm pipe)
- Addition of Council's pipes on Aylesbury Street
- Drainage duplication near junction of Pemberton Street and Clevedon Street

- Option 16

- New culverts across Fremlins Lane
- New culverts to drain the water from pond into the Botany Bay via existing pipes
- The undulating ground is to be levelled along southern edge of properties on Dent Street to improve drainage.

Legend

- Open channels
- Existing stormwater networks
- Study area

Proposed Mitigation

- Ground leveling
- New stormwater pipes
- Low flow pipe
- Detention basin
- Embankment removal

Change in Flood Levels (m)

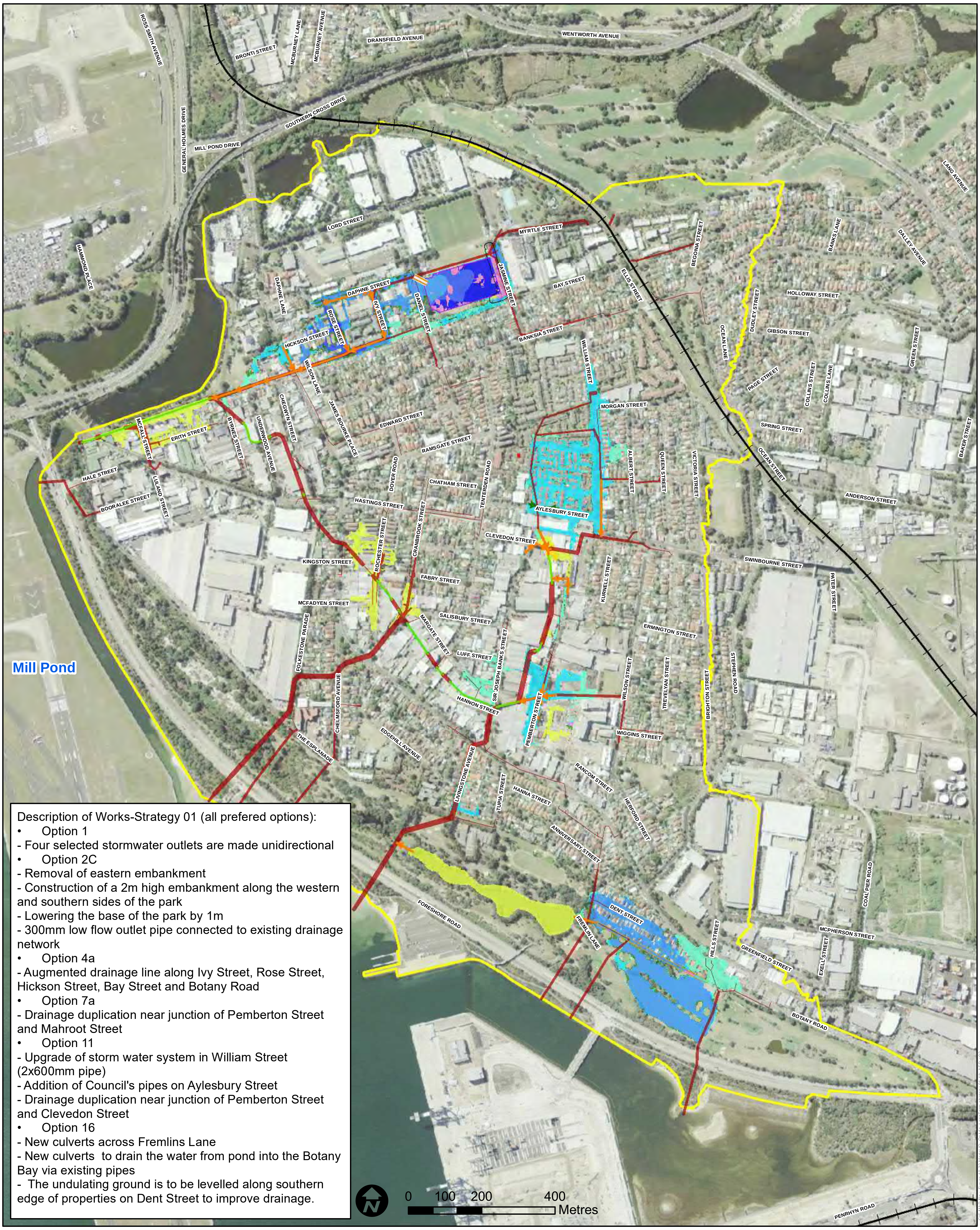
- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:10,000		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	Long term strategy-01 - 5% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.31	REV 1 VER 1
CHECK AH	DATE 29/06/2020		



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes
- Low flow pipe
- Detention basin
- Embankment removal
- Ground leveling

Change in Flood Levels (m)

Was wet now dry	-0.1 to -0.05	0.05 to 0.1
< -0.5	-0.05 to -0.01	0.1 to 0.3
-0.5 to -0.3	-0.01 to 0.01	0.3 to 0.5
-0.3 to -0.1	0.01 to 0.05	> 0.5
		Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:10,000		A3
SHEET	1 of 1	GDA 1994 MGA Zone 56	
TITLE	Long term strategy-01 - 1% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.32	REV 1 VER 1
CHECK AH	DATE 29/06/2020		

10.2.3.2 Long term strategy scenario-02

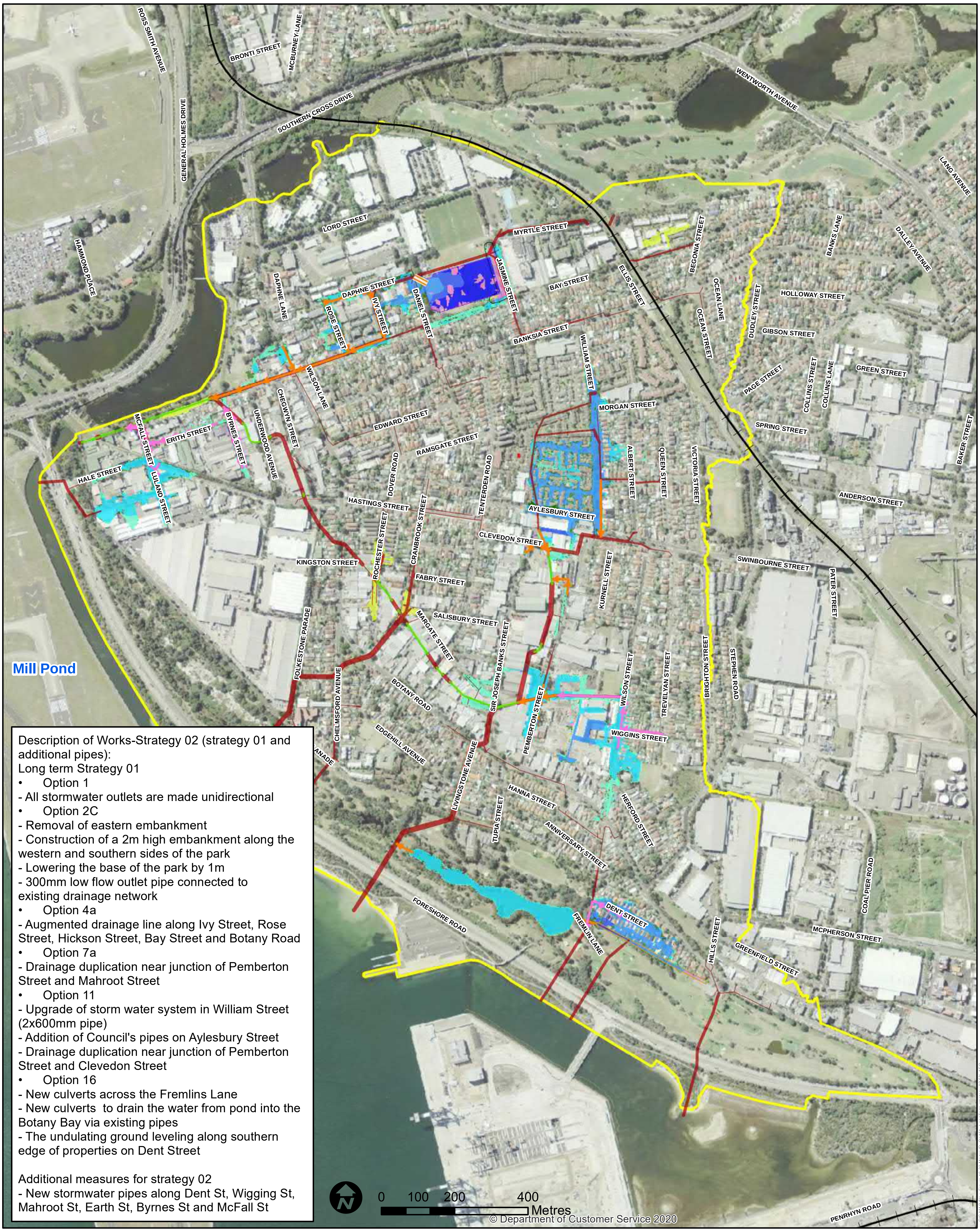
This scenario is simulated by combining the Long-term strategy scenario-01 with additional pipes along the Dent Street, Wiggins Street, Mahroot Street, Erith Street and Byrnes Street. Additional pipes with 300mm to 1500mm diameter (new or duplicate) are proposed for the areas where the impacted properties in 5% AEP are not benefited by Long-term strategy scenario-01 and/or there is a possibility of future development.

Hydraulic performance

This scenario provides reductions in flood levels similar to the Long-term strategy 01 in areas adjacent to the Booralee park and in Hickson Street, Rose Street and Daphne Street, William Street and adjacent properties. In addition, there are reductions in flood levels of 0.3m in the 5% AEP and 1% AEP in Dent Street; reduction in flood levels of 0.07m in 5% AEP and 0.05m in 1% AEP in Wilson Street and reduction in flood levels of 0.08m in 5% AEP and 0.04m in 1% AEP in Hale Street.

This option will result in increases flood level in Bay Street and Rochester Street of 0.03m in the 1% AEP event. Refer to and for mapping of changes to flood levels in the 5% and 1% AEP events, respectively.

This option reduces the number of properties with above-floor flooding by 85 residences commercial properties in the 1% AEP event, and 69 residential and commercial properties in the 5% AEP event. However, the option also causes eight new properties to experience above-floor flooding in the 1% AEP event and five properties to experience above-floor flooding in 5% AEP event.



Description of Works-Strategy 02 (strategy 01 and additional pipes):

Long term Strategy 01

- Option 1
- All stormwater outlets are made unidirectional
- Option 2C
- Removal of eastern embankment
- Construction of a 2m high embankment along the western and southern sides of the park
- Lowering the base of the park by 1m
- 300mm low flow outlet pipe connected to existing drainage network
- Option 4a
- Augmented drainage line along Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road
- Option 7a
- Drainage duplication near junction of Pemberton Street and Mahroot Street
- Option 11
- Upgrade of storm water system in William Street (2x600mm pipe)
- Addition of Council's pipes on Aylesbury Street
- Drainage duplication near junction of Pemberton Street and Clevedon Street
- Option 16
- New culverts across the Fremlins Lane
- New culverts to drain the water from pond into the Botany Bay via existing pipes
- The undulating ground leveling along southern edge of properties on Dent Street

Additional measures for strategy 02

- New stormwater pipes along Dent St, Wigging St, Mahroot St, Earth St, Byrnes St and McFall St

Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes (stratery 01)
- New stormwater pipes (stratery 02)
- Low flow pipe
- Detention basin
- Embankment removal
- Ground leveling

Change in Flood Levels (m)

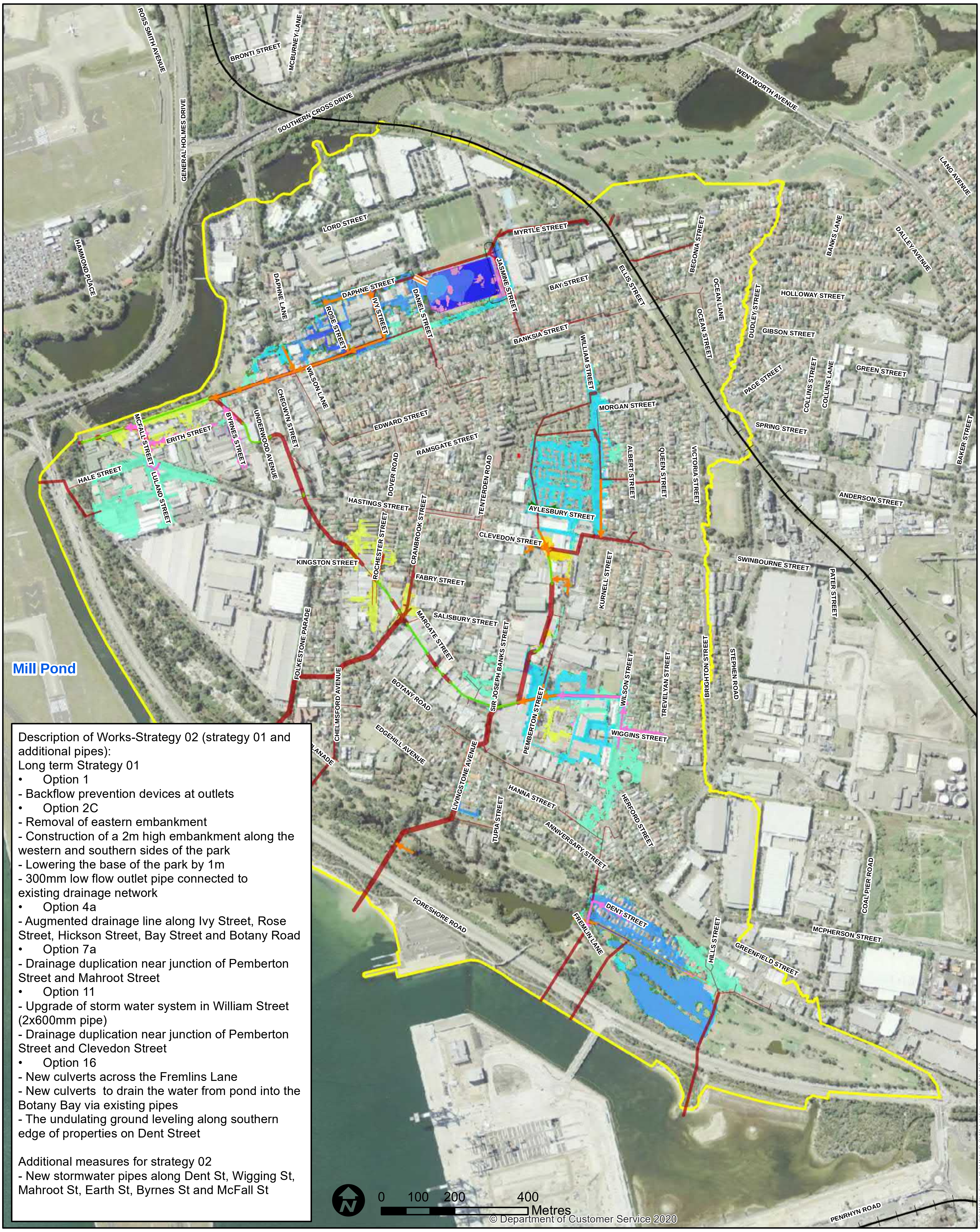
- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:10,000		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	Long term strategy-02 - 5% AEP Change in Flood Level		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # Figure 10.33	REV 1 VER 1
CHECK AH	DATE 29/06/2020		



Legend

- Study area
- Existing stormwater networks
- Open channels

Proposed Mitigation

- New stormwater pipes (stratery 01)
- New stormwater pipes (stratery 02)
- Low flow pipe
- Detention basin
- Embankment removal
- Ground leveling

Change in Flood Levels (m)

- Was wet now dry
- < -0.5
- -0.5 to -0.3
- -0.3 to -0.1
- -0.1 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.1
- 0.1 to 0.3
- 0.3 to 0.5
- > 0.5
- Was dry now wet

JACOBS

Data Sources: Bayside Council

LIMITATIONS: This mapping is based on data provided by the Bayside Council. Jacobs does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

SCALE	1:10,000		A3
SHEET	1 of 1		GDA 1994 MGA Zone 56
TITLE	**Long term strategy-02 - 1% AEP Change in Flood Level**		
PROJECT	Botany Bay Foreshore Beach FRMS		
CLIENT	Bayside Council		
DRAWN PK	PROJECT # IA190100	MAP # **Figure 10.34**	REV 1 VER 1
CHECK AH	DATE 29/06/2020		

10.2.4 Installation of pump

There are 218 residential and 202 commercial/industrial buildings in the study area with floor levels located below RL 4m AHD which are likely to be impacted by storm surge, tide and sea level rise. Several buildings on Hale Street have floor levels below RL 2m AHD (refer to Figure 7.3). Drainage pumping in combination with backflow devices could be a long term option for this area and properties located at the south eastern corner of the study area. This long term strategy has not been scoped or evaluated in this FRMS.

10.2.5 Summary on Long Term Strategies assessment

Two scenarios were tested based on combined implementation of the shortlisted options, with scenario 2 also including further targeted drainage upgrades. These scenarios improve flooding in areas targeted by the mitigation options, however, both scenarios have the potential to result in downstream flooding impacts.

Further assessment outside the scope of this study should be considered to identify and assess mitigation for the resultant impacts. This may include further assessment of trunk drainage upgrades or other additional options. It is acknowledged that the range of options required to fully mitigate flooding problems may not be feasible from and economic standpoint. The future assessment is proposed to be scoped separately by Council and has not been recommended for inclusion in the floodplain risk management plan.

10.3 Property flood benefits and impacts from proposed options

An assessment of the benefits and impacts of the proposed short-term flood modification options tested in the TUFLOW model was conducted, which included a count of individual properties where above-floor flooding was removed as a result of the option, and where new above-floor flooding was resultant from the options. The assessment was undertaken for the 1% and 5% AEP events for each option tested individually and in combination. The properties are characterised according to their residential (R), commercial (C) or industrial (I) land uses. Refer to Table 10-6 for the summarised results. The outcomes are stated for each option in the sections above.

Table 10-6 Change in property above-floor flooding from mitigation options

Option	Properties with eliminated above-floor flooding				Properties with new above-floor flooding			
	1%AEP event		5%AEP event		1%AEP event		5%AEP event	
	No. of properties	Type	No. of properties	Type	No. of properties	Type	No. of properties	Type
Op1	1	1 I	0	0	0	0	0	0
Op2a	1	1 R	NA	NA	0	0	NA	NA
Op2b	28	28 R	NA	NA	0	0	NA	NA
Op2c	28	28 R	5	1 C and 4 R	0	0	1	1 R
Op3	0	0	0	0	0	0	1	1 R
Op4	25	25 R	5	1 C and 4 R	2	2 C	2	1C and 1 R
Op5	1	1 R	3	3 R	0	0	0	0
Op6	3	3 R	1	1 R	1	1 C	1	1 R
Op7	2	1 C and 1 R	2	2 R	1	1 C	1	1 R
Op7a	4	1 C, 1 I and 2 R	6	6 R	2	2 C	0	0
Op8	29	29 R	25	1 I and 24 R	0	0	1	1 R
Op10	3	3 R	0	0	0	0	1	1 R
Op11	33	33 R	30	2 I, 1 C and 27 R	0	0	2	2 R
Op12	3	1 I and 2 R	2	2 I	0	0	1	1 R
Op13a	12	1 I and 11 R	16	16 R	0	0	0	0
Op16	13	1 I and 12 R	16	16 R	0	0	0	0
Op17	26	1 I and 25 R	7	1 C, 2 I and 4 R	2	2 C	2	1C and 1 R
Op18	27	1 I and 26 R	7	1 C, 2 I and 4 R	2	2 C	2	1C and 1 R
Op19	36	1 C, 1 I and 34 R	11	1 C, 2 I and 8 R	2	2 C	1	1 R
Long term strategy 01	79	1 C, 2 I and 76 R	57	2C, 3 I and 52 R	7	5 C and 2 R	4	1 C and 3 R
Long term strategy 02	85	3C, 3I and 79R	69	3C, 5 I and 61 R	8	5 C 1 I and 2 R	5	1 I and 4 R

Property types: R = residential; C = commercial; I = industrial

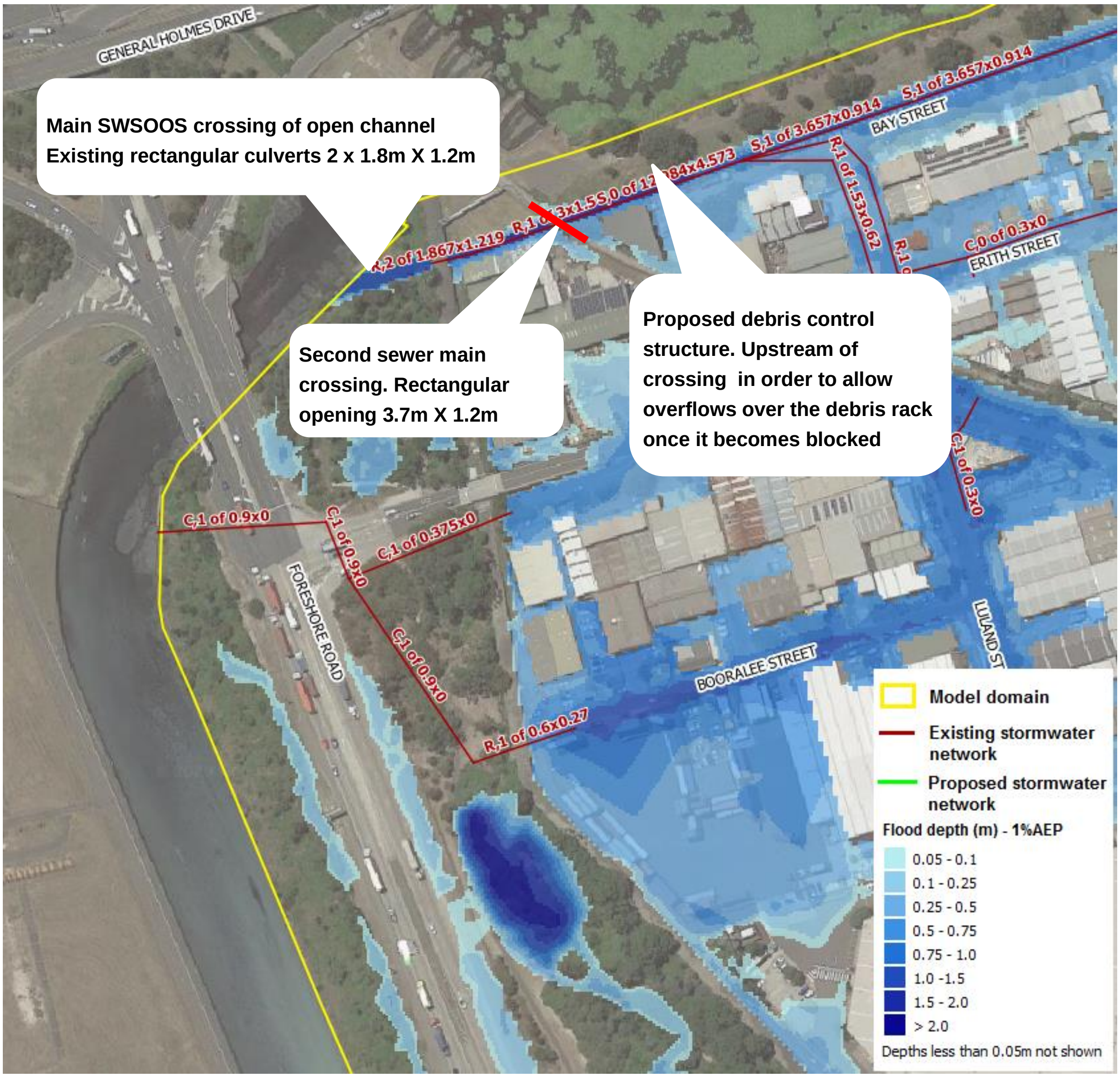
Total number of properties impacted in design flood case: 1% AEP: 517 (341 R, 99 I and 77 C); 5% AEP: 396 (253 R, 88 I and 55 C)

10.4 Other Options – Measure for debris control

The existing trunk drainage open channel alongside Bay Street which is the main outlet to Mill Stream is crossed by two large Sydney Water sewer mains between Bay Street and Foreshore Drive, both of which are the Southern and Western Suburbs Ocean Outfall Sewer (SWSOOS). The sewer crossing conduits are about 2-3m high and the height of the conduits above the channel bed is about 1.2m. Blockage of theses crossings by flood-borne debris would impact on the upstream catchment area due to backwater flooding and reduced drainage capacity.

Blockage of the crossing due to urban debris such as bikes, shopping trolleys, bins in addition to large vegetation is possible. Large debris screens should be considered for installation on the upstream side of the sewer crossings to reduce the risk of debris blockage and reduction in drainage capacity. Inspection and maintenance of the screen would be required following storm events to remove any caught debris. The location proposed for the debris control structure is shown on Figure 10.35.

Figure 10.35 Measures for debris control at Bay Street



10.5 Evaluation of options

A number of modelled options were further shortlisted for detailed evaluation based on their hydraulic performance. Those which provided minimal or no benefits to flooding of properties were not expected to be economically feasible and hence were excluded from further consideration.

To enable the options evaluation, cost estimates were prepared for each option. A summary of costings for each of the options is provided in Appendix F. Costings cover the basic design and construction costs and do not include the cost for physical location or the relocation of existing underground utilities or excavation and disposal of contaminated or acid sulphate soils. Nominal costs are provisioned for relocation of existing utilities during the construction.

Table 10-7 summarises the evaluation of potentially feasible options including likely constraints, hydraulic performance (changes to flooding conditions as estimated in the hydraulic model), savings in flood damages, cost of works and economic appraisal. The flood damages are presented in terms of the reduction in Net Present Value (NPV) of the damages from the base case to the mitigation case. The NPV was calculated by discounting the value of the AAD during each successive year after the present year for the design life of the proposed mitigation measures. In this study a design life of 50 years and a discount rate of 7% have been assumed. The flood damages used in the options evaluation are based on “no protection level” (refer to Section 7.4.3). The flood damages calculations are based on OEH (2016b) guidelines.

The difference in the NPV of flood damages is the theoretical savings in flood damages which can be achieved by a particular mitigation option, over the design life of the option. Comparison of this saving in NPV to the cost of the mitigation option provides a basis for evaluating the economic feasibility of an option, whereby the reduction in NPV (“Benefit”) are divided by the capital cost (“Cost”). A benefit-cost ratio greater than 1.0 would indicate that the capital cost of the works would be less than the savings in flood damages over the life of the works, and vice-versa for a ratio less than 1.0.

The options evaluation is based on a scoring system, with scores from -3 (strongly negative) to +3 (strongly positive) with 0 being a neutral score, for a range of aspects and issues relating to implementation of the mitigation options. The scoring system matrix is shown on Table 10-8.

A summary evaluation table of the mitigation options is presented in Table 10-9. Each option is given a relative rating for each criterion and is given a total score for further consideration by Council. For some criteria, all options provide a neutral or near neutral score because there is minimal change from existing conditions, for example, impact on risk to life and impact to SES, as there is only minor reduction in high flood hazard areas as a result of the options.

10.6 Climate change considerations in the Mitigation Options Assessment

Parts of the study area are highly constrained by its low elevations, where sea level rise is likely to impact on the future performance of the mitigation options. Increased rainfall and runoff with climate change would also have an impact on hydraulic performance but to a lesser degree. The impact of climate change on the long-term performance of the options is considered in the evaluation matrix.

Most of the options are located at higher parts of the catchment where the climate change impacts on performance are relatively neutral. A couple of the options are in or partly in lower areas, less than 2m AHD, and may be impacted by the effects of sea level rise on drainage capacity. The options have been scored accordingly.

Table 10-7 Summary of Selected Flood Modification Options for Detailed Evaluation

Option	Location	Description	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*	Savings in Flood Damages (50 years life, 7% Discount Factor)	Cost of Works	Benefit Cost Ratio (BCR)
Option 2c	Detention Basin-Booralee Park	• Removal of informal embankment along western side of Jasmine Street • Lowering the base of the park by 1m • 300mm low flow outlet pipe connected to existing drainage network	• The park would be subject to more frequent flooding and for longer durations • May not be acceptable to community • Likely disturbance/removal of vegetation including EECs • Disturbance of cricket pitches, soccer field and other park facilities • High groundwater table may result in park being frequently waterlogged • Potential for unrecorded Aboriginal sites/items in south-western portion of park • Dam safety issues need to be considered	• Reductions in flood levels up to 0.13m in 5% AEP event, and 0.15m in 1% AEP, on Daniel Street • Reductions in flood levels up to 0.03m in 5% AEP event, and 0.30m in 1% AEP, on Rose Street • Reductions in flood levels up to 0.08m in 5% AEP event, and 0.30m in 1% AEP, on Bay Street and Jasmin Street • 28 less properties with above floor flooding in 1% AEP event. • Five less properties with above floor flooding in 5% AEP event • One property with above floor flooding in 5% AEP event which is flood free in the existing scenario • Flood hazard changes from H3 to H1 on Daniel Street and Ivy Street in both 1% and 5% AEP events, on Daphne Street for 1%AEP event only.	$1.5M	$1.1M	1.4
Option 4a	Drainage Augmentation-around Bay Street	• Augmented drainage line along Ivy Street, Rose Street, Hickson Street, Bay Street and Botany Road	• Disruption to major arterial road during construction. Likely closure of major road with traffic diverted via local roads • Limited space for construction activities on footpath • Potential clash with existing utilities (Ausgrid cables, Telstra networks, NBN facilities, Jemena high pressure gas main, RMS traffic signal cable). Significant number of main drainage lines already in place • Likely closure of driveways to existing properties • Likely disturbance/removal of vegetation	• Increase in flood levels up to 0.02m in 5% AEP event, and 0.08m in 1% AEP, on downstream of Bay Street • Reductions in flood levels up to 0.38m in 5% AEP event, and 0.31m in 1% AEP, on Rose Street • Reductions in flood levels up to 0.10m in 5% AEP event, and 0.40m in 1% AEP, on upstream of Bay Street • Reductions in flood levels up to 0.06m in 5% AEP event, and 0.10m in 1% AEP, on Botany Road • 26 less properties with above floor flooding in 1% AEP event • Five less properties with above floor flooding in 5% AEP event • Two properties with above floor flooding in 5% AEP and 1% AEP event which are flood free in the existing scenarios • Flood hazard changes from H2 to H1 on Rose Street and Ivy Street in both 1% and 5% AEP event • Flood hazard changes from H3 to H1 on Hickson Street flood in 1% AEP event.	$0.8M	$14.2M	0.05
Option 7a	Drainage Augmentation-around Pemberton Street	• Drainage duplication near junction of Pemberton Street and Mahroot Street	• Limited space for construction activities on footpath • Potential clash with existing utilities (Ausgrid cables, Telstra networks, NBN facilities, Jemena high pressure gas main). • Likely closure of driveways to existing properties • Works on private property, which will require micro-tunnelling	• Reductions in flood levels up to 0.08m in 5% AEP event, and 0.09m in 1% AEP, on Pemberton Street and Mahroot Street • Reductions in flood levels up to 0.02m in 5% AEP event, and 0.08m in 1% AEP, on Rancom Street • Reductions in flood levels up to 0.05m in 5% AEP event, and 0.03m in 1% AEP, on Sir Joseph Bank Street • Four less properties with above floor flooding in 1% AEP event • Six less properties with above floor flooding in 5% AEP event • Two properties with above floor flooding in 1% AEP event which are flood free in the existing scenarios	$3.2M	$12.9M	0.25

Option	Location	Description	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*	Savings in Flood Damages (50 years life, 7% Discount Factor)	Cost of Works	Benefit Cost Ratio (BCR)
				• Flood hazard becomes H1 on a large part of Pemberton Street and Mahroot Street in both 1%AEP and 5%AEP events.			
Option 8	Drainage Augmentation- William Street	• Upgrade of stormwater system in William Street (2x600mm pipe)	• Limited space for construction activities on footpath • Potential clash with existing utilities (Ausgrid cables, Telstra networks, NBN facilities, Jemena high pressure gas main)	• Reduction in flood levels up to 0.14m in 5% AEP event, and 0.07m in 1% AEP, on William Street • Reductions in flood levels up to 0.13m in 5% AEP event, and 0.06m in 1% AEP, on Aylesbury Street • 29 less properties with above floor flooding in 1% AEP event. • 25 less properties with above floor flooding in 5% AEP event • One property with above floor flooding in 5% AEP event which is flood free in the existing scenario • Flood hazard becomes H1 on a part of William Street and Aylesbury Street in both 1%AEP and 5%AEP events.	$3.9M	$1M	4
Option 11	Drainage Augmentation Option 8 plus near Pemberton Street and Clevedon Street	• Option 8 plus • Drainage duplication near Pemberton Street and Clevedon Street	• Limited space for construction activities on footpath • Potential clash with existing utilities (Ausgrid cables, Telstra networks, NBN facilities, Jemena high pressure gas main) • Likely closure of driveways to existing properties • Works on private property, which will require micro-tunnelling	• Increase in flood levels up to 0.08m in 1% AEP, on Clevedon Street • Reduction in flood levels up to 0.18m in 5% AEP event, and 0.09m in 1% AEP, on William Street • Reductions in flood levels up to 0.18m in 5% AEP event, and 0.07m in 1% AEP, on Aylesbury Street • 33 less properties with above floor flooding in 1% AEP event. • 30 less properties with above floor flooding in 5% AEP event • Two properties with above floor flooding in 5% AEP which are flood free in the existing scenarios • Flood hazard becomes H1 on a part of William Street and Aylesbury Street in both 1%AEP and 5%AEP events.	$4.8M	$13M	0.37
Option 13a	Drainage Augmentation- Dent St	• New culverts to drain water into the existing pond • Connect pond with existing outlets to drain water into Botany Bay + local backflow deivices	• Likely disturbance/removal of vegetation including EECs • Potential clash with existing utilities (Ausgrid cables, Caltex pipe/Jemena high pressure gas main) • Potential environmental issue • Likely closure of park entrance • Potential for unrecorded Aboriginal sites/items in Sir Joseph Banks Park	• Reductions in flood levels up to 0.2m in 5% AEP event, and 0.23m in 1% AEP, on Dent Street • 12 less properties with above floor flooding in 1% AEP event • 16 less properties with above floor flooding in 5% AEP event • Flood hazard becomes H1 on a significant part of Dent Street in both 1%AEP and 5%AEP events.	$1M	$1.7M	0.59
Option 16	Combined option	• Option 13a plus • Option 1: Backflow prevention devices for all outlets	• Similar to Option 13a plus 4 backflow prevention devices •	• Reductions in flood levels up to 0.2m in 5% AEP event, and 0.23m in 1% AEP, on Dent Street • 13 less properties with above floor flooding in 1% AEP event • 16 less properties with above floor flooding in 5% AEP event • Flood hazard becomes H1 on a significant part of Dent Street in both 1%AEP and 5%AEP events.	$1.4M	$2.1M	0.67
Option 17	Combined option	• Combination of Option 1, Option 4a and Option 12	• Similar to Option 4a and Option 12 plus 4 backflow prevention devices	• Increase in flood levels up to 0.02m in 5% AEP event, and 0.07m in 1% AEP, on downstream of Bay Street • Reductions in flood levels up to 0.32m in 5% AEP event, and 0.4m in 1% AEP, on Rose Street	$1.4M	$27.7M	0.05

Option	Location	Description	Constraints and Impacts Plus other comments	Hydraulic Benefits *And Negative Impacts if Any*	Savings in Flood Damages (50 years life, 7% Discount Factor)	Cost of Works	Benefit Cost Ratio (BCR)
				• Reductions in flood levels up to 0.14m in 5% AEP event, and 0.40m in 1% AEP, on Bay Street • Reductions in flood levels up to 0.05m in 5% AEP event, and 0.09m in 1% AEP, on Botany Road • Reductions in flood levels up to 0.08m in 5% AEP event, and -0.02m in 1% AEP, on Hale Street • 26 less properties with above floor flooding in 1% AEP event • Seven less properties with above floor flooding in 5% AEP event • Two properties with above floor flooding in 5% AEP and 1% AEP event which are flood free in the existing scenarios • Flood hazard changes from H2 to H1 on Rose Street and Ivy Street in both 1% and 5% AEP events and on Daniel Street and Daphne Street in 1%AEP event only • Extent of flood hazard of H1 increases on Booralee Street, Hale Street and Luland Street in both 1%AEP and 5%AEP events			
Option 18	Combined option	• Combination of Option 4a and Option 12	• Similar to Option 4a and Option 12	• No significant change in flood behaviour compare to Option 17	$1.5M	$27.4M	0.05
Option 19	Combined option	• Combination of Option 2c, Option 4a and Option 12	• Similar to Option 2c, Option 4a and Option 12	• Increase in flood levels up to 0.03m in 5% AEP event, and 0.02m in 1% AEP, on downstream of Bay Street • Reductions in flood levels up to 0.32m in 5% AEP event, and 0.6m in 1% AEP, on Rose Street • Reductions in flood levels up to 0.2m in 5% AEP event, and 0.57m in 1% AEP, on Bay Street • Reductions in flood levels up to 0.06m in 5% AEP event, and 0.10m in 1% AEP, on Botany Road • Reductions in flood levels up to 0.08m in 5% AEP event, and 0.05m in 1% AEP, on Hale Street • 36 less properties with above floor flooding in 1% AEP event • 11 less properties with above floor flooding in 5% AEP event • Two properties with above floor flooding in 5% AEP and 1% AEP event which are flood free in the existing scenarios • Flood hazard changes completely to H1 on Rose Street, Ivy Street and Daniel Street in both 1% and 5% AEP events. • Extent of flood hazard of H1 increases on Booralee Street, Hale Street and Luland Street in both 1%AEP and 5%AEP events.	$2M	$28.3M	0.07

Table 10-8 Options scoring system matrix

Aspect	Score						
	-3	-2	-1	0	1	2	3
	Negative			Neutral	Positive		
Impact on Flood Behaviour	> 100mm increase	50 – 100mm increase	< 50mm increase	Neutral, or benefits countered by negative impacts	< 50mm decrease	50 – 100mm decrease	> 100mm decrease
Number of Properties Benefited	>5 properties negatively impacted	2-5 properties negatively impacted	< 2 properties negatively impacted	Neutral, or benefits countered by negative impacts	< 2 properties benefitted	2-5 benefitted	>5 properties benefitted
Technical Feasibility	Significant issues (unproven, high risk)	Some issues (complex, some difficulty)	Minor issues	Neutral	Moderately straightforward	Straightforward	No issues (proven, well established, no risk)
Economic Merit (benefit/cost ratio)	Very low (0-0.4)	Low (0.4-0.6)	Slightly low (0.6-0.8)	Neutral (0.8-1.2)	Slightly high (1.2-1.5)	High (1.5-2)	Very high (>2)
Financial Feasibility (funding, Government assistance & grants)	Very unlikely to receive funding	-	Unlikely to receive funding	Neutral	Likely to receive funding	-	Very likely to receive funding
Environmental and Ecological Benefits	Significant disbenefits	Some disbenefits	Minor disbenefits	Neutral	Minor benefits	Some benefits	Significant benefits
Impact on Risk to Life	Significant increase in risk to life	Some increase in risk to life	Minor increase in risk to life	Neutral	Minor decrease in risk to life	Some decrease in risk to life	Significant decrease in risk to life
Impacts on SES	Significant disbenefit to SES	-	Some disbenefit to SES	Neutral	Some benefit to SES	-	Significant benefit to SES
Long-term Performance (design life & climate change)	Significant reduction	Some reduction	Slight reduction	Neutral	Slight increase	Some increase	Significant increase
Legislative & Permissibility Requirements (including political & administrative	Significant issues affecting implementation	-	Some issues affecting implementation	Minor issues affecting implementation	Negligible issues affecting implementation	-	No issues affecting implementation
Social Impact / Community Acceptance	Large majority against	Most against	Some against	Neutral	Some for	Most for	Large majority for

Table 10-9 Evaluation of Options†

Option	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Economic Merit (benefit/cost ratio)	Financial Feasibility (cost, funding, Government assistance & grants)	Environmental and Ecological Benefits	Impact on Risk to Life	Impacts on SES	Long-term Performance (design life & climate change)	Legislative & Permissibility Requirements (including political & administrative)	Social Impact / Community Acceptance	Total score	Rank
Op2c	3	3	-2	2	1	0	-1	1	0	0	-1	6	**2**
Op4a	-2	3	-3	-3	-3	0	0	1	-1	-1	-1	-10	**10**
Op7a	2	2	-3	-3	-1	0	0	0	0	-1	-1	-5	**5**
Op8	3	3	-1	3	1	0	0	0	0	1	0	10	**1**
Op11	-2	3	-3	-2	-1	0	0	0	0	-1	-1	-7	**9**
Op13a	3	3	-2	-1	1	-1	0	1	-2	-1	0	1	**3**
Op16	3	3	-2	-1	1	-1	0	1	-2	-1	0	1	**3**
Op17	3	3	-3	-3	-3	0	0	1	-1	-1	-1	-5	**5**
Op18	3	3	-3	-3	-3	0	0	1	-1	-1	-1	-5	**5**
Op19	3	3	-3	-3	-3	0	0	1	-1	-1	-1	-5	**5**

†*Note: neutral or fairly neutral score adopted if no significant change in flood behaviour*

10.7 Conclusions on detailed options assessment

10.7.1.1 Options feasibility

Two options were assessed as being economically feasible, with BCR values above 1.0. Feasibility is rated as high, with values of approximately 1.5 and above. The remaining options were found to be economically unfeasible due to BCR values below 1.0. The economically feasible options are:

- Option 2c: Detention basin at Booralee Park (lowering of basin bed). BCR = 1.4
- Option 8: Drainage augmentation, William Street. BCR = 4.

Option 13a (new culvert drainage at Dent Street low point) is rated 3rd in the option list and, while having a BCR value below 1.0 (BCR = 0.59), should not be precluded from implementation. This proposed upgrade of the drainage system would improve flood immunity to a significant number of properties around Dent Street which are impacted by above floor flooding. Additionally, Dent Street is in a high hazard zone in the 1% AEP event which would be improved by mitigation. Further, the damages to vehicles and infrastructure is not included in the economic assessment and their inclusion would likely justify the nomination of this option based on economic feasibility.

Option 16, which includes installation of backflow devices at 4 trunk drainage outlet locations on top of Option 13a, is also recommended in the Floodplain Risk Management Plan to protect against oceanic (tidal and storm surge) flooding from backflow up the trunk drainage for existing climate conditions. Installation of backflow devices is recommended at 5 additional outlets in the long term to protect against oceanic flooding under future sea level rise scenario. This has not been included in the Floodplain Risk Management Plan.

The BCR values are contingent on the cost estimates for the options. Based on the available information it is assumed that contaminated soils are not present at the mitigation option sites. Further site investigations would need to be undertaken to confirm the absence of contaminated materials. If contaminated materials are found, the costs of the options may increase to account for management and/or disposal of this material. At this stage the management of contaminated soils is excluded.

Similarly, based on the available information including Dial-Before-You-Dig etc. it is assumed that the options can be designed to fit in or around existing utilities. Physical search and relocation of utilities is excluded from the cost estimates and if required would increase the option costs.

Increases in cost of options due to the above and other factors is likely to affect the feasibility of the options. The summaries of the cost estimates are provided in Appendix F.

10.7.1.2 Recommendations

Council and the floodplain risk management committee have reviewed the scoring/rating of the multiple criteria in Table 10-9 and feedback has been incorporated into the options scoring. Further feedback may be obtained from the community during public exhibition and consultation. For example, residents and stakeholders may have a different perspective on the impact of proposed works on the environment, community and land owners compared to the scoring in the table.

It is recommended that further community feedback on the options, with any revisions to the evaluations, be incorporated as required into the subsequent floodplain risk management study and plan.