Planning and Environment Act 1987

MELBOURNE PLANNING SCHEME

AMENDMENT C384melb

EXPLANATORY REPORT

Who is the planning authority?

The Amendment has been prepared by the Melbourne City Council, which is the planning authority for this Amendment.

The Amendment has been made at the request of the Melbourne City Council and Melbourne Water.

Land affected by the amendment

The Amendment applies to land identified as being subject to inundation from riverine flooding (Land Subject to Inundation Overlay) (LSIO) in the Moonee Ponds Creek and Lower Yarra River waterways, and drainage flooding (Special Building Overlay) (SBO) in the Arden, Macaulay and Moonee Ponds Creek, Elizabeth Street, Fishermans Bend, Hobsons Road and Southbank catchments (see Figure 1). Attachment 1 (mapping reference table) to this explanatory report specifies the catchments and associated planning scheme map numbers to be amended.

The mapping extent of the existing LSIO1 (generally along the Maribyrnong River, Childers Street and Dynon Road) and LSIO2 (Flemington Racecourse) are not proposed to be amended as the modelling for these catchments has not yet been updated. The format of the existing LSIO1 and LSIO2 schedules are proposed to be amended to comply with the *Ministerial Direction Form and Content of Planning Schemes* which is correctional in nature and not transformative.

The mapping extent of the existing SBO in the planning scheme (outside the catchments included in this Amendment) is not proposed to be amended as the modelling for these catchments has not been updated. The existing SBO maps require deletion and have been renamed SBO1 to comply with new naming convention of the Schedule which is a correctional change.

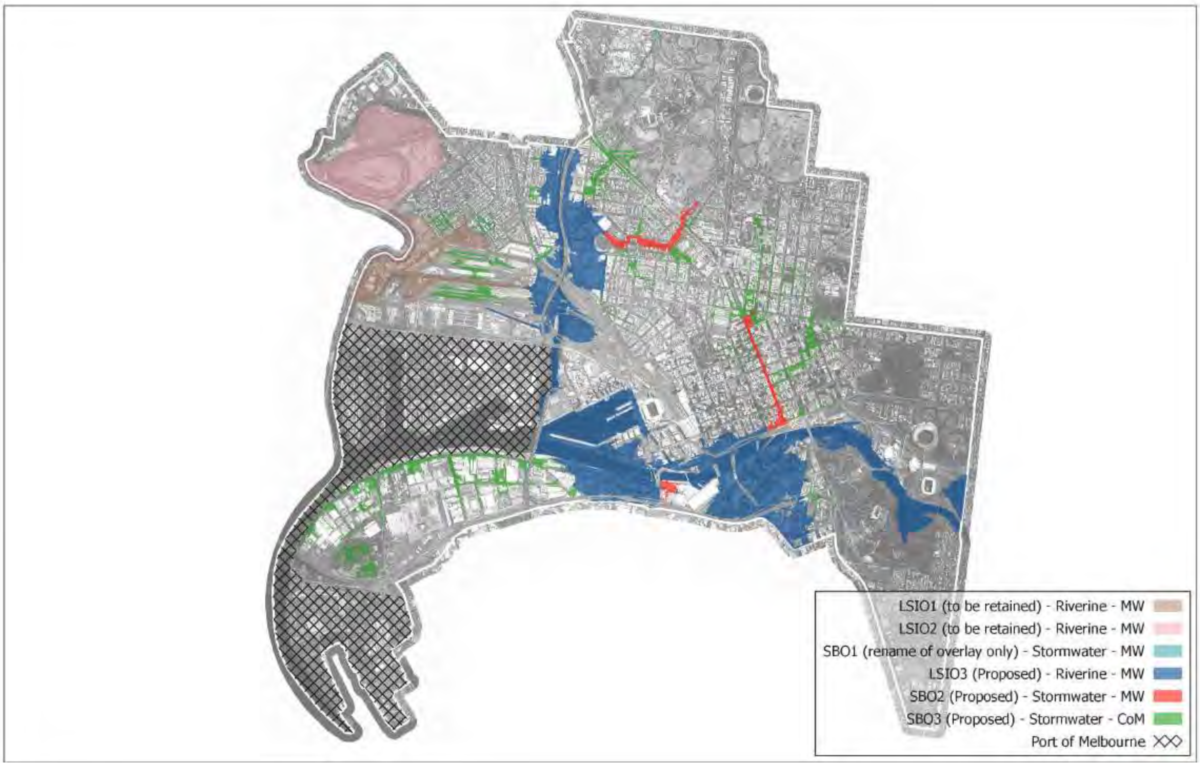


Figure 1 – Indicative map showing proposed overlays (refer to Attachment 1 for amendment map references).

What the amendment does

The Amendment updates the LSIO and SBO extents in certain catchments in the Melbourne Planning Scheme to reflect updated flood modelling to the Australian Rainfall and Runoff (ARR) 1987 standards with the inclusion of criteria defined in the ARR 2019 standard to model for the effects of climate change. The modelling was prepared on behalf of Melbourne City Council and Melbourne Water. The Amendment proposes to change the following in the ordinance:

- Amends Schedule 1 (Maribyrnong River Environs) and Schedule 2 (Flemington Racecourse) of Clause 44.04 to update the format to comply with the requirements set out in *Ministerial Direction Form and Content of Planning Schemes* which is an administrative change. The mapping of the existing LSIO1 in the planning scheme (generally along the Maribyrnong River, Childers Street and Dynon Road) and LSIO2 (Flemington Racecourse) is unchanged.

- Introduces a new Schedule 3 '*Moonee Ponds Creek and Lower Yarra River Waterways'* to Clause 44.04 which includes land subject to inundation objectives to be achieved, a statement of risk, permit requirements, application requirements and decision guidelines.

- Introduces a new Schedule 1 '*Melbourne Water Main Drains*' to Clause 44.05 to update the format to comply with the requirements set out in *Ministerial Direction Form and Content of Planning Schemes* which is an administrative change. The mapping extent of the existing SBO in the planning scheme (outside the catchments included in this Amendment) is unchanged. The existing SBO maps require deletion and identical maps have been prepared which are named SBO1 to comply with the new naming convention of the Schedule which is a form and content change.

- Introduces a new Schedule 2 '*Melbourne Water Main Drains - Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek, Fishermans Bend and Southbank catchments*' to Clause 44.05 which includes flood management objectives to be achieved, statement of risk, permit requirements, application requirements and decision guidelines.

- Introduces a new Schedule 3 '*Council Drains - Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek, Hobsons Road, Fishermans Bend and Southbank catchments*' to Clause 44.05 which includes flood management objectives to be achieved, statement of risk, permit requirements, application requirements and decision guidelines.

- Amends the Schedule to Clause 72.03 (What does this planning scheme consist of?) to update the list of maps that form part of the planning scheme.

- Amends the Schedule to Clause 72.08 (Schedule to Background Documents) to introduce new background documents as listed below:

  - Technical Report 01: Australian Rainfall Runoff Sensitivity Analysis (Engeny Water Management dated 22 July 2020)
  - Technical Report 02: Southbank Flood Modelling Update and Climate Change Scenarios (Water Modelling Solutions dated 21 April 2020)
  - Technical Report 03: Southbank Stormwater Infrastructure Assessment: Final Report (BMT WBM dated August 2015)
  - Technical Report 04: Elizabeth Street Melbourne Flood Modelling Report (Water Technology, dated August 2017) including the Memorandum's dated 9 April 2020 and 13 February 2020
  - Technical Report 05: Arden Macaulay Precinct & Moonee Ponds Creek Flood Modelling (Engeny Water Management dated August 2020)
  - Technical Report 06: Lower Yarra River Flood Mapping (GHD dated 24 September 2020)
  - Technical Report 07: Hobsons Road Catchment Flood Mapping Update (Venant Solutions dated 17 June 2020) including the review response dated 22 April 2020
  - Technical Report 08: Fishermans Bend Flood Mapping (GHD dated November 2020)
  - Technical Report 09: Overlay Delineation Report (Engeny Water Management dated 27 October 2020)
  - Guidelines for Development in Flood Affected Areas (Department of Environment, Land, Water and Planning, 2019)
  - Planning for Sea Level Rise Guidelines (Melbourne Water, 2017)

- Good Design Guide for Buildings in Flood Affected Areas in Fishermans Bend, Arden and Macaulay (Melbourne City Council, Melbourne Water and City of Port Phillip, 2021)

The Amendment proposes to change the following maps:

<u>Map no. 1SBO</u>

- Amends map no. 1SBO to delete the SBO from the corner of Langs Road and Epsom Road, Flemington.
- Amends map no. 1SBO to introduce the SBO1 to corner of Langs Road and Epsom Road, Flemington. The existing SBO maps require deletion and identical maps have been prepared which are named SBO1 to comply with the new naming convention of the Schedule which is a form and content change.

<u>Map no. 2SBO and 4SBO</u>

- Amends map no. 2SBO and 4SBO to delete the SBO from the Arden, Macaulay and Moonee Ponds Creek catchment and Royal Park Main Drain.
- Amends map no. 2SBO and 4SBO to introduce the SBO1 to the Arden, Macaulay and Moonee Ponds Creek catchment and Royal Park Main Drain. The existing SBO maps require deletion and identical maps have been prepared which are named SBO1 to comply with the new naming convention of the Schedule which is a form and content change.
- Amends map no. 4SBO to introduce a new SBO2 (*Melbourne Water Main Drains - Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek, Fishermans Bend and Southbank catchments*) to the Arden, Macaulay and Moonee Ponds Creek catchment and a new SBO3 (*Council Drains - Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek, Hobsons Road, Fishermans Bend and Southbank catchments*) to the Arden, Macaulay and Moonee Ponds Creek and Hobsons Road catchments.

<u>Map no. 5SBO</u>

- Amends map no. 5SBO to delete the SBO from the Arden, Macaulay and Moonee Ponds Creek catchment.
- Amends map no. 5SBO to introduce the SBO1 to the Alexandra Parade Main Drain catchment to the area generally bound by Princes Street, Station Street, Kay Street and Nicholson Street, Carlton. The existing SBO maps require deletion and identical maps have been prepared which are named SBO1 to comply with the new naming convention of the Schedule which is a form and content change.
- Amends map no. 5SBO introduce a new SBO2 *(Melbourne Water Main Drains - Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek, Fishermans Bend and Southbank catchments*) to the Arden, Macaulay and Moonee Ponds Creek catchment and a new SBO3 (*Council Drains - Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek, Hobsons Road, Fishermans Bend and Southbank catchments*) to the Arden, Macaulay and Moonee Ponds Creek and Elizabeth Street catchments.

<u>New map no. 6SBO</u>

- Inserts a new map no. 6SBO to introduce a new SBO3 (*Council Drains - Elizabeth Street, Arden Macaulay and Moonee Ponds Creek, Hobsons Road, Fishermans Bend and Southbank catchments*) to the Fishermans Bend catchment.

<u>Map no. 7SBO</u>

- Amends map no. 7SBO to delete the SBO from the Fishermans Bend catchment.
- Amends map no. 7SBO to introduce a new SBO3 (*Council Drains - Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek, Hobsons Road, Fishermans Bend and Southbank catchments*) to the Arden, Macaulay and Moonee Ponds Creek and Fishermans Bend catchments.

Map no. 8SBO

- Amends map no. 8SBO to delete the SBO from the Elizabeth Street catchment.
- Amends map no. 8SBO to introduce a new SBO2 (*Melbourne Water Main Drains - Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek, Fishermans Bend and Southbank catchments*) to the Elizabeth Street, Fishermans Bend and Southbank catchments and a new SBO3 (*Council Drains - Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek, Hobsons Road, Fishermans Bend and Southbank catchment*s) to the Elizabeth Street, Arden, Macaulay and Moonee Ponds Creek and Southbank catchments.

Map no. 9SBO

- Amends map no. 9SBO to delete the SBO from the Yarra Park Main Drain as it has been replaced by the LSIO3 and therefore is a redundant control.

New map no. 10SBO

- Inserts a new map no. 10SBO to introduce a new SBO3 (*Council Drains - Elizabeth Street, Arden Macaulay and Moonee Ponds Creek, Hobsons Road, Fishermans Bend and Southbank catchments*) to the Fishermans Bend catchment.

New map no. 11SBO

- Inserts a new map no. 11SBO to introduce a new SBO3 (*Council Drains - Elizabeth Street, Arden Macaulay and Moonee Ponds Creek, Hobsons Road, Fishermans Bend and Southbank catchments*) to the Southbank catchment.

Map no. 4LSIO

- Amends map no. 4LSIO to delete the LSIO1 from the Arden, Macaulay and Moonee Ponds Creek catchment within the City of Melbourne municipal boundary. The LSIO1 which is generally along the Maribyrnong River, Childers Street and Dynon Road and the LSIO2 (Flemington Racecourse) in map nos. 3LSIO, 4LSIO and 6LSIO are not proposed to be amended as the modelling for these catchments has not been updated.

Map no. 7LSIO

- Amends map no. 7LSIO to delete the LSIO1 from the Arden, Macaulay and Moonee Ponds Creek catchment.

Map nos. 8LSIO, 9LSIO and 11LSIO

- Amends map nos. 8LSIO, 9LSIO & 11LSIO to delete the LSIO1.

Map nos. 4LSIO, 7LSIO, 8LSIO, 9LSIO & 11LSIO

- Amends map nos. 4LSIO, 7LSIO, 8LSIO, 9LSIO & 11LSIO to introduce a new LSIO3 (Moonee Ponds Creek and Lower Yarra River Waterways).

Strategic assessment of the amendment

Why is the amendment required?

Flood hazard risk in the Victorian Planning Provisions (VPPs) is managed through the Urban Floodway Zone (UFZ), LSIO (riverine flooding) and the SBO (overland flows from the underground drainage system).

Amendment C384 is required to identify land within the LSIO and SBO areas that modelling has identified as being highly likely to be subject to inundation in the event of a flood, and to apply risk appropriate controls and measures to manage new development in a way that minimises potential flood damage through the planning permit process. This provides clarity and certainty to landowners, developers and prospective purchasers that flood hazard must be considered early in the development feasibility, engineering, planning and design processes. Flood risk in these areas will form part of the basis for determining future planning permit applications balanced with the need to achieve good design outcomes in the municipality. The SBO was last updated on 31 May 2001 (Amendment C012) and the LSIO on 10 February 2011 (Amendment C153).

Melbourne City Council and Melbourne Water have a statutory obligation to protect life, property, public health, assets and the environment under the *Planning and Environment Act 1987* and to plan for the effects of climate change. Amendment C384 is required to update the LSIO and SBO extents in the Melbourne Planning Scheme to reflect updated flood modelling in the Arden, Macaulay and Moonee Ponds Creek, Elizabeth Street, Fishermans Bend, Hobsons Road, Lower Yarra River and Southbank catchments which are justified in the technical modelling reports.

Melbourne City Council and Melbourne Water have prepared the Amendment in partnership. The flood modelling includes the following ARR 2019 standards for climate change:

- An 18.5% increase in rainfall intensity by 2100;
- For Moonee Ponds Creek and the Lower Yarra River a boundary condition inclusive of a starting water surface level of a 10% Annual Exceedance Probability (AEP) tidal level plus a 0.8 metre sea level rise in 2100

The Department of Environment, Land, Water and Planning's *Local Government Climate Change Adaptation Roles and Responsibilities under Victorian Legislation (2020)* states the threat of climate change is now clearly established through legislation, national and state policy and international agreements. Councils have a duty of care in the context of climate change adaptation which has been recognised by VCAT and other jurisdictions.

The Amendment is required to ensure the precinct planning for the urban renewal areas of Arden, Macaulay and Fishermans Bend appropriately consider and plan for flood risk in the public and private realm. At the time of drafting this Amendment, the structure plans and associated planning scheme amendments were not finalised, however the draft Arden and refreshed Macaulay Structure Plans acknowledge flood risk as a key challenge. The Amendment is also required to afford contemporary flood risk information for the Lower Yarra and Southbank areas

The Amendment seeks to improve consistency and clarity of how to design buildings in flood affected areas to ensure safety, equitable and universal access and good urban design are simultaneously achieved. Melbourne City Council in partnership with Melbourne Water and Port Phillip City Council have prepared the *Good Design Guide for buildings in Flood Affected Areas in Fishermans Bend, Arden and Macaulay* to assist the development industry, applicants and decision makers with designing new development in flood affected areas. The Guide is proposed to be listed as a background document.

How does the amendment implement the objectives of planning in Victoria?

The amendment implements the following objectives in section 4 (1) of the *Planning and Environment Act 1987*:

a) to provide for fair, orderly, economic and sustainable use and development of land;

b) to provide for the protection of natural and man-made resources and the maintenance of ecological processes and genetic diversity;

c) to secure a pleasant, efficient and safe working, living, and recreational environment for all Victorians and visitors to Victoria;

e) to protect public utilities and other assets and enable the orderly provision and coordination of public utilities and other facilities for the benefit of the community.

f) to facilitate development in accordance with the objectives set out in paragraphs (a), (b), (c), and (e); and

g) to balance the present and future interests of all Victorians.

The amendment implements the following objectives of the planning framework established in section 4 (2) of the *Planning and Environment Act 1987:*

c) to enable land use and development planning and policy to be easily integrated with environmental, social, economic, conservation and resource management policies at State, regional and municipal levels;

(d) to ensure that the effects on the environment are considered and provide for explicit consideration of social and economic effects when decisions are made about the use and development of land;

(e) to facilitate development which achieves the objectives of planning in Victoria and planning objectives set up in planning schemes;

(g) to encourage the achievement of planning objectives through positive actions by responsible authorities and planning authorities;

The Amendment implements the objectives of planning in Victoria by implementing up to date controls into the scheme to ensure water management issues are considered as part of planning permit applications.

How does the amendment address any environmental, social and economic effects?

The Amendment is expected to deliver positive environmental outcomes as the proposed controls ensure that the environmental health of Melbourne's rivers, wetlands and waterways is maintained or improved.

Climate change alters flood risk through increased rainfall intensities. Flooding can result in significant costs for the community and the State. It can severely disrupt communities and in extreme cases, cause extensive damage to public and private property, personal hardship and potential loss of life. The Amendment has positive economic and social benefits by ensuring that new buildings and works are appropriately designed to minimise flood damage and respond to climate change.

Further, the Amendment ensures that flood risk and good design is considered in the early stages of development feasibility and planning assessment.

Does the amendment address relevant bushfire risk?

The amendment does not have a direct relevance to bushfire risk.

Does the amendment comply with the requirements of any Minister's Direction applicable to the amendment?

<u>Ministerial Direction on the Form and Content of Planning Schemes</u>

The Amendment is consistent with the Ministerial Direction on the Form and Content of Planning Schemes under section 7(5) of the Planning and Environment Act 1987.

<u>Ministerial Direction No. 9 – Metropolitan Strategy</u>

The Amendment is consistent with Ministerial Direction No. 9 pursuant to section 12 of the Planning and Environment Act 1987 which requires planning authorities to have regard to the Metropolitan Strategy (Plan Melbourne 2017-2050).

The Amendment supports the following directions and policies of the Metropolitan Strategy (Plan Melbourne):

- Direction 4.3: Achieve and promote design excellence
  Policy 4.3.1: Promote urban design excellence in every aspect of the built environment

- Direction 6.2: Reduce the likelihood and consequences of natural hazard events and adapt to climate change
  Policy 6.2.1: Mitigate exposure to natural hazards and adapt to the impacts of climate change
  Policy 6.2.2: Require climate change risks to be considered in infrastructure planning

- Direction 6.3: Integrate urban development and water cycle management to support a resilient and liveable city

Policy 6.3.2: Improve alignment between urban water management and planning by adopting an integrated water management approach
Policy 6.3.3: Protect water, drainage and sewerage assets

The Amendment enables the council and Melbourne Water to better manage flood and climate change impacts by identifying the risk in the scheme which ensures orderly planning can be achieved. In turn, this will help protect Melbourne's water quality and ensure flood impacts are minimised to protect life, property, assets and the environment.

Ministerial Direction No. 11 – Strategic Assessment of Amendments

The Amendment complies with Ministerial Direction No. 11 (Strategic Assessment of Amendments) under section 12 of the Planning and Environment Act 1987. The Amendment is consistent with this direction which ensures a comprehensive strategic evaluation of a Planning Scheme Amendment and the outcomes it produces.

The Amendment complies with Ministerial Direction No. 15 (The Planning Scheme Amendment Process).

How does the amendment support or implement the Planning Policy Framework and any adopted State policy?

The Amendment has been assessed against the objectives of the Planning Policy Framework and is consistent with the principles of State policy, in particular:

Clause 11.02-1S (Supply of urban land)

The relevant strategies of this provision are:

- Planning for growth should consider the limits of land capability and natural hazards and environmental quality.

Clause 13.01-1S (Natural hazards and climate change)

The objective of this provision is to minimise the impacts of natural hazards and adapt to the impacts of climate change through risk-based planning.

The relevant strategies are:

- Consider the risks associated with climate change in planning and management decision making processes.
- Identify at risk areas using the best available data and climate change science.
- Integrate strategic land use planning with emergency management decision making.
- Ensure planning controls allow for risk mitigation or risk adaptation strategies to be implemented.
- Site and design development to minimise risk to life, property, the natural environment and community infrastructure from natural hazards.

Clause 13.03-1S (Floodplain management)

The objective of this provision is for floodplain management is to assist in the protection of:

- Life, property and community infrastructure from flood hazard.
- The natural flood-carrying capacity of rivers, streams and floodways.
- The flood storage function of floodplains and waterways; and
- Floodplain areas of environmental significance or of importance to river health.

The relevant strategies are:

- Identify land affected by flooding, including land inundated by the 1 in 100 year flood event or as determined by the floodplain management authority in planning schemes.
- Avoid intensifying the impact of flooding through inappropriately located use and development.
- Locate emergency and community facilities (including hospitals, ambulance stations, police stations, fire stations, residential aged care facilities, communication facilities, transport facilities, community shelters and schools) outside the 1 in 100 year floodplain and, where possible, at levels above the height of the probable maximum flood.

<u>Clause 15.01-1S (Urban design)</u>

The objective of this provision is to create urban environments that are safe, healthy, functional and enjoyable and that contribute to a sense of place and cultural identity.

The relevant strategies are:

- Require development to respond to its context in terms of character, cultural identity, natural features, surrounding landscape and climate.
- Ensure the interface between the private and public realm protects and enhances personal safety.
- Ensure development supports public realm amenity and safe access to walking and cycling environments and public transport.

<u>Clause 15.01-2S (Building design)</u>

The objective of this provision is to achieve building design outcomes that contribute positively to the local context and enhance the public realm.

The relevant strategies are:

- Ensure the form, scale, and appearance of development enhances the function and amenity of the public realm.
- Ensure buildings and their interface with the public realm support personal safety, perceptions of safety and property security.
- Ensure development provides safe access and egress for pedestrians, cyclists and vehicles.

How does the amendment support or implement the Local Planning Policy Framework, and specifically the Municipal Strategic Statement?

The Amendment supports and implements the following policies from the MSS:

<u>Clause 21.06-1 (Urban Design)</u>

- Objective 5 – To increase the vitality, amenity, comfort, safety and distinctive City experience of the public realm.
- Strategy 6.2 – Ensure the design of buildings and public spaces enhances the public realm and the pedestrian environment.

<u>Clause 21.06-3 (Sustainable development)</u>

- Objective 2 – To make the built environment resilient to heatwaves, water shortages, extreme storm events and sea level rise.
- Strategy 2.3 – Ensure that flood risk by storm water surges, waterway flooding and sea level rise is mitigated and managed.

Clause 21.13-3 (Fishermans Bend Urban Renewal Area)

- Ensure the individual and combined impacts of sea level rise and flooding from storm events is appropriately managed through a combination of precinct wide and property specific physical and management measures.

The Amendment supports and implements the following Local Planning Policies:

Clause 22.27 (Fishermans Bend Urban Renewal Area Policy)

- Only consider the raising of internal ground floor level above the street level as a last resort, except where the implementation of other measures coupled with an evidence based approach to risk management reasonably necessitates raising internal floor levels above street level.
- Design elements and materials should be resilient to flood including water proof doors and windows and elevated power outlets and the like.
- Land uses at ground floor should be able to easily recover from the impacts of temporary flooding.
- Any level change required between street level and internal ground floor should be integrated into the design of the building to maintain good physical and visual connection between the street and internal ground floor.
- Essential services, such as power connections, switchboards and other critical services should be located to address potential flooding events.
- Development and public realm layout and design should integrate best practice Water Sensitive Urban Design.

Does the amendment make proper use of the Victoria Planning Provisions?

The Amendment makes proper use of the Victoria Planning Provisions. The LSIO and SBO is the appropriate tool within the Victoria Planning Provisions to identify and minimise flood risk.

How does the amendment address the views of any relevant agency?

The views of relevant agencies will be considered as part of the exhibition process. Melbourne City Council has worked in partnership with Melbourne Water in the preparation of this Amendment.

Does the amendment address relevant requirements of the Transport Integration Act 2010?

The Amendment will not impact on the transport system as defined by the Transport Integration Act 2010.

Resource and administrative costs

- **What impact will the new planning provisions have on the resource and administrative costs of the responsible authority?**

The Amendment will increase the resource and administrative costs of the responsible authority. However, the Amendment will not pose unreasonable resource and administrative costs on Council in its normal capacity as the responsible authority. The Amendment minimises the need for protracted permit application negotiations and amended planning applications by requiring the application to be lodged with information that is essential for decision making for permits. This in turn is likely to decrease the resource and administrative impacts on both the responsible authority and the floodplain manager.

Where you may inspect this amendment

The Amendment is available for public inspection, free of charge, during office hours at the following places: TBC

The amendment can also be inspected free of charge at the Department of Environment, Land, Water and Planning website at: [www.planning.vic.gov.au/public-inspection.](http://www.planning.vic.gov.au/public-inspection)

Planning and Environment Act 1987

MELBOURNE PLANNING SCHEME

AMENDMENT C384melb

INSTRUCTION SHEET

The planning authority for this amendment is the City of Melbourne.

The Melbourne Planning Scheme is amended as follows:

Planning Scheme Maps

The Planning Scheme Maps are amended by a total of 26 attached map sheets.

Overlay Maps

1. Amend Planning Scheme Map Nos. 1SBO, 2SBO, 4SBO, 5SBO, 7SBO, 8SBO, 9SBO, 4LSIO, 7LSIO, 8LSIO, 9LSIO and 11LSIO in the manner shown on the 23 attached maps marked "Melbourne Planning Scheme, Amendment C384melb".

2. Insert new Planning Scheme Map Nos. 6SBO, 10SBO and 11SBO in the manner shown on the 3 attached maps marked "Melbourne Planning Scheme, Amendment C384melb".

Planning Scheme Ordinance

The Planning Scheme Ordinance is amended as follows:

3. In **Overlays** – Clause 44.04 (Land Subject to Inundation Overlay), replace Schedule 1 with a new Schedule 1 in the form of the attached document.

4. In **Overlays** – Clause 44.04 (Land Subject to Inundation Overlay), replace Schedule 2 with a new Schedule 2 in the form of the attached document.

5. In **Overlays** – Clause 44.04 (Land Subject to Inundation Overlay), insert a new Schedule 3 in the form of the attached document.

6. In **Overlays** – Clause 44.05 (Special Building Overlay), insert a new Schedule 1 in the form of the attached document.

7. In **Overlays** – Clause 44.05 (Special Building Overlay), insert a new Schedule 2 in the form of the attached document.

8. In **Overlays** – Clause 44.05 (Special Building Overlay), insert a new Schedule 3 in the form of the attached document.

9. In **Operational Provisions** – Clause 72.03, replace the Schedule with a new Schedule in the form of the attached document.

10. In **Operational Provisions** – Clause 72.08, replace the Schedule with a new Schedule in the form of the attached document.

    End of document

Submissions

Any person who may be affected by the Amendment may make a submission to the planning authority. Submissions about the Amendment must be received by: TBC

A submission must be sent to: TBC

Panel hearing dates

In accordance with clause 4(2) of Ministerial Direction No.15 the following panel hearing dates have been set for this Amendment:

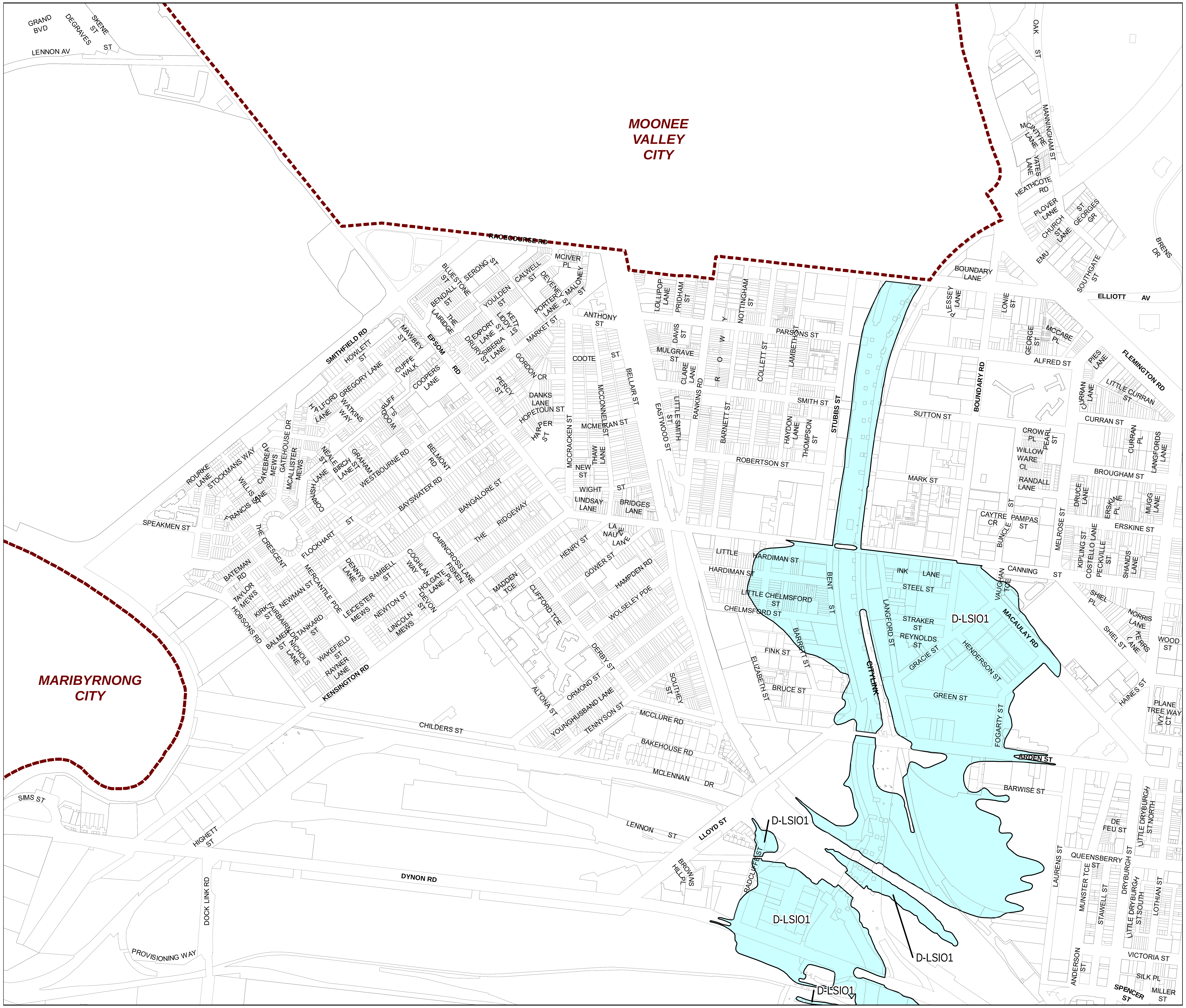
- Directions hearing: TBC
- Panel hearing: TBC

Attachment 1 - Mapping reference table

Catchment/Area	Mapping References
Corner of Langs Road and Epsom Road, Flemington	1SBO
Arden, Macaulay and Moonee Ponds Creek, Royal Park Main Drain and Alexandra Parade Main Drain	2SBO, 4SBO, 5SBO, 7SBO, 8SBO, 4LSIO & 7LSIO
Southbank	8SBO, 11SBO, 8LSIO, 9LSIO & 11LSIO
Lower Yarra River	7LSIO, 8LSIO, 9LSIO & 11LSIO
Fishermans Bend	6SBO, 7SBO, 8SBO, 10SBO, 7LSIO & 8LSIO
Elizabeth Street	5SBO & 8SBO
Hobsons Road	4SBO

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

D-LSIO1 - Area to be deleted from a Land Subject to Inundation Overlay

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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Printed: 16/10/2020

Amendment Version: 1

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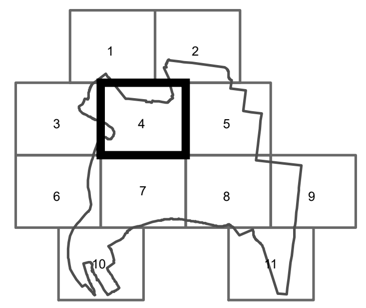
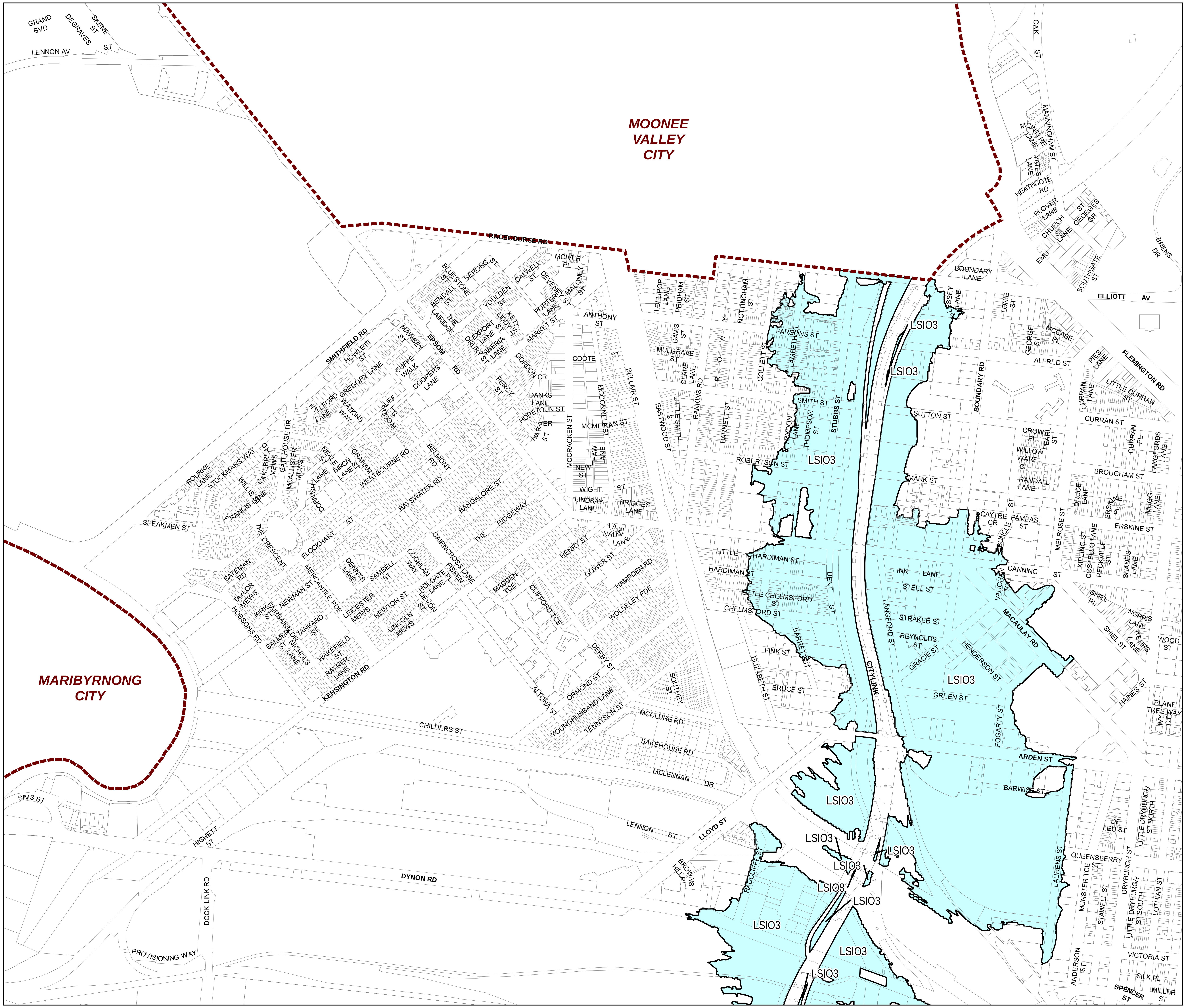
INDEX TO ADJOINING SCHEME MAPS



AREA TO BE DELETED FROM A LAND SUBJECT TO INUNDATION OVERLAY/FLOODWAY OVERLAY

MAP No 4LSIO-FO



LEGEND

LSIO3 - Land Subject to Inundation Overlay - Schedule 3

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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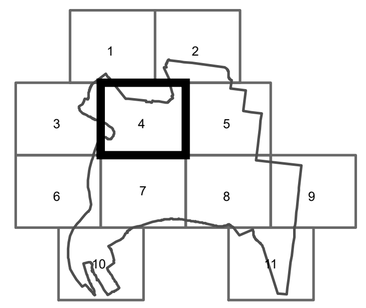

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb

LEGEND

D-LSIO - Area to be deleted from a Land Subject to Inundation Overlay

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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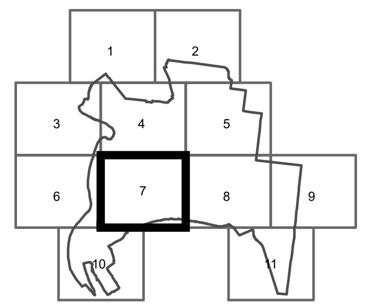
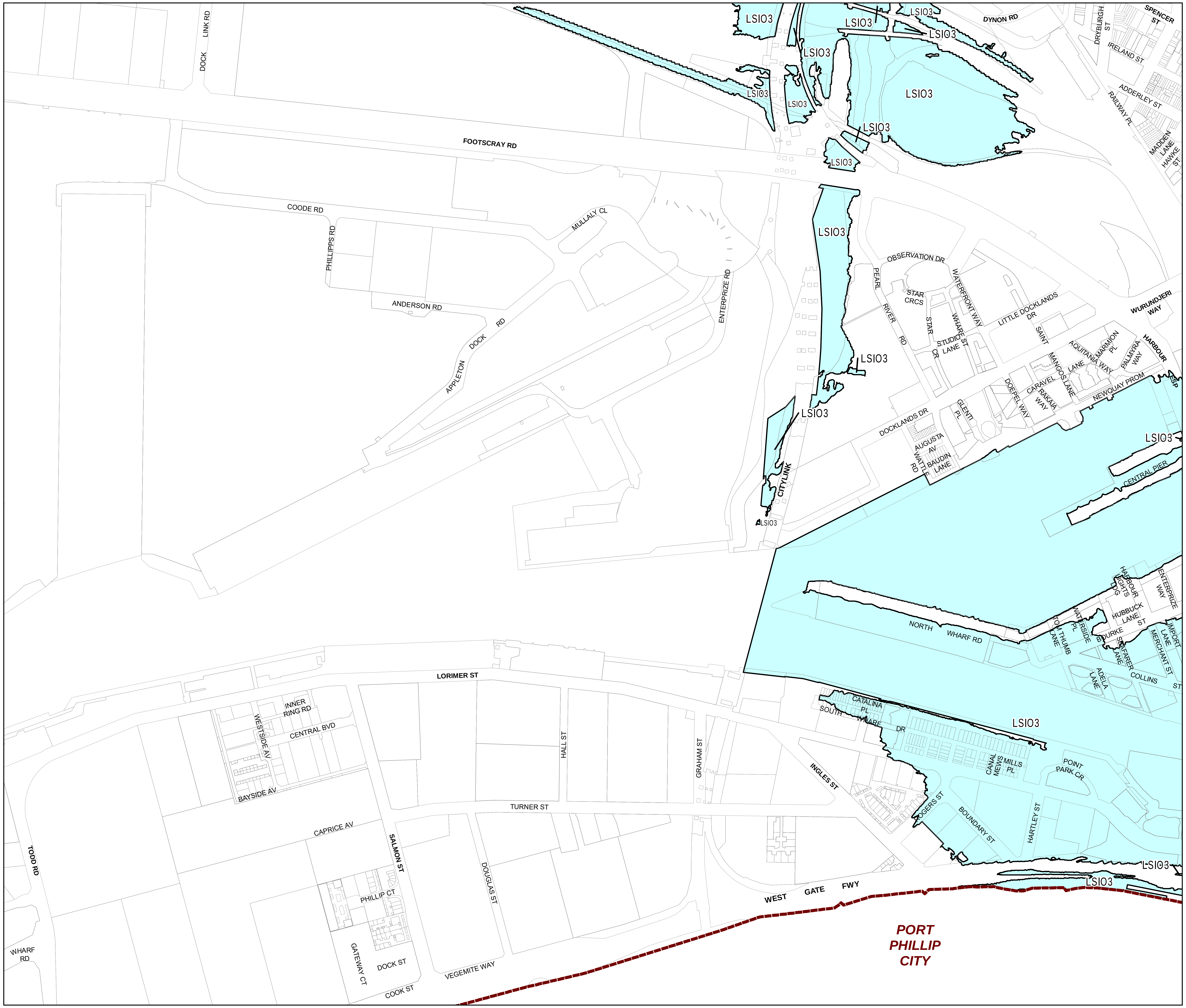


AREA TO BE DELETED FROM A LAND SUBJECT TO INUNDATION OVERLAY/FLOODWAY OVERLAY

MAP No 7LSIO-FO

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

LSIO3 - Land Subject to Inundation Overlay - Schedule 3

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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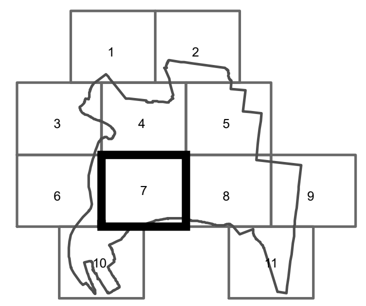

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb

LEGEND

D-LSIO - Area to be deleted from a Land Subject to Inundation Overlay

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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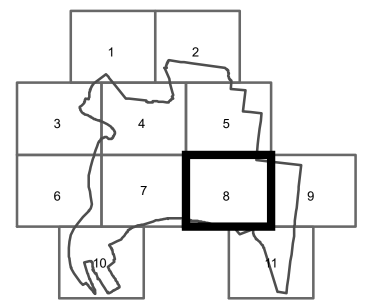
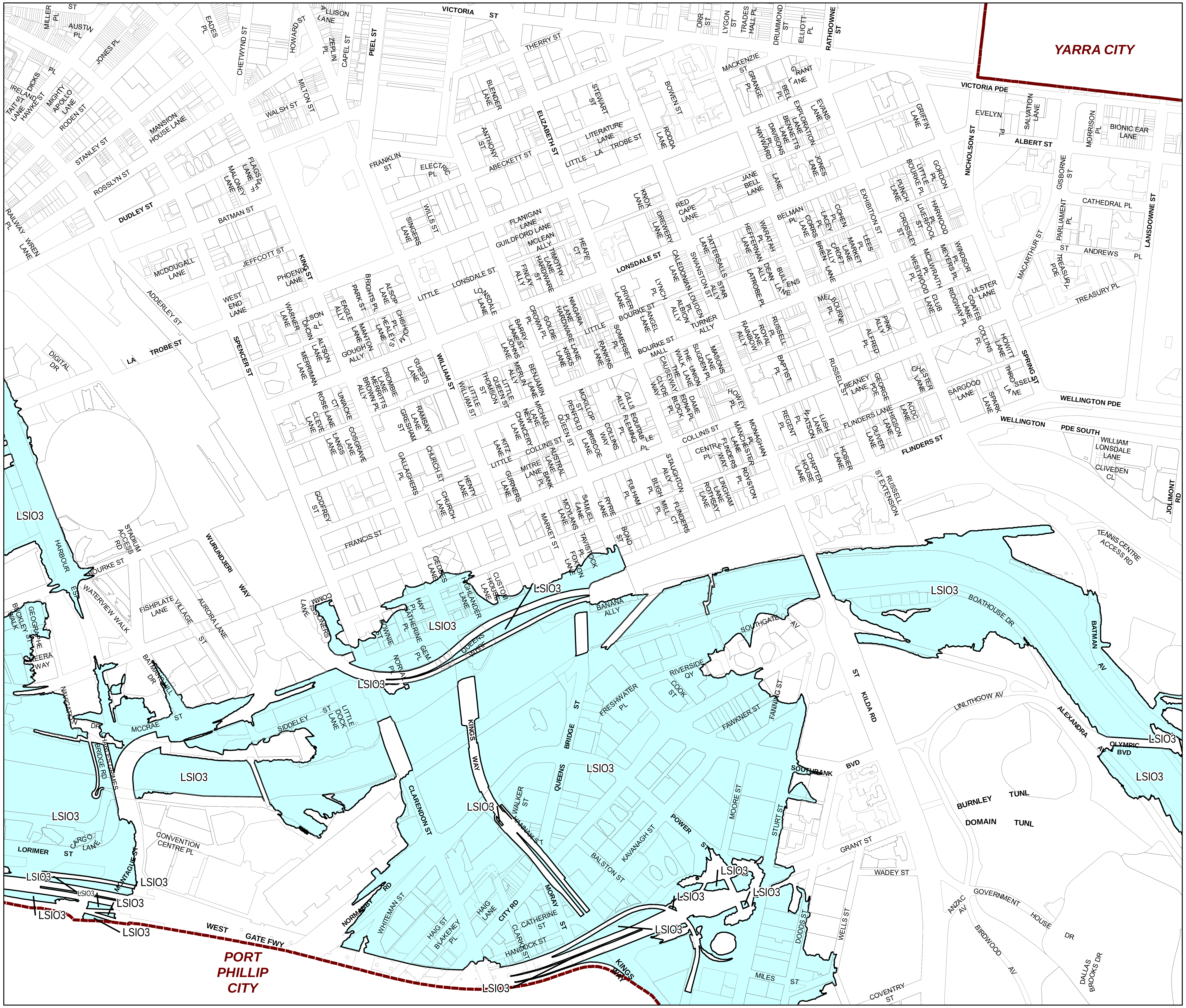


AREA TO BE DELETED FROM A LAND SUBJECT TO INUNDATION OVERLAY/FLOODWAY OVERLAY

MAP No 8LSIO-FO

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

LSIO3 - Land Subject to Inundation Overlay - Schedule 3

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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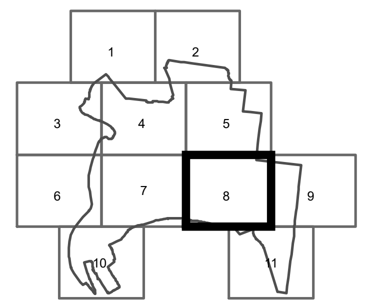

LAND SUBJECT TO INUNDATION OVERLAY

MAP No 8LSIO

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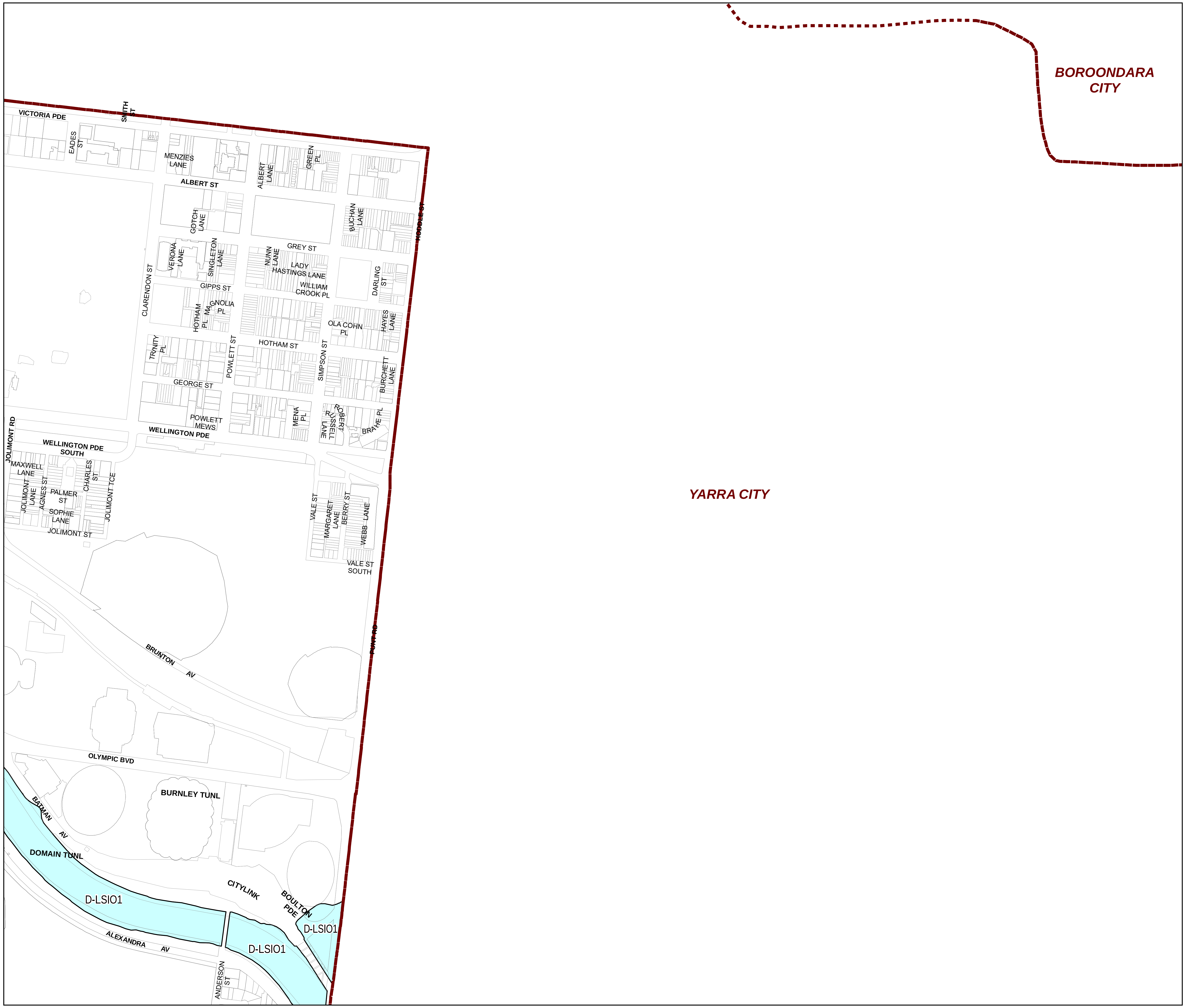
AMENDMENT C384melb



LEGEND

D-LSIO - Area to be deleted from a Land Subject to Inundation Overlay

Municipal Boundary

0 310 620

Meters

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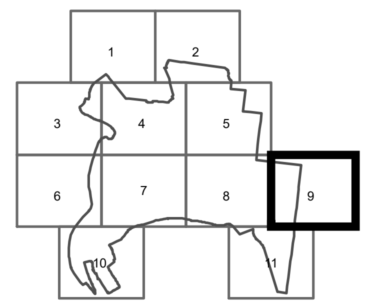
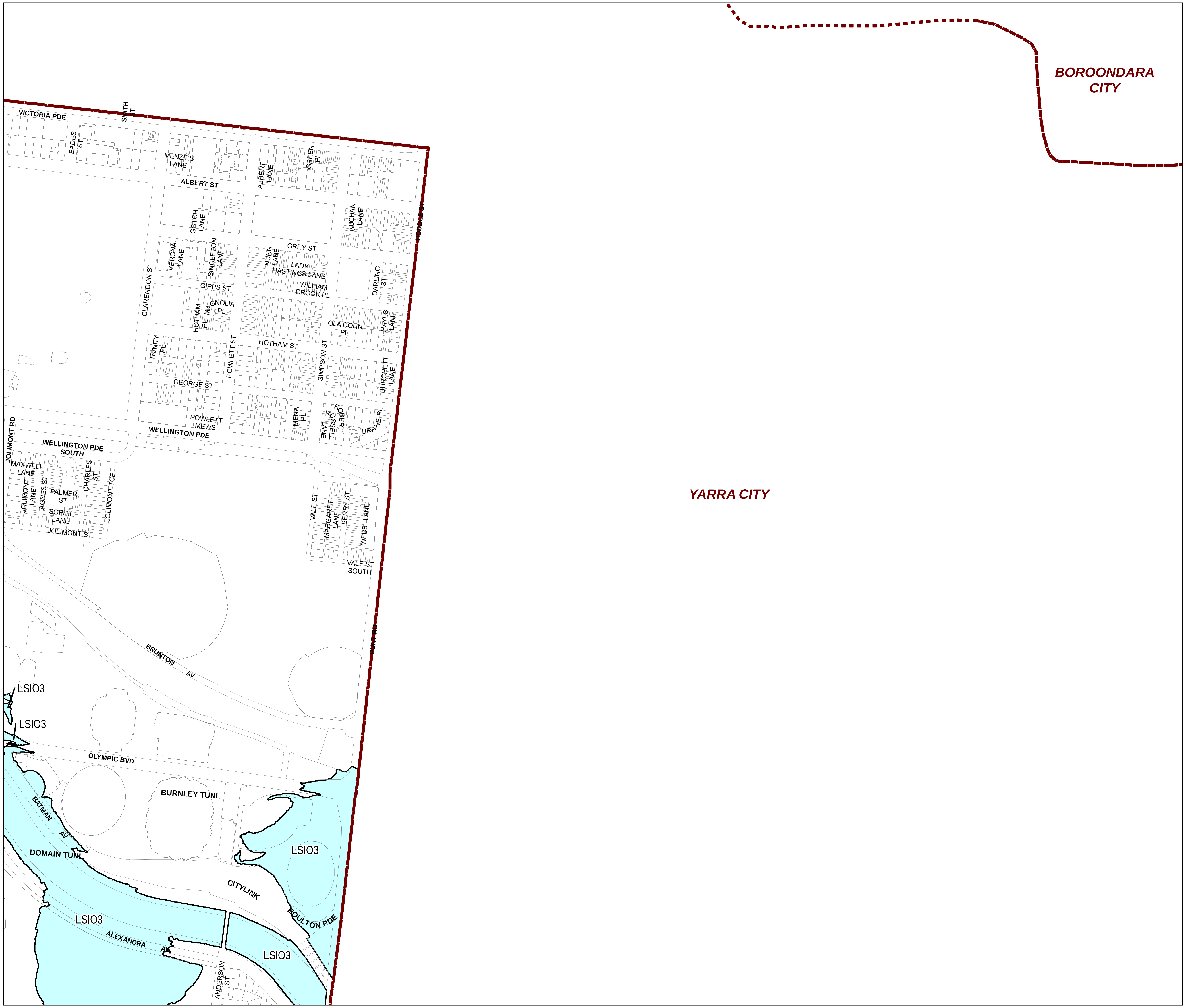


AREA TO BE DELETED FROM A LAND SUBJECT TO INUNDATION OVERLAY/FLOODWAY OVERLAY

MAP No 9LSIO-FO

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

LSIO3 - Land Subject to Inundation Overlay - Schedule 3

Municipal Boundary

0 310 620
Meters

Australian Map Grid Zone 55

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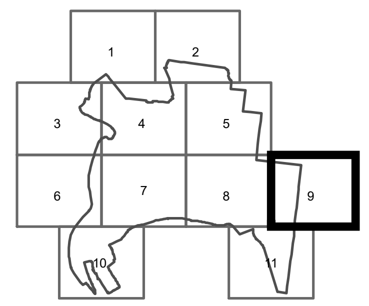

LAND SUBJECT TO INUNDATION OVERLAY

MAP No 9LSIO

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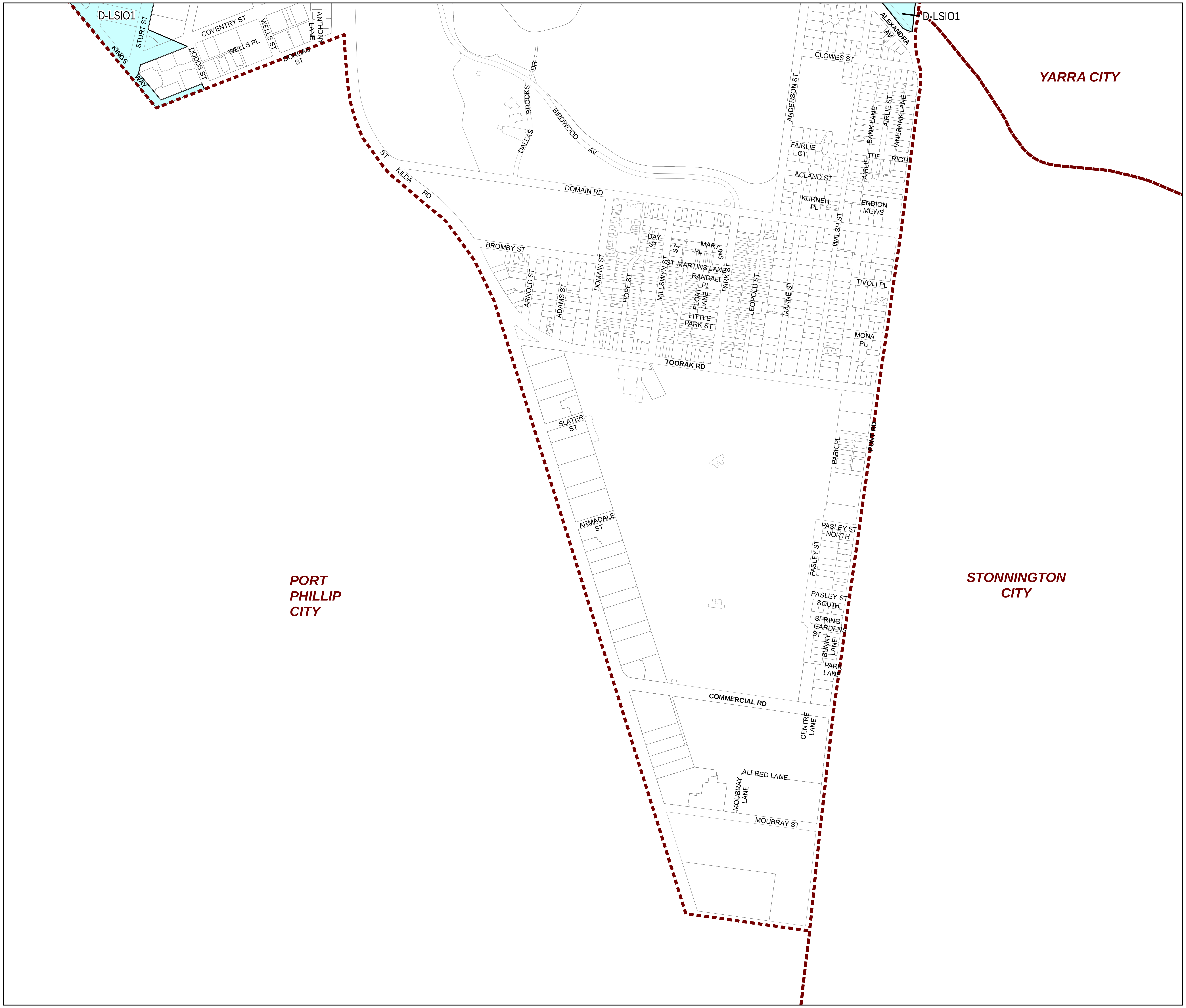
AMENDMENT C384melb



LEGEND

D-LSIO - Area to be deleted from a Land Subject to Inundation Overlay

Municipal Boundary

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Meters

Australian Map Grid Zone 55

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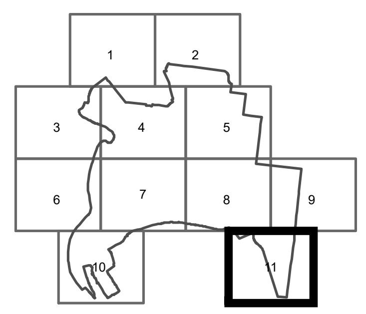
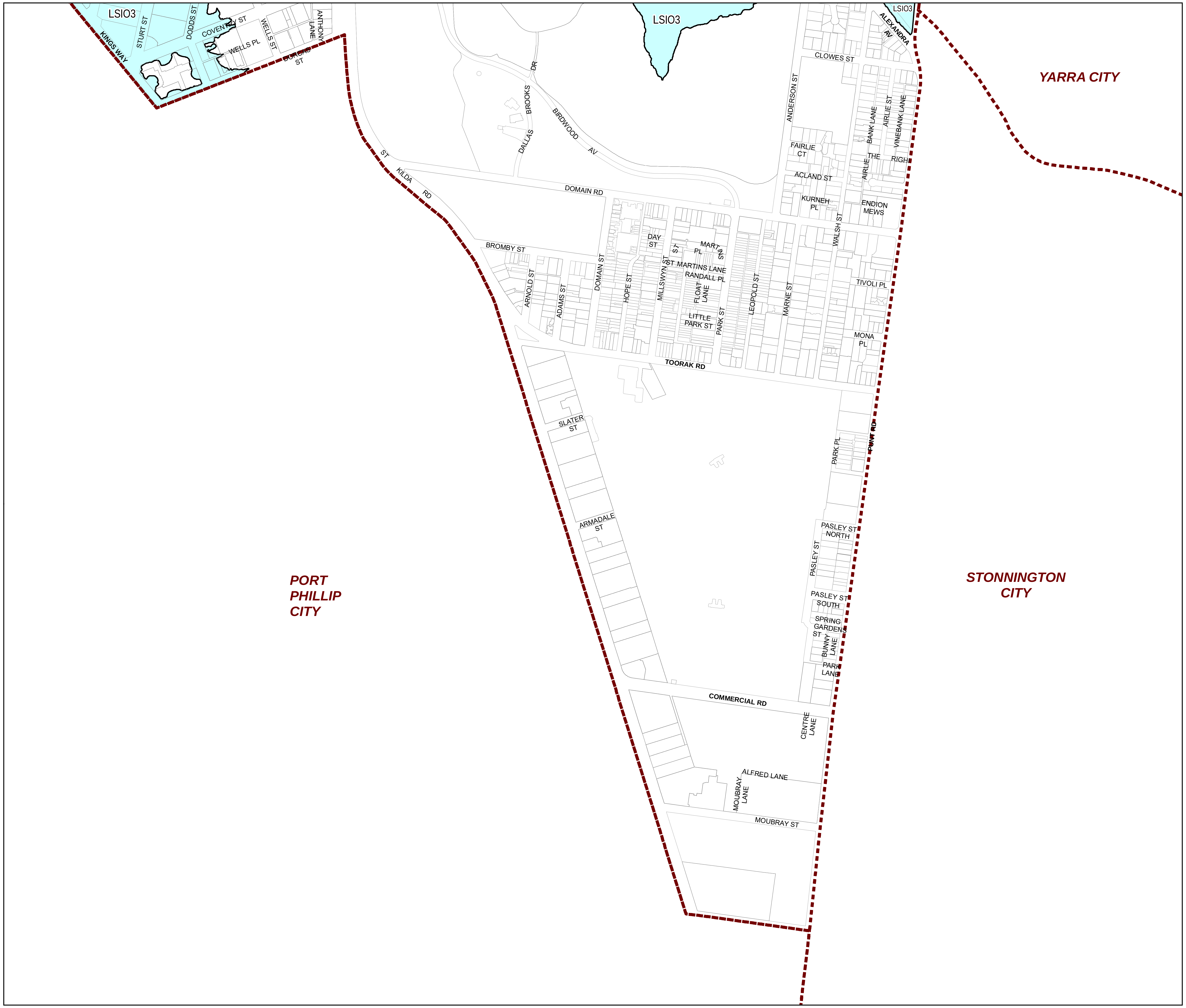


AREA TO BE DELETED FROM A LAND SUBJECT TO INUNDATION OVERLAY/FLOODWAY OVERLAY **MAP No 11LSIO-FO**

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

LSIO3 - Land Subject to Inundation Overlay - Schedule 3

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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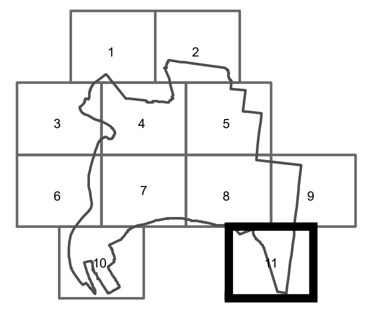
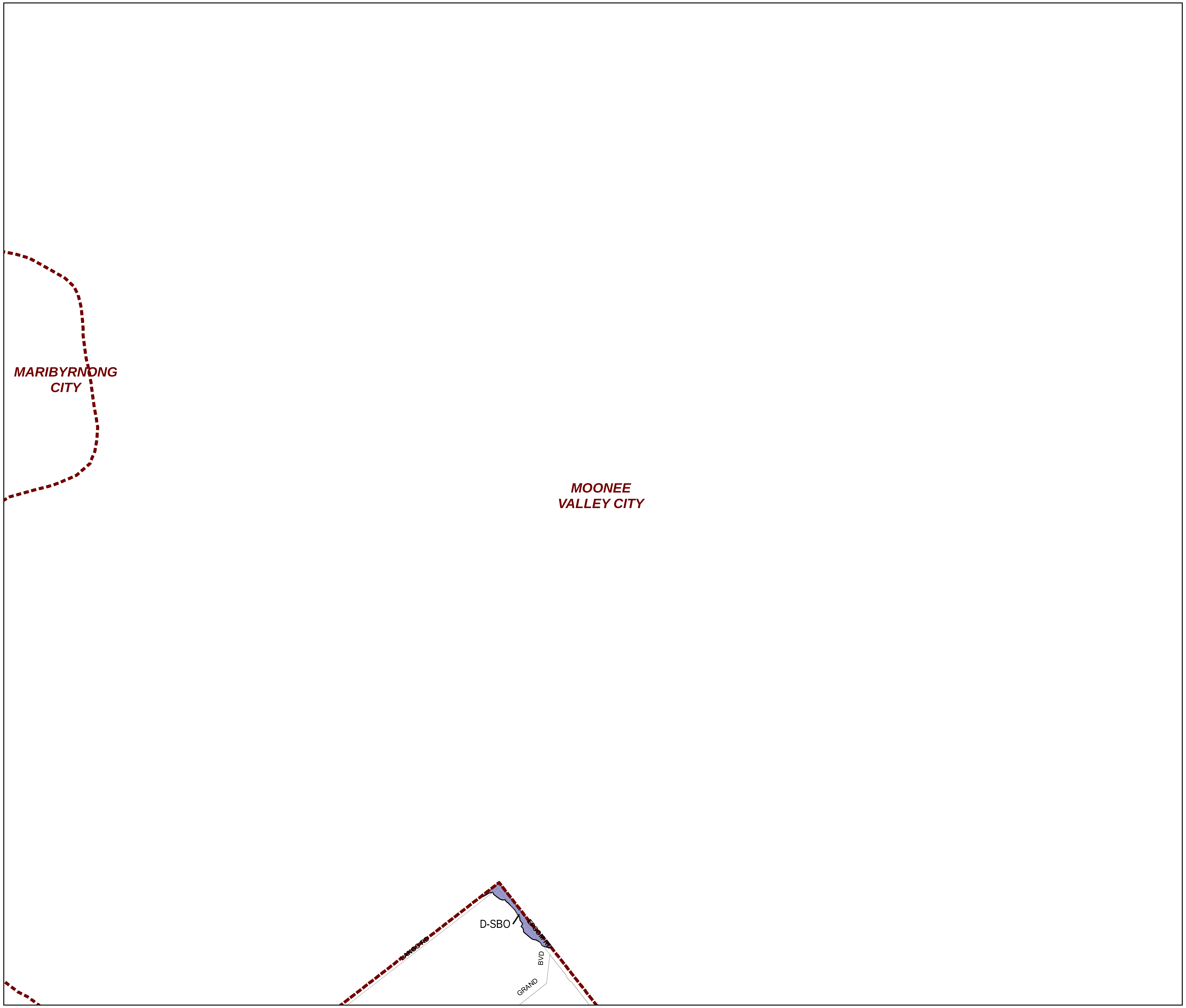


LAND SUBJECT TO INUNDATION OVERLAY **MAP No 11LSIO**

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

D-SBO - Area to be deleted from a Special Building Overlay

Municipal Boundary

0 310 620
Meters

Australian Map Grid Zone 55

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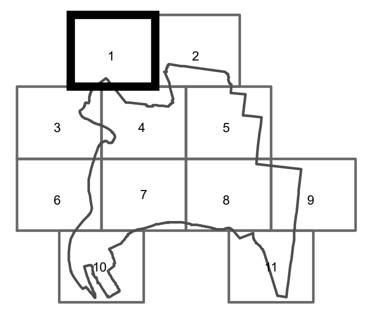
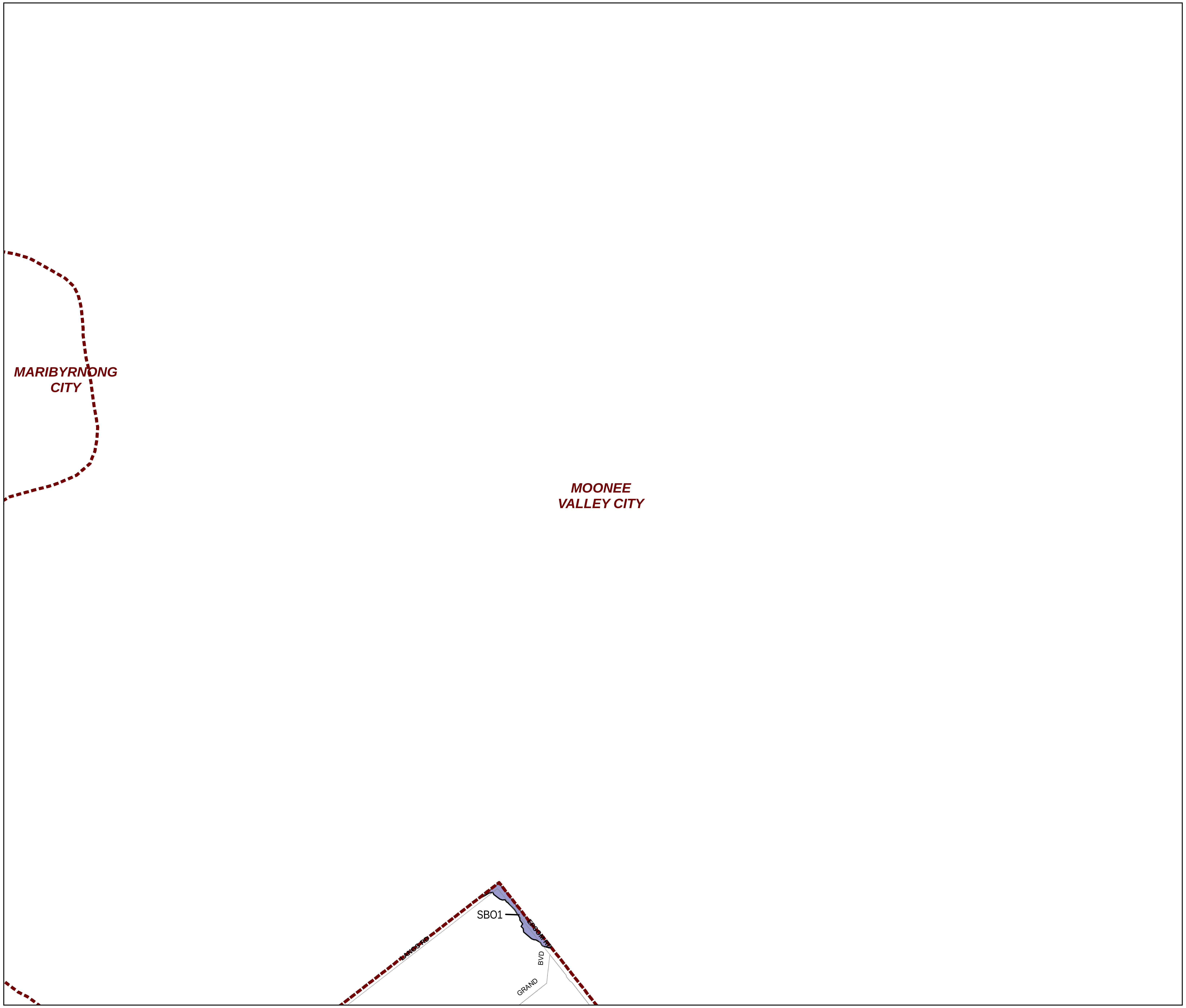


AREA TO BE DELETED FROM A SPECIAL BUILDING OVERLAY **MAP No 1SBO**

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

SBO1 - Special Building Overlay - Schedule 1

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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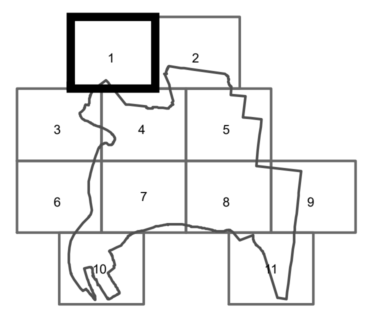
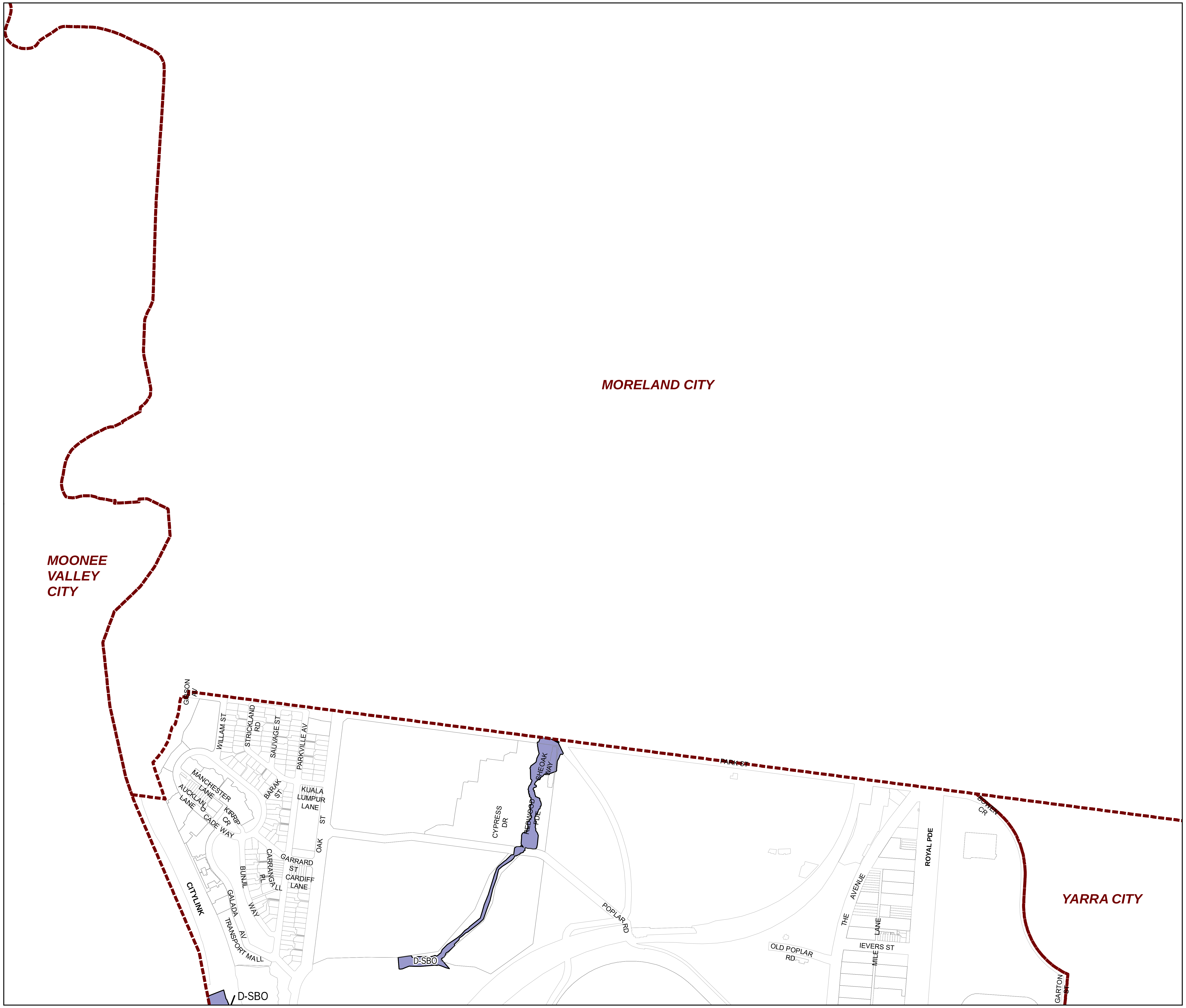


MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

D-SBO - Area to be deleted from a Special Building Overlay

Municipal Boundary

0 310 620

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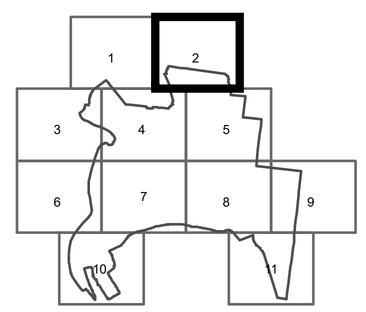
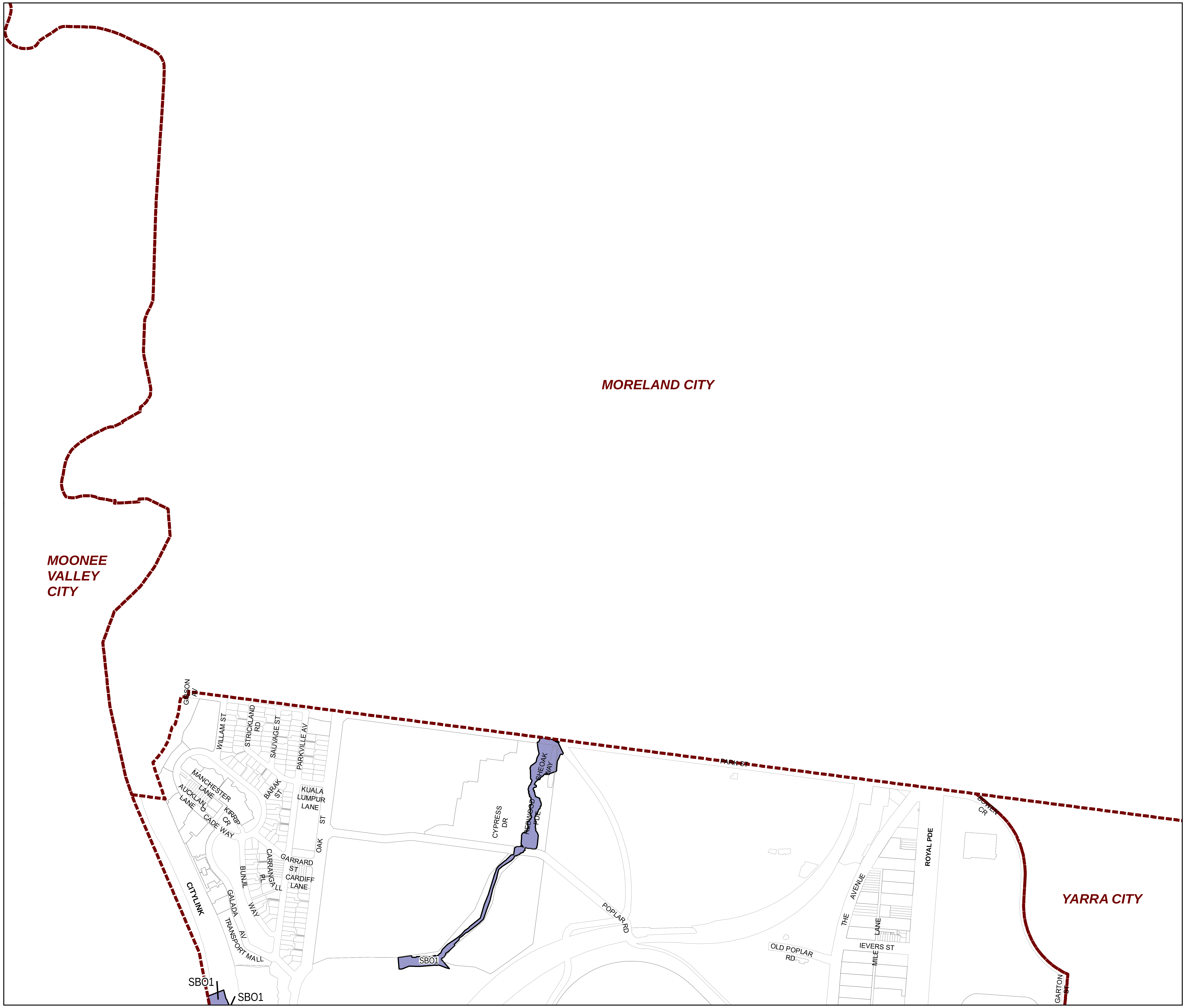


MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

SBO1 - Special Building Overlay - Schedule 1

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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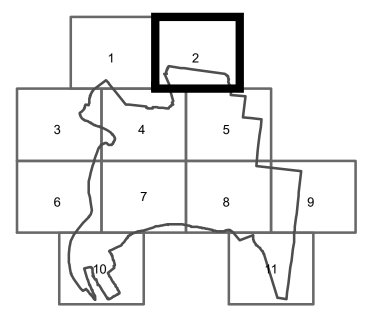
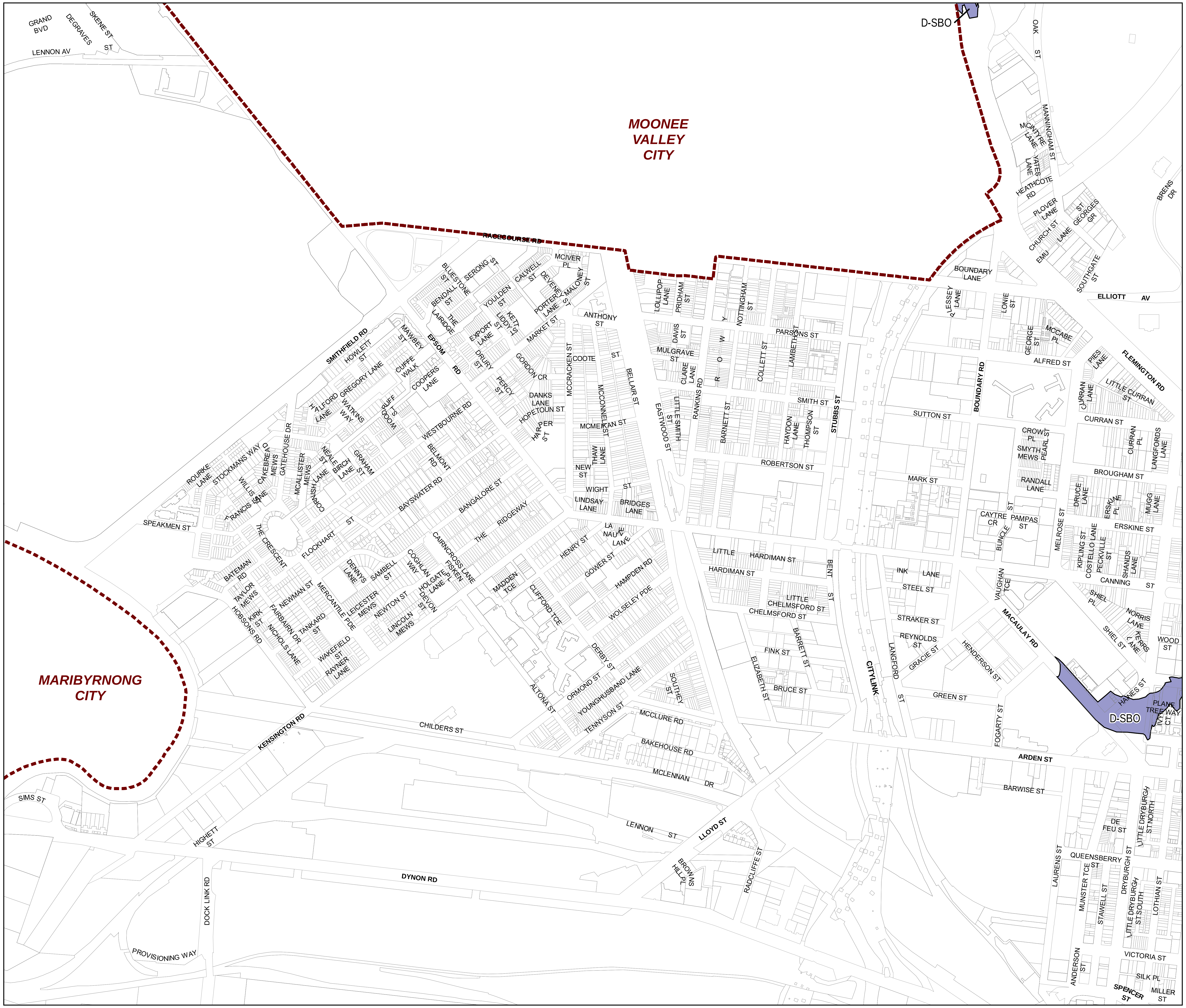


SPECIAL BUILDING OVERLAY **MAP No 2SBO**

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

D-SBO - Area to be deleted from a Special Building Overlay

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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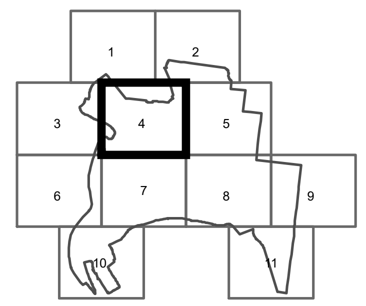

AREA TO BE DELETED FROM A SPECIAL BUILDING OVERLAY

MAP No 4SBO

MELBOURNE PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C384melb

LEGEND

- SBO1 - Special Building Overlay - Schedule 1
- SBO2 - Special Building Overlay - Schedule 2
- SBO3 - Special Building Overlay - Schedule 3

Municipal Boundary

0 310 620
Meters

Australian Map Grid Zone 55

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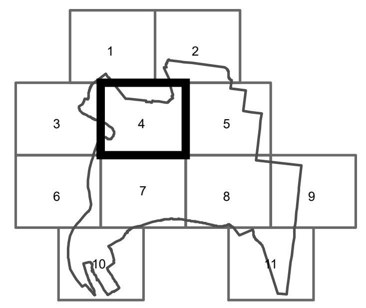
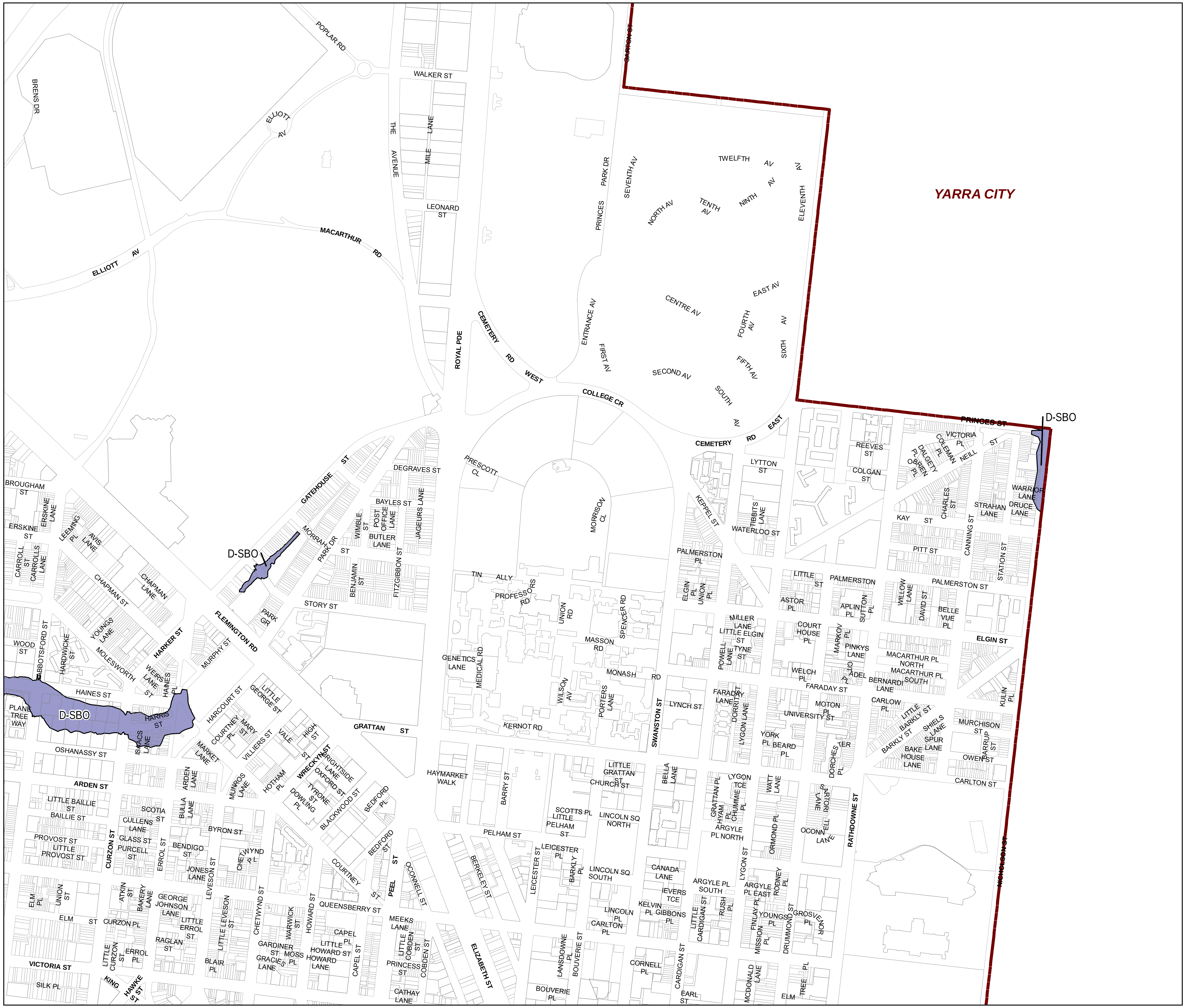


MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

D-SBO - Area to be deleted from a Special Building Overlay

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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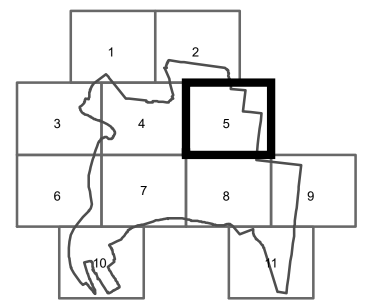
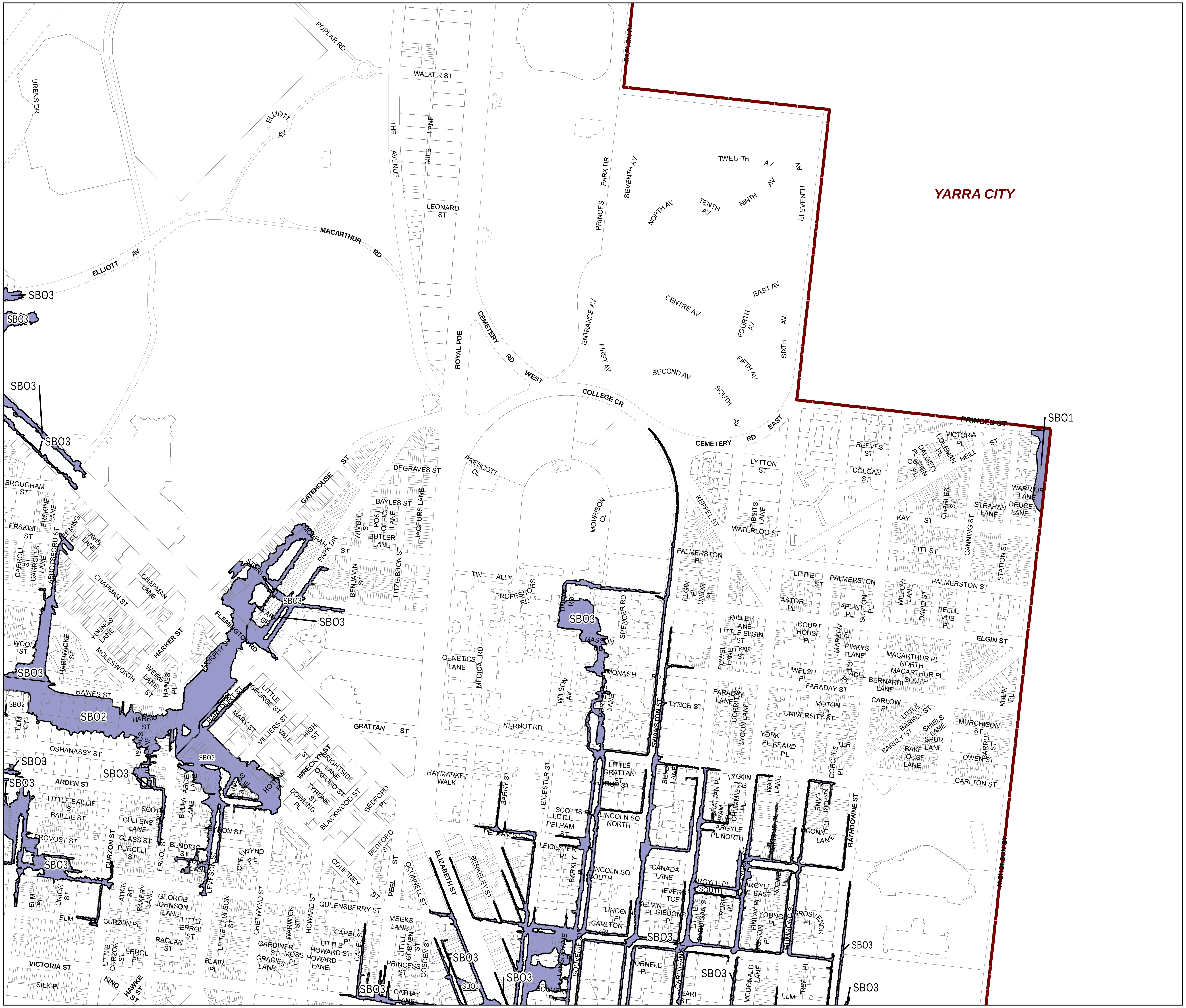


AREA TO BE DELETED FROM A SPECIAL BUILDING OVERLAY

MAP No 5SBO

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

- SBO1 - Special Building Overlay - Schedule 1
- SBO2 - Special Building Overlay - Schedule 2
- SBO3 - Special Building Overlay - Schedule 3

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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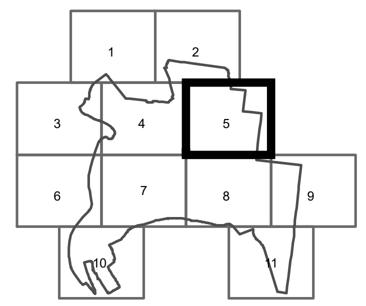
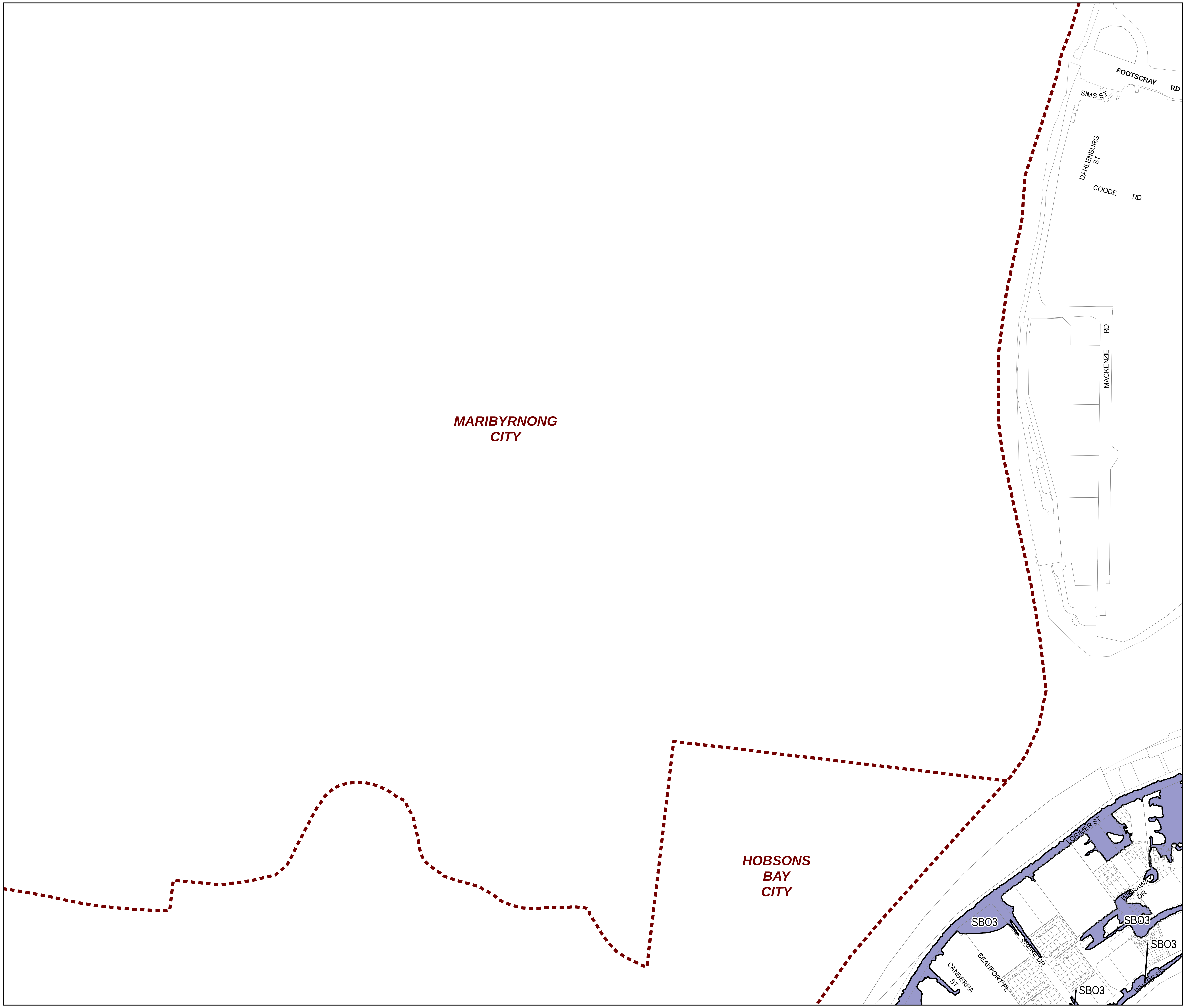


MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

SBO3 - Special Building Overlay - Schedule 3

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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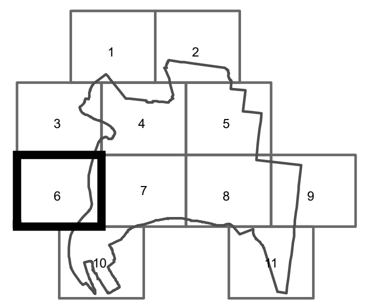
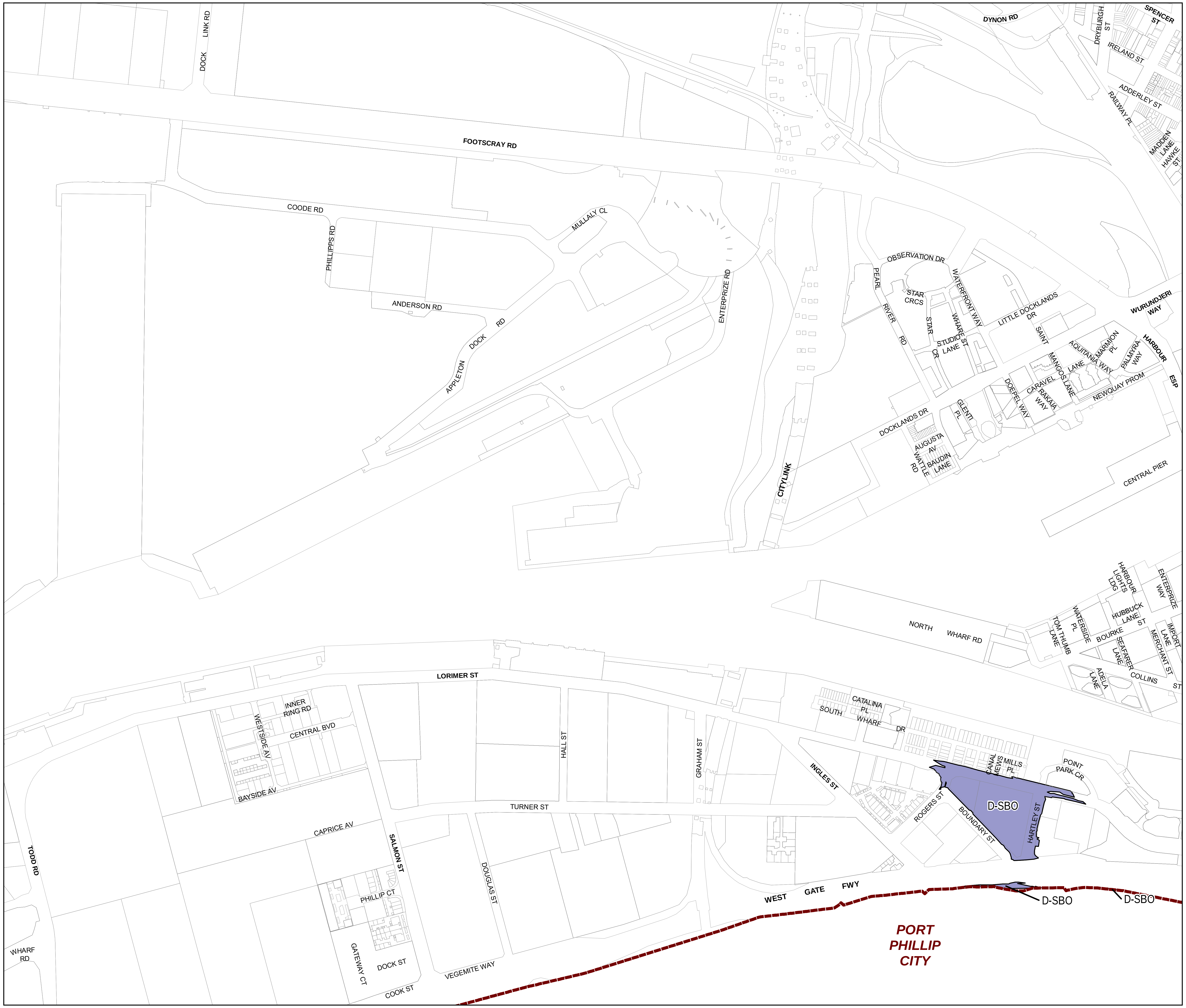


SPECIAL BUILDING OVERLAY

MAP No 6SBO

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

D-SBO - Area to be deleted from a Special Building Overlay

Municipal Boundary

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Australian Map Grid Zone 55

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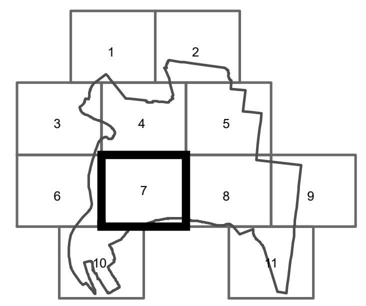

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb

LEGEND

SBO3 - Special Building Overlay - Schedule 3

Municipal Boundary

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Meters

Australian Map Grid Zone 55

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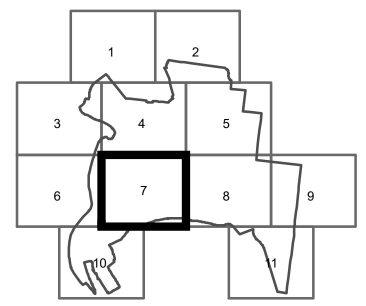

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb

LEGEND

D-SBO - Area to be deleted from a Special Building Overlay

Municipal Boundary

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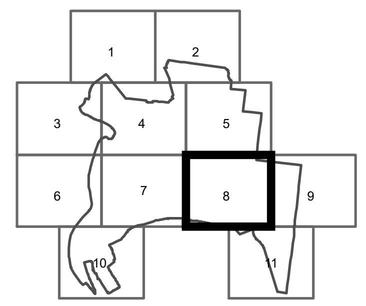
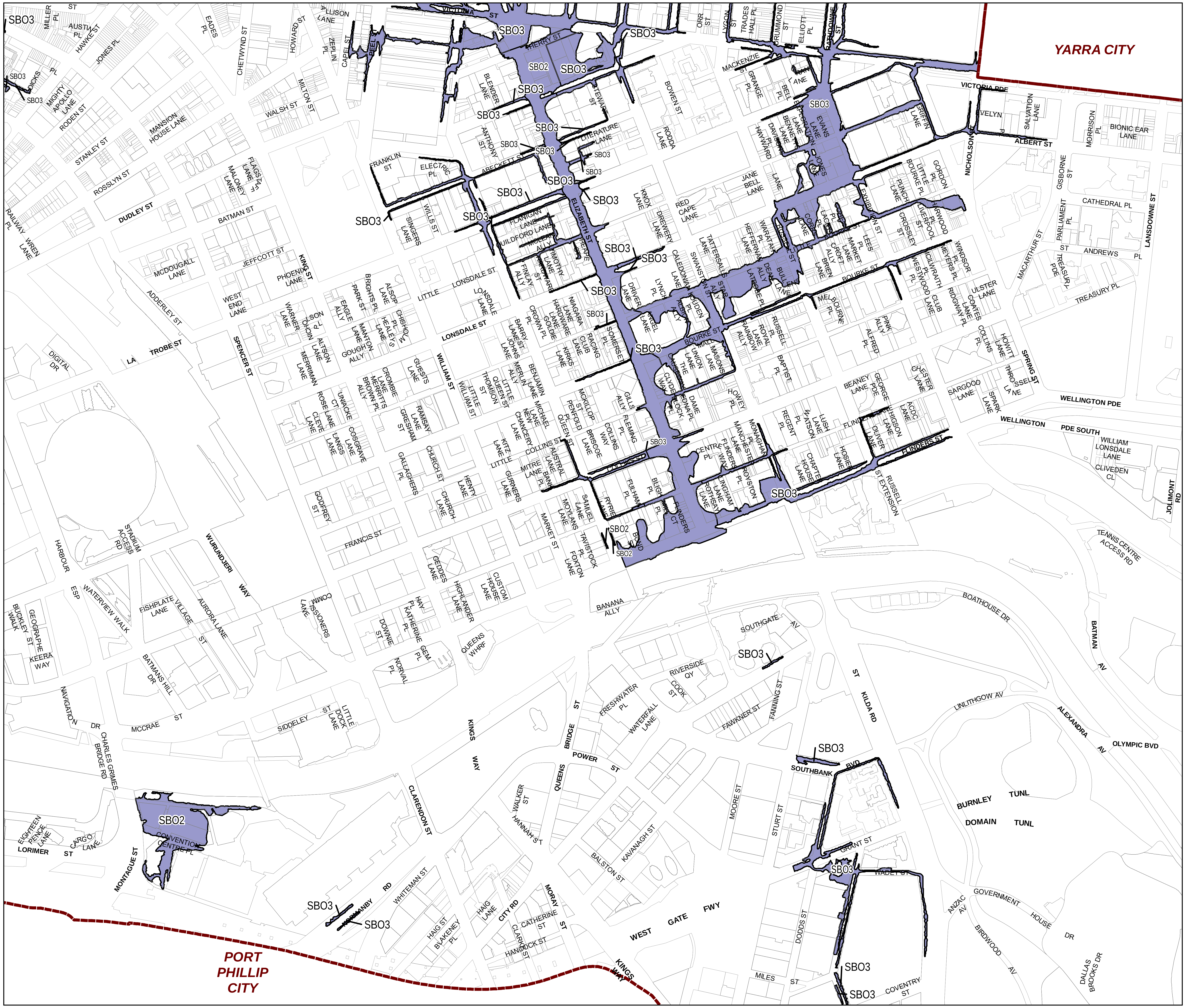


AREA TO BE DELETED FROM A SPECIAL BUILDING OVERLAY

MAP No 8SBO

MELBOURNE PLANNING SCHEME - LOCAL PROVISION
AMENDMENT C384melb



LEGEND

- SBO2 - Special Building Overlay - Schedule 2
- SBO3 - Special Building Overlay - Schedule 3

Municipal Boundary

0 310 620
Meters

Australian Map Grid Zone 55

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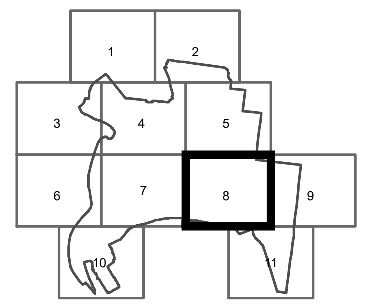
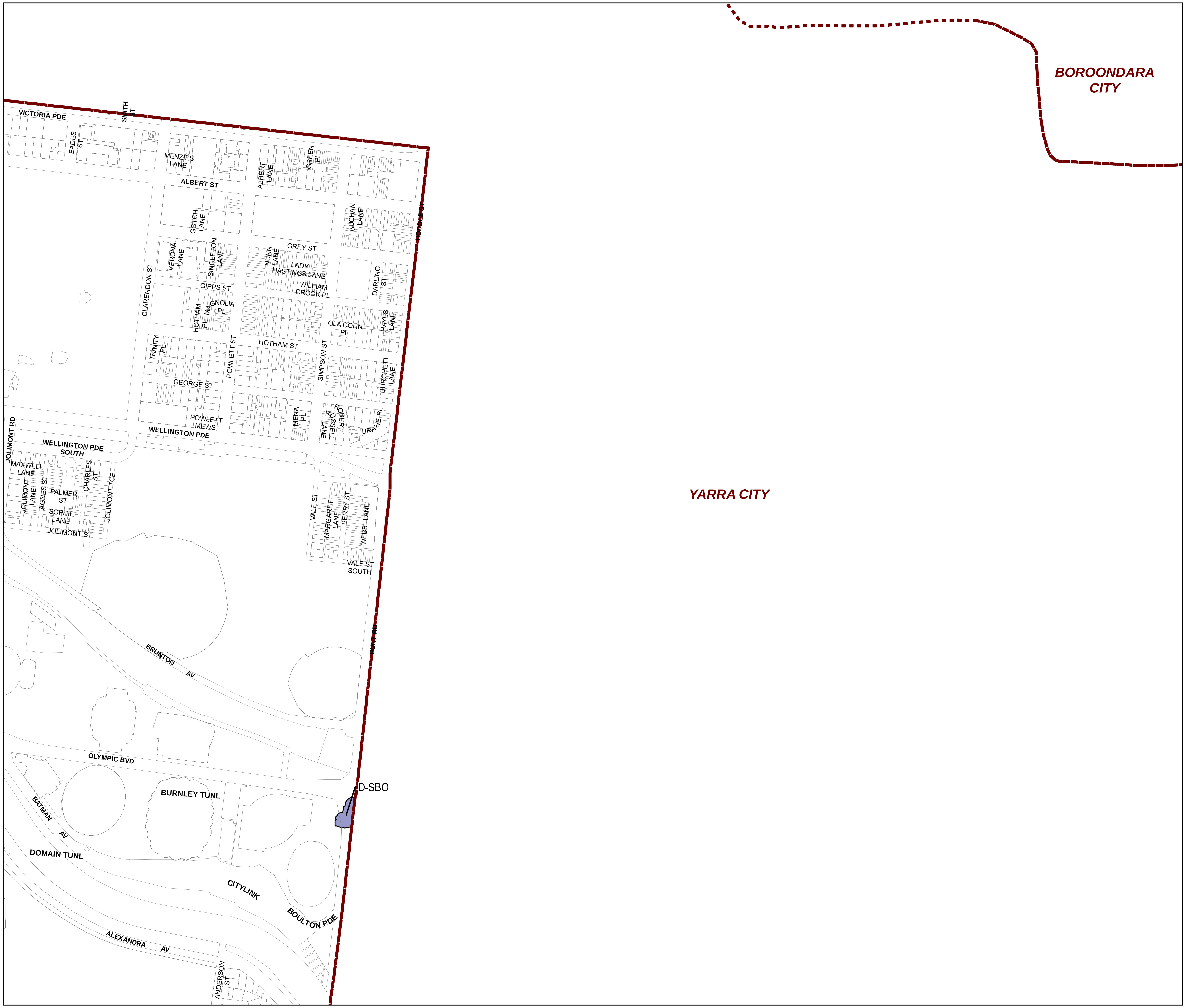


MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

D-SBO - Area to be deleted from a Special Building Overlay

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

Disclaimer
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NORTH

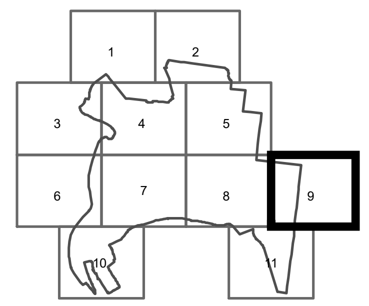
Planning Group

Printed: 18/10/2020

Amendment Version: 1

VICTORIA State Government | Environment, Land, Water and Planning

INDEX TO ADJOINING SCHEME MAPS

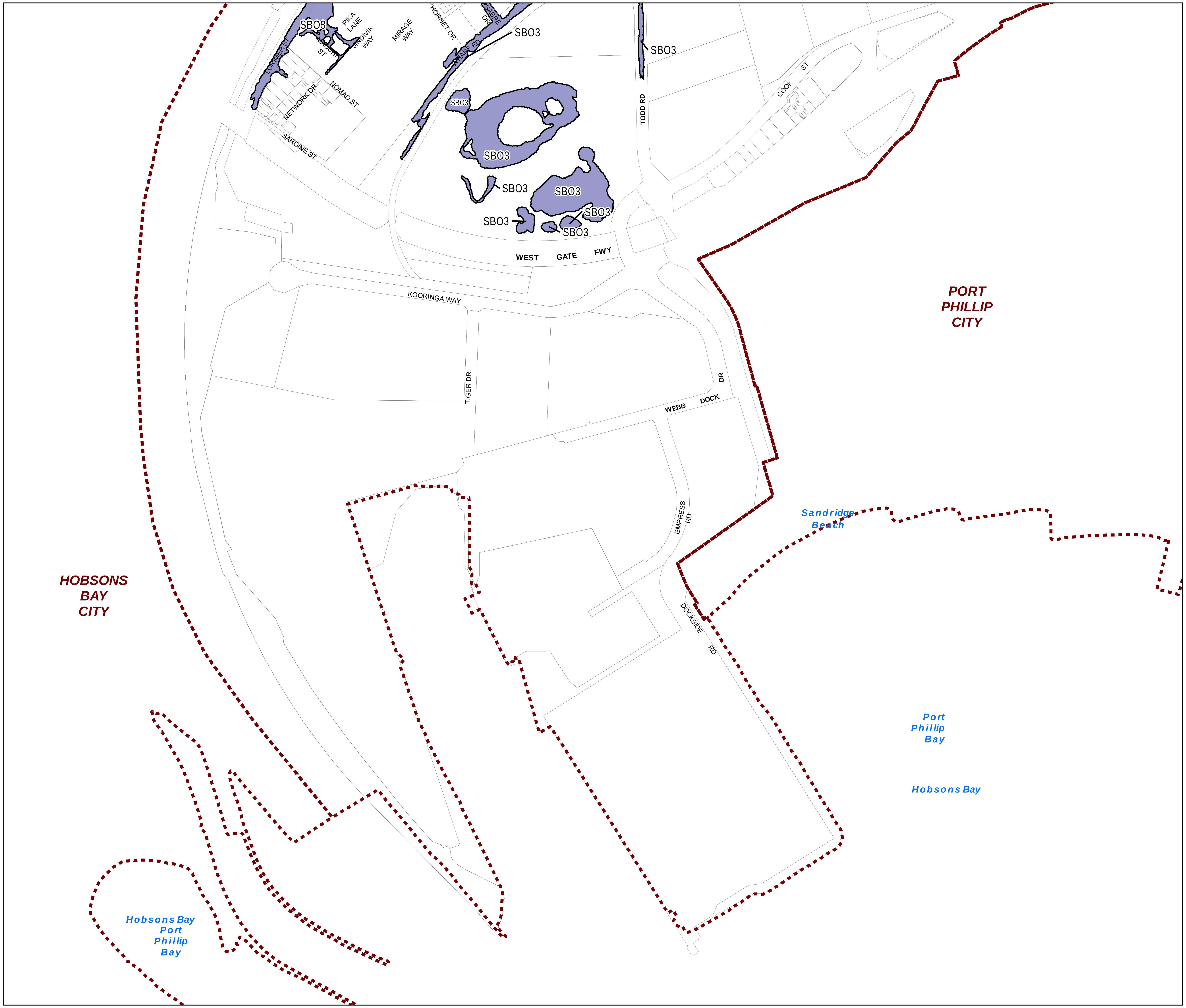


AREA TO BE DELETED FROM A SPECIAL BUILDING OVERLAY

MAP No 9SBO

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

SBO3 - Special Building Overlay - Schedule 3

Municipal Boundary

0 310 620

Meters

Australian Map Grid Zone 55

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Printed: 18/10/2020

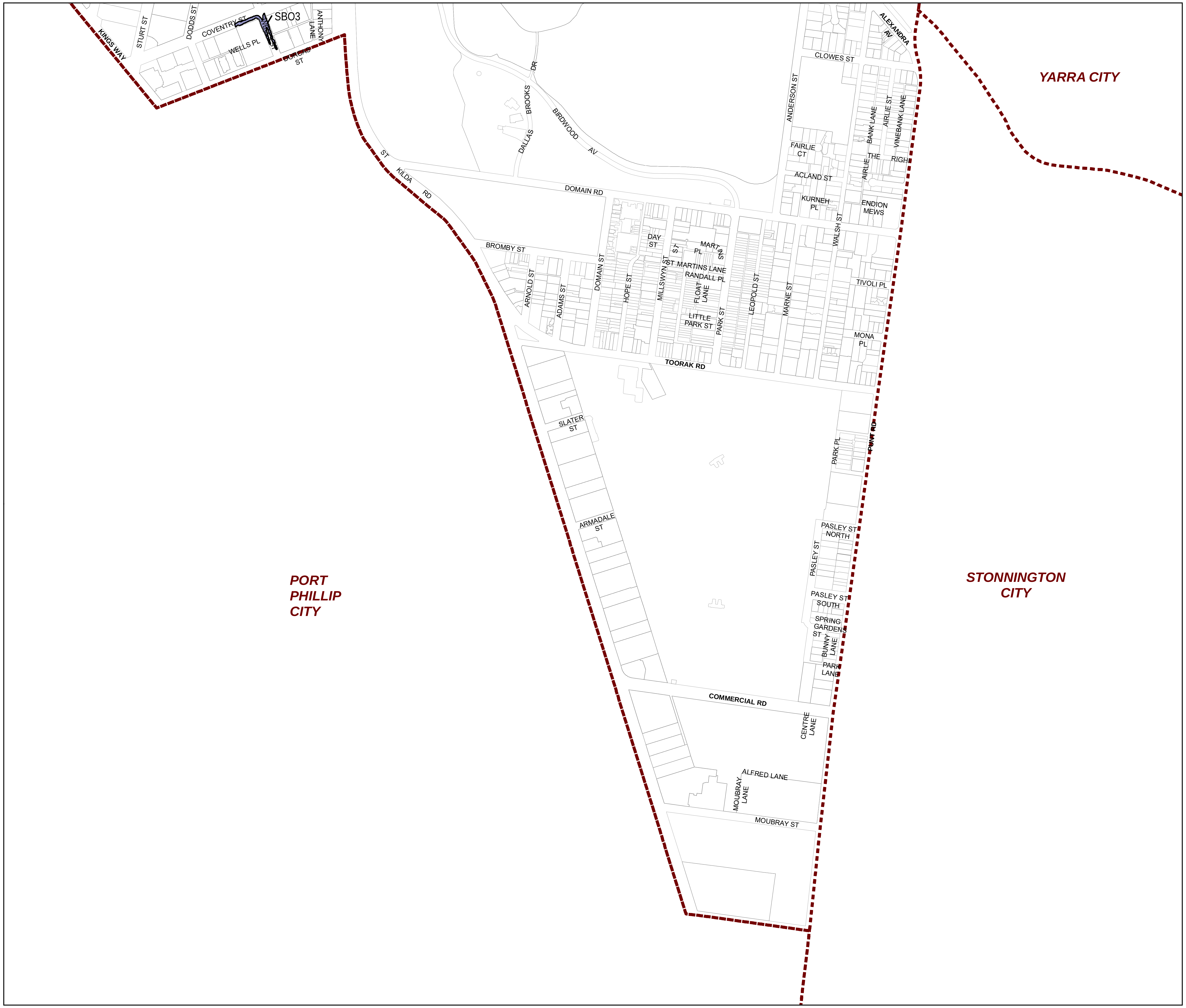
Amendment Version: 1

INDEX TO ADJOINING SCHEME MAPS

SPECIAL BUILDING OVERLAY **MAP No 10SBO**

MELBOURNE PLANNING SCHEME - LOCAL PROVISION

AMENDMENT C384melb



LEGEND

SBO3 - Special Building Overlay - Schedule 3

Municipal Boundary

0 310 620
Meters

Australian Map Grid Zone 55

Disclaimer
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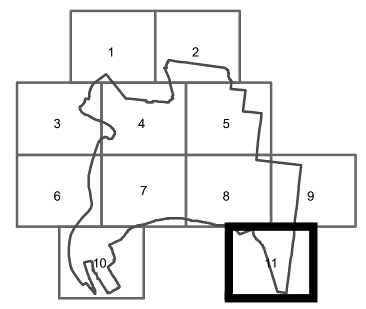


10/02/2011
C153
-/--/----
Proposed
C384melb

SCHEDULE 1 TO CLAUSE 44.04 THE LAND SUBJECT TO INUNDATION OVERLAY

Shown on the planning scheme map as **LSIO1**.

MARIBYRNONG RIVER ENVIRONS None specified.

1.0 Land subject to inundation objectives to be achieved

-/--/----
Proposed
C384melb

None specified.

2.0 Statement of risk

-/--/----
Proposed
C384melb

None specified.

3.0 Permit requirement

-/--/----
Proposed
C384melb

None specified.

4.0 Application requirements

-/--/----
Proposed
C384melb

None specified.

5.0 Decision guidelines

-/--/----
Proposed
C384melb

None specified.

10/02/2011
C153
-/--/----
Proposed
C384melb

SCHEDULE 2 TO CLAUSE 44.04 THE LAND SUBJECT TO INUNDATION OVERLAY

Shown on the planning scheme map as **LSIO2**.

FLEMINGTON RACECOURSE

1.0 Land subject to inundation objectives to be achieved Permit requirement

10/02/2011
C153
-/--/----
Proposed
C384melb

None specified.

2.0 Statement of risk Application requirements

-/--/----
Proposed
C384melb

None specified.

3.0 Permit requirement

-/--/----
Proposed
C384melb

A permit is not required to construct or carry out any of the following buildings and works on land subject to Schedule 1 to the Special Use Zone (Flemington Racecourse):

- A non-habitable building or an extension of a non-habitable building
- A building for the purpose of an office, where floor levels are at least 500mm above natural surface levels
- A building for the purpose of exhibitions
- A building for the purpose of place of assembly
- A building for the purpose of betting agency
- A building for the purpose of spectators
- An open style building with no walls
- Upper storey extensions or alterations to existing building
- Racing and equine related buildings such as horse stables and yards, swimming pools, sand rolls, TV tote screens, steward towers, tack stores and maintenance workshops and amenities for staff
- Racing and training tracks including trotting and exercise tracks
- An open style fence
- Replacement fences with the same or similar materials as the existing fence
- Advertising signs or posts attached to buildings
- Earth works and landscaping, where no fill is imported to the site and where no flood storage is reduced
- Process equipment and plant
- Footpaths and bicycle paths Road
- Car park
- Public toilets
- Pergola
- Marquee

~~2~~4.0
~~10/02/2011~~
~~C153~~
Proposed
C384melb

Application requirements

The following application requirements apply to an application for a permit under Clause 44.04, in addition to those specified in Clause 44.04 and elsewhere in the scheme and must accompany an application, as appropriate, to the satisfaction of the responsible authority:

~~An application to construct a building or construct or carry out works must be accompanied by four sets of plans drawn to scale which show:~~

- The boundaries and dimensions of the site.
- Relevant existing ground levels on and surrounding the site, to Australian Height Datum, taken by or under the direction or supervision of a licensed land surveyor.
- The layout of all existing and proposed buildings and works.
- The existing Finished Floor levels of any existing ~~and proposed~~ buildings~~,~~ to Australian Height Datum, taken by or under the direction or supervision of a licensed land surveyor.
- The proposed Finished Floor Level and Nominated Flood Protection Level (NFPL) of any proposed buildings, to Australian Height Datum, taken by or under the direction or supervision of a licensed land surveyor.

~~An application to construct a building or construct or carry out works or an application to amend a permit does not have to be referred to the floodplain management authority if the application:is accompanied by the relevant floodplain management authority's written approval.~~ The written approval of the floodplain management authority must:

- Be granted not more than three months prior to lodging with the responsible authority.
- Quote the reference number of the ~~approved~~ plans which are being consented.
- State the applicable F~~f~~lood L~~l~~evel and the approved Finished Floor Levels that meet the Nominated Flood Protection Level. ~~and any required floor levels~~
- Must confirm that the proposal is in accordance with an adopted local floodplain development plan.
- State that the proposal ~~C~~complies with the Flood Guidelines.~~building envelope, filling levels and floor levels specified by Melbourne Water in the previous six months.~~

~~3~~5.0
~~10/02/2011~~
~~C153~~
Proposed
C384melb

Decision guidelines ~~Referral of Applications~~

None specified.

~~An application to construct a building or construct or carry out works or an application to amend a permit does not have to be referred to the floodplain management authority if the application:~~

~~is accompanied by the relevant floodplain management authority's written approval, The written approval must:~~

- ~~Be granted not more than three months prior to lodging with the responsible authority~~
- ~~Quote the reference number of the approved plans~~
  - ~~State applicable flood level and any required floor levels~~
- ~~is in accordance with an adopted local floodplain development plan.~~
- ~~Complies with building envelope, filling levels and floor levels specified by Melbourne Water in the previous six months~~

--/--/--
Proposed
C384melb

SCHEDULE 3 TO CLAUSE 44.04 LAND SUBJECT TO INUNDATION OVERLAY

Shown on the planning scheme map as **LSIO3.**

MOONEE PONDS CREEK AND LOWER YARRA RIVER WATERWAYS

1.0 Land subject to inundation objectives to be achieved

--/--/--
Proposed
C384melb

To identify land in areas that may be inundated by the combined effects of the 1% Annual Exceedance Probability (AEP) flood event incorporating an 18.5% increase in rainfall intensity due to climate change by the year 2100.

To protect life, property, public health, assets and the environment from flood hazard.

To minimise the impact of development on flood extent, depth and the flow velocity.

To ensure new development is suitably designed to be compatible with local drainage characteristics and identified flood hazard.

To ensure development simultaneously achieves safe access and egress, good urban design and equitable access.

2.0 Statement of risk

--/--/--
Proposed
C384melb

The City of Melbourne includes the lower reaches of the Yarra River and Moonee Ponds Creek. Riverine flooding is caused when runoff from major storms exceeds the channel capacity of a river or creek and overflows onto the surrounding floodplain. While riverine flooding is generally associated with a longer rate of rise and in some instances warning times, flood events may have a longer duration and therefore a longer period of exposure to flood hazard. Flooding may have the potential to result in significant risk to:

- Human life and safety
- Property
- Public infrastructure and assets
- Public health through contaminated floodwaters
- The environment
- Economic and social cohesion of communities

To minimise the impact of such events, it is important buildings are sensitively and appropriately designed to minimise flood damage and protect life, property, assets and the environment. The mapping which forms the basis of the Land Subject to Inundation Overlay identifies areas that would be subject to inundation by the combined effects of the 1% Annual Exceedance Probability (AEP) flood event incorporating an 18.5% increase in rainfall intensity due to climate change by the year 2100. For Moonee Ponds Creek and the Lower Yarra River a boundary condition inclusive of a starting water surface level of a 10% Annual Exceedance Probability (AEP) tidal level plus a 0.8 metre sea level rise in 2100 has been included in the modelling. This information is contained in the background documents listed in the Schedule to Clause 72.08 which is the source of mapping for this overlay.

3.0 Permit requirement

--/--/--
Proposed
C384melb

A permit is not required to construct a building or carry out works for:

- An elevated boardwalk provided that the boardwalk is constructed above the applicable levels set by the relevant floodplain management authority.
- Earthworks that do not change the rate of flow or the discharge point of water across a property boundary.

- A sign on a single support pole, or structure that is at least 50 per cent permeable up to the applicable flood level.
- Bollards, bus and tram shelters.

See 44.04-2 for relevant provisions.

4.0 Application requirements

--/--/--
Proposed
C384melb

The following application requirements apply to an application for a permit under Clause 44.04, in addition to those specified in Clause 44.04 and elsewhere in the scheme and must accompany an application, as appropriate, to the satisfaction of the responsible authority:

- Existing survey plans taken by or under the direction and supervision of a licensed land surveyor showing natural ground level, the current Flood Level, and the ground and finished floor levels to Australian Height Datum (AHD).
- Proposed, plans, elevations and section drawings (1:50 or 1:20) showing the proposed ground and finished floor level and the Nominated Flood Protection Level (NFPL) of all new structures on the land.
- A written Flood Risk and Design Statement that must include but not be limited to:
  - A comprehensive description of the proposed plans, elevations and drawings stating the design of the lower levels of the building including entries, shop front design, the current Flood Level, the proposed Finished Floor Level(s) and Nominated Flood Protection Level (NFPL) as nominated by the relevant floodplain management authority, flood proofing and use of flood-resistant materials, flood storage, stairs, ramps and access/egress points and possible refuge spaces within the development (if applicable).
  - A description of proposed actions, flood mitigation strategies or measures required, if any, to the siting and design of the buildings or works, or in association with the use and occupation of all aspects of the proposal in order to reduce the risk to individuals, property, infrastructure and the environment. These actions may include the consideration of adaptation options such as planned retreat, setbacks, accommodation of changes through floor heights, site and land forming and proposed drainage works.

See 44.04-4 for relevant provisions.

5.0 Decision guidelines

The following decision guidelines apply to an application for a permit under Clause 44.04, in addition to those specified in Clause 44.04 and elsewhere in the scheme which must be considered, as appropriate, by the responsible authority:

- *Guidelines for Development in Flood Affected Areas* (the Department of Environment, Land, Water and Planning, 2019).
- *Good Design Guide for Buildings in Flood Affected Areas in Fishermans Bend, Arden and Macaulay* (City of Melbourne, Melbourne Water and City of Port Phillip, 2021)
- The proposal appropriately responds to the identified site specific flood risk to the satisfaction of the relevant floodplain management authority.
- Development achieves good urban design and equitable access.
- Ground floor design of the building maintains good physical and visual connection between the street and internal ground floor.
- Development activates the street edge and frontage.
- Development and design response manage the flood risk appropriately.

See 44.04-8 for relevant provisions.

-/--/----
Proposed
C384melb

SCHEDULE 1 TO CLAUSE 44.05 SPECIAL BUILDING OVERLAY

Shown on the planning scheme map as **SBO1.**

MELBOURNE WATER MAIN DRAINS

1.0 Flooding management objectives to be achieved

-/--/----
Proposed
C384melb

None specified.

2.0 Statement of risk

-/--/----
Proposed
C384melb

None specified.

3.0 Permit requirement

-/--/----
Proposed
C384melb

None specified.

4.0 Application requirements

-/--/----
Proposed
C384melb

None specified.

5.0 Decision guidelines

-/--/----
Proposed
C384melb

None specified.

--/--/--
Proposed
C384melb

SCHEDULE 2 TO CLAUSE 44.05 SPECIAL BUILDING OVERLAY

Shown on the planning scheme map as **SBO2.**

MELBOURNE WATER MAIN DRAINS – ELIZABETH STREET, ARDEN, MACAULAY AND MOONEE PONDS CREEK, FISHERMANS BEND AND SOUTHBANK CATCHMENTS

1.0 Flooding management objectives to be achieved

--/--/--
Proposed
C384melb

To identify land in areas that may be inundated by the combined effects of the 1% Annual Exceedance Probability (AEP) flood event incorporating an 18.5% increase in rainfall intensity due to climate change by the year 2100.

To protect life, property, public health, assets and the environment from flood hazard.

To minimise the impact of development on flood extent, depth and the flow velocity.

To ensure new development is suitably designed to be compatible with local drainage characteristics and identified flood hazard.

To ensure development simultaneously achieves safe access and egress, good urban design and equitable access.

2.0 Statement of risk

--/--/--
Proposed
C384melb

Areas across the municipality are susceptible to overland flows when runoff from severe storm events exceeds the capacity of the underground drainage system. Overland flows can be localised or widespread depending on the path or extent of the storm activity. Flooding may have the potential to result in significant risk to:

- Human life and safety
- Property
- Public infrastructure and assets
- Public health through contaminated floodwaters
- The environment
- Economic and social cohesion of communities

To minimise the impact of such events, it is important buildings are sensitively and appropriately designed to minimise flood damage and protect life, property, assets and the environment. The mapping which forms the basis of the Special Building Overlay identifies areas that may be subject to overland flows by the combined effects of the 1% Annual Exceedance Probability (AEP) flood event incorporating an 18.5% increase in rainfall intensity due to climate change by the year 2100. This information is contained in the background documents listed in the Schedule to Clause 72.08 which is the source of mapping for this overlay.

3.0 Permit requirement

--/--/--
Proposed
C384melb

A permit is not required to construct a building or carry out works for:

- An elevated boardwalk provided that the boardwalk is constructed above the applicable levels set by the relevant floodplain management authority.
- Earthworks that do not change the rate of flow or the discharge point of water across a property boundary.
- A sign on a single support pole, or structure that is at least 50 per cent permeable up to the applicable flood level.
- Bollards, bus and tram shelters.

See 44.05-2 for relevant provisions.

4.0 Application requirements

--/--/--
Proposed
C384melb

The following application requirements apply to an application for a permit under Clause 44.05, in addition to those specified in Clause 44.05 and elsewhere in the scheme and must accompany an application, as appropriate, to the satisfaction of the responsible authority:

- Existing survey plans taken by or under the direction and supervision of a licensed land surveyor showing natural ground level, the current Flood Level, and the ground and finished floor levels to Australian Height Datum (AHD).
- Proposed, plans, elevations and section drawings (1:50 or 1:20) showing the proposed ground and finished floor level and the Nominated Flood Protection Level (NFPL) of all new structures on the land.
- A written Flood Risk and Design Statement that must include but not be limited to:
  - A comprehensive description of the proposed plans, elevations and drawings stating the design of the lower levels of the building including entries, shop front design, the current Flood Level, the proposed Finished Floor Level(s) and Nominated Flood Protection Level (NFPL) as nominated by the relevant floodplain management authority, flood proofing and use of flood-resistant materials, flood storage, stairs, ramps and access/egress points and possible refuge spaces within the development (if applicable).
  - A written description of proposed actions, flood mitigation strategies or measures required, if any, to the siting and design of the buildings or works, or in association with the use and occupation of all aspects of the proposal in order to reduce the risk to individuals, property, infrastructure and the environment. These actions may include the consideration of adaptation options such as planned retreat, setbacks, accommodation of changes through floor heights, site and land forming and proposed drainage works.

See 44.05-4 for relevant provisions.

5.0 Decision guidelines

The following decision guidelines apply to an application for a permit under Clause 44.05, in addition to those specified in Clause 44.05 and elsewhere in the scheme which must be considered, as appropriate, by the responsible authority:

- *Guidelines for Development in Flood Affected Areas* (the Department of Environment, Land, Water and Planning, 2019).
- *Good Design Guide for Buildings in Flood Affected Areas in Fishermans Bend, Arden and Macaulay* (City of Melbourne, Melbourne Water and City of Port Phillip, 2021)
- The proposal appropriately responds to the identified site specific flood risk to the satisfaction of the relevant floodplain management authority.
- Development achieves good urban design and equitable access.
- Ground floor design of the building maintains good physical and visual connection between the street and internal ground floor.
- Development activates the street edge and frontage.
- Development and design response manage the flood risk appropriately.
- Materials and finishes are resilient to damage in flood events.

See 44.05-7 for relevant provisions.

--/--/--
Proposed
C384melb

SCHEDULE 3 TO CLAUSE 44.05 SPECIAL BUILDING OVERLAY

Shown on the planning scheme map as **SBO3.**

COUNCIL DRAINS – ELIZABETH STREET, ARDEN, MACAULAY AND MOONEE PONDS CREEK, HOBSONS ROAD, FISHERMANS BEND AND SOUTHBANK CATCHMENTS

1.0 Flooding management objectives to be achieved

--/--/--
Proposed
C384melb

To identify land in areas that may be inundated by the combined effects of the 1% Annual Exceedance Probability (AEP) flood event incorporating an 18.5% increase in rainfall intensity due to climate change by the year 2100.

To protect life, property, public health, assets and the environment from flood hazard.

To minimise the impact of development on flood extent, depth and the flow velocity.

To ensure new development is suitably designed to be compatible with local drainage characteristics and identified flood hazard.

To ensure development simultaneously achieves safe access and egress, good urban design and equitable access.

2.0 Statement of risk

--/--/--
Proposed
C384melb

Areas across the municipality are susceptible to overland flows when runoff from severe storm events exceeds the capacity of the underground drainage system. Overland flows can be localised or widespread depending on the path or extent of the storm activity. Flooding may have the potential to result in significant risk to:

- Human life and safety
- Property
- Public infrastructure and assets
- Public health through contaminated floodwaters
- The environment
- Economic and social cohesion of communities

To minimise the impact of such events, it is important buildings are sensitively and appropriately designed to minimise flood damage and protect life, property, assets and the environment. The mapping which forms the basis of the Special Building Overlay identifies areas that may be subject to overland flows by the combined effects of the 1% Annual Exceedance Probability (AEP) flood event incorporating an 18.5% increase in rainfall intensity due to climate change by the year 2100. This information is contained in the background documents listed in the Schedule to Clause 72.08 which is the source of mapping for this overlay.

3.0 Permit requirement

--/--/--
Proposed
C384melb

A permit is not required to construct a building or carry out works for:

- An elevated boardwalk provided that the boardwalk is constructed above the applicable levels set by the relevant floodplain management authority.
- Earthworks that do not change the rate of flow or the discharge point of water across

a property boundary.

- A sign on a single support pole, or structure that is at least 50 per cent permeable up to the applicable flood level.
- Bollards, bus and tram shelters.

See 44.05-2 for relevant provisions.

4.0 Application requirements

--/--/--
Proposed
C384melb

The following application requirements apply to an application for a permit under Clause 44.05, in addition to those specified in Clause 44.05 and elsewhere in the scheme and must accompany an application, as appropriate, to the satisfaction of the responsible authority:

- Existing survey plans taken by or under the direction and supervision of a licensed land surveyor showing natural ground level, the current Flood Level, and the ground and finished floor levels to Australian Height Datum (AHD).
- Proposed, plans, elevations and section drawings (1:50 or 1:20) showing the proposed ground and finished floor level and the Nominated Flood Protection Level (NFPL) of all new structures on the land.
- A written Flood Risk and Design Statement that must include but not be limited to:
  - A comprehensive description of the proposed plans, elevations and drawings stating the design of the lower levels of the building including entries, shop front design, the current Flood Level, the proposed Finished Floor Level(s) and Nominated Flood Protection Level (NFPL) as nominated by the relevant floodplain management authority, flood proofing and use of flood-resistant materials, flood storage, stairs, ramps and access/egress points and possible refuge spaces within the development (if applicable).
  - A written description of proposed actions, flood mitigation strategies or measures required, if any, to the siting and design of the buildings or works, or in association with the use and occupation of all aspects of the proposal in order to reduce the risk to individuals, property, infrastructure and the environment. These actions may include the consideration of adaptation options such as planned retreat, setbacks, accommodation of changes through floor heights, site and land forming and proposed drainage works.

See 44.05-4 for relevant provisions.

5.0 Decision guidelines

The following decision guidelines apply to an application for a permit under Clause 44.05, in addition to those specified in Clause 44.05 and elsewhere in the scheme which must be considered, as appropriate, by the responsible authority:

- *Guidelines for Development in Flood Affected Areas* (the Department of Environment, Land, Water and Planning, 2019).
- *Good Design Guide for Buildings in Flood Affected Areas in Fishermans Bend, Arden and Macaulay* (City of Melbourne, Melbourne Water and City of Port Phillip, 2021)
- The proposal appropriately responds to the identified site specific flood risk to the satisfaction of the relevant floodplain management authority.
- Development achieves good urban design and equitable access.
- Ground floor design of the building maintains good physical and visual connection between the street and internal ground floor.
- Development activates the street edge and frontage.
- Development and design response manage the flood risk appropriately.
- Materials and finishes are resilient to damage in flood events.

See 44.05-7 for relevant provisions.

18/10/2018
C346melb

SCHEDULE TO CLAUSE 72.03 WHAT DOES THIS PLANNING SCHEME CONSIST OF?

1.0 Maps comprising part of this planning scheme:

~~11/09/2020~~
~~C397melb~~
--/---/----
Proposed
C384melb

- 1, 1HO, 1SBO, 1PO.
- 2, 2CLPO, 2DDOPT3, 2 ESO, 2HO, 2SBO, 2PAO, 2SCO
- 3, 3HO, 3LSIO, 3PAO, 3PO
- 4, 4CLPO, 4DCPO, 4DDOPT1, 4DDOPT3, 4DPO, 4EAO, 4ESO, 4HO, 4IPO, 4LSIO, 4PAO, 4SBO, 4PO, 4SCO.
- 5, 5DDOPT1, 5DDOPT3, 5ESO, 5HO, 5IPO, 5PAO, 5RXO, 5SBO, 5SCO, 5DPO, 5PO.
- 6, 6ESO, 6LSIO, 6SBO.
- 7, 7CLPO, 7DCPO, 7DDOPT1, 7DDOPT3, 7DPO, 7EAO, 7ESO, 7HO, 7ICO, 7LSIO, 7PAO, 7SBO, 7PO.
- 8, 8CLPO, 8DDO1, 8DDO2_14_62, 8DDO3, 8DDO4, 8DDO5, 8DDO6, 8DDOPT1, 8DDOPT2, 8DDOPT3, 8DDOPT7, 8DDOPT8, 8DDO10, 8DPO, 8EAO, 8ESO, 8HO, 8HO1, 8HO2, 8IPO, 8LSIO, 8PAO, 8RXO, 8SBO, 8SCO, 8PO
- 9, 9CLPO, 9DDOPT1, 9ESO, 9HO, 9LSIO, 9PAO, 9SBO, 9PO, 9SCO
- 10, 10ESO, 10SBO.
- 11, 11DDOPT1, 11DDOPT2, 11DDOPT3, 11DDOPT7, 11EAO, 11ESO, 11HO, 11LSIO, 11RXO, 11PO, 11SBO.

31/07/2018
VC148

SCHEDULE TO CLAUSE 72.08 BACKGROUND DOCUMENTS

1.0
31/07/2018
VC148
--/--/----
Proposed
C384melb

Background documents

Name of background document	Amendment number - clause reference
None specified Technical Report 01: Australian Rainfall Runoff Sensitivity Analysis (Engeny Water Management dated 22 July 2020)	C384 – Clause 44.04 and Clause 44.05
Technical Report 02: Southbank Flood Modelling Update and Climate Change Scenarios (Water Modelling Solutions dated 21 April 2020)	C384 – Clause 44.04 and Clause 44.05
Technical Report 03: Southbank Stormwater Infrastructure Assessment: Final Report (BMT WBM dated August 2015)	C384 – Clause 44.04 and Clause 44.05
Technical Report 04: Elizabeth Street Melbourne Flood Modelling Report (Water Technology, dated August 2017) including the Memorandum's dated 9 April 2020 and 13 February 2020	C384 – Clause 44.04 and Clause 44.05
Technical Report 05: Arden Macaulay Precinct & Moonee Ponds Creek Flood Modelling (Engeny Water Management dated August 2020)	C384 – Clause 44.04 and Clause 44.05
Technical Report 06: Lower Yarra River Flood Mapping (GHD dated 24 September 2020)	C384 – Clause 44.04 and Clause 44.05
Technical Report 07: Hobsons Road Catchment Flood Mapping Update (Venant Solutions dated 17 June 2020) including the review response dated 22 April 2020	C384 – Clause 44.04 and Clause 44.05
Technical Report 08: Fishermans Bend Flood Mapping (GHD dated November 2020)	C384 – Clause 44.04 and Clause 44.05
Technical Report 09: Overlay Delineation Report (Engeny Water Management dated 27 October 2020)	C384 – Clause 44.04 and Clause 44.05
Planning for Sea Level Rise Guidelines (Melbourne Water. February 2017)	C384 – Clause 44.04 and Clause 44.05
Guidelines for Development in Flood Affected Areas (Department of Environment, Land, Water and Planning, 2019)	C384 – Clause 44.04 and Clause 44.05
Good Design Guide for Buildings in Flood Affected Areas in Fishermans Bend, Arden and Macaulay (City of Melbourne, Melbourne Water and City of Port Phillip, 2021)	C384 – Clause 44.04 and Clause 44.05

Technical Report: Australian Rainfall and Runoff Sensitivity Analysis

Project: V3000_111 City of Melbourne Planning Scheme Overlays	**Date:** 22 July 2020
To: Ruwan Jayasinghe, Melbourne Water **CC:** Kate Berg, City of Melbourne Alex Barton, Melbourne Water Luke Cunningham, Rain Consulting Rianda Mills, Rain Consulting	**From:** Paul Clemson, Engeny Water Management
Subject: ARR2019 sensitivity analysis	

INTRODUCTION

The City of Melbourne and Melbourne Water have prepared an update to the extents of the Land Subject to Inundation Overlay (LSIO) and Special Building Overlay (SBO), which are proposed to be included in the City of Melbourne Planning Scheme through Amendment C384. The overlays are based on a number of previous flood modelling studies undertaken within the City of Melbourne in accordance with Australian Rainfall and Runoff (ARR) 1987, and include an 18.5 % increase in rainfall intensity due to the predicted impacts of climate change by the year 2100.

ARR2019 has been released since the development of the flood models that have been used as the basis of updating the LSIO and SBO. This technical report documents the outcomes of a sensitivity analysis undertaken by Engeny Water Management (Engeny) to examine the impact of ARR2019 in comparison to ARR1987, based on the results of flood modelling for the Arden Macaulay Precinct / Moonee Ponds Creek model, which is one of six flood models that will be used to delineate the LSIO and SBO. A key objective is to determine whether it is justifiable to apply ARR1987 to delineate the LSIO and SBO, based on differences predicted between the flood mapping results of ARR2019 and ARR1987 for the Arden Macaulay Precinct / Moonee Ponds Creek model.

The Arden Macaulay Precinct / Moonee Ponds Creek flood modelling is based on RORB and TUFLOW. Two RORB models have been used as part of the modelling, one for the overall Moonee Ponds Creek catchment (developed by Melbourne Water) to provide an inflow to Moonee Ponds Creek at Flemington Road and one for the local catchment draining into Moonee Ponds Creek downstream of Flemington (developed by AECOM). A combination of runoff excess hydrographs and routed flows have been used from the local catchment RORB model.

ARR1987 HYDROLOGY MODELLING

Key parameters adopted in the ARR1987 modelling, consistent with previous studies using these models, are outlined below:

- Moonee Ponds Creek RORB model:
  - IFD data for the centroid of the Moonee Ponds Creek catchment
  - kc: 26.0
  - m: 0.8
  - Initial loss: 15 millimetres
  - Pervious area 1 % annual exceedance probability (AEP) runoff coefficient: 0.65
  - Areal reduction factors based on ARR87 Bk II, Figs 1.6 and 1.7
- Local catchment RORB model:
  - IFD data for the centroid of the local catchment RORB model
  - kc: 3.4
  - m: 0.8
  - Initial loss: 10 millimetres
  - Pervious area 1 % AEP runoff coefficient: 0.6
  - Areal reduction factors based on ARR87 Bk II, Figs 1.6 and 1.7

The key results from the Moonee Ponds Creek RORB model in terms of the peak flow in Moonee Ponds Creek at Flemington Road are:

- Existing climate conditions: 217 m^3/s
- 18.5 % climate change scenario: 263 m^3/s

ARR2019 HYDROLOGY MODELLING

Both the Moonee Ponds Creek and local catchment RORB models were updated to ARR2019, including updated design rainfall data, temporal patterns and hydrological losses.

Table 1 provides a comparison of 1 % AEP design rainfall depths between ARR1987 and ARR2019 for standard storm durations for the Moonee Ponds Creek catchment. It should be noted that a change in rainfall depth is unlikely to result in the same percentage change in flooding due to the different temporal patterns and approach to hydrological losses between ARR1987 and ARR2019.

Table 1 Comparison of design rainfall depths for the Moonee Ponds Creek catchment

Storm Duration	ARR1987 Design Rainfall Depth (mm)	ARR2019 Design Rainfall Depth (mm)	Change
10 min	23.0	24.3	+5.7 %
30 min	38.3	39.5	+3.3 %
1 hour	49.6	49.5	-0.2 %
2 hour	61.6	60.7	-1.5 %
3 hour	69.3	68.6	-1.0 %
6 hour	84.0	85.9	+2.3 %
12 hour	104.6	109.0	+4.2 %

Initial and continuing losses for effective impervious areas and indirectly connected areas are based on values recommended in ARR2019. For rural areas, as a starting point, initial and continuing loss values were adopted based on the datahub values. For the Moonee Ponds Creek RORB model the datahub losses for rural areas are:

- Initial loss: 12 millimetres
- Continuing loss: 1.9 millimetres

Areal reduction factors (ARF) for the Moonee Ponds Creek RORB model have been based on the approach outlined in ARR2019 for the total catchment of Moonee Ponds Creek. For the 2 hour duration event (which is critical for the Moonee Ponds Creek catchment), this results in a reduction in ARF from 0.91 for ARR1987 to 0.78 for ARR2019.

ARR2019 recommends the consideration of spatial variation for catchments exceeding 20 square kilometres, which would include the Moonee Ponds Creek catchment (which has a catchment area of approximately 135 square kilometres). The variation of design rainfall intensity across the catchment was analysed using the IFD data and it was found to be within +/- 5 %. Due to the small variation, a single source of IFD has been used for the Moonee Ponds Creek catchment.

Adopting the above losses and ARFs resulted in a considerable increase in peak flows at Flemington Road (from 217 m^3/s in ARR1987 to 245 m^3/s in ARR2019 for existing climate conditions). In ARR2019, the peak flow is identified as the peak of the median flows for the range of temporal patterns for each storm duration.

There is uncertainty regarding how the ARR1987 Moonee Ponds Creek RORB model was validated. To understand whether the ARR1987 flows were reasonable, Engeny undertook a flood frequency analysis (FFA) on flow gauge data at Flemington Road.

The FFA was undertaken using FLIKE software package to determine peak flow rates for different AEP events based on the provided historical gauged data ranging from July 1991 to

October 2019. The 6 minute interval gauge data was process to determine peak flows for each year in Moonee Ponds Creek at Flemington Road, which ranged from 19 m^3/s to 186 m^3/s.

ARR2019 suggests two probability models as reasonable initial choices for annual maximum flood series, which are the Generalized Extreme Value (GEV) and Log Pearson III (LP III) families. Of the widely used distribution families, the GEV distribution has the strongest theoretical appeal and has gained widespread acceptance. For this investigation the GEV model with LH-moments was adopted. LH-moments can be used to deal with situations where the lower discharges exert undue influence on the fit and give insufficient weight to the higher discharges which are the principal object of interest.

The 1 % AEP flood quantile estimated by the FFA for the GEV model with LH-moments is 207 m^3/s and 192 m^3/s for the LP III model.

Figure 1 presents the flood frequency curve for the GEV model with LH-moments.

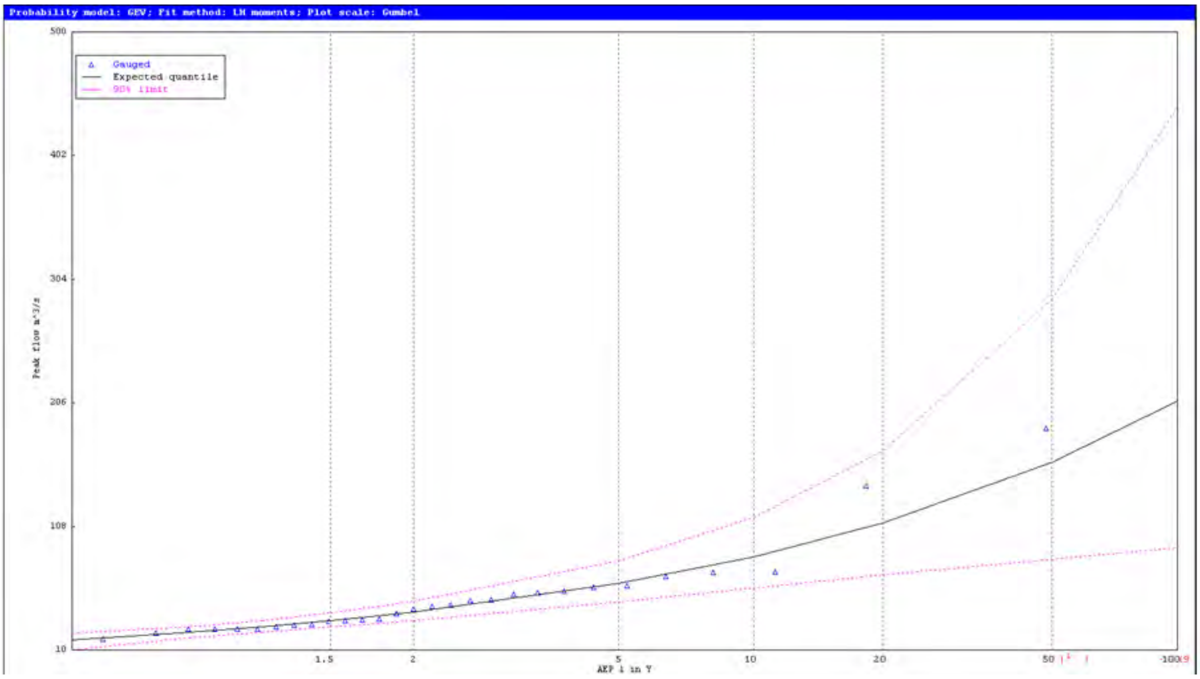


Figure 1 FFA GEV model curve

The flood frequency analysis 1 % AEP flow of 207 m^3/s is an appropriate match to the ARR1987 peak flow (217 m^3/s) and it was therefore decided that it would be appropriate to adjust the ARR2019 losses so that the ARR2019 peak flow matches the ARR1987 peak flow.

The final hydrological losses adopted for the ARR2019 Moonee Ponds Creek RORB model are:

- Rural areas initial loss: 28 millimetres
- Rural areas continuing loss: 3.0 millimetres
- Effective impervious areas initial loss: 1.5 millimetres
- Effective impervious areas continuing loss: 0 millimetres

- Indirectly connected areas initial loss: 19.6 millimetres
- Indirectly connected areas continuing loss: 2.5 millimetres

Following the validation of the ARR2019 flows to the ARR1987 flows, the 18.5 % climate change factor was added to the ARR2019 design rainfall.

Table 2 provides a comparison of the peak flows in Moonee Ponds Creek at Flemington Road for ARR1987 and ARR2019.

Table 2 Comparison of peak flows in Moonee Ponds Creek at Flemington Road

Scenario	ARR1987	ARR2019	Change
Existing Climate	217 m^3/s	217 m^3/s	-
18.5 % Climate Change	263 m^3/s	278 m^3/s	+5.7 %

For both ARR1987 and ARR2019, in existing climate and 18.5 % climate change scenarios, the critical storm duration for Moonee Ponds Creek at Flemington Road is the 2 hour event. The higher peak flow in the ARR2019 18.5 % climate change scenario is attributed to the difference in the adopted hydrological losses between ARR1987 and ARR2019.

For the local catchment RORB model the datahub losses were used and for rural areas are:

- Initial loss: 12 millimetres
- Continuing loss: 1.9 millimetres

The local catchment RORB model was originally developed by AECOM and the ARR1987 model was validated at three locations using Rational Method calculations. Use of the Rational Method to validate a model the size of the local catchment is not supported by ARR2019.

It should be noted that while some routed hydrographs are used from the local catchment RORB model, the majority of the outputs that are used from the local catchment RORB model are rainfall excess hydrographs, with routing accounted for in the TUFLOW model. Rainfall excess hydrographs are not dependent on the RORB routing parameter kc. This means that the adopted routing parameter kc in the local catchment RORB model does not have a significant impact on the results of the flood modelling.

There is no available gauge data to use to validate the local catchment RORB model. It was therefore decided to:

- Revise the local catchment RORB model routing parameter kc based on the Yarra and Maribyrnong Catchments regional equation, $kc = 1.19 \times A^{0.56}$
- Use the datahub losses.

The final hydrological parameters adopted for the ARR2019 local catchment RORB model are:

- kc: 4.17
- Rural areas initial loss: 12.0 millimetres
- Rural areas continuing loss: 1.9 millimetres
- Effective impervious areas initial loss: 1.5 millimetres
- Effective impervious areas continuing loss: 0 millimetres
- Indirectly connected areas initial loss: 8.4 millimetres
- Indirectly connected areas continuing loss: 1.3 millimetres

Figure 2 compares the 1 % AEP 2 hour duration hydrographs for ARR1987 and ARR2019 (median temporal pattern) along the Arden Street Drain at Dryburgh Street, for the 18.5 % climate change scenario. The hydrographs show very similar peak flows, but there is a 35 % increase in the volume of the hydrograph in ARR2019 compared to ARR1987.

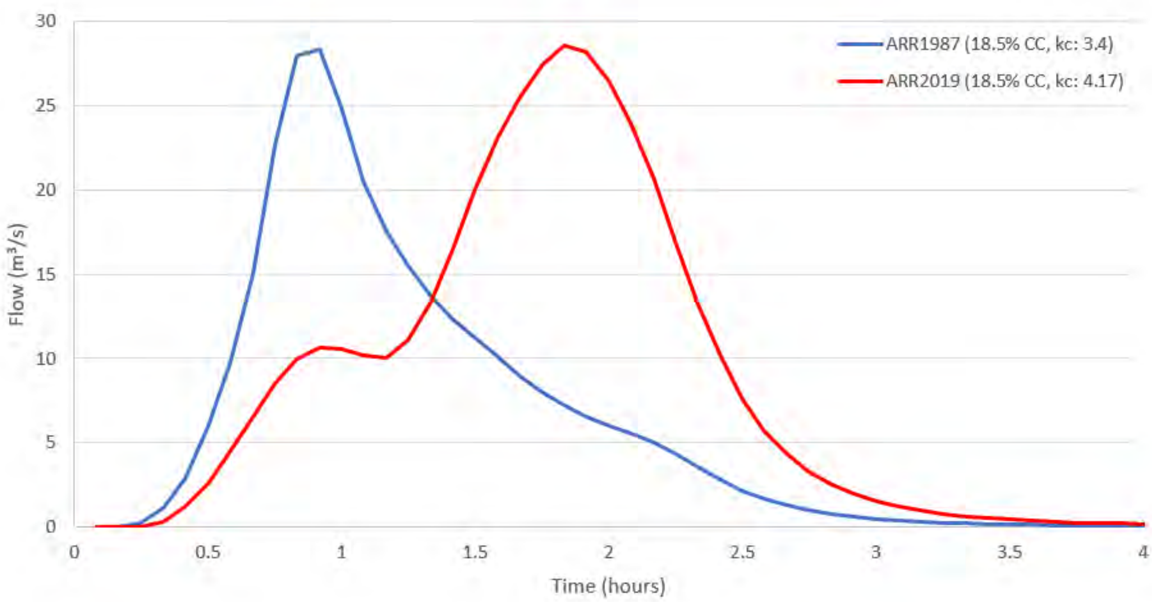


Figure 2 Local catchment RORB model, 1 % AEP 2 hour duration hydrograph comparison along the Arden St Drain at Dryburgh Street

HYDRAULIC MODELLING AND FLOOD MAPPING

Both the ARR1987 and ARR2019 flows identified by the Moonee Ponds Creek and local catchment RORB models have been simulated in the TUFLOW model of the Arden Macaulay Precinct and downstream reach of Moonee Ponds Creek. The setup of the TUFLOW model is identical for ARR1987 and ARR2019, with the exception of reading in different hydrographs. The TUFLOW modelling is based on the six pump stations that service the low lying areas behind Moonee Ponds Creek's levees between Arden Street and Racecourse Road failing to operate. The pump station failure represents the pumps not turning on during the storm event, but that the penstocks that prevent backflow of water from Moonee Ponds Creek into the local drainage system behind the levees still operate.

The downstream end of the flood model is the confluence of Moonee Ponds Creek and the Yarra River. This section of the Yarra River is heavily influenced by the tide level in Port Phillip Bay and this tidal impact extends up through Moonee Ponds Creek.

For both ARR1987 and ARR2019, the TUFLOW model includes a cyclical tide boundary condition in order to represent the dynamic impact of the Port Phillip Bay tide level on flooding within the model extent. The boundary condition is based on a 10 % AEP tide, with an allowance of 0.8 metres of sea level rise. The peak of the cyclical tide is 1.975 m AHD.

The timing of the cyclical tide has been tailored for each duration storm event so that the peak of the tide occurs at the end of the rainfall event. This means that for the 2 hour storm event, the peak tide occurs 2 hours into the model simulations and for the 9 hour event the peak tide occurs 9 hours into the model simulation. While there is some variance between the different storm durations, the adopted approach results in the peak tide level occurring when flows in Moonee Ponds Creek are close to their peak.

The use of a cyclical tide boundary is consistent with the methodology of the other flood models that have been used to delineate the LSIO and SBO through Amendment C384 (where the flood model is influenced by tidal impacts).

For ARR1987, standard storm durations from 10 minutes to 12 hours have been simulated in the TUFLOW model. In general, the critical storm duration is 2 hours and storms longer than 12 hours to do not contribute to critical flooding in the study area. The flood map for the ARR1987 scenario represents a combination of the maximum flood level from the range of the storm durations simulated for the 1 % AEP event.

For ARR2019, all 10 temporal patterns for standard storm durations up to and including 2 hour event have been simulated in the TUFLOW model. For storm durations between 3 hours and 12 hours, a single temporal pattern has been simulated in the TUFLOW model. The temporal pattern was selected by using the RORB model to identify the temporal pattern that results in the median volume of runoff that would overflow Moonee Ponds Creek's levees into the urban areas behind the levees. The flood map for the ARR2019 scenario represents a combination of the maximum flood level from the median peak flood level of storm durations up to 2 hours and the peak flood level of storm durations between 3 hours and 12 hours.

Provided with this memorandum are the following flood maps:

- ARR1987 18.5 % Climate Change Scenario, 1 % AEP Flood Depth
- ARR2019 18.5 % Climate Change Scenario, 1 % AEP Flood Depth
- 1 % AEP Flood Difference – Change in Flooding in ARR2019 Compared to ARR1987

The ARR1987 and ARR2019 flood depth maps show consistency in the areas that are predicted to be flood prone in a 1 % AEP event based on ARR1987 and ARR2019 methodologies.

As shown on the flood difference map, the modelling predicts that in the upstream sections of flow paths ARR2019 generally results in higher flood depths compared to ARR1987. The increase in flood depths is typically less than 100 millimetres, with increases just exceeding 100 millimetres in Moonee Ponds Creek upstream of Flemington Road. This is attributed to the higher peak flows in the ARR2019 18.5 % climate change scenario.

In the low-lying areas of the catchment behind Moonee Ponds Creek's levees north of Macaulay Road, the modelling predicts that peak flood depths in the ARR2019 scenario are also higher than ARR1987. The increase in flood depths in the low-lying areas behind the levees north of Macaulay Road is typically 10-30 millimetres.

As the TUFLOW model simulates the pumps failing to operate, flooding in the low-lying areas behind the levees is influenced by:

- the volume of the local catchment runoff
- the volume of creek flow overtopping the levees.

Figure 3 provides a graph showing the rate of flow spilling over the western levee between Racecourse Road and Macaulay Road. This flow then contributes to flooding in the low-lying area behind the levee along Stubbs Street (flooding in this area is also impacted by flow spilling from Moonee Ponds Creek upstream of Racecourse Road and local catchment runoff). The graph shows that the peak flow overtopping this section of the levee is higher in ARR2019 and there is a slightly higher volume spilling over the levee (the area under the hydrograph), with a volume of approximately 138,000 cubic metres spilling over the levee in the ARR2019 modelling compared to 134,000 cubic metres spilling over the levee in the ARR1987 modelling.

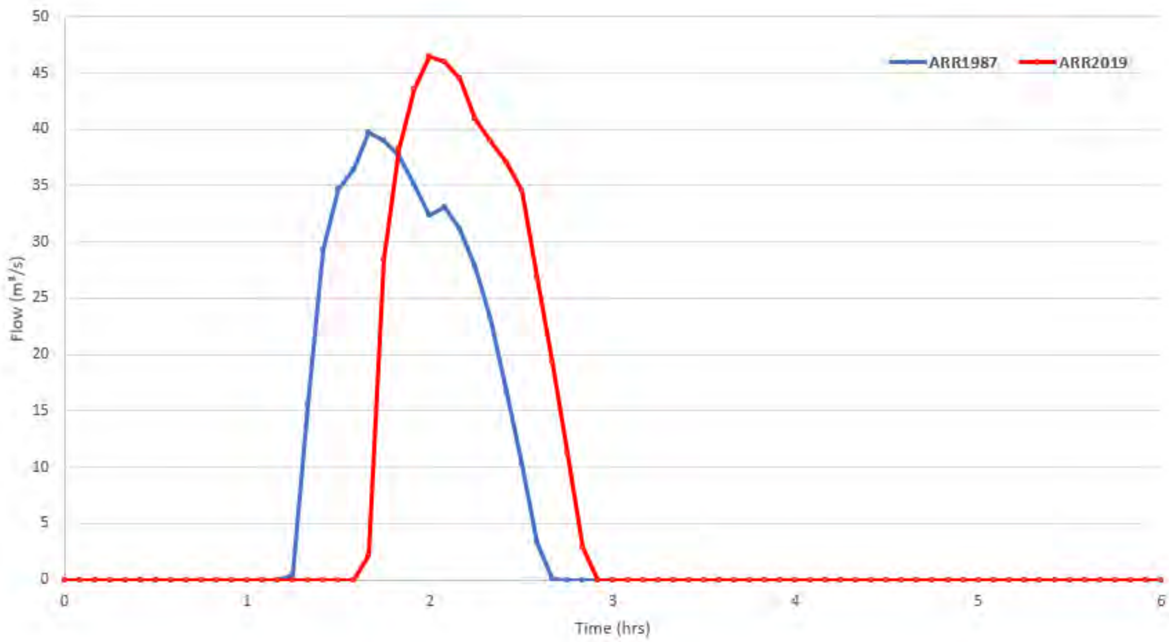


Figure 3 Flow Overtopping Western Levee between Racecourse Rd and Macaulay Rd (1 % AEP 2 hour event, 18.5 % climate change scenario)

In addition to the higher flows from Moonee Ponds Creek entering the area around Stubbs Street, there is also a higher volume of runoff from the local catchment (refer to previous Figure 2).

Along Moonee Ponds Creek and in the low lying areas behind the creek's levees south of Macaulay Road, the modelling predicts that there is a very close match between the ARR2019 and ARR1987 results (typically within +/- 10 millimetres, with an area within +/- 70 millimetres). While there is a higher volume of runoff from the local catchment entering these areas in the ARR2019 modelling compared to the ARR1987 modelling, the peak flows in Moonee Ponds Creek south of Macaulay Road are very similar (within 1 %) and the volume of flow of the Moonee Ponds Creek hydrograph for the 2 hour event is marginally (6 %) less in ARR2019 compared to ARR1987. Results in this area may also be more influenced by the relative timing of peak flows in the creek and the peak tidal level.

SUMMARY

Based on the analysis summarised in this memorandum, the key conclusions are as follows:

- A comparison of 1 % AEP design rainfall depths between ARR1987 and ARR2019 for standard storm durations for the Moonee Ponds Creek catchment shows that the difference is within +/- 6 %. It should be noted that a change in rainfall depth is unlikely to result in the same change in flooding due to the different temporal patterns and approach to hydrological losses between ARR1987 and ARR2019.

- When the Moonee Ponds Creek RORB model was updated to ARR2019 with the datahub hydrological losses, a considerable increase in peak flows at Flemington Road occurred (from 217 m^3/s in ARR1987 to 245 m^3/s in ARR2019 for existing climate conditions). The results of a flood frequency analysis compared well to the ARR1987 peak flow and it was therefore decided that it would be appropriate to adjust the ARR2019 losses so that the ARR2019 peak flow matches the ARR1987 peak flow.

- While the ARR2019 validation means that the existing climate flows are essentially the same for ARR1987 and ARR2019, when the 18.5 % climate change increase in rainfall is added, the peak ARR2019 flow is higher than ARR1987 (278 m^3/s compared to 263 m^3/s). The higher peak flow in the ARR2019 18.5 % climate change scenario is attributed to the difference in the hydrological losses between ARR1987 and ARR2019.

- The modelling predicts that there is a reduced volume of flow (but higher peak flow) in ARR2019 compared ARR1987 for the Moonee Ponds Creek hydrograph for the critical duration storm event (2 hours), but higher volume of runoff in the local catchment RORB model in ARR2019 compared to ARR1987.

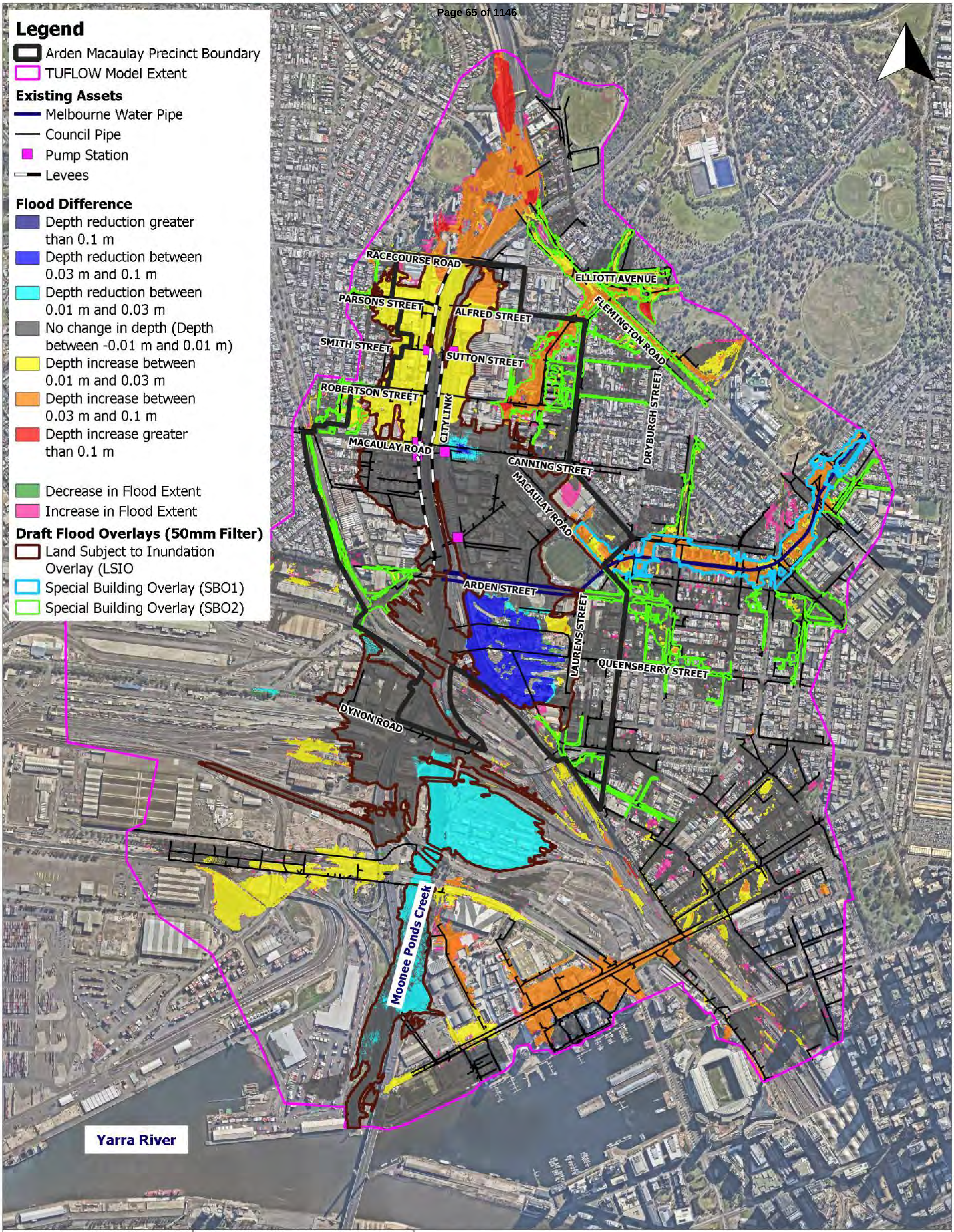
- For the Arden Macaulay Precinct / Moonee Ponds Creek model, there is consistency in the areas that are predicted to be flood prone for the 18.5 % climate change scenario based on ARR1987 and ARR2019 methodologies and the predicted difference in peak flood depths between ARR2019 and ARR1987 is generally within +/- 100 millimetres. As the results of ARR1987 are within reasonable tolerance of ARR2019, Engeny's opinion is that using ARR1987 to delineate the LSIO and SBO for the Arden Macaulay Precinct / Moonee Ponds Creek is acceptable.

- In the areas of the Arden Macaulay Precinct / Moonee Ponds Creek model that are more sensitive to peak flows (free draining overland flow paths), the ARR2019 18.5 % climate change scenario results in slightly higher flood depths (typically within 100 millimetres) compared to ARR1987 18.5 % climate change scenario. This is due to the higher peak flows in the ARR2019 18.5 % climate change scenario compared to the ARR1987 18.5 % climate change scenario. It is reasonable to expect similar results in free draining flow paths in urban areas represented in the other flood models being used define the LSIO and SBO.

- The outcomes of the modelling are less consistent in the areas of the Arden Macaulay Precinct / Moonee Ponds Creek model that are more sensitive to flood volumes (the low-lying areas behind the levees). Areas behind the levees north of Macaulay Road show increased flood depths in ARR2019 (typically within 10-30 millimetres), which is due to higher peak flows overtopping the levees and higher local catchment runoff volumes. Downstream of Macaulay Road, the there is a close match between the ARR2019 and ARR1987 in the low-lying areas behind the levees (typically within +/- 10 millimetres, with an area within +/- 70 millimetres). This is due to the lower volume of the Moonee Ponds Creek hydrograph in ARR2019 and potentially due to the relative timing of peak flows in the creek and the peak tidal level.

RECOMMENDATION

Based on the sensitivity analysis, which shows that the results of ARR1987 are within reasonable tolerance of ARR2019 for the Arden Macaulay Precinct / Moonee Ponds Creek model, Engeny believes that it is acceptable to use ARR1987 to update to the extents of the LSIO and SBO in the City of Melbourne Planning Scheme through Amendment C384.



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ENGENY

Melbourne Water

250 0 250 m

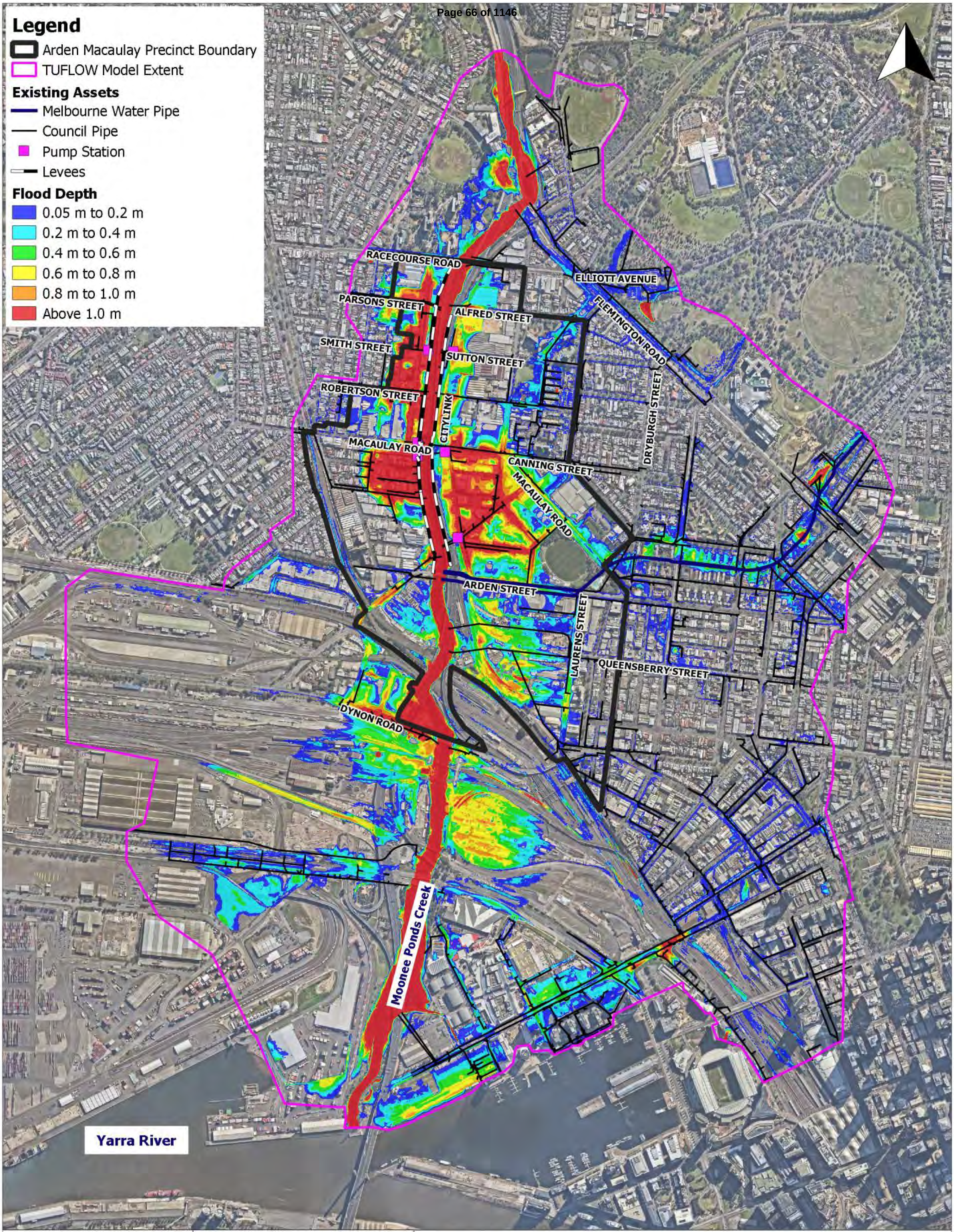
Scale in metres (1:12500@ A3)

Map Projection: Tranverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

City of Melbourne Flood Overlays

Figure 1
1 % AEP Flood Difference (ARR2019 Minus ARR1987)
Cyclical Tail Water Level (10% AEP Sea Level Rise)
Pump Failure, 18.5% CC

Job Number: V3000_111
Revision: 0
Drawn: ML
Checked: PC
Date: 5/6/2020



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City of Melbourne Flood Overlays

1 % AEP Flood Depth (ARR1987)
Cyclical Tail Water Level (10% AEP Sea Level Rise)
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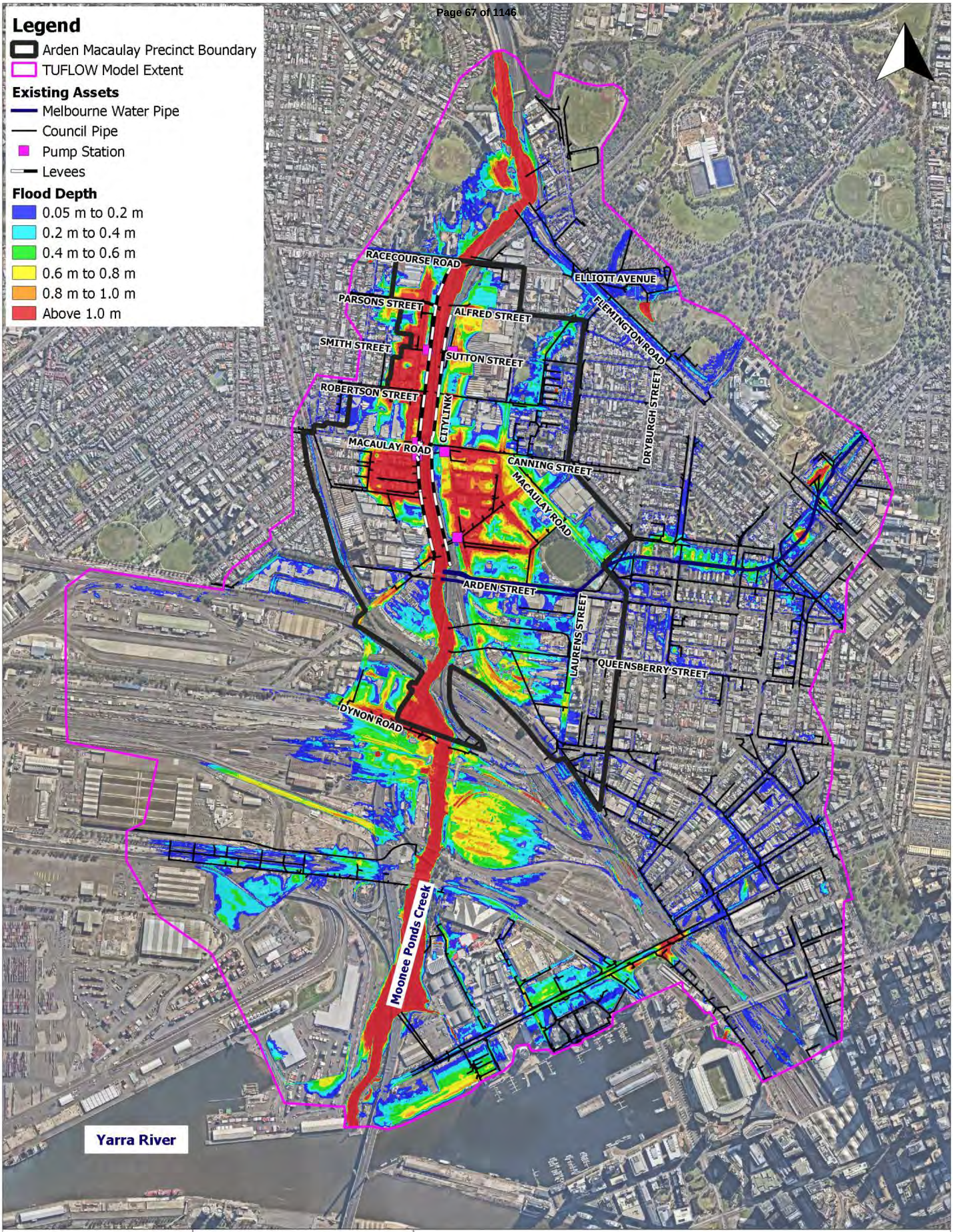

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City of Melbourne Flood Overlays

1 % AEP Flood Depth (ARR2019)
Cyclical Tail Water Level (10% AEP Sea Level Rise)
Pump Failure, 18.5% CC

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Revision: 0
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Date: 5/6/2020

MEMORANDUM

To	Kate Berg (City of Melbourne)	From	Julian Skipworth
Copy	Luke Cunningham and Rianda Mills (Rain Consulting)	Reference	30005 CityOfMelb Southbank TUFLOW Modelling
Date	21 April 2020	Pages	9
Subject	Southbank Flood Modelling Update and Climate Change Scenarios		

Dear Kate,

Water Modelling Solutions was been contracted by City of Melbourne and Melbourne Water to update the City of Melbourne Southbank TUFLOW model and model a number of climate change scenarios. The scope of works for this project included:

1) Reviewing the existing RORB and TUFLOW models for adequacy of use and noting any recommended changes
2) Updating the model in accordance with approved changes following the review
3) Creating new hydrological outputs from RORB based upon increasing the rainfall intensity by 18.5% and converting to ts1 format for input into TUFLOW
4) The inclusion of updated Yarra River tailwater conditions based on the 2019 Lower Yarra River Flood Study (GHD) for both existing and climate change scenarios
5) Running the existing conditions scenario for the 1% AEP event, and climate change scenarios for the 1%, 2%, 5%, 10% and 20% AEP events for a full range of storm durations.

A range of improvements were implemented into the TUFLOW model following a review of the model and approval by City of Melbourne and Melbourne Water and these are described below.

The project deliverables are attached with this memorandum and include gridded and vector results for the range of modelled events. A Shapefile is also attached which contains a polygon of the recommended “Limit of Mapping” for the outputs.

1 HYDROLOGY

The existing Southbank RORB model was available for use and used to generate rainfall excess design hyetographs with an 18.5% increase in rainfall intensity representing climate change scenarios. ARR1987 rainfall was adopted which is consistent with other City of Melbourne flood mapping projects completed or under completion across the municipality.

The existing (i.e. today’s climate) RORB results for the 1% AEP event were used to model the 1% AEP existing rainfall scenario and was not modified from the original RORB output files. The RORB model and output files have been included as a deliverable for the project.

2 TUFLOW MODEL UPDATES

Following a review of the TUFLOW model and with the approval of City of Melbourne and Melbourne Water a range of updates were made to the Southbank TUFLOW model. Key findings from the review and adopted changes that were implemented are summarised in the following sections.

Most changes were minor in nature and adopted in order to bring the model in accordance with best modelling practice and ensure consistency. Other changes such as new hydrology inputs and changing the tailwater boundary conditions were required to incorporate the new climate change scenario.

2.1 TCF REVIEW

The comments and changes to the TCF file are summarised below.

Item	Comment	Updates to Model
Model Build	TUFLOW Classic was used for the original modelling, the model version used was not available.	Adopted the latest version of TUFLOW Classic (2018-03-AE).
Timestep	A timestep of 0.5s was used in the original modelling and has been adopted for this project.	A timestep of 0.5 seconds was retained.
Precision	Double precision will be adopted. This is consistent with the Melbourne Water technical specifications for flood modelling which recommends double precision be used when the rainfall excess approach using TUFLOW SA polygons set to ALL is adopted	Double precision adopted.
Check MI Save Date	This could be changed from OFF to warning.	Changed to warning.
Outputs	Results could be better organised by giving each scenario and event a separate folder in the form results\<<s1>>_<<e2>>_<<e1>> etc. Currently all results are written to the same folder.	Each scenario given its own result directory when output from the model to make navigating the results easier.

2.2 TEF REVIEW

The comments and changes to the TEF file are summarised below.

Item	Comment	Updates to Model
New Event	New tidal condition to be added for Climate Change scenario.	"Yarra10y2019" event added as tailwater condition in the Yarra River for Climate Change.
End Times	Generally, the end times look fine. However, the 72hr storm has an end time of 72hrs. May need to be extended a couple of hours to ensure peak is reached, although the difference will be minimal and only relevant for areas which are purely volume-dependent and have a large storage volume available. All other longer duration end times have an extra two hours beyond the length of the storm.	Changed end time for 72hr storm to 74hrs for consistency.

2.3 ECF REVIEW

The comments and changes to the ECF file are summarised below.

Item	Comment	Updates to Model
1D Timestep	1D timestep of 0.25 timestep is lower than minimum 1D timestep of 0.5 s according to Melbourne Water guidelines.	1D time step changed to 0.5 second and resulted in no change to mass error.
Entry/Exit Losses	A form loss of 0.2 was applied to one pit layer but not to the others. No inlet and outlet losses had been applied to pit entry/exits.	0.2 form loss removed as unnecessary. A total entry/exit loss of 10 applied for side entry pits as per Melbourne Water guidelines.
Contraction Losses	The input layer **1d_nwke_WEL_E01_pipe_009.mif** had a width contraction loss of 0.9 applied. The other two pipe network layers that make up the 1d network of the model domain have no contraction loss applied which is inconsistent.	0.9 contraction losses removed from the pipes that had these losses applied.
1d_bc Boundary Condition	Due to varying tidal level with the new tidal level ascii's the 1d_bc boundary initial water levels connected to the pipes draining to the Yarra River cannot be set at a constant value. A more efficient solution is to convert those boundaries to 1D/2D SX boundary ensuring the pipes discharge into the Yarra River.	1d_bc layer removed and pipes connected via 1d/2d SX lines to the 2D domain allowing them to discharge into the Yarra River.

2.4 TBC REVIEW

The comments and changes to the TBC file are summarised below.

Item	Comment	Updates to Model
2d_bc layer	The 1d_bc boundary condition based on an initial water level for the pipes draining to the Yarra was removed due to a varying tidal level. It was considered best to connect the pipes with 2d SX connections.	2d_bc with 2d SX connections for pipes draining to the Yarra River was added.

2.5 TGC REVIEW

The comments and changes to the TGC file are summarised below.

Item	Comment	Updates to Model
Grid Size	The existing model grid cell size was 3 metres which is acceptable for the purpose of the modelling.	3 meters was retained and is consistent with Melbourne Water guidelines.

DEM Files	It is noted that the model reads in three DEM files, which haven't been provided with the supplied model files.	Files were subsequently provided as 1.5m DEM Z check files. These were manually edited to remove a number of -50 mAHD values on the periphery of the DEM.
Terrain	Some artificial depressions were noted in the terrain data in locations where there are presently high-rise buildings, and caused ponding of water. Likely a result of poor processing and filtering in the original LiDAR dataset.	Larger depressions were filled in using a Z shape to interpolate across using the MERGE ALL option.
IWL	Grids were provided for initial water level and tailwater conditions based on the 10% AEP flood event in the Yarra and the 10% AEP + sea level rise which are to be used for downstream tailwater conditions for the existing and climate change scenarios.	In some areas the provided Yarra IWL grids didn't match in well with the Southbank model topography resulting in some minor instabilities early in the model run. To improve this situation, water levels were allowed to settle, and once settled the resulting Yarra water level was extracted and used as a revised model IWL grid. This process was repeated for both existing and CC scenarios.

2.6 TMF REVIEW

The comments and changes to the TMF file are summarised below.

Item	Comment	Updates to Model
Roughness Values	The value for a water surface (applied to the Yarra River which is modelled as a standing body of water) is somewhat higher than would be expected at 0.045. A more typical value would be around 0.025 to 0.03. Given this area is the outfall of the model it won't have a significant impact on the results.	Roughness value for water bodies (Yarra River) reduced to 0.03.

2.7 OTHER COMMENTS

Some other general comments are made below:

Item	Comment	Updates to Model
Model Approach	It is noted that the modelling is based on a "rainfall excess" approach and applied in TUFLOW using a "rainfall to the kerb" approach. The rainfall excess approach refers to excess rainfall hyetographs being extracted from RORB and applied to SA polygons in TUFLOW. The "rainfall to the kerb" approach refers to rainfall being applied to SA polygons along the road kerbs and is an approach used in heavily urbanised catchments,	The modelling approach has not been altered and is deemed to be appropriate.

	with the assumption that nearly all buildings will be directly connected to the Council and road drainage network.	
Limits of Mapping	It is recommended that when the results are processed and combined with other datasets that they are clipped back to the polygon shown in Figure 3. This polygon is the recommended limit of mapping and ensures any erroneous results in close vicinity to the downstream boundary are removed from the dataset.	It is recommended that the results are clipped to the Limit of Mapping polygon shown in Figure 3 (also provided as a Shapefile).

The TUFLOW model schematisation is shown in Figure 1 and the model terrain in Figure 2.

The recommended limits of mapping are shown in Figure 3 and the Limit of Mapping Shapefile is also attached with this report.

Figure 1 TUFLOW Model Schematisation

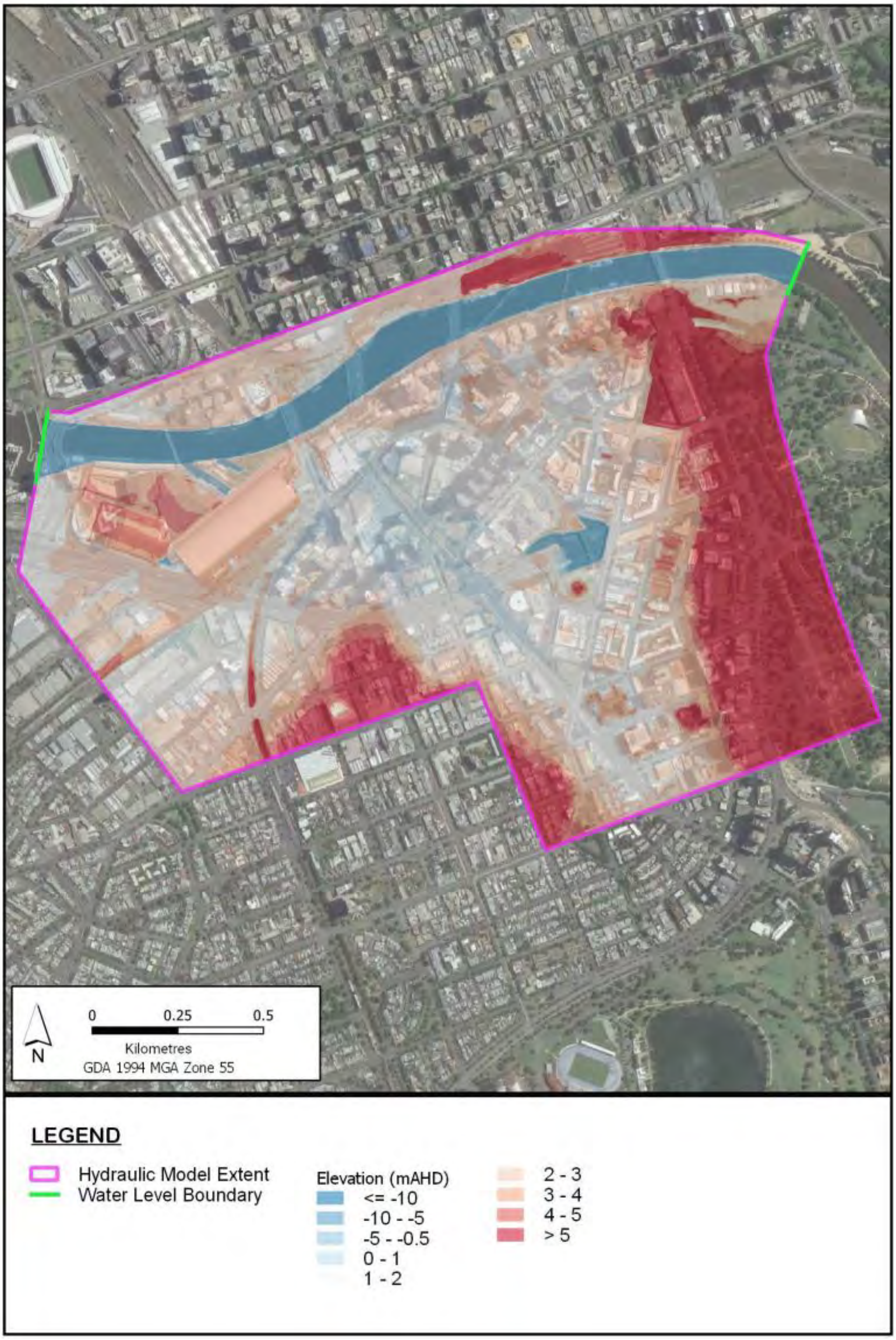


Figure 2 Model Terrain

Figure 3 Limit of Mapping

3 MODELLED EVENTS

The design events modelled were the 1%, 2%, 5%, 10% and 20% AEP storm events for climate change conditions with an 18.5% increase in rainfall intensity. The 1% AEP event was also run for existing conditions. These events were all run for durations of 10min, 15min, 30min, 45min, 1hr, 2hr, 3hr, 4.5hr, 6hr, 9hr, 12hr, 18hr, 24hr, 36hr, 48hr, and 72hrs.

4 DELIVERABLES

The deliverables for this project are:

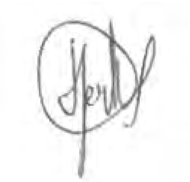
1) The Southbank RORB model and new climate change output files;
2) The updated Southbank TUFLOW model and associated files;
3) Results for the 1%, 2%, 5%, 10% and 20% AEP events for all modelled durations for the Climate Change scenario (18.5% rainfall increase) and the results for the 1% AEP event for the existing case scenario; and
4) Processed maximums for flood heights, depths and velocities for each AEP derived from all the storm durations (climate change and existing conditions).

5 SUMMARY

The Southbank TUFLOW model has been reviewed and updated with some minor changes to ensure constancy with current best practice. Climate Change scenarios have been modelled with an 18.5% increase in rainfall intensity on ARR1987 design rainfall for the 1%, 2%, 5%, 10% and 20% AEP events. The 1% AEP design event has also been modelled for current rainfall conditions.

Please do not hesitate to contact me if you have any feedback or questions.

Yours sincerely,



Julian Skipworth
Regional Manager | Principal Engineer

Southbank Stormwater Infrastructure Assessment: Final Report

Reference: R.M20555.004.01.Final.docx
Date: August 2015

Southbank Stormwater Infrastructure Assessment: Final Report

Prepared for:	City of Melbourne
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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Document:	R.M20555.004.01.Final.docx
Title:	Southbank Stormwater Infrastructure Assessment: Final Report
Project Manager:	Philip Pedruco
Author:	Joel Leister
Client:	City of Melbourne
Client Contact:	Bandara Rajapaske and Vicki Barmby
Client Reference:	RFQ 4509

Synopsis: **Results and finding of the Southbank Flood Mitigation and Stormwater Quality Improvement Opportunities.**

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
0	30/06/2015	PP & DK			
1	21/08/2015	PP	[signature]	JL	[signature]

DISTRIBUTION

Destination	Revision										
	0	1	2	3	4	5	6	7	8	9	10
CoM (electronic)	1	1									
BMT WBM File	1	1									
BMT WBM Library	1	1									

Executive Summary

Aims and Purpose

This study has been commissioned to investigate solutions to the flooding and drainage issues in and around the Southbank precinct. Specifically the aims of the Study are to:

- Define flooding conditions, under existing conditions and also for future conditions
- Map where the drainage network is under capacity
- Develop recommendations for flood management options for the next 15 years.
- Identify the major drainage infrastructure systems required to manage the impacts of climate change until 2100.

Background

The Southbank precinct has a history of flooding with the inundation of private property, interruption to transport links and the flooding of underground car parks. The proximity of the precinct to the Yarra River and its relatively low grounds levels means that Southbank is at risk of flooding from a number of different sources, either individually or in combination. The sources include local drainage, fluvial flooding from the Yarra River and tidal flooding from Port Phillip Bay / the Yarra River. Furthermore, the drainage network can be tide locked by high tides or Yarra River flooding, which can exacerbate the flooding from the local drainage network.

The risk from these sources flooding will increase in the future due to the expected impacts of climate change. These include increased extreme rainfall intensity and sea level rise. Given the quantum of expected increases the relative importance of the source of flood risk will change over time.

Assessment Method

In order to define flooding conditions, now and in the future, a flood model of the entire Southbank precinct was developed. This model accounted for runoff generated from the catchment including an allowance for impermeable surfaces and incorporated all the relevant catchment features such as the pipe drainage network and ground surfaces. It also accounted for tidal levels in the Yarra River. Once this model replicated the existing conditions, allowances for future climates were incorporated in terms of increased rainfall and sea level rise.

One of the key outputs of the flood modelling was flood mapping. These maps were reviewed to identify areas at risk of flooding as well as potential measures to manage flooding. Lists of flood management options were developed and the most feasible of these were incorporated into the flood model to assess their effectiveness. The resulting flood maps were then used to inform recommendations across different time horizons.

Time Horizons

The flood modelling and analysis undertaken as part of this study has shown that there is currently a significant flood risk to the Southbank precinct. Further, this risk will increase into the future due to the expected impacts of climate change. This means that the level of risk and also the predominant source of risk to Southbank will change over time. For these reasons the report has considered three time horizons;

- The current period (0 to 15 years);
- The medium term (15 to 50 years); and
- The long term (50 years and beyond).

Impacts

Current period

Existing flooding behaviour within the Southbank precinct is a result of excessive rainfall within the catchment. Whilst the tailwater level can impact the existing drainage network, significant disruption will only occur in conjunction with heavy rainfall. The existing flood depths are shown in Figure 1, the existing flood depths represent the 1 in 100 year ARI flood level under mean sea level conditions.

The medium term

As sea levels start to rise, the flooding behaviour within the Southbank Precinct will progressively worsen due to the influence of the tailwater on the catchment's ability to discharge stormwater runoff. As the tailwater levels increase over time, consideration will need to be given to drainage network upgrades. In its current configuration medium to small rainfall events will not be able to drain from Southbank due to these high tailwater levels leading to regular flood events (multiple times a year).

The long term

Flooding under a future climate scenario within the Southbank precinct is dominated by the tailwater conditions in the Yarra River. Under the future climate scenario, the 2100 storm surge level will be greater than the current Yarra River 1 in 100 year ARI flood level. This storm surge level will result in flooding of the Southbank Promenade, although the flooding will not extend into the Southbank Precinct. The increased tailwater levels compromise the ability of the underground drainage network to function as designed, resulting in large ponding of floodwaters within the precinct. Flood events would occur regularly, with outfall to the Yarra River being tide locked on a daily basis. Without significant investment this regular flooding will significantly hamper the day-to-day function of Southbank. The 2100 flood depths are presented in Figure 2 for the future mean sea level condition.

Recommendations

Current period

In the current period source control measures are effective in reducing flood levels at both a local and regional scale, whilst pipe augmentation works are able to provide localised flooding benefits.

Source control measures can readily incorporate features which contribute to pollutant reduction and provide a source of harvestable water.

It is recommended that opportunities for incorporating source control measures into public space are sought. For instance, any significant redevelopment in the precinct, such as the Southbank Boulevard, will incorporate source control measures.

For sites being developed or significantly redeveloped it is recommended that a Site Integrated Water Cycle Management Plan is developed that assesses and incorporates source control measures where feasible.

To enable the CoM to implement these recommendations, planning controls will be utilised. These controls will either set a requirement for developers or trigger a referral to the appropriate CoM division.

While the above measures will contribute to the overall management of flood risk from rainfall, maintenance of existing assets as well as new assets must be considered. The outlets to the Yarra River are particularly important. The flooding modelling has demonstrated the impacts of failure of these outfalls. To manage this, these should be regularly inspected. Further, it is recommended that an automated system that monitors the status of the outfall is investigated.

The medium term

Source control measures will continue to be effective in the medium term and it is recommended that these measures are continued with. However, it is expected that flooding due to the tide locking of the outfalls will become more frequent during this period. To manage this, it is recommended that a fully pumped drainage system is investigated. A fully pumped drainage system will be required as the drain outfalls will regularly be below the Yarra River levels. The investigation into this system should commence well in advance of the required delivery. The reason for this is that obtaining the relevant land for pumping stations will be difficult and the likely costs will be significant.

The long term

In the long term the largest source of flood risk is the increased levels in Port Phillip Bay translated upstream into the Yarra River. Managing this source of flood risk will require significant capital works across local government area boundaries and involving multiple state government agencies.

The form of these capital works is likely to be hard defences such as sea walls or a tidal barrage or a combination of the two. Given the scale of these works, in terms of investment and the potential impacts, it is recommended that a feasibility study is carried out at an early stage. This feasibility study should contain an economic assessment, such as a Real Options Analysis, that considers the phasing and timing of works.

Title:

Southbank
100 Year ARI Peak Flood Depth - MSL

Figure: 1

Rev: A

N

0 125 250m
Approx. Scale

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Title:

Southbank - Climate Change +15%
100 Year ARI Peak Flood Depth - MSL

Figure: 2

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\SBK_Final_FigES-2_100y_MSL_C01+15%_dmax_RevA.WOR

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List of Tables

1 Introduction

BMT WBM was commissioned by the City of Melbourne (CoM) to undertake the Southbank Stormwater Infrastructure Assessment (the Study). The objective of the Study was to investigate potential solutions to alleviate flooding in and around the Southbank precinct while contributing to Council's overall water management strategy.

The Southbank precinct is located in inner Melbourne, on the southern bank of the Yarra River (as shown in Figure 1-1).

1.1 Background

The Southbank precinct has a history of flooding with the inundation of private property, interruption to transport links and the flooding of underground car parks in the recent past. The proximity of the precinct to the Yarra River and its relatively low ground levels (in comparison to the Yarra River) means that the drainage network is regularly compromised by high tides, which often exacerbate the flooding experienced in the catchment.

Two of the most severe flooding hotspots within the City of Melbourne occur at Queens Bridge Street and the intersection of Whiteman Street and Clarendon Street, both of which are part of the Southbank precinct. Recent rainfall events in Melbourne, including the rainfall between Sunday 10th May 2015 and Wednesday 13th May 2015 have shown how susceptible the Whiteman Street/Clarendon Street intersection in particular is to flooding.

Previous studies undertaken in the catchment have looked at understanding and solving localised flood risks. These studies have included:

- Normanby Road Pump Station Project (Draft Report), Halcrow (2008)
- Flood Alleviation Study – Queens Bridge Street, Cardno (2015)
- Wells Street Flood Mitigation & Stormwater Quality Improvement Opportunities, BMT WBM (2015)

1.2 Report Purpose/Aims

The purpose of the Study is to investigate solutions to the flooding and drainage issues in and around the Southbank precinct. These solutions are primarily associated with WSUD treatments, whereby stormwater is stored near to where it is generated, rather than being conveyed to a main drain system.

This report documents the three stages of the Study which characterises the existing flood risk within the Southbank precinct, presents the benefits of the proposed opportunities to reduce flood risk within the catchment and demonstrates how future climate conditions and management practices will impact the flood risk of the catchment in the future.

Title:

Southbank Stormwater Infrastructure Assessment
Site Location Plan

Figure: **1-1**

Rev: **A**

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2 Date Collation

The initial phases of the investigation involved data gathering, site visits and preliminary analysis together with flood modelling. These are tasks are described below.

2.1 Data Gathering

As part of the Study, datasets and information were obtained from a variety of organisations as outlined below.

Previous Studies

The CoM provided a number of previous reports that focussed on drainage issues within the Southbank precinct, including:

- Normanby Road Pump Station Project (Draft Report), Halcrow (2008)
- Flood Alleviation Study – Queens Bridge Street, Cardno (2015)

GIS Datasets

The CoM supplied the GIS layers listed in Table 2-1 and an extract of their MapBase system showing all properties in the Southbank precinct as well as LiDAR data of the area.

Table 2-1 List of supplied GIS layers

Carriageway	Retaining Wall
Drainage Pipe	Shrub Bed
Drainage Pit	Tramway
Footpath	Tree Plot
Kerb Channel	Turf
Median	Water Feature
Nature Strip	Wharf
Recreational Surface	

2.2 Site Visit

A number of informal site visits were undertaken between 16th March 2015 and 30th April 2015 to characterise the catchment in addition to regular inspections of the catchment using aerial photography. During these site visits a number of observations were made. Key observations are outlined below.

Catchment Topography

The catchment extends to the Domain and St. Kilda Road in the east, South Wharf in the west, the Yarra River to the North and Dorcas Street, Kingsway and the Westgate Freeway in the south as indicated in Figure 2-1[1]. The catchment generally flows in a north-westerly direction towards the Yarra River, however, there are a number of localised low points where floodwaters pond prior to

[1] Delineation of the catchment boundary is discussed in Section 3.1 below.

discharge into the Yarra River. Most notably, these low points occur at the intersection of Whiteman Street and Clarendon Street, and along Queens Bridge Street. Both of these sites have a history of flooding.

Development

The catchment is fully developed with a mixture of high density residential, retail, office, industrial and other commercial premises many of which are multistorey developments. There is some limited public green space within and in the vicinity of the catchment, as well as green space within private property. During the site visits a number of significant land uses were noted, including,

- The State Emergency Service - 168-172 Sturt Street;
- Victoria Police Mounted Branch – 13-39 Dodds Street;
- Metropolitan Fire Brigade Station No. 38 – 26 Moray Street
- Victorian Institute of Forensic Medicine – Moore Street
- ABC Southbank Studio – 120 Southbank Boulevard
- Crown Entertainment Complex (and associated hotels) – Whiteman Street
- Melbourne Exhibition and Convention Centre – Clarendon Street (carpark access via Normanby Street)

Additionally, a number of major transport links are present in the Southbank precinct, some of which have a history of disruption due to flooding, including,

- Clarendon Street,
- City Road;
- Queens Bridge Street; and
- Tram Routes 1,12, 55, 96 and 109

Numerous underground car parks were also noted in the area as well as near ground level floor levels.

All of these factors significantly increase the flood risk in the catchment.

Drainage Features

While it was not possible to inspect underground drainage infrastructure a number of features were observed during the site visits and noted following conversations with Council Staff:

- Numerous grated drainage pits partially full with debris (particularly leave debris); and,
- Backflow preventers are installed on the drainage outlets adjacent to Queens Bridge Street and Clarendon Street (Hanna Street Main Drain and Council Drain) to prevent high water levels in the Yarra River flowing into the drainage system.

Title:
Southbank Stormwater Infrastructure Assessment
Southbank Precinct Catchment

Figure: 2-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 7.5 15km
Approx. Scale

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3 Current Condition Analysis and Modelling

The preliminary analysis of the catchment involved catchment delineation, rainfall-runoff modelling using RORB, 1D-2D linked hydraulic modelling using TUFLOW.

3.1 Catchment Delineation

The catchment and sub-catchments were delineated from the supplied LiDAR data (using the software program Encom Discover). The resulting catchment and sub-catchments were trimmed to property boundaries where appropriate as shown in Figure 3-1.

Initial review of the catchment boundary demonstrated that the three largest landholders within the catchment were Victoria Barracks, the Crown Entertainment precinct and the Melbourne Convention and Exhibition Centre. Combined, these three property holders account for approximately 15% of the available land within the study area.

3.2 Rainfall-runoff Modelling

A RORB rainfall-runoff model was developed for the catchment in accordance with the Flood Mapping Guidelines and Technical Specification (Melbourne Water, 2012). The layout of the RORB indicating the sub-catchment breakdown is shown in Figure 3-1.

BMT WBM has previously developed a RORB model of the Wells Street catchment (BMT WBM, 2015) and this model is entirely enveloped by the RORB model developed for the Southbank precinct.

In the absence of recorded calibration data the Wells Street RORB model was calibrated to the Rational Method as outlined in Australian Rainfall and Runoff (ARR, 1987). GHD (2011) has previously determined Rational Method calculations for the Wells Street catchment and these values have been adopted for the Wells Street Study (Refer to BMT WBM, 2015, for more details). In order to maintain consistency between the Wells Street Study and the current Southbank Study, the same loss parameters were adopted and the k_c/d_{av} relationship between the two RORB models was maintained. This approach ensured that consistent hydrology was adopted between the Wells Street and Southbank studies.

The critical storm duration (the storm resulting in the peak flow rate) varied throughout the catchment. Consequently, a range of flood durations (ranging from 10 mins to 6 hours) were simulated. The critical storm durations are shown in Table 3-1 and the corresponding peak discharges are shown in Table 3-2.

Table 3-1 Critical Storms for the Southbank Precinct

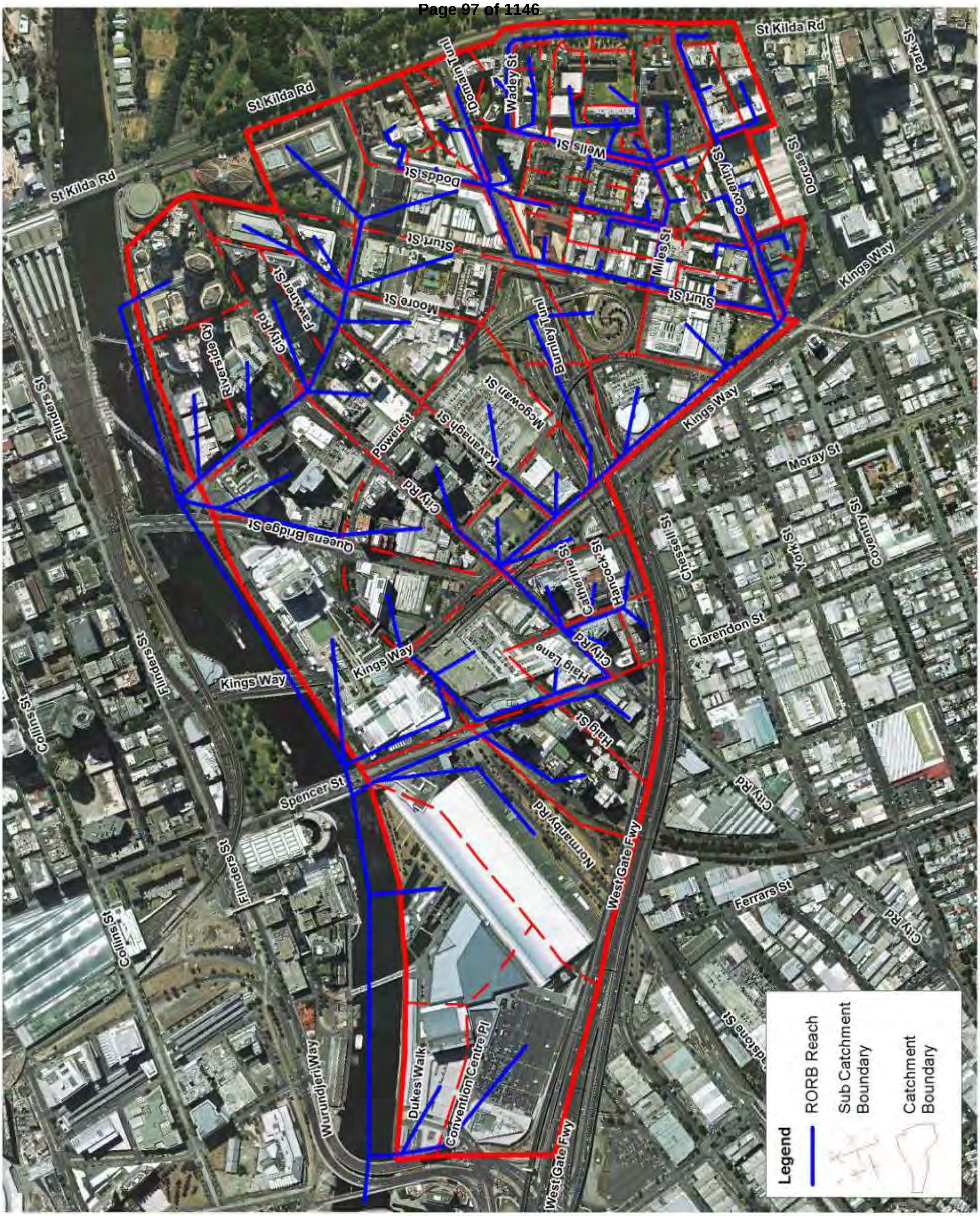
	Clarendon Street Outlet*	Southbank Boulevard Outlet	Queens Bridge Street Outlet
Critical Duration	2 hour	1 hour	25 minute

* Contribution of the Southbank precinct catchment only

Table 3-2 Peak Discharges for the Southbank Precinct

ARI	Clarendon Street Outlet* (m^3/s)	Southbank Boulevard Outlet (m^3/s)	Queens Bridge Street Outlet (m^3/s)
100y	5.8	4.3	1.4
50y	4.9	3.6	1.2
20y	3.9	2.9	0.9
10y	3.2	2.3	0.7
5y	2.6	1.9	0.6

* Contribution of the Southbank precinct catchment only



Title:
Southbank Stormwater Infrastructure Assessment
Southbank RORB Model Layout

Figure: 3-1

Rev: A

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3.3 Hydraulic Modelling

A 1D-2D linked hydraulic TUFLOW model of the catchment was developed in accordance with the Flood Mapping Guidelines and Technical Specification (Melbourne Water, 2012). The floodplain topography and other significant hydraulic features were represented within the 2D domain. The underground drainage system was represented as a 1D network in the hydraulic model.

3.3.1 TUFLOW model description

The TUFLOW model covered the entire catchment to its multiple outlets along the Yarra River, as shown in Figure 3-2. The 2D domain was developed using a 3 m grid resolution based on the LiDAR elevation data provided by CoM. The model was extended beyond the study area to ensure any boundary influences were not evident in the study area.

The drainage information supplied by the CoM was used to represent the underground drainage network. In many instances the drainage information did not have pipe inverts. In agreement with the CoM these missing inverts were infilled by assuming a minimum cover (0.45m) and minimum pipe grade (1 in 2000).

Inflow boundaries were taken from the RORB model (refer to section 3.2). These inflows were distributed throughout the catchment to ensure a realistic flow distribution. Inflows were, in general, applied to roads as the LiDAR data filtered out buildings and therefore the ground levels are not considered reliable, particularly in dense urban environments such as the study catchment. An external inflow was applied for the Hanna Street Main Drain which originates to the south of the catchment (in the City of Port Phillip). The external inflows were from the TUFLOW modelling previously undertaken for the City of Port Phillip by URS.

Water was removed through an external boundary representing the Yarra River. Due to the relatively short storm durations being modelled, a static level in the Yarra River was applied. The influence of the Yarra River level is assessed through a range of river conditions that will, to varying degrees, inhibit the ability of the catchment to drain.

Title:

Southbank Stormwater Infrastructure Assessment
TUFLOW Model Setup

Figure: 3-2

Rev: A

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0 125 250m
Approx. Scale

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3.3.2 Hydraulically Modelled Events

The hydraulic model was run for the 5 year through to the 100 year Average Recurrence Interval (ARI) flood events with durations from 15 minutes through to 6 hours. Additionally, a number of downstream boundary (Yarra River) conditions were assessed. These downstream boundaries are summarised in Table 3-3.

Table 3-3 Yarra River Boundary Conditions

Boundary Condition	Yarra River Level (mAHD)
Mean Sea Level (MSL)	0
Highest Astronomical Tide (HAT)	0.52
100 Year ARI Storm Surge Level	0.9
Yarra River 100 year ARI Flood Level	1.6

3.3.3 Results

The TUFLOW model produced geo-referenced datasets defining peak water depths and levels throughout the catchment. The peak value from each of the 10 modelled storm durations for each event were selected for each computational cell to generate an envelope of peak flood level and peak flood depth. The data were imported into GIS to generate a digital model of the flood surface and flood depth.

The resulting peak flow depth maps are presented in a series of figures over the following pages for each of the modelled flood events and for each boundary condition. These maps show increasing flood extents and flood depths from the 5 year ARI event through to the 100 year ARI event as expected.

The summary below is based upon the results using the Mean Sea Level as the downstream boundary condition.

5 year ARI

In the 5 year ARI event results (Figure 3-3) there is inundation of a number of streets with ponding of water occurring at the following locations:

- Coventry Street
- Wells Street
- Dodds Street
- Sturt Street
- Southbank Boulevard
- Queens Bridge Street
- Clarendon Street
- Whiteman Street
- City Road

10 year ARI

The pattern of inundation in the 10 year ARI event (Figure 3-4) is similar to that of the 5 year ARI event, with all inundated areas and flow paths enhanced. In particular, flooding begins to encroach on a large number of private properties. Flooding at known hotspots is deeper and more expansive.

20 year ARI

The pattern of inundation in the 20 year ARI event (Figure 3-5) is similar to that of the 10 year ARI event, with all inundated areas and flow paths enhanced. In particular, flooding further encroaches on a large number of private properties. Key roads are now entirely inundated, potentially resulting in road closures and tram disruptions.

50 year ARI

The pattern of inundation in the 50 year ARI event is similar to that of the 20 year ARI event (Figure 3-6), with all inundated areas and flow paths further enhanced. Flooding at key locations is now quite deep resulting in road closures and tram disruptions. Access to buildings and carparks may be compromised resulting in short term isolation of business and residents.

100 year ARI

Large areas of the Southbank precinct are inundated to a depth that will cause significant disruption to those living, working and travelling in the region (Figure 3-7). Access to private and public facilities will be compromised, resulting in potential isolation as well as resulting in the closure of major traffic routes through the precinct.

Other boundary conditions

The existing condition flood depths maps for the other tailwater scenarios have been included in Appendix A.

In comparison to the MSL results, those using the Highest Astronomical Tide (HAT) result in slightly deeper flood depths due to the higher tailwater level compromising the ability of the drainage network to drain effectively.

The models which use the 1 in 100 year ARI storm surge event as the tailwater result in significantly more expansive flooding in the Southbank precinct. These high water levels in the Yarra River severely restrict the drainage systems ability to drain effectively resulting in a significant ponding of flood waters in the known low points of the catchment.

The results for those models using the Yarra River 1 in 100 year ARI flood level as tailwater levels results in significant flooding throughout the Southbank precinct. However, these results need to consider the likelihood of coincident occurrence, that is, how likely is it that the 1 in 100 year ARI Yarra River flood event peak at Southbank would occur at the same time as the 1 in 100 year ARI storm event in Southbank. This particular event is considered extremely unlikely. On-the-other-hand, the coincident occurrence of the 1 in 100 year ARI Yarra River flood event peak at Southbank with the 1 in 5 year ARI storm event in Southbank is far more likely.

These types of problems are known as joint probability problems. To correctly understand the resulting flood risk form the Yarra River and stormwater flooding in Southbank occurring together would require this analysis.

For the purposes of this report, the probability of the 1 in 100 year ARI Yarra River flood event peak at Southbank with the 1 in 5 year ARI storm event in Southbank are considered to be rarer than the 1 in 100 year ARI event.

3.3.4 Summary of Existing Flooding Conditions

A summary of the existing flood conditions (number of properties flooded and peak inundation depth) is provided in the following tables. Summary tables are provided for each of the five investigated tailwater levels. The results indicated that whilst the overall number of properties inundated is not overly sensitive to the tailwater level, there is greater variance in the peak flood depth on a particular property depending upon the adopted tailwater.

Table 3-4 Existing Properties Flooded – Mean Sea Level

Properties Inundated	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
0 – 0.02 m	47	37	32	26	21
0.02 – 0.05 m	39	46	39	43	38
0.05 – 0.10 m	31	35	43	32	31
0.10 – 0.25 m	48	52	55	70	78
0.25 – 0.50 m	15	16	26	33	37
> 0.5 m	19	22	23	25	28
Total	199	208	218	229	233

Table 3-5 Existing Properties Flooded – Highest Astronomical Tide

Properties Inundated	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
0 – 0.02 m	40	33	28	26	19
0.02 – 0.05 m	42	46	41	43	36
0.05 – 0.10 m	30	31	41	32	30
0.10 – 0.25 m	57	57	60	70	75
0.25 – 0.50 m	17	22	30	33	43
> 0.5 m	22	25	26	25	32
Total	208	214	226	229	235

Table 3-6 Existing Properties Flooded – Storm Surge

Properties Inundated	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
0 – 0.02 m	35	31	24	19	18
0.02 – 0.05 m	36	40	39	36	31
0.05 – 0.10 m	25	27	29	28	30
0.10 – 0.25 m	49	48	55	63	59
0.25 – 0.50 m	40	44	50	55	61
> 0.5 m	28	31	32	35	38
Total	213	221	229	236	237

Table 3-7 Existing Properties Flooded – Yarra River 100 Year ARI Flood

Properties Inundated	5 Year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 Year ARI
0 – 0.02 m	35	28	22	18	18
0.02 – 0.05 m	32	33	32	29	24
0.05 – 0.10 m	26	29	26	25	25
0.10 – 0.25 m	49	50	55	57	52
0.25 – 0.50 m	45	44	50	54	56
> 0.5 m	34	43	50	57	67
Total	221	227	235	240	242

3.3.5 Limitations and suitability

The TUFLOW hydraulic model has been designed to investigate the overland flooding issues in and around the Southbank precinct. The model is suitable for investigating overland flow paths, flood extents and the impact of flood management methods. This model has not been developed to determine flood levels. The mapped flood results presented in the provided figures include areas where buildings have been filtered out of the LiDAR. Where inundation is shown in these filtered out areas it should be considered as indicative only. In these areas, the terrain has been heavily filtered and the resulting DTM does not represent possible flow paths. For instance, there are numerous underground car parks in the area, including along Wells Street, Dodds Street, Whiteman Street and Southbank Boulevard, where water could enter however, these features are not captured by LiDAR. Furthermore, some flow paths are also the result of the filtering process, for instance, the flow path indicated between Kavanagh Street and Fawkner Street.

While, some of the flow paths are considered to be the result of the LiDAR filtering process, the modelled results represent the best available information on overland flow paths throughout the catchment.

Title:

Southbank

5 Year ARI Peak Flood Depth - MSL

Figure: 3-3

Rev: A

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Title:

Southbank

10 Year ARI Peak Flood Depth - MSL

Figure: 3-4

Rev: A

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N

0 125 250m

Approx. Scale

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Title:

Southbank
20 Year ARI Peak Flood Depth - MSL

Figure: 3-5

Rev: A

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Title:

Southbank

50 Year ARI Peak Flood Depth - MSL

Figure: **3-6**

Rev: **A**

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0 125 250m

Approx. Scale

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Title:

Southbank
100 Year ARI Peak Flood Depth - MSL

Figure: 3-7

Rev: A

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Approx. Scale

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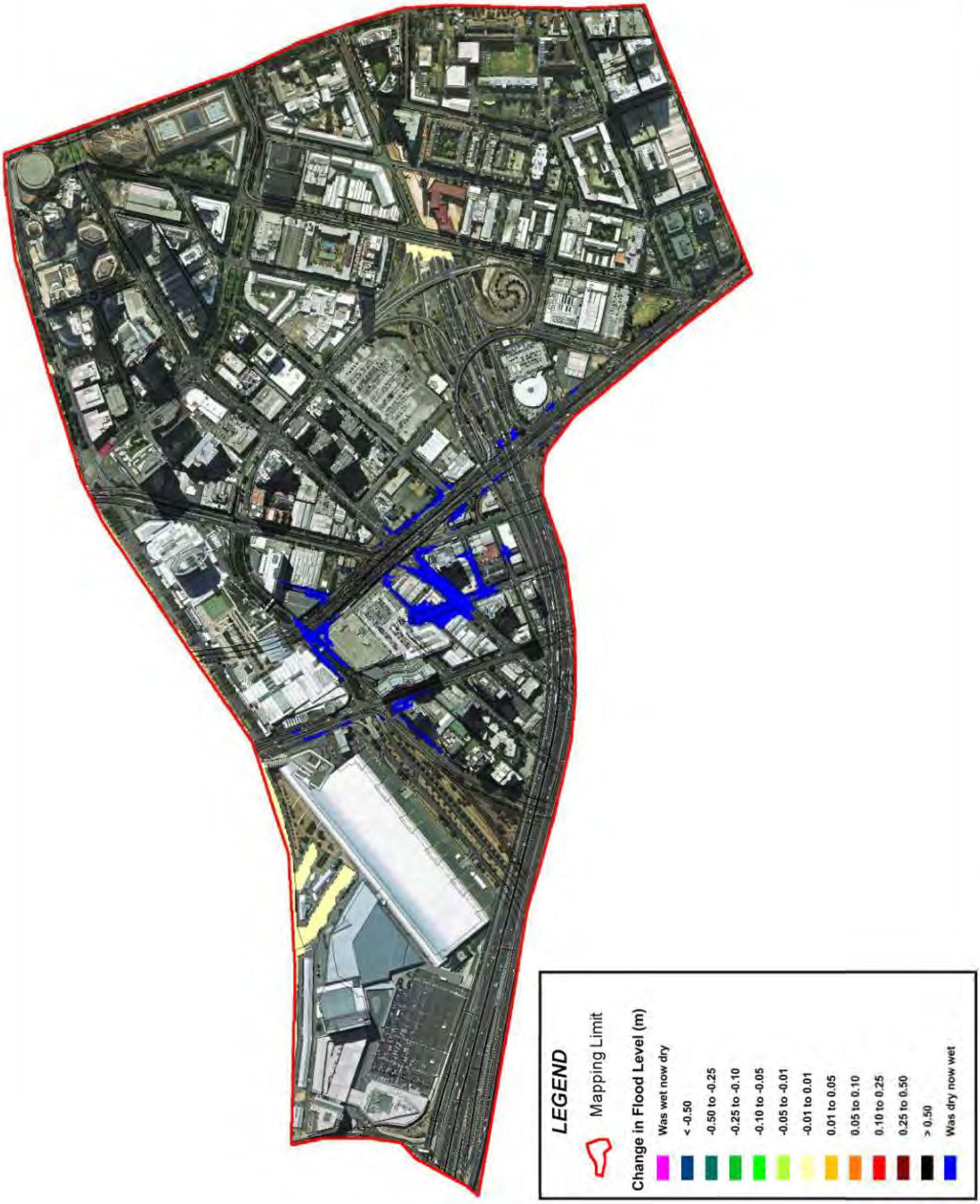
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\SBK_Final_Fig3-7_100y_MSL_dMax_RevA.WOR

4 Impact of Back Flow Preventers (Tide Valves)

There is a number of back flow preventers located on the outfalls from the Southbank precinct to the Yarra River. These back flow preventers are designed to prevent water from the Yarra River entering the underground drainage system and flooding the low lying areas of Southbank (some of which is often below the level of the Yarra River).

Information provided by the City of Melbourne has indicated that historically there have been issues with the operation of the back flow preventers (including on the Queens Bridge Street outfall which had been jammed open by a tree branch). When these back flow preventers do not operate correctly and the Yarra River is sufficiently elevated, flooding of the low-lying areas of the Southbank precinct can occur without any rainfall in the catchment (Figure 4-1 and Figure 4-2). If rainfall were to occur, and the back flow preventers were not operating correctly, the flooding would be greater than the maps presented in Section 3.3.3.

With the expectations of future sea level rise and increased storm surge levels, the operation of the back flow preventers becomes critical in the flood management of the Southbank precinct



Title:

Southbank Precinct - Flood Valve Failure Change in Peak Flood Heights - Storm

Figure: 4-1

Rev: A

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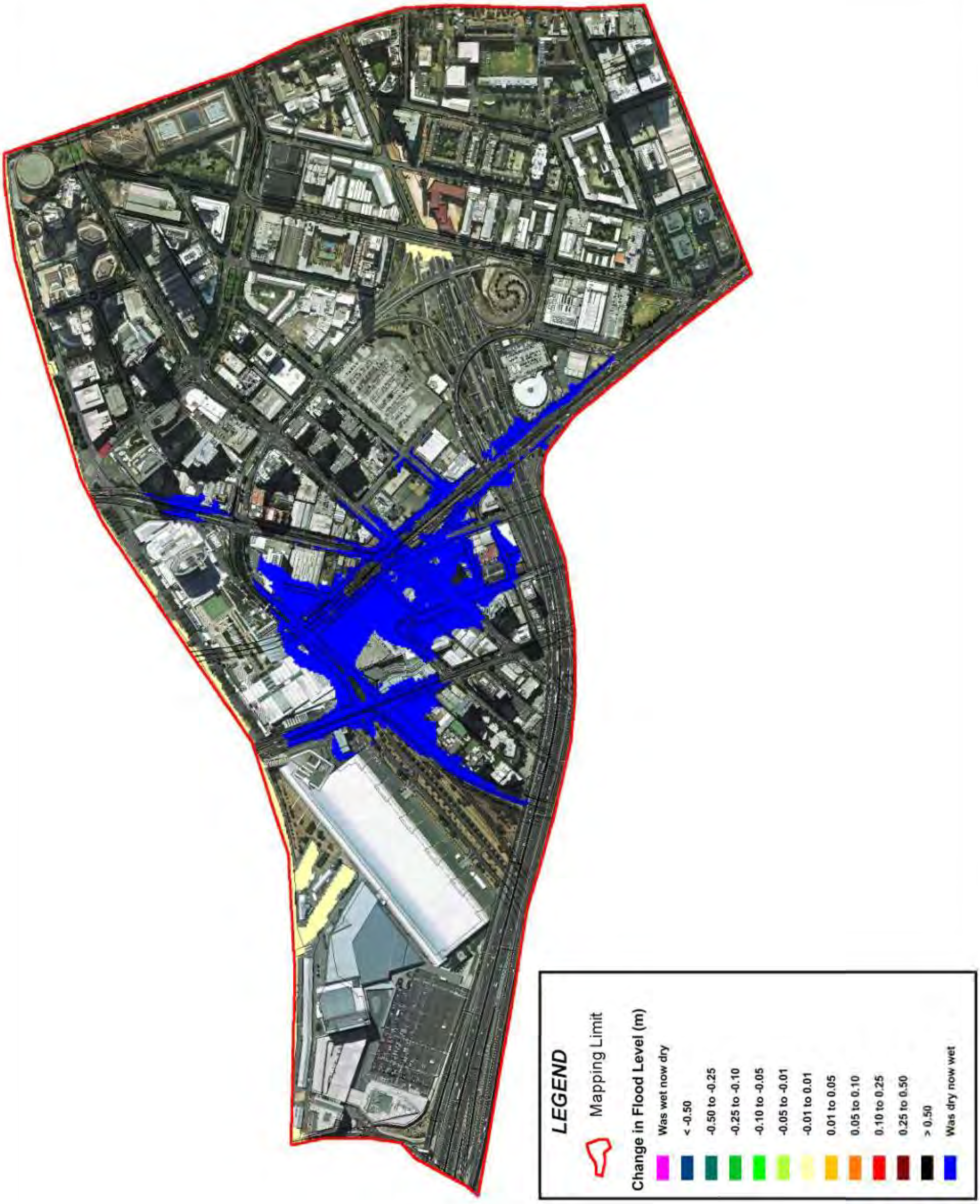


Title:

Southbank Precinct - Flood Valve Failure Change in Peak Flood Heights - Yarra 100y

Figure: 4-2

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\SBK_Final_Fig4-2_FVF_Yarra100y_RevA.WOR

5 Identified Opportunities

A number of opportunities to manage stormwater in the catchment have been identified in the Study. In addition to these opportunities, on-lot solutions with property owners and street scape Water Sensitive Urban Design (WSUD) have also been identified.

Details of each opportunity are discussed below.

5.1 Wells Street Opportunities

A number of opportunities have previously been identified as part of BMT WBM (2015). Whilst BMT WBM (2015) was focussed on the Wells Street precinct, the opportunities identified as part of the previous study have the potential to provide benefits to the broader Southbank precinct. The details of these opportunities are not reproduced in detail in this report; however, they are listed below:

- Victoria Barracks
- VicRoads Power Street Off Ramp Reserve (Power Street Loop)
- Dodds Street Park
- Malthouse Plaza
- Miles and Dodd Street Park
- Sturt Street Reserve
- 252-274 Sturt Street Car Park

5.2 Crown Entertainment Precinct

The Crown Entertainment precinct is one of the largest single land holders within the Southbank precinct. The various sites that constitute the Crown land holding are adjacent to two of the most identifiable flooding issues within the catchment (Whiteman Street/Clarendon Street and Queens Bridge Street). Whilst the site is located at the downstream end of the catchment, there may still be some opportunities to alleviate the local flooding issues.

During the numerous site visits undertaken by BMT WBM, it was noted that there are multiple outlets adjacent to the Clarendon Street Bridge that appear to pump a stormwater discharge into the Yarra River. There may be possibilities to explore the ability to drain additional flood volume from Clarendon Street and Whiteman Street into this existing drainage system.

Figure 5-1 Pumped discharge from the Crown Entertainment Precinct

5.3 Melbourne Exhibition and Convention Centre

Along with Crown Entertainment, the Melbourne Exhibition and Convention Centre (MECC) is one of the largest single land holders in the Southbank precinct. In a similar vein to Crown Entertainment, the MECC is located at the downstream end of the catchment, but is located adjacent to one of the City of Melbourne's most significant flooding hotspots, the Whiteman Street and Clarendon Street intersection. Whilst the site is located at the downstream end of the catchment, there may still be some opportunities to alleviate the local flooding issues.

The use of underground storage tanks (installed in the existing underground carpark) is an option that may be worth further exploration.

5.4 Tram Reserve between Whiteman Street and Normanby Street

The tram reserve between Whiteman Street and Normanby Street in conjunction with the street median along Normanby Street constitutes a relatively large amount of open space at the site of one of Council's most severe flooding issues (Figure 5-2). However, any works in this area would require the cooperation of a number of stakeholders, including Yarra Trams and VicRoads. Despite this, it would be advantageous for Yarra Trams and VicRoads to be involved in any potential flooding solutions as it would improve the reliability of tram services and minimise road closures due to flooding.

Given the size of the open space available, this opportunity has the potential to provide meaningful storage volumes in the context of the flooding issues in lower Southbank precinct.

Figure 5-2 Existing flooding preventing tram routes 96 and 109 (Intersection of Whiteman Street and Clarendon Street)

5.5 Southbank Boulevard

The City of Melbourne is already planning a revitalisation of Southbank Boulevard. The incorporation of WSUD features into the planned changes along Southbank Boulevard will help to alleviate the flooding issues in and around Southbank Boulevard. WSUD features to explore include on-site detention, street scale rain gardens, infiltration and porous pavements.

5.6 93-115 Kavanagh Street Car Park

The site at 93-115 Kavanagh Street is understood to be privately controlled and currently used as a car park. The surface is completely impermeable and the sub-surface is likely to be contaminated. Due to the nature of the site and likelihood of future development, it is impractical to explore this site further at this stage.

However, such a large scale potential development would provide the CoM with an opportunity to work hand-in-hand with a future developer to implement a series of on-site stormwater management initiatives. Such initiatives could be in the same vein as those currently proposed for the Fishermans Bend developments.

5.7 1-25 Queens Bridge Street

The site at 1-25 Queens Bridge Street is understood to be privately controlled and currently earmarked for redevelopment. Redevelopment of key strategic sites in the Southbank precinct offer unique opportunities for the City of Melbourne and private developers to collaborate on Integrated Water Cycle Management (IWCM) and/or Water Sensitive Urban Design (WSUD) techniques which have the potential to benefit not only the proposed development, but also assist the City of Melbourne in addressing a key flooding concern (Queens Bridge Street)

5.8 Queens Bridge Square / Southbank Promenade / Riverside Quay

The Queens Bridge Street Square (Figure 5-3) and Southbank Promenade area is at the lower end of the catchment, although it is adjacent to some of the frequent stormwater flooding issues within the Southbank precinct (Queens Bridge Street and the lower end of Southbank Boulevard). Along with the planned works to Southbank Boulevard, opportunities exist to explore WSUD features in the Queens Bridge Street Square/Southbank Promenade area. Any works could be difficult to initiate due to the close proximity to the Yarra River, however, the potential benefits in reducing flooding along Queens Bridge Street mean that this option is worth exploring.

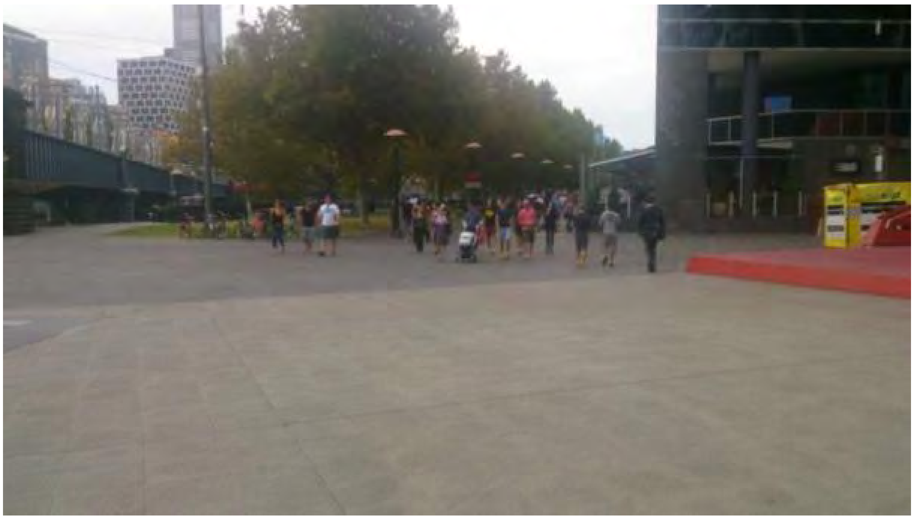


Figure 5-3 Queens Bridge Street Square

5.9 Whiteman Street

The relatively wide median that exists along Whiteman Street (Figure 5-4) provides some opportunities for WSUD features to be incorporated. The lowering of the median strip will facilitate further infiltration and low levels of on-site detention that will help to alleviate the flooding issues along this part of the catchment. Such works could be extended further upstream to the land underneath the Kingsway Overpass (adjacent to Hannah Street). This land is not well utilised and could provide opportunities as it is located along the alignment of the Hanna Street Main Drain.

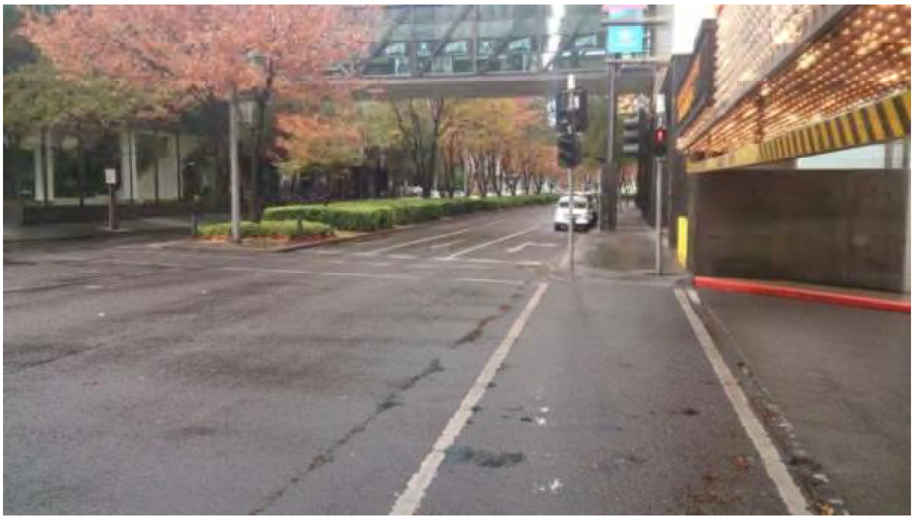


Figure 5-4 Whiteman Street

5.10 On-Lot Works to Private Property

Land ownership in the catchment is likely to be with a diverse set of stakeholders, including government agencies, private companies, body corporates and individuals. This would mean that a complex consultation process would be required to engage with this diverse set of land owners. Further, as shown in Figure 3-1 there is a significant area of open space in the control private landowners with a range of uses. This means that there would need to be a range of stormwater management solutions with many of them being bespoke adding to the complexity of the solution.

A further complication is that of providing an incentive to landowners. While there will be an incentive for those directly affected by flooding, other landowners would require some sort of incentive. These incentives could be:

- An amendment to the planning scheme;
- Development of environmentally sustainable design guidelines for the catchment;
- Enforcement of a clause similar to clause 56 of the Victoria Planning Provisions; or
- Provision of an economic incentive.

5.11 Streetscape WSUD

There are a large number of streets (in addition to Southbank Boulevard) within the Southbank precinct that are wide enough to consider street scape WSUD features. Street scape WSUD or linear parks could provide storage for stormwater such as Power Street and Sturt Street. Such measures would incorporate similar features to those currently proposed in CoM projects near North Melbourne Railway Station and Kensington Railway Station.[2]

[2] http://www.theage.com.au/victoria/underperforming-roads-to-be-ripped-up-and-turned-into-parks-20150507-ggwl9r.html

5.12 Pipe Augmentation Works

In addition to the WSUD treatments, some drainage issues will require a traditional solution consisting of pipes and constructed drains. The Clarendon Street and Whiteman Street intersection has been a focus of the previous study to determine whether a pumped pipe solution could alleviate flooding in this localised region. An augmented pipe solution along Clarendon Street is one such option that could provide benefits for the local area.

6 Modelled Opportunities (Current Conditions)

This section details the impact on flooding of each of the options identified for the Southbank precinct. These options included:

- Water Sensitive Urban Design storages at Victoria Barracks and the Power Street Loop
- Storage Tanks at the Crown Entertainment precinct and Melbourne Exhibition and Convention Centre
- Infiltration Measures along Southbank Boulevard, Whiteman Street and Normanby Road
- Storage tanks for the proposed development at 93-115 Kavanagh Street
- Augmented pipe along Clarendon Street (from Normanby Road to the Yarra River)

The performance of the concepts was tested in the existing case hydraulic model to ensure that they were able to achieve optimal flood alleviation outcomes. The performance of the concepts in terms of water quality improvements and potential harvestable water was not investigated as part of this report.

6.1 Wells Street Opportunities

For details of the Wells Street Opportunities, please refer to the Final Report for the Wells Street Flood Mitigation and Stormwater Quality Improvement Opportunities Project (BMT WBM, 2015) Key elements of the opportunities have been reproduced in the sections below. In summary, these opportunities include:

- Victoria Barracks
- VicRoads Power Street Off Ramp Reserve (Power Street Loop)
- Dodds Street Park
- Malthouse Plaza
- Miles and Dodd Street Park
- Sturt Street Reserve
- 252-274 Sturt Street Car Park

6.1.1 Victoria Barracks

A review of the Victoria Barracks site indicates that there are a number of opportunities for stormwater intervention measures, including three car parking areas and the existing tennis courts. The concept for Victoria Barracks was to use the three car parks to temporarily store local runoff as well as an underground tank under the tennis courts. Stormwater treatment could also be undertaken in these areas.

In addition to providing flood alleviation for the Wells Street catchment, the proposed Victoria Barracks works would provide a water quality benefit and, potentially, a source of harvested water.

The following four sites within the Barracks have been investigated. Two options at each site have been assessed, one incorporating only storage, and the other WSUD elements. These are listed in Table 6-1.

Table 6-1 Option Descriptions

Site	Description
Tennis Courts	Detention tank under tennis courts
	Stormwater harvesting tanks used for re-use
Car Park 1	Porous paving with detention.
	Porous paving with detention and incorporation of vegetated WSUD features.
Car Park 2	Porous paving with detention.
	Porous paving with detention and incorporation of vegetated WSUD features.
Car Park 3	Porous paving with detention.
	Porous paving with detention and incorporation of vegetated WSUD features.

6.1.2 Power Street Loop

The Power Street Loop is one of the largest parcels of open space in and around the Wells Street catchment and it currently has some form of drainage function. In this concept, the Power Street Loop could be developed so to temporarily store water assisting the alleviation of flooding in and around Wells Street.

TransUrban have recently undertaken a design competition for this site indicating a desire to develop the space. It is understood that the winning entry had no allowance for water storage purposes.

The Power Street Loop has an area of approximately 14,000 m^2, a portion of which could be used as a storage. This storage could be a wetland or a harvesting pond. Ponding flood water on Dodds Street would be directed, by the construction of a new 120 m underground drainage pipe, from Wells Street through the car park at 86-90 Dodds Street to the loop. It is of note that the car park already has an existing spoon drain. Alternatively, the existing underground drainage network could be augmented to convey water to the reserve.

Initial calculations indicate that lowering a portion of the loop to 0.5 mAHD (from existing levels around 1.5 mAHD) would provide a storage volume of approximately 900 m^3. With the invert of the storage at 0.5 mAHD there is sufficient grade and cover for a pipe from Dodds Street.

Alternatives to this option are outlined below; however, from a flood alleviation perspective these have not been explored as part of this study as these options will not provide significant flood alleviation benefit. These alternative options do, on-the-other-hand, have additional water quality and harvesting benefits which were investigated. These alternatives involve capturing local runoff and diverting frequent flows to the storage area.

The first of these options would involve pipework to divert local runoff to the new pipe between Dodds Street and the loop. This would provide a harvestable area of 2.5 ha.

The second option would require significant work to the existing drainage system to divert flow to the storage in the loop. The reason for the significant work is that the invert of the Sturt Street pipes appears to be around -0.2 mAHD (at this time no information about the pipe inverts is available). This option would therefore require, either raising the pipe, pumping or another form of engineering solution. This option would have a harvestable area of 8.3 ha.

These options would have the advantage of:

- Reducing flood depths in the Wells Street catchment; and
- Providing water for harvesting.

At this stage the storage in the Power Street loop has been conceptualised as a storage pond. This storage could also be a wetland or other type of storage.

6.2 Storage Tanks (Crown Entertainment Precinct and MECC)

Individual storage tanks of 215 ML (215 m^3) were included in the basement carparks of both the Crown Entertainment precinct and the Melbourne Exhibition and Conference Centre (MECC). The storage tanks were modelled to be gravity fed from connections made into the existing stormwater system (no new connections to the surface were assumed). Once full the storages would not take any more flow, and discharge was assumed to be after the event had passed either into the Yarra or stored for future extraction. Controls would need to be installed so that the tank was emptied in readiness when a storm was forecast.

6.3 Infiltration Measures (Southbank Boulevard, Whiteman Street and Normanby Road)

The various proposed infiltration measures (along Southbank Boulevard, Whiteman Street and Normanby Road) consisted of infiltration storages of 0.3 metres depth. These infiltration storages were sized based on the existing (Whiteman Street), proposed (Southbank Boulevard) or potential (Normanby Road) median widths available for the respective treatments.

The water entering these infiltration measures is assumed to not enter the drainage system downstream and will infiltrate the ground (or be extracted for re-use)

6.4 93 – 115 Kavanagh Street

A combination of storage tanks totalling of 590 ML (590 m^3) were included in what will become the basement of the proposed development of 93 – 115 Kavanagh Street. For the purposes of the modelling, these tanks would discharge to the stormwater pipe network post the flood event or stored for on-site water reuse. Controls would need to be installed so that the tank would empty in readiness when a storm was forecast.

The storage tanks were modelled to be gravity fed from connections made into the existing stormwater system (no new connections to the surface were assumed).

6.5 Augment Pipe along Clarendon Street

The existing Council owned and maintained stormwater pipe on the west side of Clarendon Street could be duplicated (with the same diameter and invert levels as the existing pipe). No changes have been made to the side entry pits or their respective inlet capacities and the pipes still discharge directly to the Yarra River via a tide valve. The underground network on the east side of Clarendon Street, including the Melbourne Water Main Drain is not affected by the proposed pipe augmentation. No determination has been made as to whether there is sufficient space to include a duplicated pipe along this alignment.

6.6 Flood Modelling

The concepts outlined above were applied to flood model developed for the Southbank precinct catchment. This section discusses the incorporation of the concepts into the flood model and the results of the flood modelling. The results of the flood modelling have been presented as Flood Impact Maps.

The concepts were tested in the flood model for the same ARI events and durations as the base case modelling. The modelling was undertaken using the MSL tailwater condition. Section 7 considers possible future climate scenarios.

6.6.1 Flood Impact Maps

Flood Impact Maps, are maps that show the change in flood depths between, typically, the existing case conditions and a modelled flood mitigation option. Flood Impact Maps are presented for each modelled option comparing the existing conditions flooding to the modelled options flooding. For each ARI event modelled, peak flood envelopes were prepared that calculate the peak flood level for each of the durations modelled.

In these figures, the pale yellow colour represents nominal change in modelled flood depth within +/- 50mm. Green colours represent a reduction in flood depths, whereas red and brown colours represent increases in flood depth. Areas that are pink are areas that were wet and are now dry in the modelled option, whereas areas that were dry and are now wet are represented as dark blue.

6.6.2 Water Sensitive Urban Design Treatments

This modelling scenario includes all the proposed WSUD treatments (identified in section 6.1 to 6.5) and is used to determine the flood impact/benefit of the proposed WSUD treatments. The mapping presents the impacts of the implementation of a range of identified WSUD treatments throughout the catchment. The treatment measures incorporated in the model include:

- WSUD measures along Southbank Boulevard, Whiteman Street and Normanby Road;
- All proposed WSUD measures from the Wells Street project;
- Storage tanks at MCEC and Crown Casino; and,
- Storage tanks at the proposed development of Kavanagh Street.

6.6.2.1 Discussion of Results

The implementation of the WSUD treatments results in noticeable reductions in flood levels during the 5 year ARI flood event (reductions of more than 0.05 metres) and reductions in the flood extent throughout the Wells Street area and along Southbank Boulevard. Minor reductions are noted downstream of the Kavanagh Street development and near the intersection of Clarendon Street and Whiteman Street.

During the 100 year ARI flood event, widespread flood reductions of up to 0.05 metres are observed throughout the upper portion of the catchment (Wells Street area Southbank Boulevard and along Kings Way).

The reductions observed near the Clarendon Street and Whiteman Street intersection during the smaller flood events are not seen during the larger flood events. However the benefits observed in the upper part of the catchment continue to improve as the flood events get larger.

6.6.2.2 Summary of WSUD Treatments

A summary of the existing flood conditions with the WSUD treatments in place (number of properties flooded and peak inundation depth) is provided in the following tables. Summary tables are provided for each of the four investigated tailwater levels. The summary tables also detail the change (from existing conditions) in the number of properties flooded within each depth band. A negative number indicates a reduction in the number of properties. Whilst there are no significant changes in the number of flooded properties overall, there is a trend that indicates flooding across a reasonable number of properties decreases (in terms of peak flood depth). This would also result in lower flood volumes on each flood affected lot.

Table 6-2 WSUD Treatments Properties Flooded – Mean Sea Level

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	49	2	42	5	34	2	27	1	22	1
0.02 – 0.05 m	39	0	41	-5	42	3	45	2	41	3
0.05 – 0.10 m	35	4	38	3	39	-4	33	1	30	-1
0.10 – 0.25 m	43	-5	47	-5	55	0	69	-1	75	-3
0.25 – 0.50 m	15	0	16	0	25	-1	30	-3	38	1
> 0.5 m	18	-1	21	-1	21	-2	23	-2	27	-1
Total	199	0	205	-3	216	-2	227	-2	233	0

Table 6-3 WSUD Treatments Properties Flooded – Highest Astronomical Tide

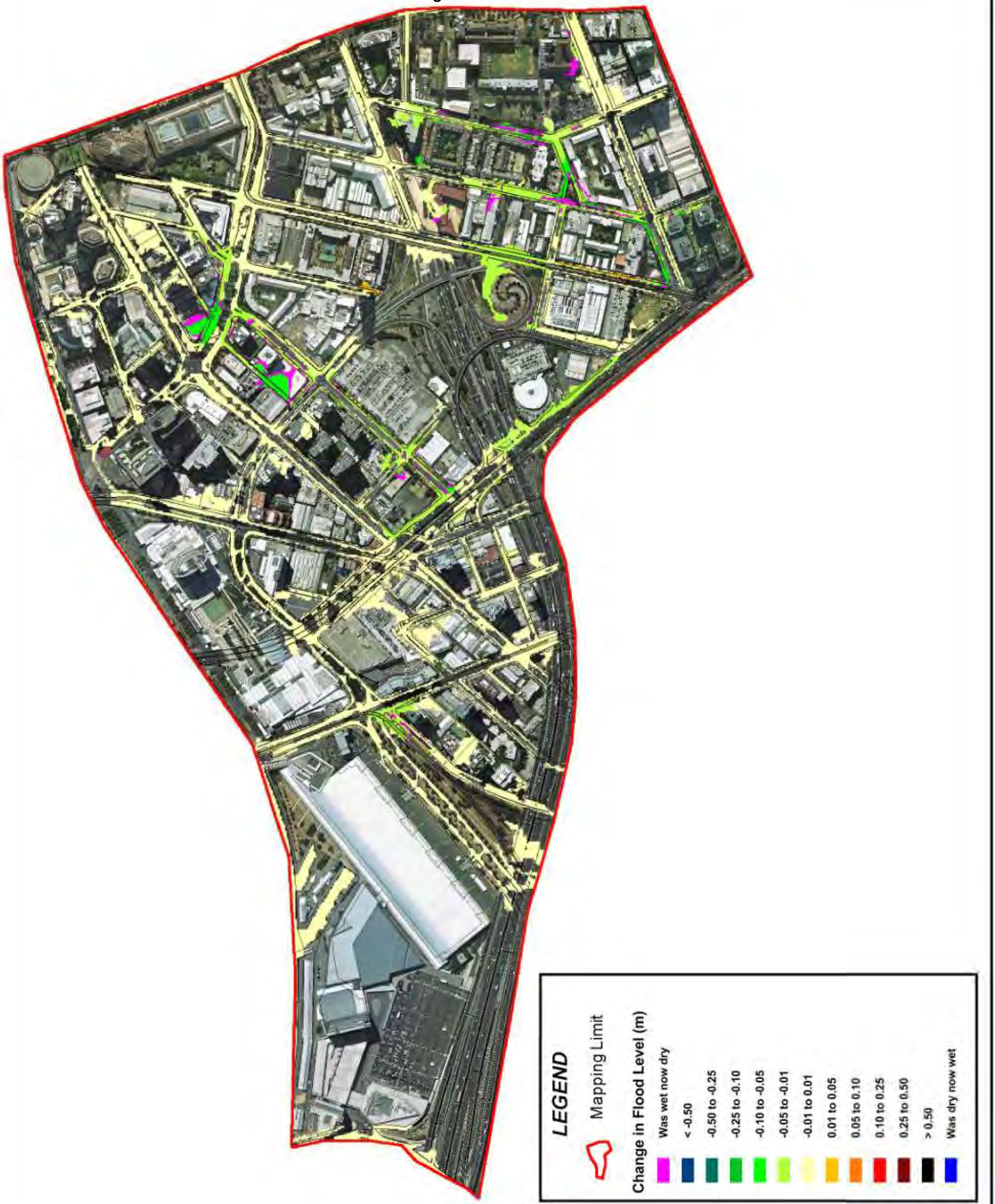
Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	42	2	37	4	33	5	27	1	19	0
0.02 – 0.05 m	42	0	43	-3	42	1	45	2	38	2
0.05 – 0.10 m	33	3	35	4	38	-3	33	1	30	0
0.10 – 0.25 m	53	-4	51	-6	58	-2	69	-1	73	-2
0.25 – 0.50 m	16	-1	22	0	30	0	30	-3	43	0
> 0.5 m	21	-1	24	-1	24	-2	23	-2	32	0
Total	207	-1	212	-2	225	-1	227	-2	235	0

Table 6-4 WSUD Treatments Properties Flooded – Storm Surge

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	37	2	33	2	29	5	21	2	20	2
0.02 – 0.05 m	37	1	37	-3	38	-1	38	2	31	0
0.05 – 0.10 m	26	1	28	1	26	-3	29	1	30	0
0.10 – 0.25 m	45	-4	45	-3	54	-1	58	-5	59	0
0.25 – 0.50 m	41	1	44	0	50	0	55	0	59	-2
> 0.5 m	27	-1	30	-1	30	-2	34	-1	38	0
Total	213	0	217	-4	227	-2	235	-1	237	0

Table 6-5 WSUD Treatments Properties Flooded – Yarra River 100 Year ARI Flood

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	36	1	29	1	25	3	19	1	17	-1
0.02 – 0.05 m	35	3	32	-1	33	1	32	3	25	1
0.05 – 0.10 m	27	1	32	3	25	-1	24	-1	26	1
0.10 – 0.25 m	46	-3	44	-6	54	-1	56	-1	52	0
0.25 – 0.50 m	43	-2	44	0	48	-2	52	-2	53	-3
> 0.5 m	33	-1	42	-1	48	-2	56	-1	68	1
Total	220	-1	223	-4	233	-2	239	-1	241	-1



Title:
Southbank - WSUD
Change in 5 Year ARI Peak Flood Heights - MSL

Figure: **6-1**

Rev: **A**

N

0 125 250m
Approx. Scale

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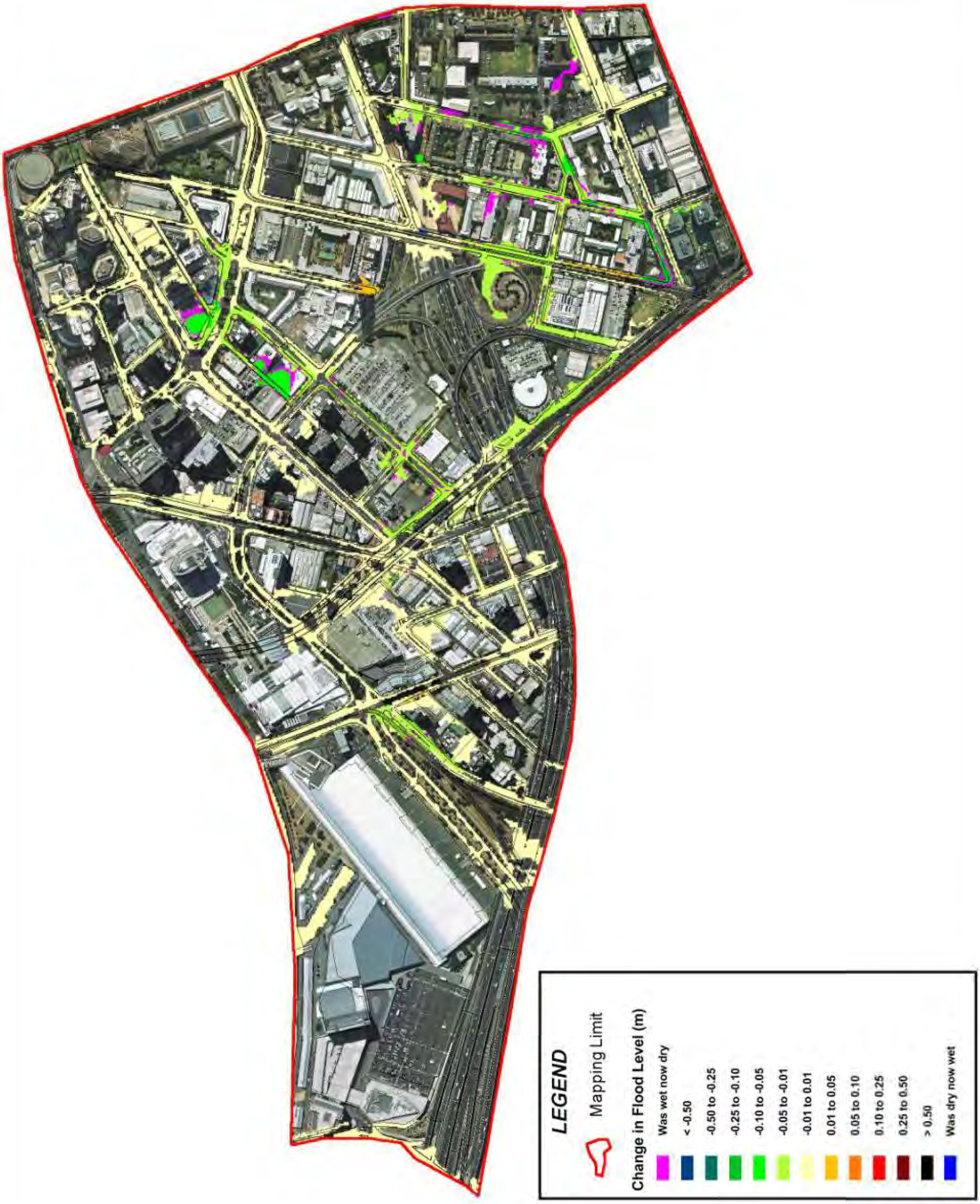
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\SBK_Final_Fig6-1_FldDif_D01_E01_5y_MSL_RevA.WOR



Title:

Southbank - WSUD

Change in 10 Year ARI Peak Flood Heights - MSL

Figure: **6-2**

Rev: **A**

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Approx. Scale

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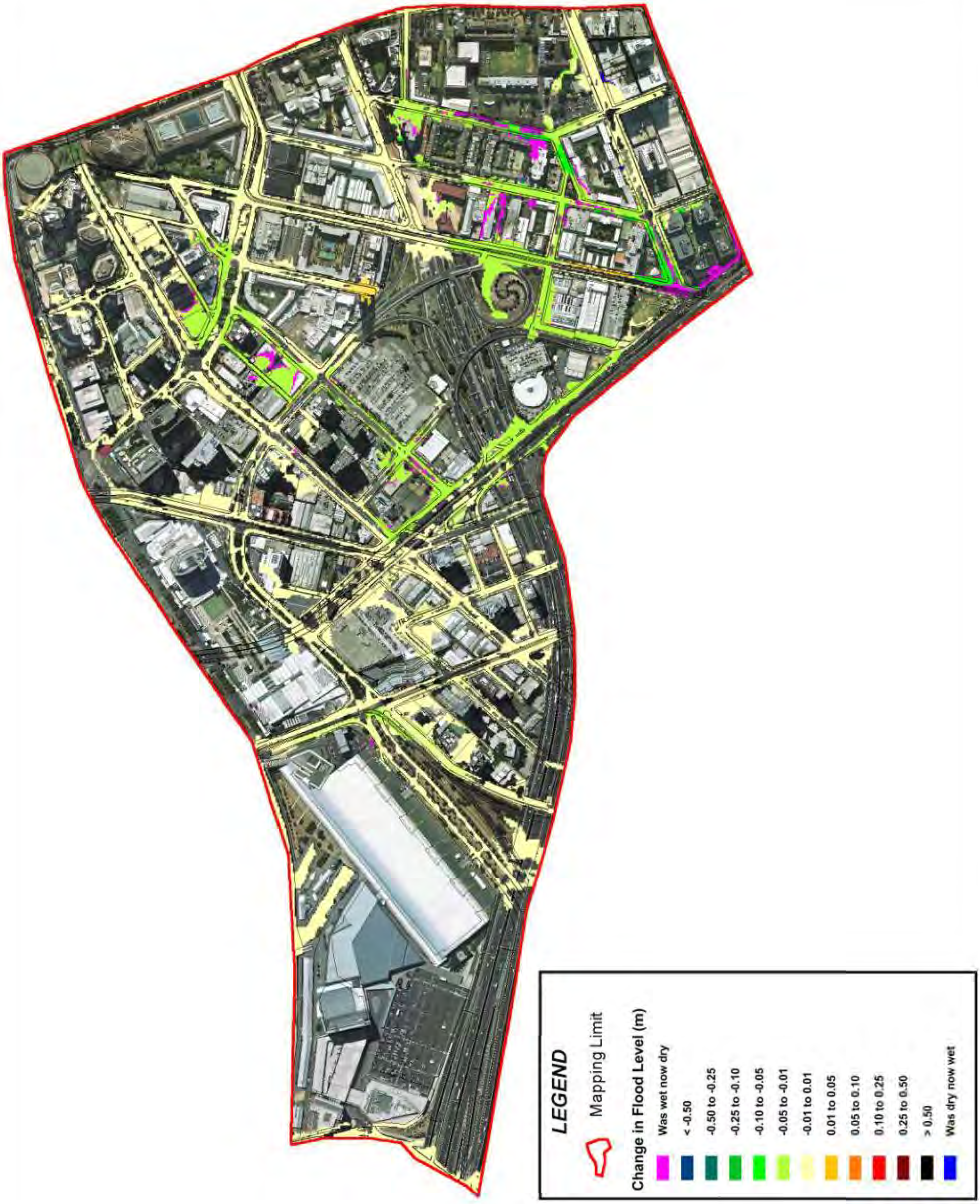

Title:

Southbank - WSUD
Change in 20 Year ARI Peak Flood Heights - MSL

Figure: 6-3

Rev: A

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Approx. Scale

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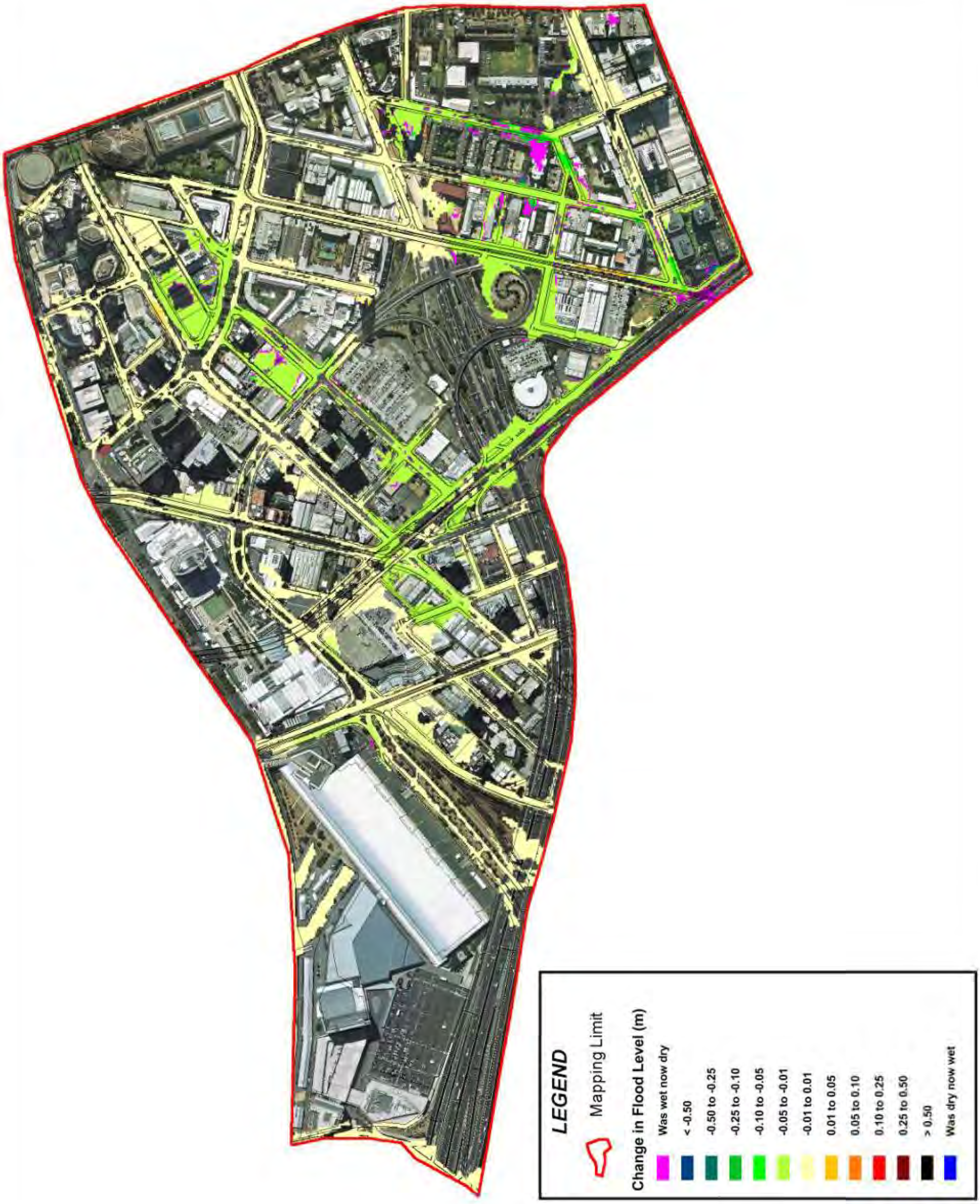
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\SBK_Final_Fig6-3_FldDif_D01_E01_20y_MSL_RevA.WOR



Title:

Southbank - WSUD

Change in 50 Year ARI Peak Flood Heights - MSL

Figure: 6-4

Rev: A

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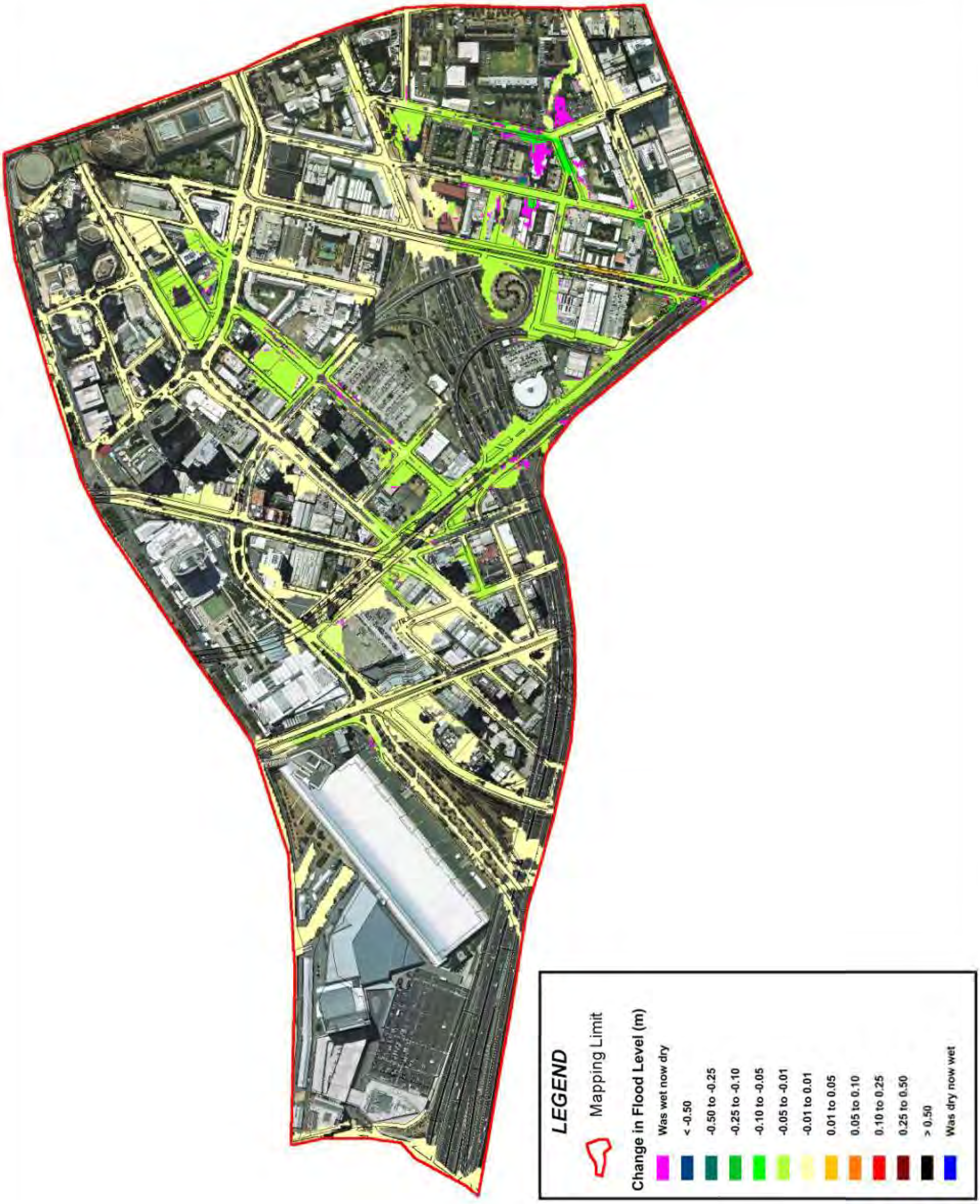

Title:

Southbank - WSUD

Change in 100 Year ARI Peak Flood Heights - MSL

Figure: **6-5**

Rev: **A**

N

0 125 250m

Approx. Scale

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\SBK_Final_Fig6-5_FldDif_D01_E01_100y_MSL_RevA.WOR

6.6.3 Pipe Augmentation

The subsequent flood impact mapping presents the impact of the construction of a duplicated pipe from the intersection of Clarendon Street and Whiteman Street to the Yarra River. The pipe duplication includes the City of Melbourne pipes only and does not impact the Melbourne Water pipe network.

The inverts of the duplicated pipe are identical to the existing pipe network.

6.6.3.1 Discussion of Results

The augmentation of the pipe along Clarendon Street results localised reductions of up to 0.10 metres during the 5 year ARI flood event in and around the Clarendon Street and Whiteman Street intersection. The reductions are confined to the western side of Clarendon Street and include reductions along the tram alignment.

During the 100 year ARI event the mitigation measure does not cause the flood extent to significantly reduce, however there are reductions in flood levels along Whiteman Street (both east and west of Clarendon Street) and south along Clarendon Street. The increase volumes in the large flood events renders the duplicated pipe less effective when compared to the smaller flood events.

6.6.3.2 Summary of Pipe Augmentation

A summary of the existing flood conditions with the pipe augmentation in place (number of properties flooded and peak inundation depth) is provided in the following tables. Summary tables are provided for each of the four investigated tailwater levels. The summary tables also detail the change (from existing conditions) in the number of properties flooded within each depth band. A negative number indicates a reduction in the number of properties.

The results indicate that the presence of the pipe, although delivering benefits to the local area around the Clarendon Street and Whiteman Street intersection, there is no significant change to the depth of flooding of the inundated properties.

Table 6-6 Pipe Augmentation Properties Flooded – Mean Sea Level

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	47	0	37	0	32	0	26	0	22	1
0.02 – 0.05 m	40	1	46	0	39	0	43	0	39	1
0.05 – 0.10 m	30	-1	36	1	44	1	32	0	30	-1
0.10 – 0.25 m	48	0	51	-1	55	0	70	0	77	-1
0.25 – 0.50 m	15	0	16	0	25	-1	33	0	37	0
> 0.5 m	19	0	22	0	23	0	25	0	28	0
Total	199	0	208	0	218	0	229	0	233	0

Table 6-7 Pipe Augmentation Properties Flooded – Highest Astronomical Tide

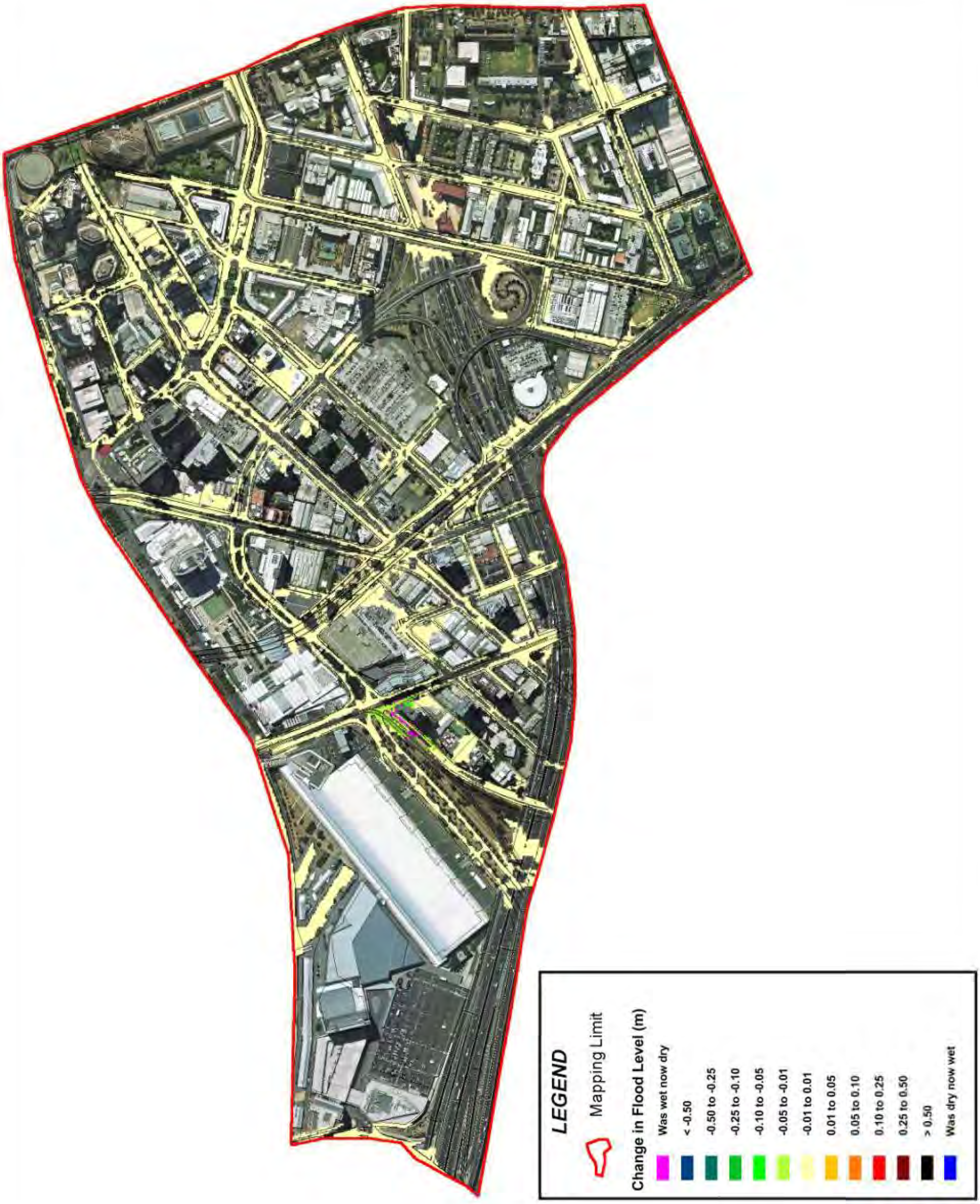
Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	40	0	33	0	28	0	26	0	19	0
0.02 – 0.05 m	42	0	46	0	41	0	43	0	37	1
0.05 – 0.10 m	31	1	32	1	41	0	32	0	29	-1
0.10 – 0.25 m	57	0	57	0	60	0	70	0	75	0
0.25 – 0.50 m	16	-1	21	-1	30	0	33	0	43	0
> 0.5 m	22	0	25	0	26	0	25	0	32	0
Total	208	0	214	0	226	0	229	0	235	0

Table 6-8 Pipe Augmentation Properties Flooded – Storm Surge

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	35	0	30	-1	24	0	20	1	18	0
0.02 – 0.05 m	36	0	41	1	38	-1	36	0	32	1
0.05 – 0.10 m	25	0	26	-1	30	1	27	-1	29	-1
0.10 – 0.25 m	49	0	48	0	54	-1	63	0	59	0
0.25 – 0.50 m	40	0	44	0	50	0	55	0	61	0
> 0.5 m	28	0	31	0	32	0	35	0	38	0
Total	213	0	220	-1	228	-1	236	0	237	0

Table 6-9 Pipe Augmentation Properties Flooded – Yarra River 100 Year Flood

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	35	0	28	0	22	0	18	0	18	0
0.02 – 0.05 m	32	0	33	0	32	0	29	0	24	0
0.05 – 0.10 m	26	0	29	0	26	0	25	0	25	0
0.10 – 0.25 m	49	0	50	0	55	0	57	0	52	0
0.25 – 0.50 m	45	0	44	0	50	0	54	0	56	0
> 0.5 m	34	0	43	0	50	0	57	0	67	0
Total	221	0	227	0	235	0	240	0	242	0



Title:
Southbank - Pipe
Change in 5 Year ARI Peak Flood Heights - MSL

Figure: **6-6**

Rev: **A**

N

0 125 250m
Approx. Scale

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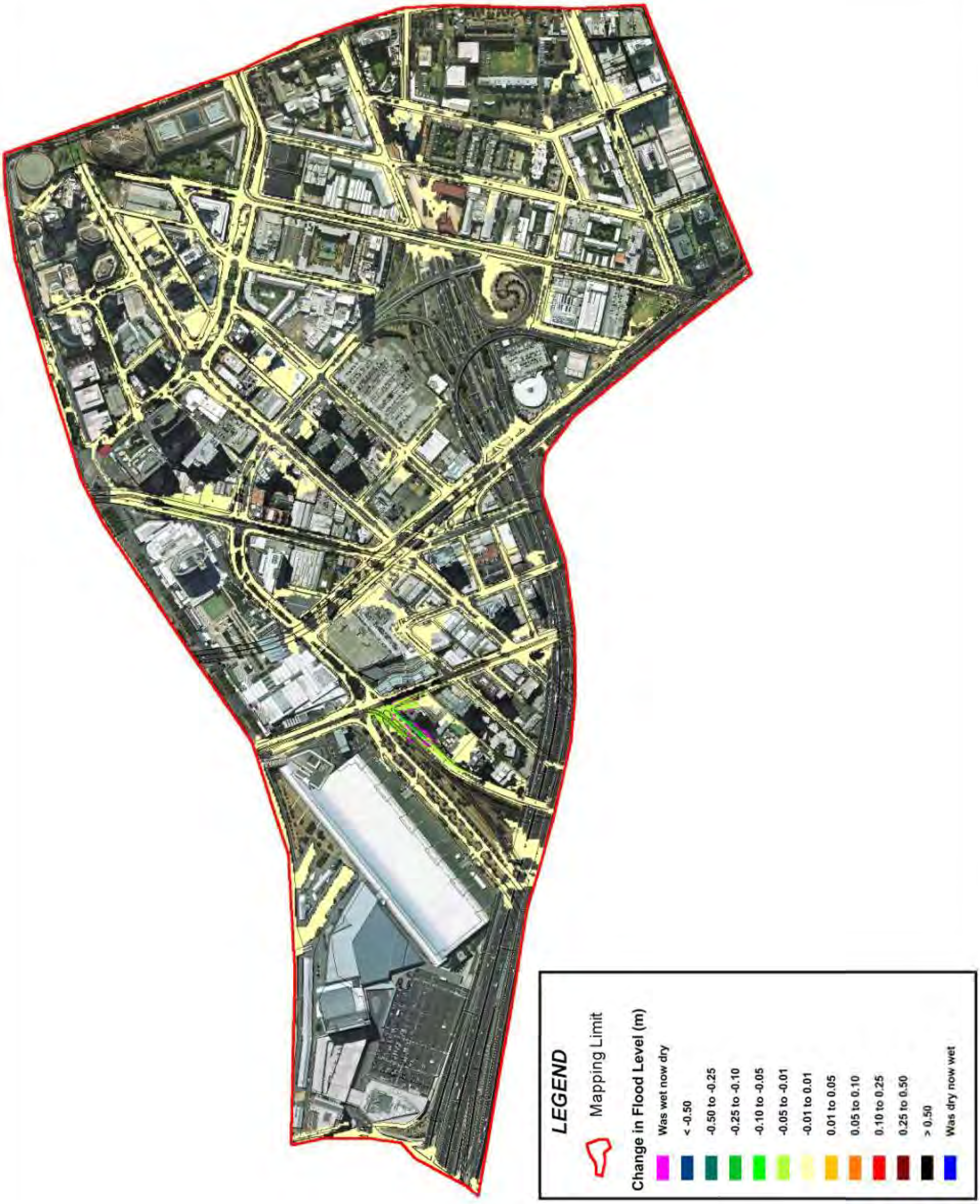

Title:
Southbank - Pipe
Change in 10 Year ARI Peak Flood Heights - MSL

Figure: 6-7

Rev: A

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Approx. Scale

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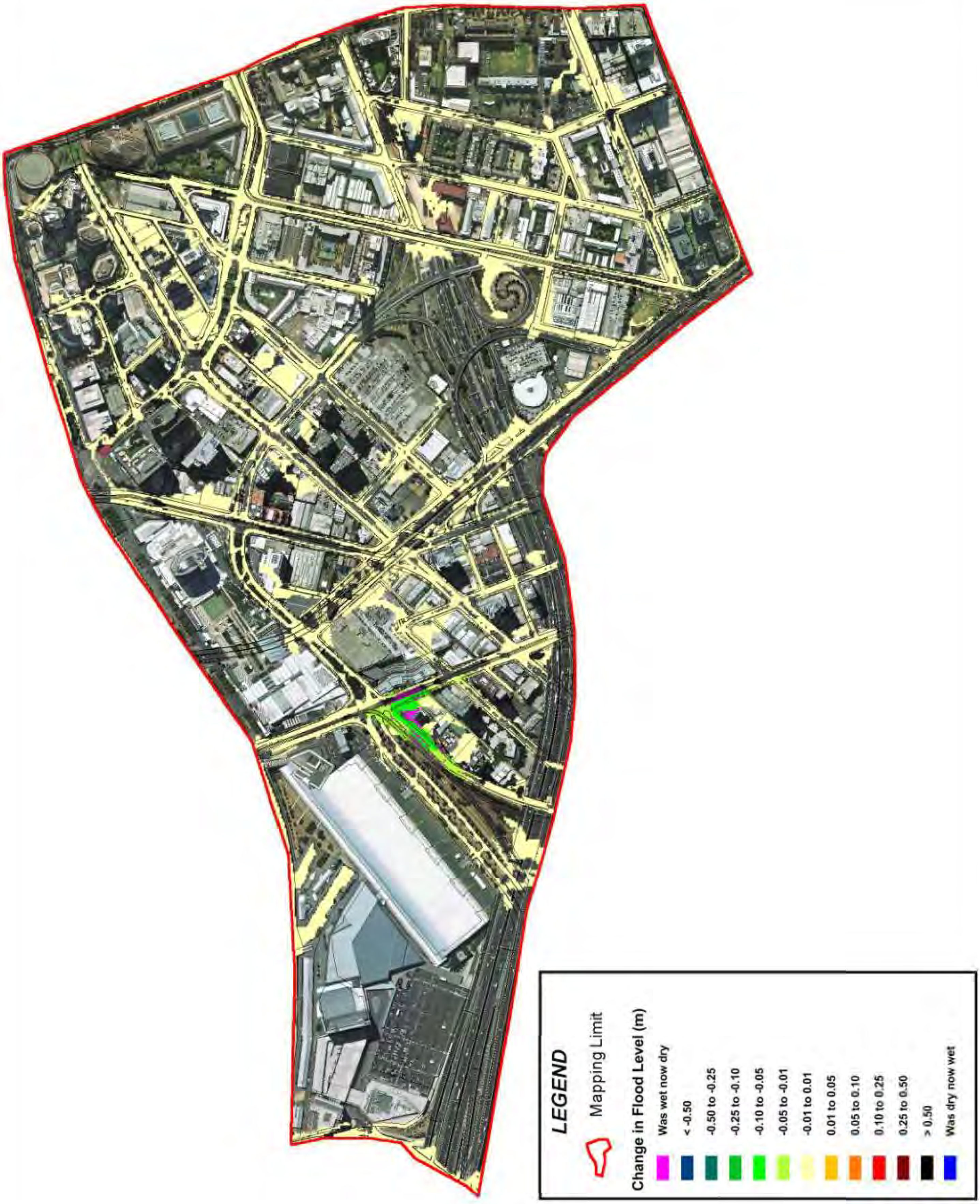

Title:
Southbank - Pipe
Change in 20 Year ARI Peak Flood Heights - MSL

Figure: 6-8

Rev: A

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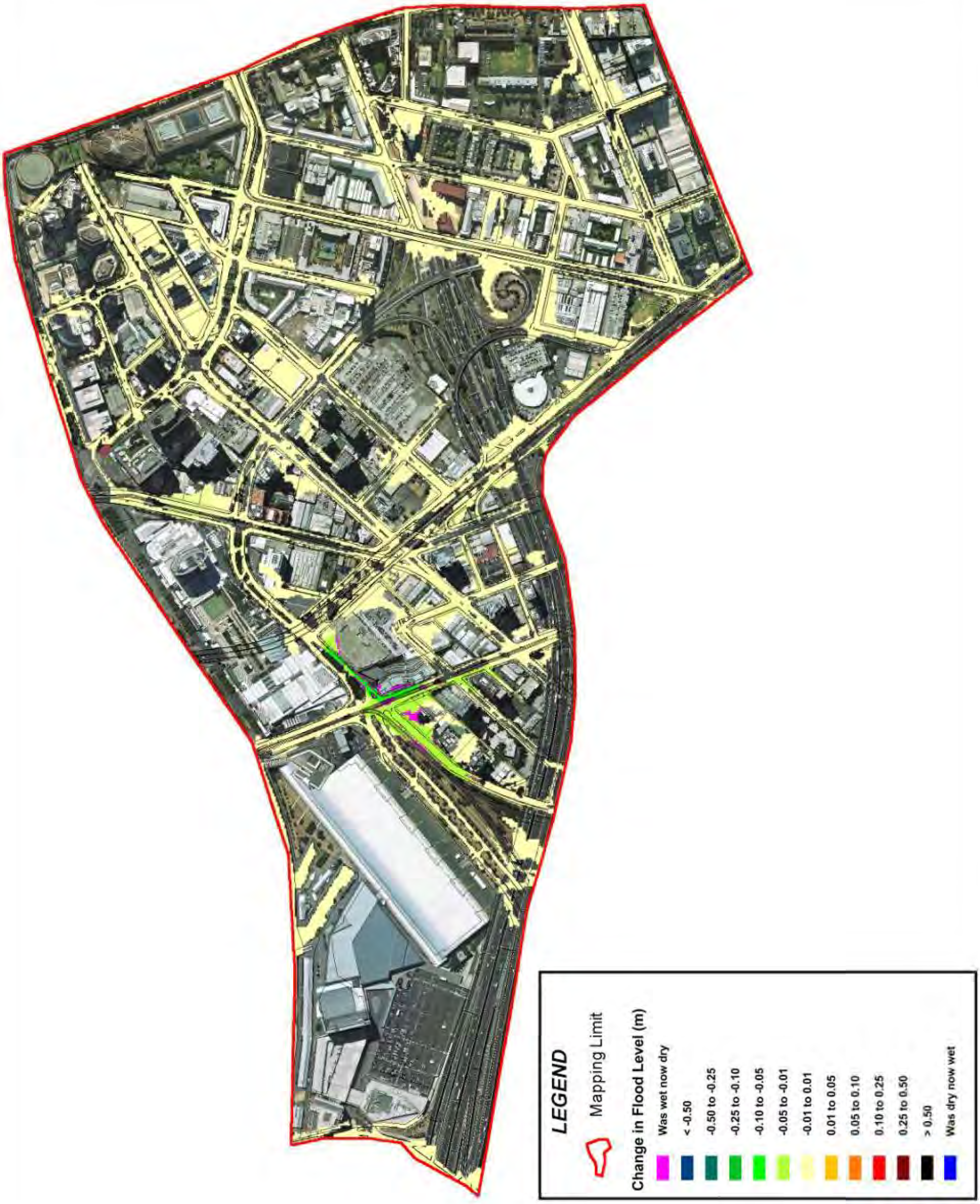

Title:
Southbank - Pipe
Change in 50 Year ARI Peak Flood Heights - MSL

Figure: **6-9**

Rev: **A**

N

0 125 250m
Approx. Scale

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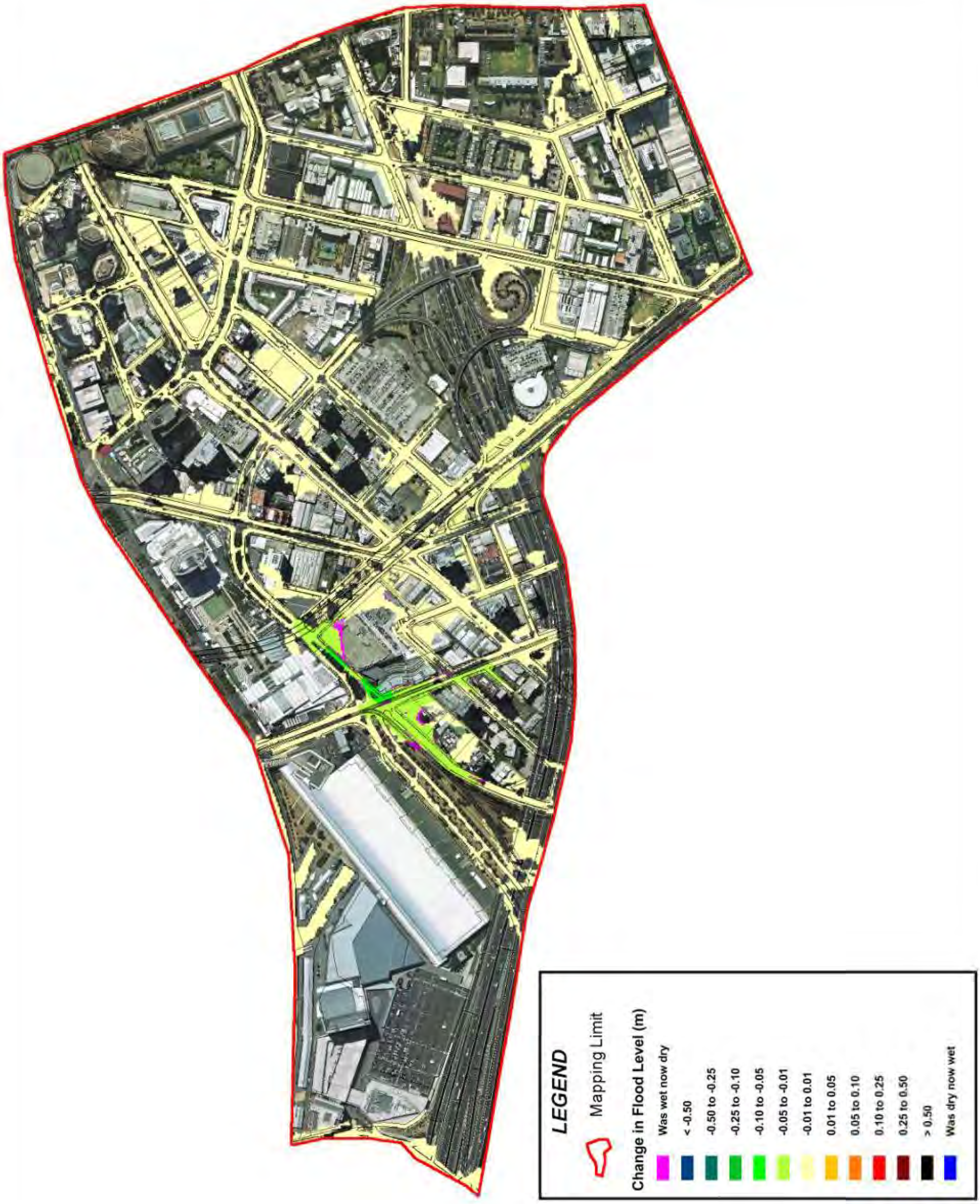

Title:

Southbank - Pipe
Change in 100 Year ARI Peak Flood Heights - MSL

Figure: **6-10**

Rev: **A**

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0 125 250m
Approx. Scale

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\SBK_Final_Fig6-10_FldDif_D02_E01_100y_MSL_RevA.WOR

6.7 Summary of Modelled Opportunities

The flood modelling indicates that a larger benefit (in terms of reduction in flooded properties and reductions in peak flood depths) occurs as a result of the implementation of WSUD treatments. There is also additional potential to implement WSUD treatment throughout the precinct (other than those identified in this report) as further redevelopment and road upgrades occur.

Assuming that WSUD treatments are implemented in an opportunistic manner (during road upgrades, redevelopment) rather than as a retrofit, the costs are likely to be significantly less than drainage system upgrades.

7 Future Climate Conditions

This section details the future climate condition scenarios that were adopted for the Southbank precinct modelling. The study considered two future climate scenarios, one consistent with current Melbourne Water guidelines, and the other consistent with the current CSIRO guidance regarding changes to rainfall intensity under a future climate. Whilst other future climate scenarios exist, they were not considered as part of this assessment.

Although the rainfall scenarios were different in the modelled future climate scenarios, both approaches adopted the same set of future climate tailwater conditions.

7.1 Tailwater Conditions

Current scientific research, including by the Intergovernmental Panel on Climate Change (IPCC, 2014), indicates that future climate change resulting from global warming is likely to affect extreme sea water levels at Port Philip Bay in the following ways:

- Mean sea level rise;
- Changes in tidal propagation; and,
- Changes to storm occurrences and storm wind intensity.

7.1.1 Mean Sea Level Rise

Global-average temperatures increased 0.7 degrees Celsius since 1900 and the global-average sea-level has risen 1.7 mm per year since 1900 (Church and White, 2006). Due to anthropogenic greenhouse gas emissions the rates of both temperature increase and Sea Level Rise are likely to be increasing and are expected to further accelerate in the future (IPCC, 2001; IPCC, 2007; IPCC, 2014).

There are significant uncertainties as to the actual magnitude and rate of future sea level rise. This has led to various scenarios being adopted by the Intergovernmental Panel on Climate Change (IPCC), based on the range of model results available and dependent upon the amount of future emissions assumed.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) reports that global sea level rise is projected to be 18–59 cm by year 2100 relative to 1990 levels. These projections do not include a contribution from ice flow rates, however if these were to continue to grow linearly with global warming, then the upper ranges of sea level rise would increase by a further 10 to 20 cm (by year 2100 relative to 1990) (IPCC, 2007). There is an acknowledged risk that the contribution of ice sheets to sea level rise this century may be substantially higher than this.

In summary the mean sea level rise in Port Philip Bay is estimated to be in the range 28–79 cm to the year 2100. This will occur gradually at first as we continue to accelerate from the historic rate of 1.7 mm per year and then more rapidly as the year 2100 is approached.

Melbourne Water (2012) and the Victorian Coastal Strategy (2014) recommends a precautionary approach based on the latest IPCC data at the time of their publication (IPCC, 2007) to planning for mean sea level rise and recommends that a sea level rise value of not less than 0.8 m by 2100 be considered for development planning purposes. This is approximately equal to the high-end of the IPCC estimates. The adopted allowances for mean sea level rise (relative to present-day levels) are presented in Table 7-1.

Table 7-1 Adopted Mean Sea Level Rise Allowance

Year	Mean Sea Level Rise (m)
2030	0.15 m
2070	0.47 m
2100	0.80 m

7.1.2 Changes in Tidal Propagation

Black et al. (1990) showed through a hydrodynamic modelling study that an increase in mean sea level may result in an increase in the tidal range within Port Phillip Bay due to the reduced frictional attenuation of tidal flows through the entrance. He suggested that a 0.5 m sea level rise could lead to 7% in the tidal range. This increase in tidal range could in turn affect future storm tide levels. To account for this effect, an additional allowance of 0.03 m is adopted. Potentially, this value could be considerably higher for higher levels of sea level rise.

7.1.3 Changes to Storm Surge Occurrences and Intensities

Little is known about likely future changes to prevailing winds or extreme storm behaviour, although it is probable that extreme wind speeds will change into the future. The impacts of future wind speed changes on storm tides within Port Phillip Bay were investigated in McInnes et al (CSIRO, 2009).

In the CSIRO study, the potential impacts of future wind speed changes on storm tides within Port Phillip Bay were investigated by applying scaling factors to the present extreme wind speed magnitude. The magnitude of the scaling factors was based on projections for possible changes in annual average wind speed impacts by CSIRO/Bureau of Meteorology (BoM) (2007). As such, the CSIRO study assumes that projections for annual average wind speed increases are a suitable indicator for potential increases in extreme wind speed during storm tide events.

The wind speed increase allowances adopted in the CSIRO study are based on interpretations of IPCC (2007) model simulations for the high (90th percentile) estimate of the high emissions A1F1scenario. The suggested wind speed increase allowances, presented in (CSIRO, 2009) indicate a 19% increase in peak wind speeds by 2100.

CSIRO accounted for the effect of wind increase on storm tide levels by simply increasing the present-day storm surge height estimates by a percentage equal to twice the relevant percentage wind speed increase.

It should be recognised that the methodology used in the CSIRO study represents a relatively crude method to estimate the impacts of potential changes in storm occurrences and intensities due to climate change and the effects of potential changes in storm occurrences and intensities are better investigated through a hydrodynamic modelling study.

Nevertheless, the predicted contributions are considered sufficiently accurate for the purposes of this assessment.

7.1.4 Adopted Tailwater Levels

Table 7-2 shows the adopted tailwater levels for the future climate (2100) scenarios in comparison to the current climate (existing) scenario.

The future climate MSL is based on the precautionary advice from the Victorian Coastal Strategy (2014) and is consistent with current Melbourne Water guidance.

The future HAT level is based on the future MSL and changes to the tidal propagation in accordance with Black et al (1990).

The future 100 year storm surge level is based on the CSIRO (2009) report for Port Philip Bay and includes allowances for increased wind and wave setup.

The future Yarra River 100 year ARI flood level is based on guidance from Melbourne Water (2012).

Table 7-2 Current and Future (2100) Tailwater Levels

Tailwater Condition	Existing Condition	Future Climate (2100)
MSL	0	0.80
HAT	0.52	1.36
100 yr ARI Storm Surge	0.90	2.04
Yarra River 100yr ARI Flood	1.60	2.40

7.2 Rainfall Intensity

The modelling considered two scenarios for future rainfall intensity. It is widely acknowledged in the scientific community that although an increase in surface temperature can be modelled with increasing certainty by a wide range of meteorological and climatic models, the resulting impacts on rainfall and rainfall intensity are far less uncertain.

The scenarios selected for modelling where the Melbourne Water advice and the CSIRO advice. These scenarios are outlined in this section.

7.2.1 Melbourne Water Advice on Rainfall Intensity

The 32% increase in rainfall intensity is based upon current Melbourne Water advice regarding future climate conditions. The 32% increase is consistent with the guidance contained in the Intergovernmental Panel on Climate Change (IPCC, 2007) fourth assessment report. Whilst it is noted that the IPCC fourth assessment report has been superseded, the 32% increase in rainfall intensity remains the current Melbourne Water advice for future climate scenarios.

7.2.2 CSIRO Advise on Rainfall Intensity

The CSIRO has developed climate futures website[3] that enables practioners to make informed decisions about future climate scenarios based on a series of climate models. The Southbank precinct is located within the Southern Slopes region. Under the RCP6.0 scenario, the results from the climate models indicate that the most likely change to future climate will be a 1.5 to 3.0°C rise in annual mean surface temperature and little change (-5.0 to 5.0%) to Annual Rainfall percentage (Figure 7-1).

For each 1.0°C rise in annual mean surface temperature, the rainfall intensity is also expected to increase by 5%. Therefore, with an upper limit of a 3.0°C rise in annual mean surface temperature, there will be a corresponding 15% increase in rainfall intensity.

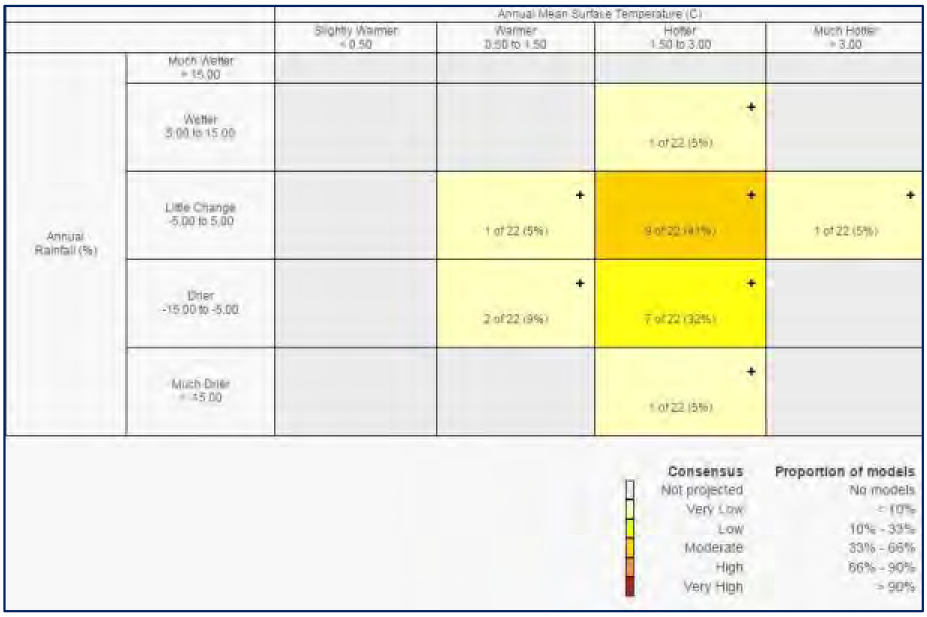


Figure 7-1 CSIRO 2090 Climate Futures (RCP6.0)

7.3 Future Climate Flood Modelling

The future climate conditions were applied to flood models developed for the Southbank precinct catchment. The results of the flood modelling have been presented as Flood Impact Maps.

7.3.1 Flood Impact Maps

Flood Impact Maps, are maps that show the change in flood depths between the existing case conditions and a future climate scenario. Flood Impact Maps are presented for each modelled option comparing the existing conditions flooding to the future climate scenario. For each ARI event modelled, peak flood envelopes were prepared that calculate the peak flood level for each of the durations modelled.

[3] http://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/introduction-climate-futures/

In these figures, the pale yellow colour represents nominal change in modelled flood depth within +/- 50 mm. Green colours represent a reduction in flood depths, whereas red and brown colours represent increases in flood depth. Areas that are pink are areas that were wet and are now dry in the modelled option, whereas areas that were dry and are now wet are represented as dark blue.

7.3.2 Melbourne Water 2100 Climate Scenario

The flood impact mapping presented in Figure 7-2 to Figure 7-6 demonstrates the impact of a future climate scenario assuming a 32% increase in the rainfall intensity by 2100. The increase in 32% is based on the current advice from Melbourne Water (2012). The value of 32% was based on the information included in the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report.

The scenarios that have been presented are based on Mean Sea Level. Other tailwater conditions are included as part of Appendix C and Appendix D. Based upon Melbourne Water's current guidance and in accordance with the current Victorian Coastal Strategy, the Mean Sea Level will increase by 0.8 metres by 2100; hence the Mean Sea Level in 2100 will be 0.8 mAHD. The Storm Surge tailwater level for 2100 is based on the latest CSIRO advice which includes an allowance for increased wind intensity and wave setup, as well as sea level rise. The adopted Storm Surge level for 2100 is 2.04 mAHD. The future Mean Sea Level is only 0.1 metres below the current Storm Surge level, whilst the future Storm Surge Level is 0.4 metres greater than the current Yarra River 100 year ARI flood level.

The models have been run for the 5 year through to the 100 year ARI flood events.

7.3.2.1 Discussion of Results

The results from this future climate scenario indicate significant increases in both flood level and flood extent for all events throughout the Southbank precinct.

The 5 year ARI event (MSL) results in flood level increases of 0.5 metres in a natural low point on City Road (between Kings Way and Clarendon Street). This natural low point is the most sensitive site for the future climate scenario and is the site for the most significant flood level and flood extent increase across all the future climate scenarios.

The results indicate that the majority of the Southbank precinct is more sensitive to the effects of sea level rise than the increases in rainfall intensity. Whilst the modelled future scenarios (both MSL and Storm Surge) show that the Yarra River does not break its bank into the Southbank precinct (some flooding does occur along Southbank Promenade), the sea level rise does comprise the constructed drainage systems ability to discharge via gravity to the Yarra River. In essence the catchment no longer has a discharge point (as the key catchment outlets become tide locked) and the rainfall simply ponds in the low points.

7.3.2.2 Summary of Melbourne Water 2100 Climate Scenario

A summary of the Melbourne Water 2100 Climate Scenario (number of properties flooded and peak inundation depth) is provided in the following tables. Summary tables are provided for each of the four investigated tailwater levels. The summary tables also detail the change (from current conditions) in the number of properties flooded within each depth band. A positive number indicates an increase in the number of properties.

Table 7-3 Melbourne Water 2100 Properties Flooded – Mean Sea Level

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	30	-17	25	-12	21	-11	22	-4	21	0
0.02 – 0.05 m	36	-3	37	-9	35	-4	25	-18	25	-13
0.05 – 0.10 m	33	2	27	-8	26	-17	29	-3	31	0
0.10 – 0.25 m	55	7	62	10	66	11	66	-4	67	-11
0.25 – 0.50 m	43	28	50	34	56	30	66	33	70	33
> 0.5 m	30	11	31	9	34	11	37	12	38	10
Total	227	28	232	24	238	20	245	16	252	19

Table 7-4 Melbourne Water 2100 Properties Flooded – Highest Astronomical Tide

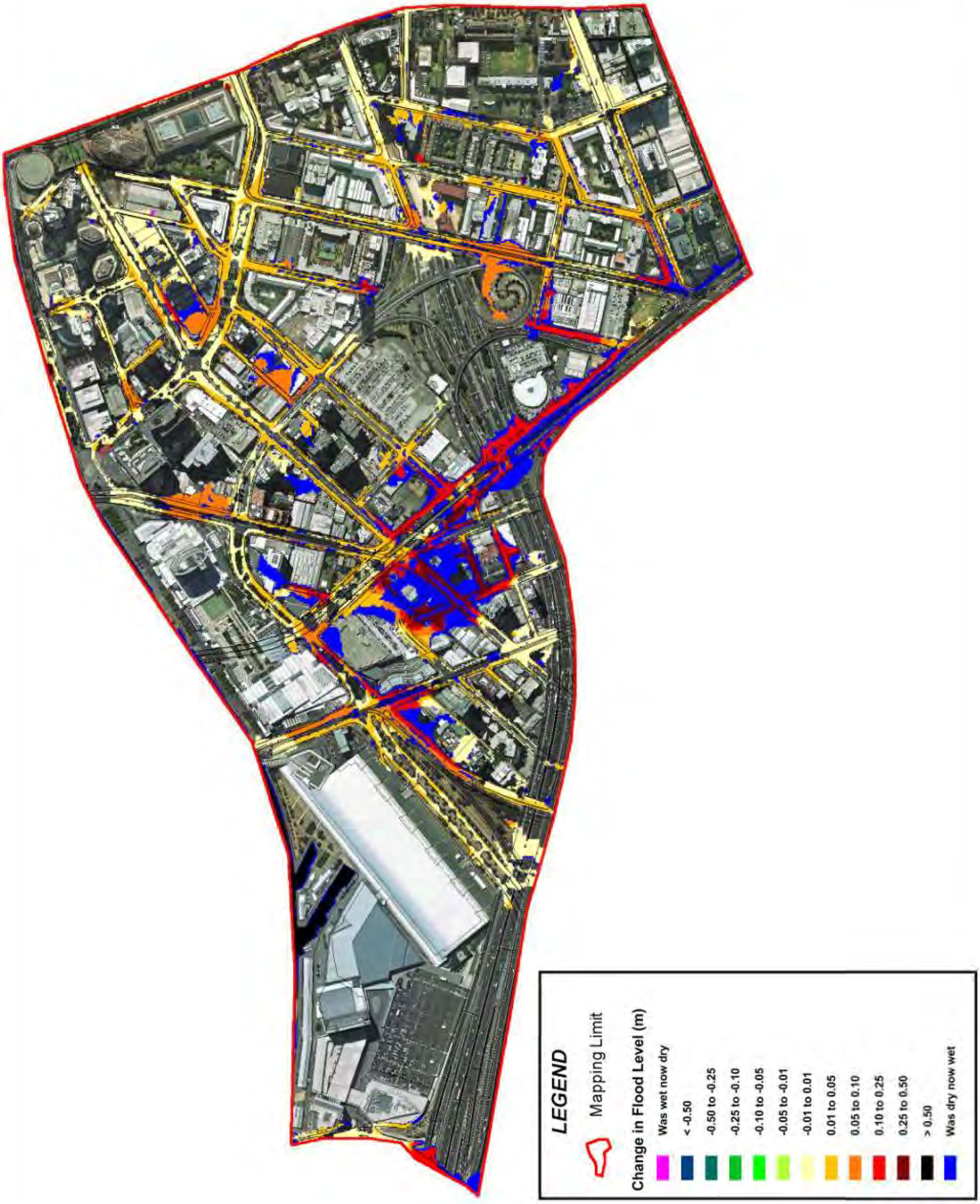
Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	27	-13	24	-9	18	-10	22	-4	20	1
0.02 – 0.05 m	29	-13	29	-17	29	-12	25	-18	14	-22
0.05 – 0.10 m	31	1	24	-7	25	-16	29	-3	29	-1
0.10 – 0.25 m	54	-3	57	0	58	-2	66	-4	54	-21
0.25 – 0.50 m	46	29	51	29	54	24	66	33	63	20
> 0.5 m	46	24	53	28	59	33	37	12	76	44
Total	233	25	238	24	243	17	245	16	256	21

Table 7-5 Melbourne Water 2100 Properties Flooded – Storm Surge

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	26	-9	22	-9	18	-6	18	-1	20	2
0.02 – 0.05 m	29	-7	30	-10	26	-13	19	-17	17	-14
0.05 – 0.10 m	24	-1	23	-4	27	-2	27	-1	24	-6
0.10 – 0.25 m	61	12	54	6	50	-5	49	-14	54	-5
0.25 – 0.50 m	47	7	54	10	60	10	67	12	64	3
> 0.5 m	49	21	56	25	64	32	73	38	80	42
Total	236	23	239	18	245	16	253	17	259	22

Table 7-6 Melbourne Water 2100 Properties Flooded – Yarra River 100 Year Flood

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	15	-20	15	-13	14	-8	17	-1	16	-2
0.02 – 0.05 m	15	-17	16	-17	15	-17	10	-19	10	-14
0.05 – 0.10 m	16	-10	14	-15	13	-13	15	-10	14	-11
0.10 – 0.25 m	33	-16	33	-17	37	-18	41	-16	38	-14
0.25 – 0.50 m	61	16	65	21	64	14	61	7	64	8
> 0.5 m	113	79	114	71	118	68	124	67	130	63
Total	253	32	257	30	261	26	268	28	272	30



Title:

Southbank - Climate Change +32%
Change in 5 Year ARI Peak Flood Heights - MSL

Figure: **7-2**

Rev: **A**

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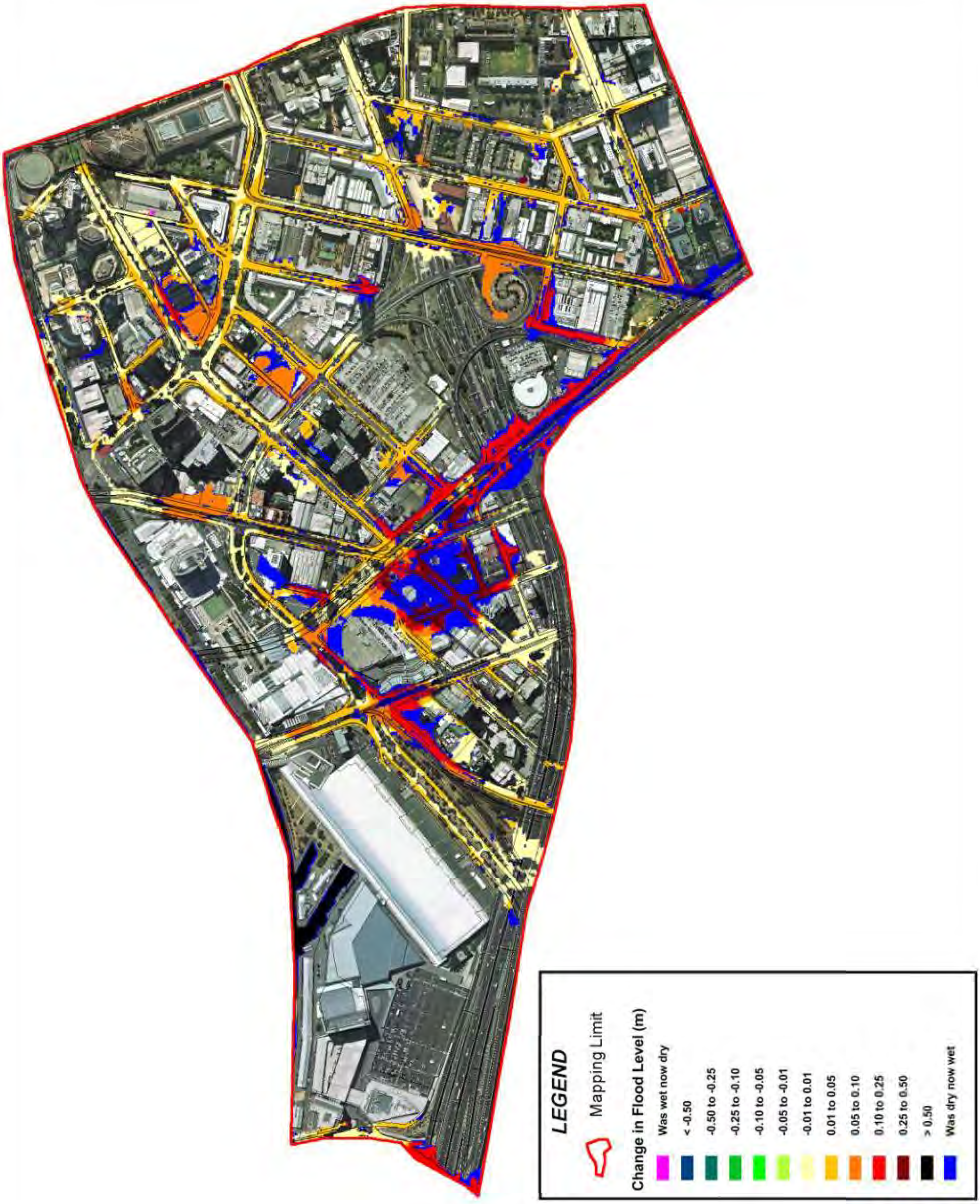

Title:
Southbank - Climate Change +32%
Change in 10 Year ARI Peak Flood Heights - MSL

Figure: 7-3

Rev: A

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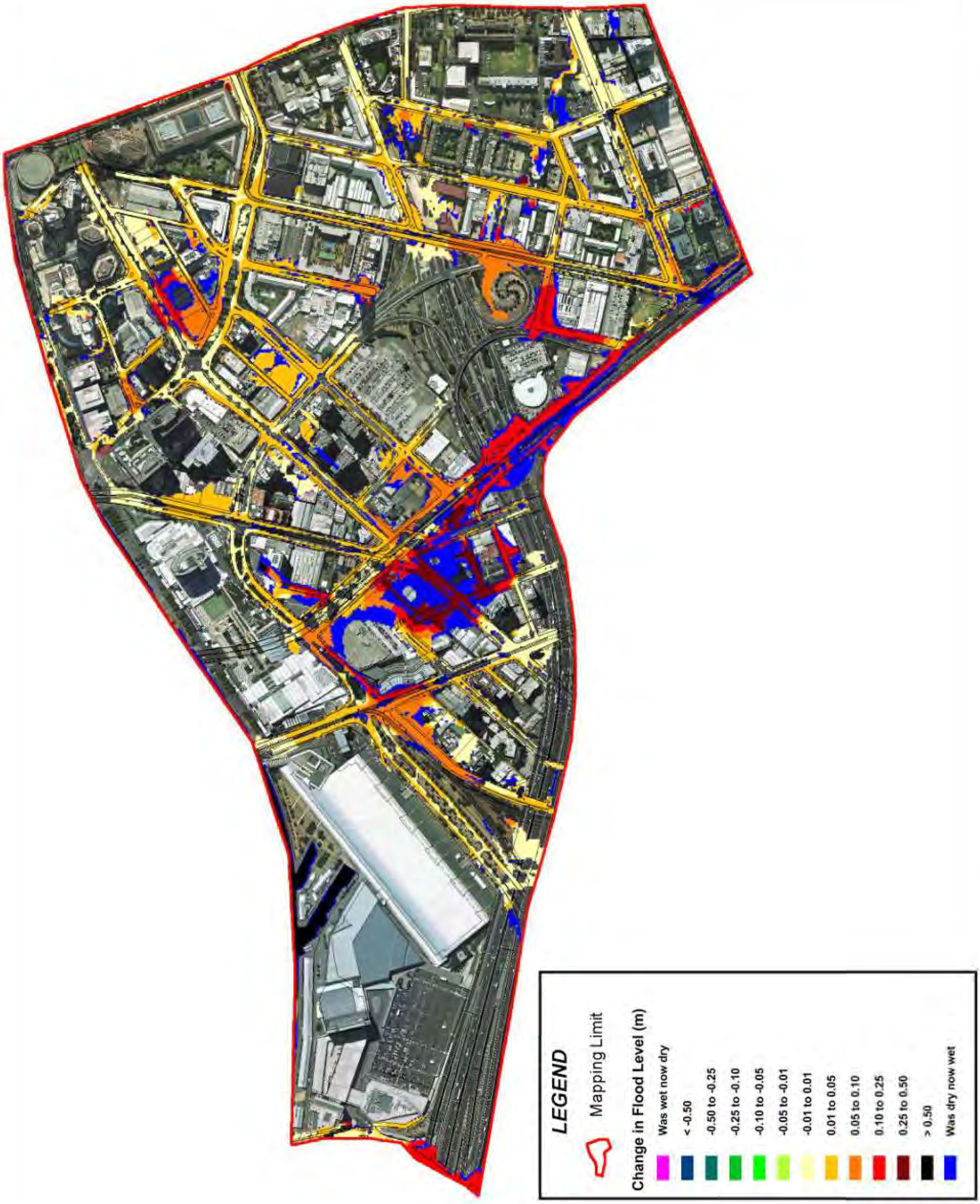

Title:

Southbank - Climate Change +32%
Change in 20 Year ARI Peak Flood Heights - MSL

Figure: 7-4

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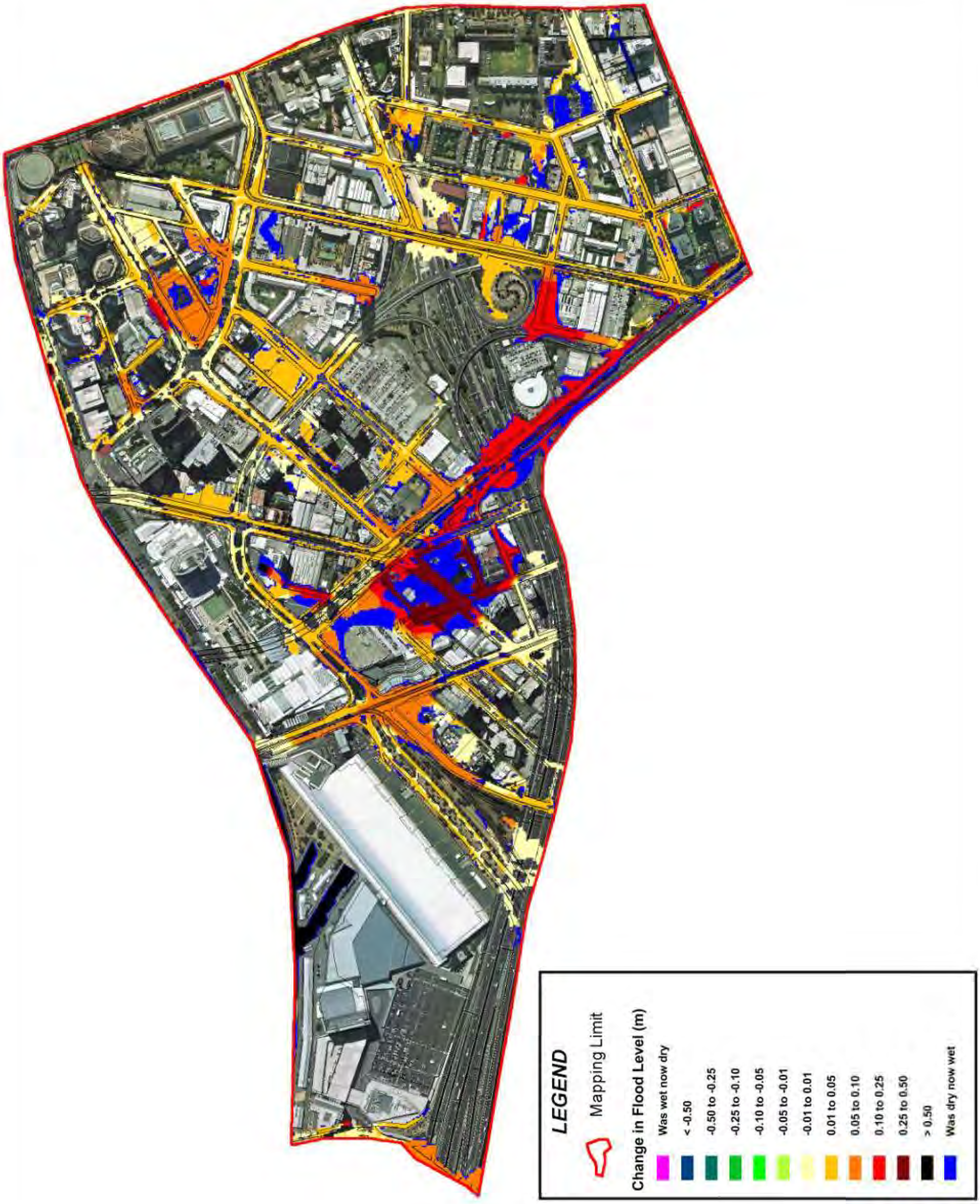

Title:

Southbank - Climate Change +32%
Change in 50 Year ARI Peak Flood Heights - MSL

Figure: **7-5**

Rev: **A**

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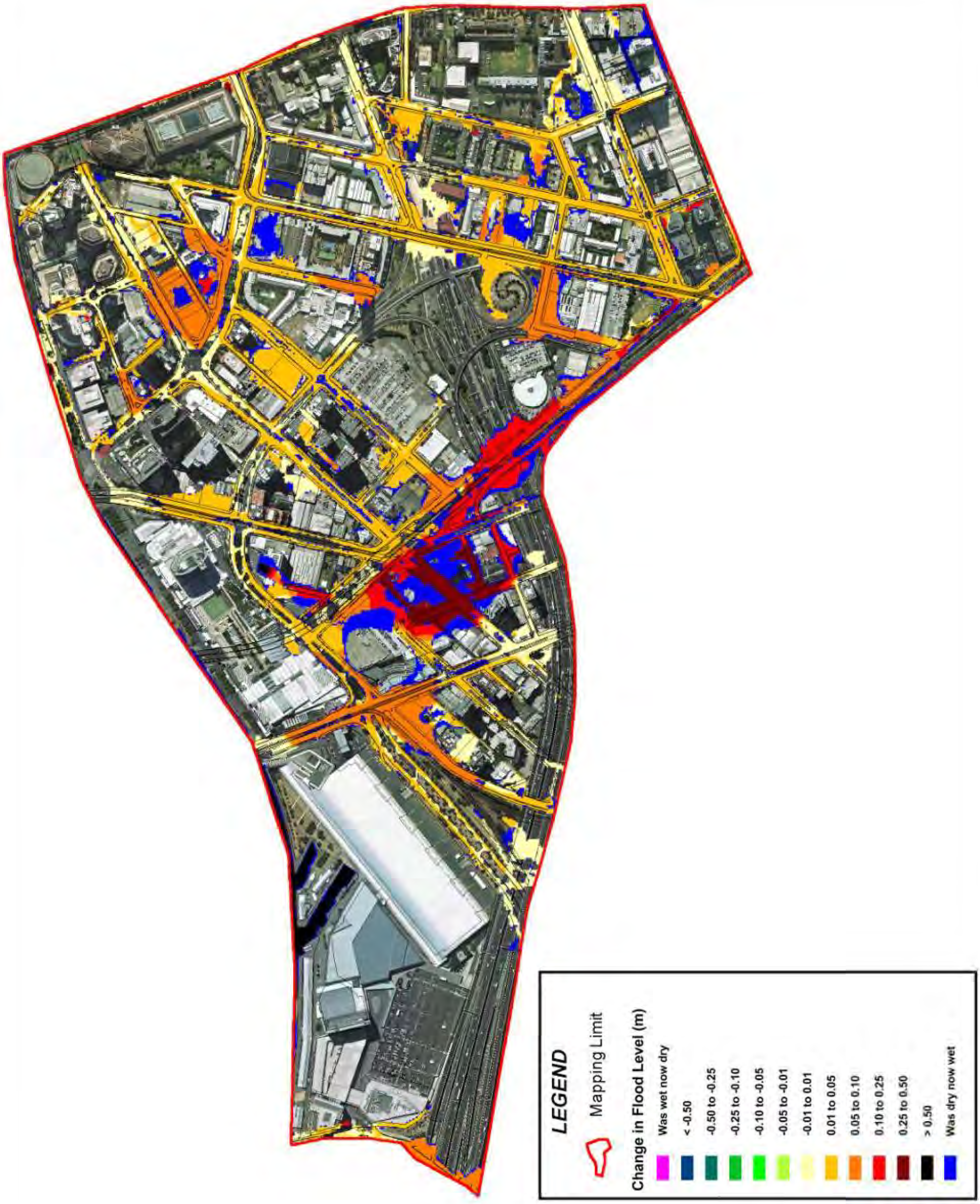

Title:

Southbank - Climate Change +32%
Change in 100 Year ARI Peak Flood Heights - MSL

Figure: 7-6

Rev: A

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7.3.3 CSIRO 2100 Rainfall Intensity Scenario

The flood impact mapping presented in Figure 7-7 to Figure 7-11 demonstrates impact of the 15% increase in the rainfall intensity climate change scenario. The increase in 15% is based on the latest information from the CSIRO which indicated that there will be a 5% increase in rainfall intensity for each 1°C rise in temperature. The future climate models utilised by the CSIRO indicate that by 2100, there will be a 3°C increase in temperature for Melbourne, and hence a 15% increase in the rainfall intensity.

The same sea level scenarios as in the Melbourne Water 2100 scenario have been adopted for this scenario namely that the Mean Sea Level in 2100 will be 0.8 mAHD. Other tailwater conditions have been assessed and the results are included in Appendix C and Appendix D.

The models have been run for the 5 year through to the 100 year ARI flood events.

7.3.3.1 Discussion of Results

The results from the future climate scenario with an increase in rainfall intensity of 15% indicate significant increases in both flood level and flood extent for all events throughout the Southbank precinct, although the change in the upper catchment are slightly less than observed under the other future climate scenario (32%).

However, the flood impacts observed under this scenario are very similar to those observed previously due to the significant influence the future climate tailwater conditions have on the model results. The results suggest that whilst increases in rainfall intensity will have impacts on the Southbank precinct, the impact of sea level rise will be far greater.

7.3.3.2 Summary of CSIRO 2100 Climate Scenario

A summary of the CSIRO 2100 Climate Scenario (number of properties flooded and peak inundation depth) is provided in the following tables. Summary tables are provided for each of the four investigated tailwater levels. The summary tables also detail the change (from current conditions) in the number of properties flooded within each depth band. A positive number indicates an increase in the number of properties.

Table 7-7 CSIRO 2100 Properties Flooded – Mean Sea Level

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	32	-15	26	-11	22	-10	18	-8	18	-3
0.02 – 0.05 m	41	2	39	-7	36	-3	35	-8	22	-16
0.05 – 0.10 m	28	-3	32	-3	30	-13	26	-6	29	-2
0.10 – 0.25 m	50	2	56	4	62	7	66	-4	67	-11
0.25 – 0.50 m	39	24	44	28	52	26	56	23	66	29
> 0.5 m	29	10	30	8	31	8	36	11	37	9
Total	219	20	227	19	233	15	237	8	239	6

Table 7-8 CSIRO 2100 Properties Flooded – Highest Astronomical Tide

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	31	-9	26	-7	20	-8	18	-8	16	-3
0.02 – 0.05 m	36	-6	30	-16	31	-10	35	-8	18	-18
0.05 – 0.10 m	26	-4	31	0	24	-17	26	-6	27	-3
0.10 – 0.25 m	47	-10	54	-3	59	-1	66	-4	53	-22
0.25 – 0.50 m	44	27	47	25	50	20	56	23	59	16
> 0.5 m	42	20	46	21	55	29	36	11	72	40
Total	226	18	234	20	239	13	237	8	245	10

Table 7-9 CSIRO 2100 Properties Flooded – Storm Surge

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	29	-6	24	-7	19	-5	17	-2	14	-4
0.02 – 0.05 m	34	-2	31	-9	31	-8	22	-14	17	-14
0.05 – 0.10 m	24	-1	23	-4	24	-5	26	-2	26	-4
0.10 – 0.25 m	50	1	60	12	53	-2	50	-13	50	-9
0.25 – 0.50 m	47	7	48	4	55	5	59	4	67	6
> 0.5 m	43	15	50	19	58	26	69	34	73	35
Total	227	14	236	15	240	11	243	7	247	10

Table 7-10 CSIRO 2100 Properties Flooded – Yarra River 100 Year Flood

Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	15	-20	13	-15	9	-13	12	-6	14	-4
0.02 – 0.05 m	18	-14	17	-16	16	-16	11	-18	7	-17
0.05 – 0.10 m	12	-14	15	-14	16	-10	17	-8	14	-11
0.10 – 0.25 m	31	-18	34	-16	32	-23	35	-22	42	-10
0.25 – 0.50 m	61	16	60	16	64	14	62	8	64	8
> 0.5 m	115	81	115	72	119	69	124	67	119	52
Total	252	31	254	27	256	21	261	21	260	18

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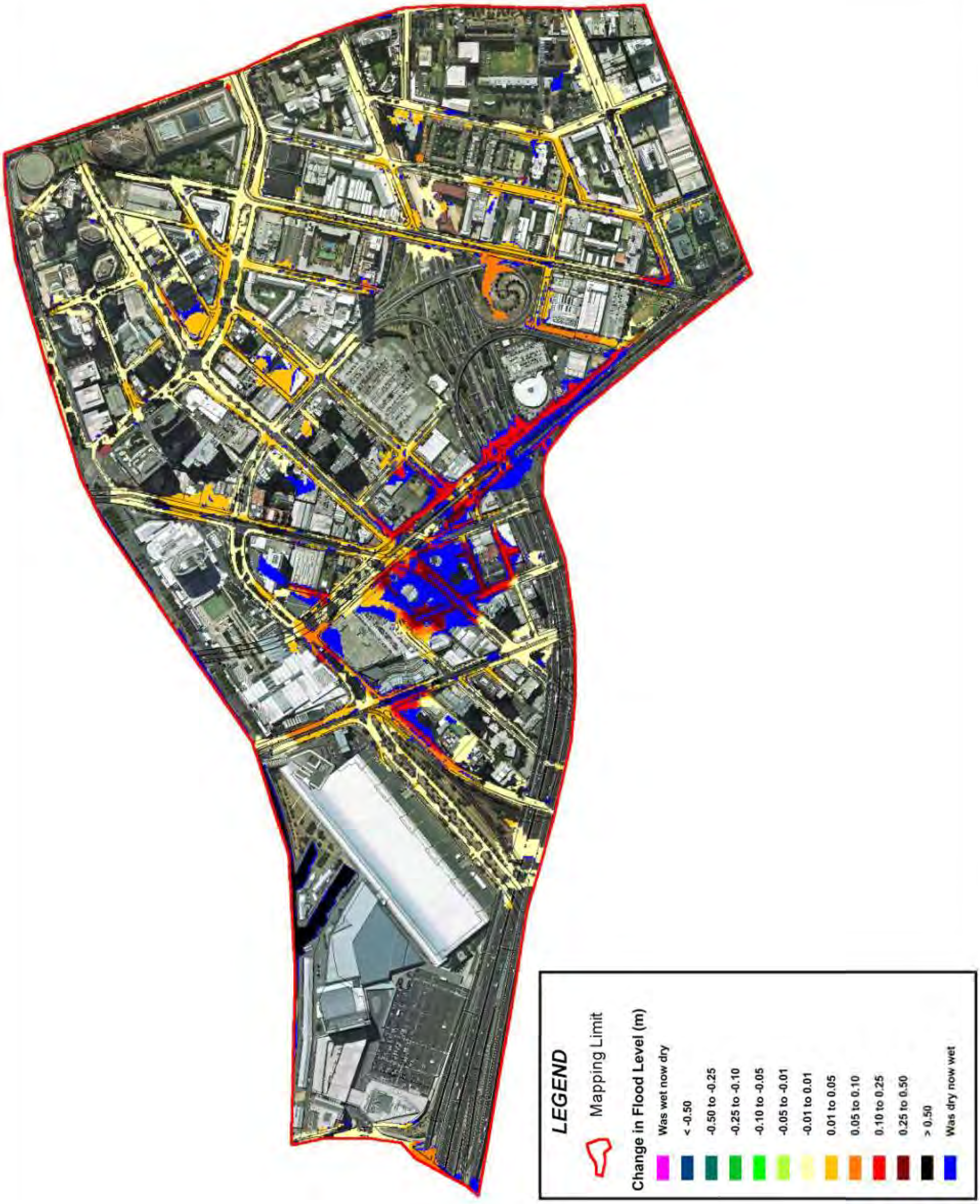

Title:

Southbank - Climate Change +15%
Change in 5 Year ARI Peak Flood Heights - MSL

Figure: 7-7

Rev: A

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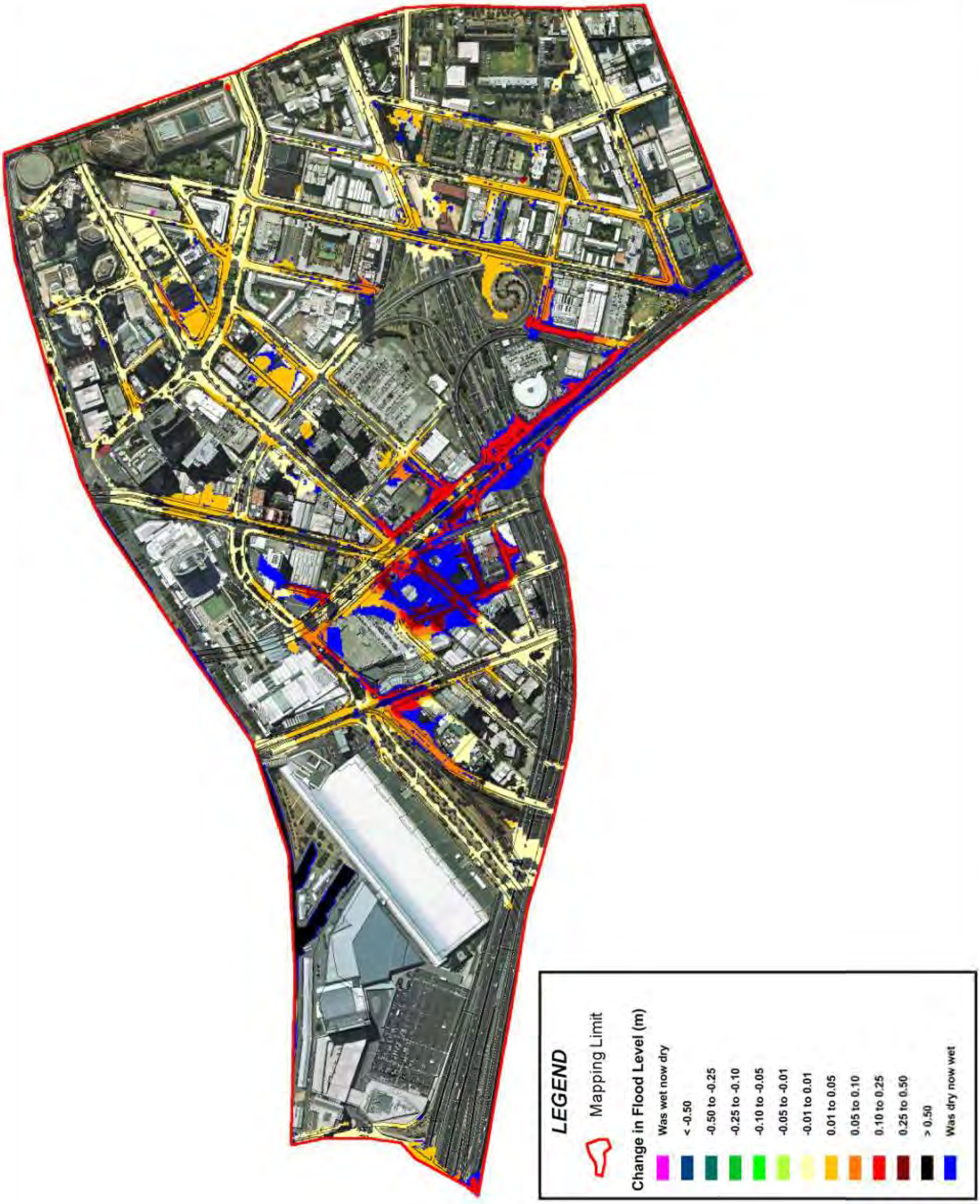

Title:

Southbank - Climate Change +15%
Change in 10 Year ARI Peak Flood Heights - MSL

Figure: 7-8

Rev: A

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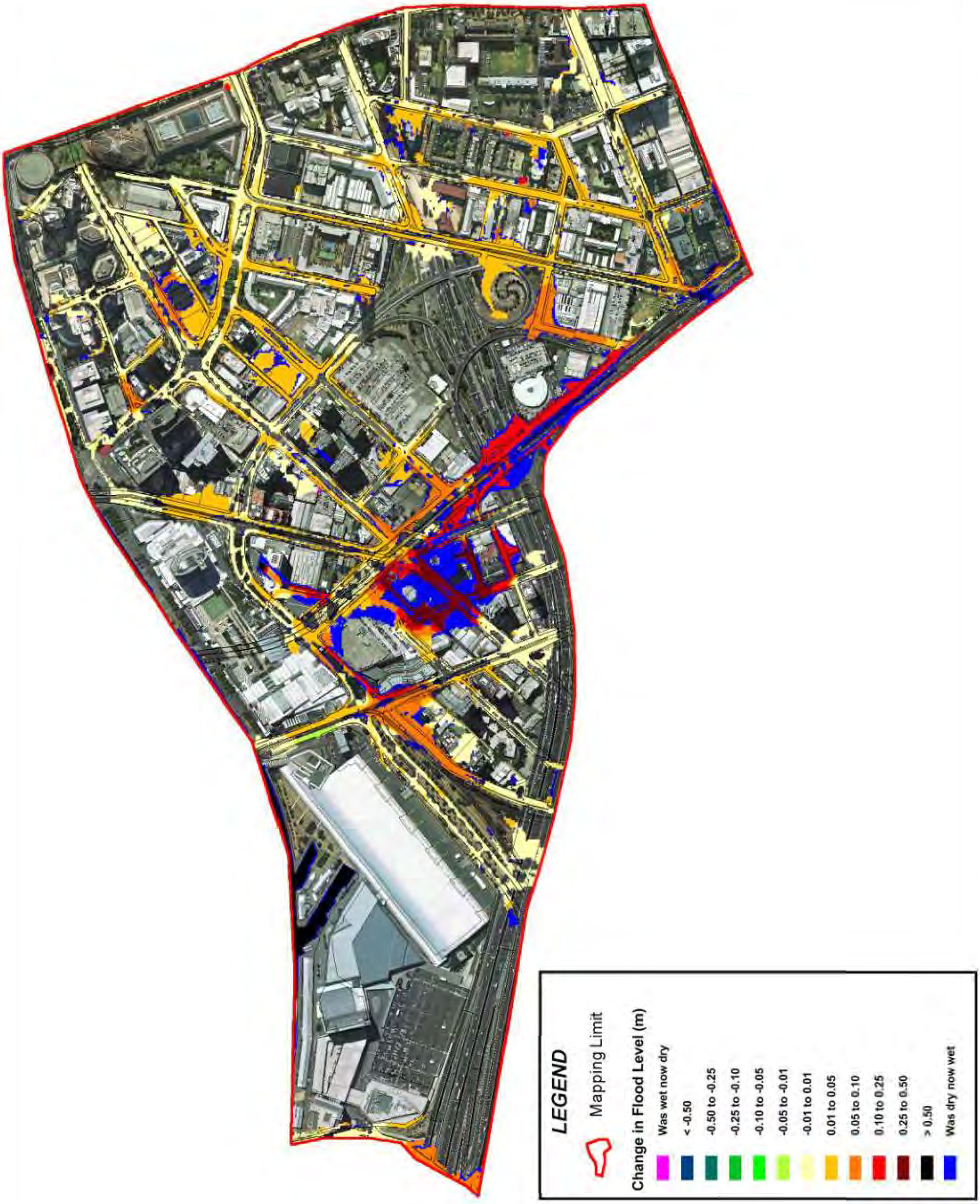

Title:

Southbank - Climate Change +15%
Change in 20 Year ARI Peak Flood Heights - MSL

Figure: 7-9

Rev: A

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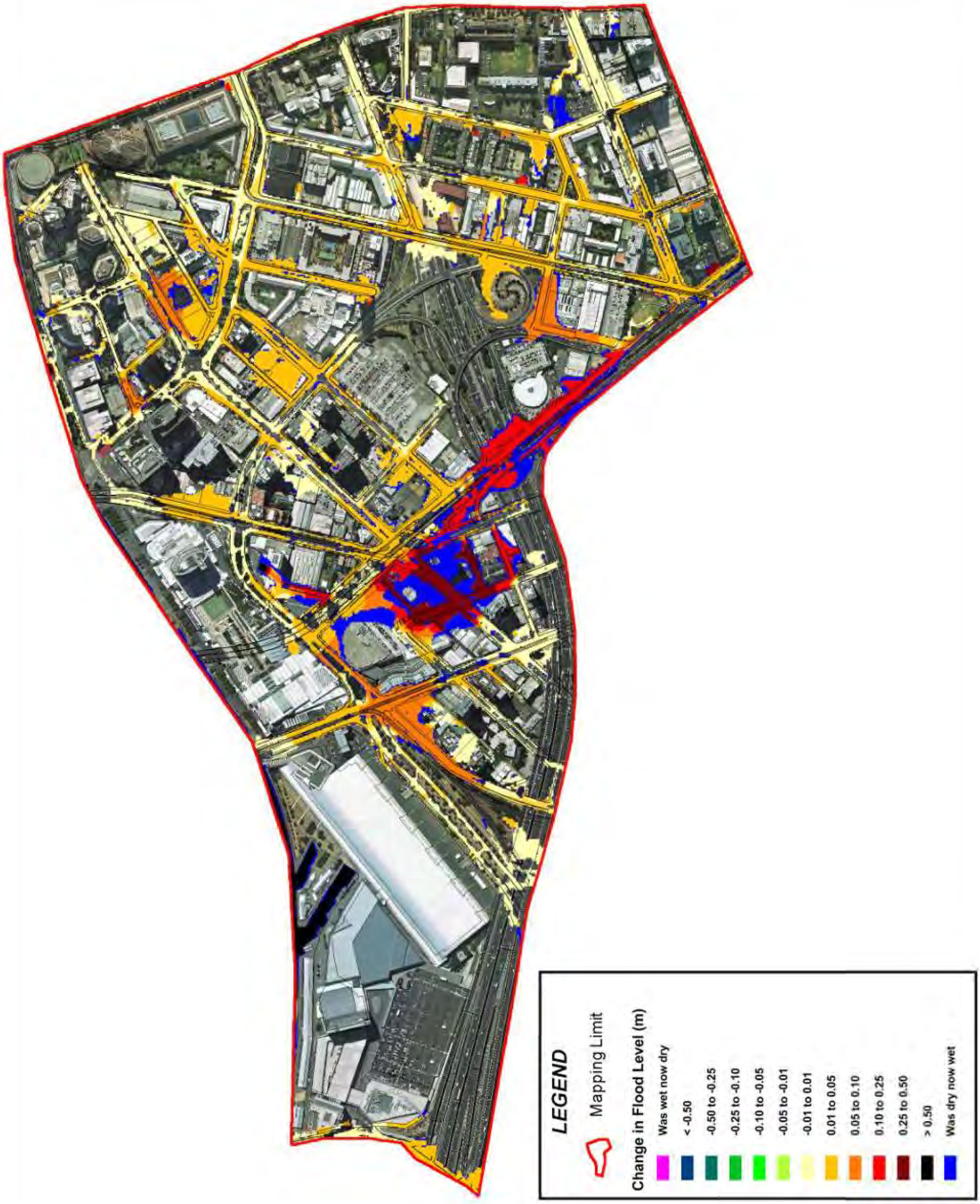

Title:
Southbank - Climate Change +15%
Change in 50 Year ARI Peak Flood Heights - MSL

Figure: **7-10**

Rev: **A**

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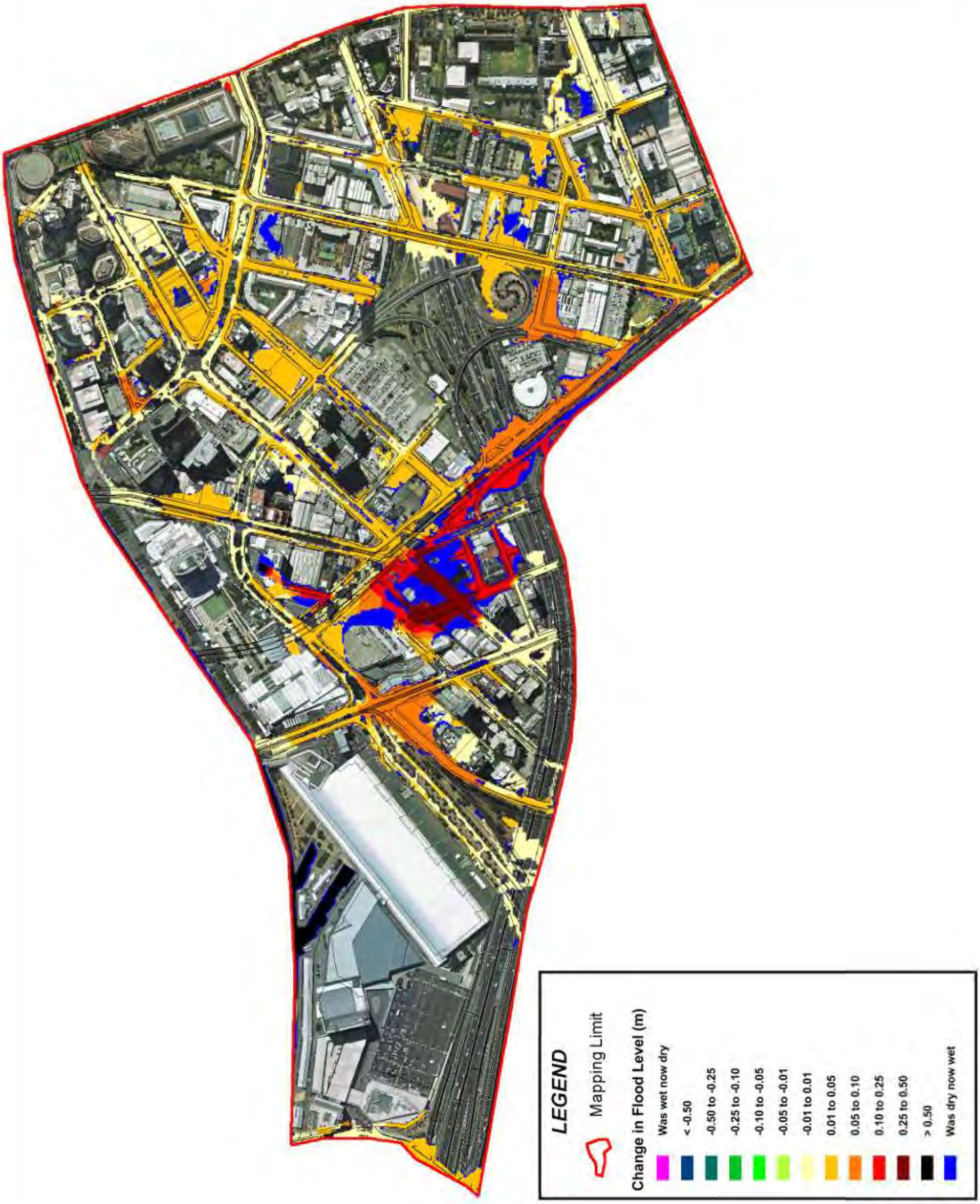

Title:

Southbank - Climate Change +15%
Change in 100 Year ARI Peak Flood Heights - MSL

Figure: **7-11**

Rev: **A**

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7.4 Summary of Future Climate Conditions

The modelling presented in this section indicates that the Southbank Precinct will be severely impacted by flooding under future climate conditions. Regardless of the increase in rainfall intensity (15% or 32%), the flooding experienced under a future climate will be dominated by the elevated tailwaters. Whilst the elevated tailwaters do not flood the Southbank Precinct (with the exception of the 100 year ARI Yarra River flood level), these tailwater conditions prevent the drainage network from operating as currently designed (by gravity).

The prolonged elevated tailwater levels experienced as part of a future climate will require the drainage system to be pumped in order to prevent ponding of floodwater within the Precinct.

8 Modelled Opportunities (Future Climate)

The opportunities identified in Section 5 and modelled in Section 6 were also modelled in the future climate scenarios to determine their respective benefits under the future climate conditions. The modelled opportunities were exactly the same as those modelled in Section 6.

8.1 Flood Modelling

The concepts outlined in Section 4 were applied to future climate flood model developed for the Southbank precinct catchment (Section 6.7). This section discusses the incorporation of the concepts into the future climate flood model and the results of the flood modelling. The results of the flood modelling have been presented as Flood Impact Maps.

The concepts were tested in the flood model for the same ARI events and durations as the base case modelling. The modelling was undertaken using the future climate MSL tailwater condition. Only the CSIRO based increase in rainfall intensity has been mapped due to the dominance of the tailwater level in flooding of the Southbank precinct.

8.1.1 Flood Impact Maps

Flood Impact Maps, are maps that show the change in flood depths between, typically, the existing case conditions and a modelled flood mitigation option. Flood Impact Maps are presented for each modelled option comparing the existing conditions flooding to the modelled options flooding. For each ARI event modelled, peak flood envelopes were prepared that calculate the peak flood level for each of the durations modelled.

In these figures, the pale yellow colour represents nominal change in modelled flood depth within +/- 50 mm. Green colours represent a reduction in flood depths, whereas red and brown colours represent increases in flood depth. Areas that are pink are areas that were wet and are now dry in the modelled option, whereas areas that were dry and are now wet are represented as dark blue.

8.1.2 Water Sensitive Urban Design Treatments

This modelling scenario includes all the proposed WSUD treatments to the subsequent flood impact mapping presents the impact of the implementation of a range of identified WSUD treatments throughout the catchment. The treatment measures incorporated in the model include:

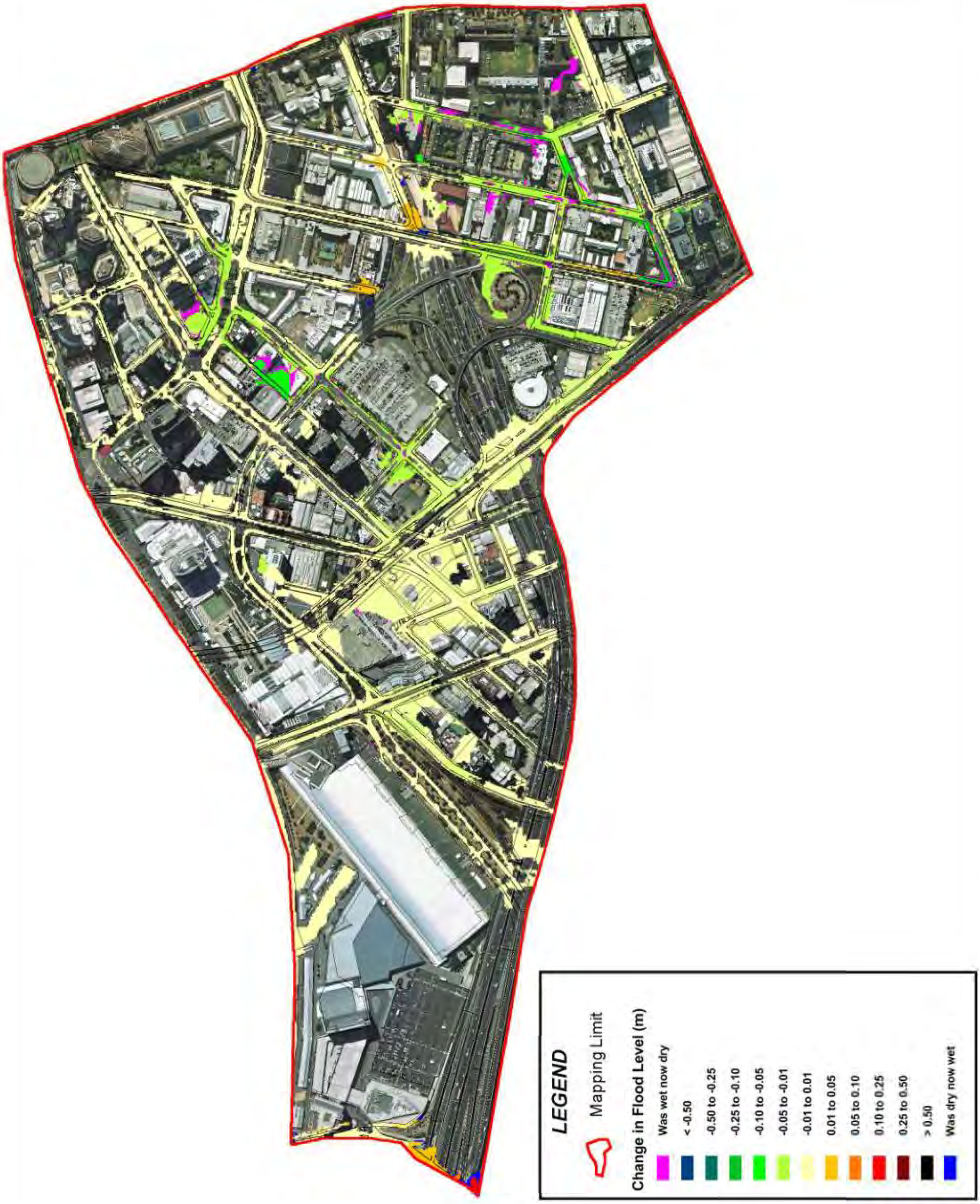
- WSUD measures along Southbank Boulevard, Whiteman Street and Normanby Road;
- All proposed WSUD measures from the Wells Street Study;
- Storage tanks at MCEC and Crown Casino; and,
- Storage tanks at the proposed development of Kavanagh Street.

8.1.2.1 Discussion of Results

While the tailwater levels of the future climate scenario dominates the flooding behaviour, there are stills in noticeable reductions in flood levels during the 5 year ARI flood event (reductions of more than 0.05 metres) and reductions in the flood extent throughout the Wells Street area and along

Southbank Boulevard (the upper parts of the catchment). Minor reductions are noted downstream of the Kavanagh Street development.

During the 100 year ARI flood event, widespread flood reductions of up to 0.05 metres are observed throughout the upper portion of the catchment (Wells Street area Southbank Boulevard and along Kings Way), although the reductions are not as significant as those experienced under the current climate conditions.



Title:

Southbank - Climate Change +32% - WSUD
Change in 5 Year ARI Peak Flood Heights - MSL

Figure: **8-1**

Rev: **A**

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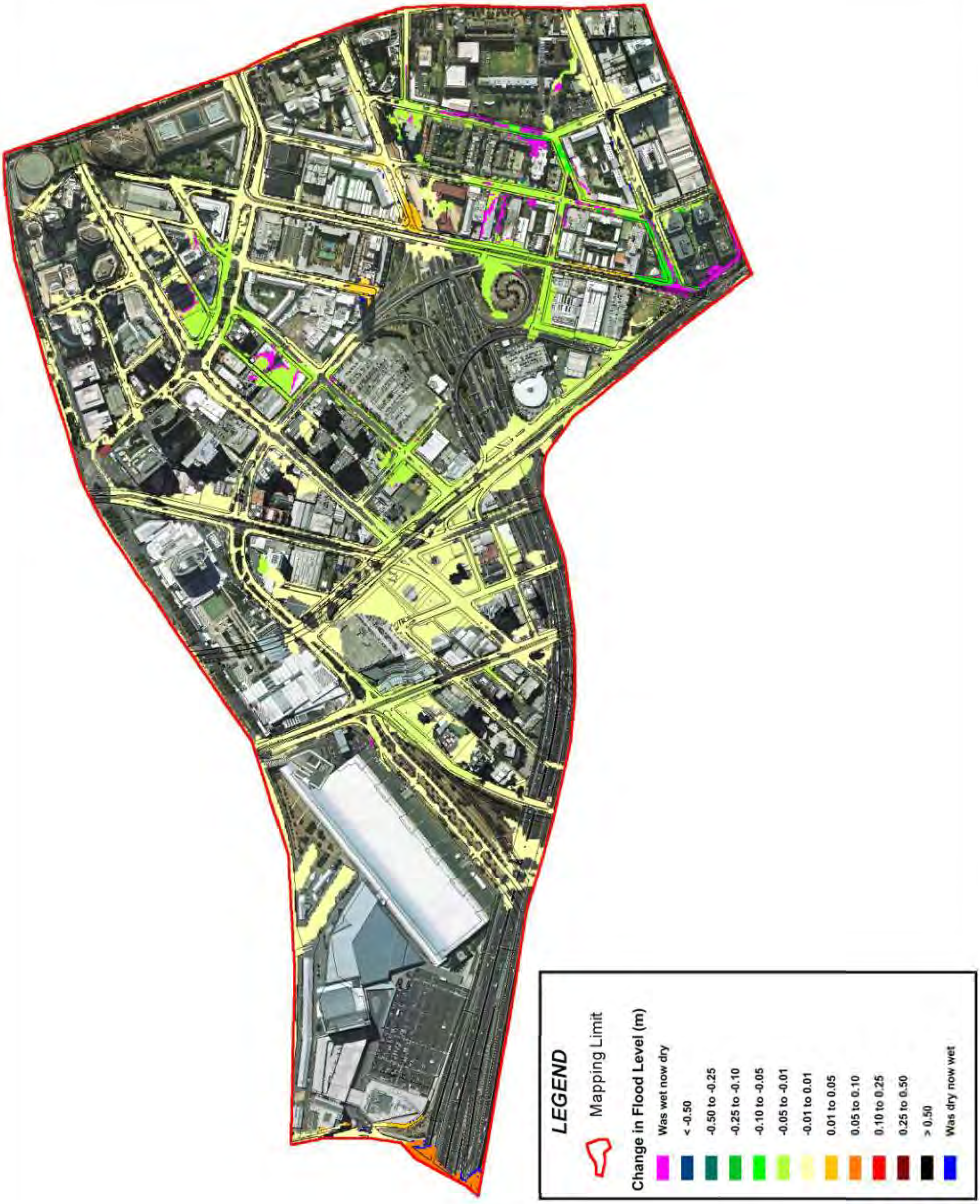

Title:

Southbank - Climate Change +32% - WSUD
Change in 10 Year ARI Peak Flood Heights - MSL

Figure: **8-2**

Rev: **A**

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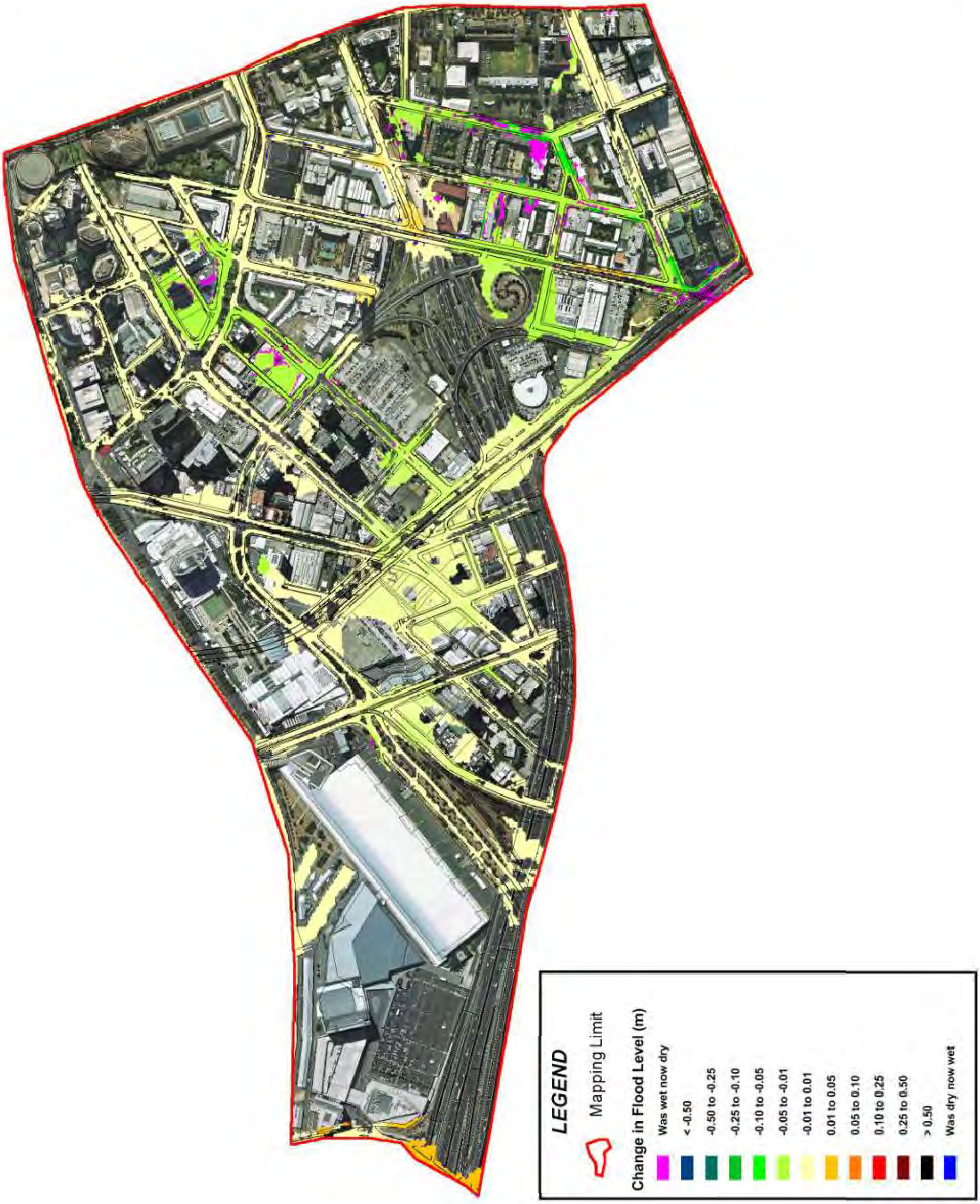

Title:

Southbank - Climate Change +32% - WSUD
Change in 20 Year ARI Peak Flood Heights - MSL

Figure: 8-3

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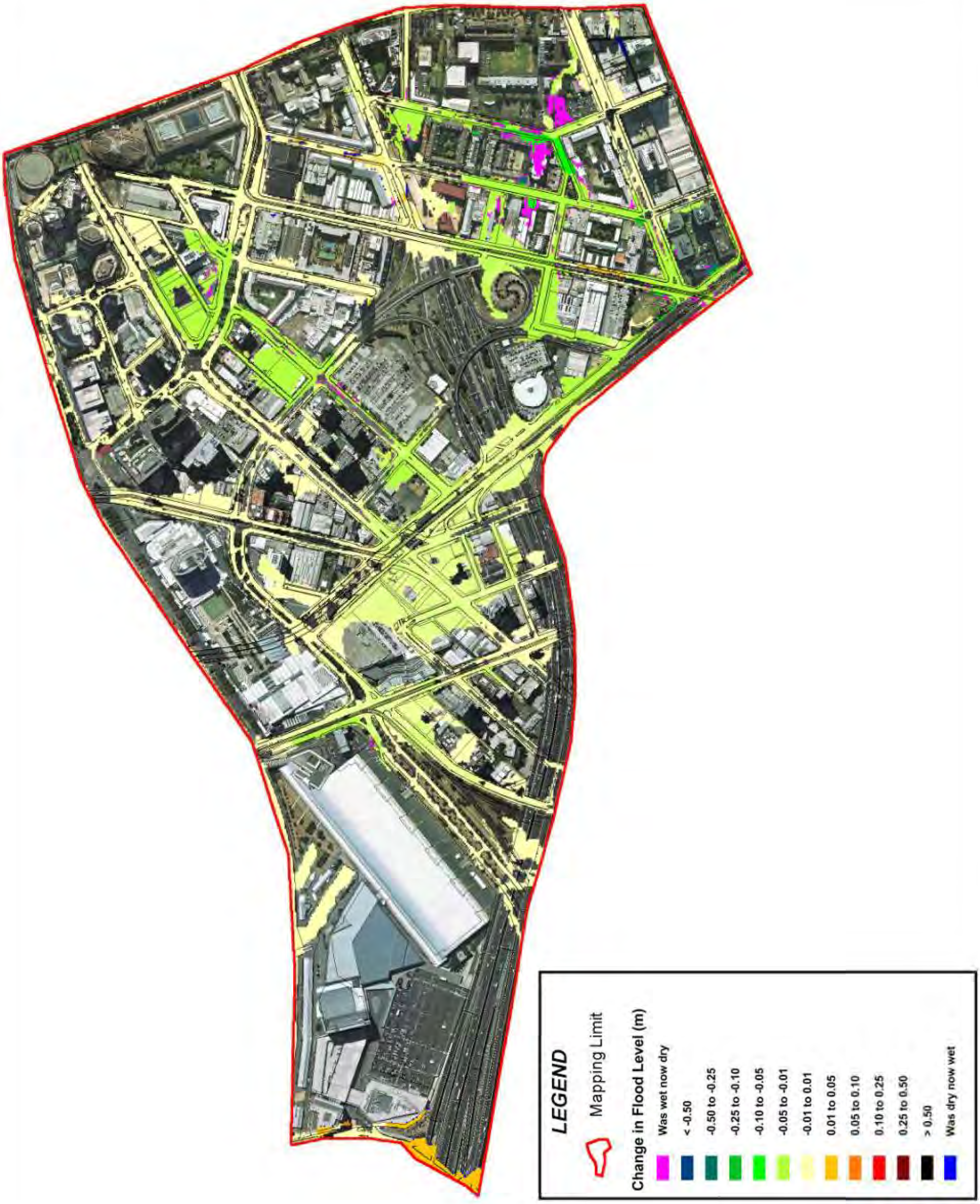

Title: **Southbank - Climate Change +32% - WSUD Change in 50 Year ARI Peak Flood Heights - MSL**	Figure: **8-4**	Rev: **A**

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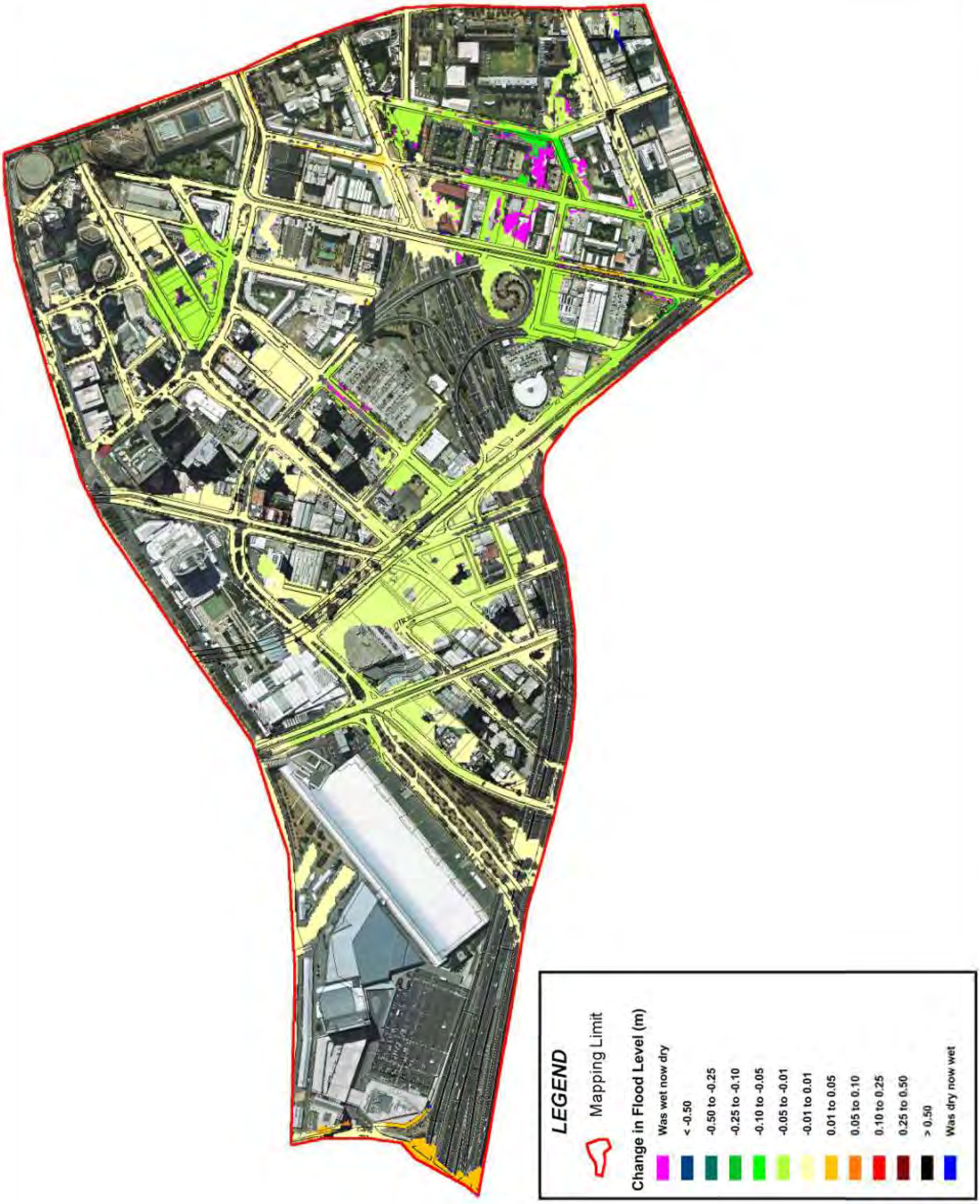

Title:
Southbank - Climate Change +32% - WSUD Change in 100 Year ARI Peak Flood Heights - MSL

Figure: 8-5

Rev: A

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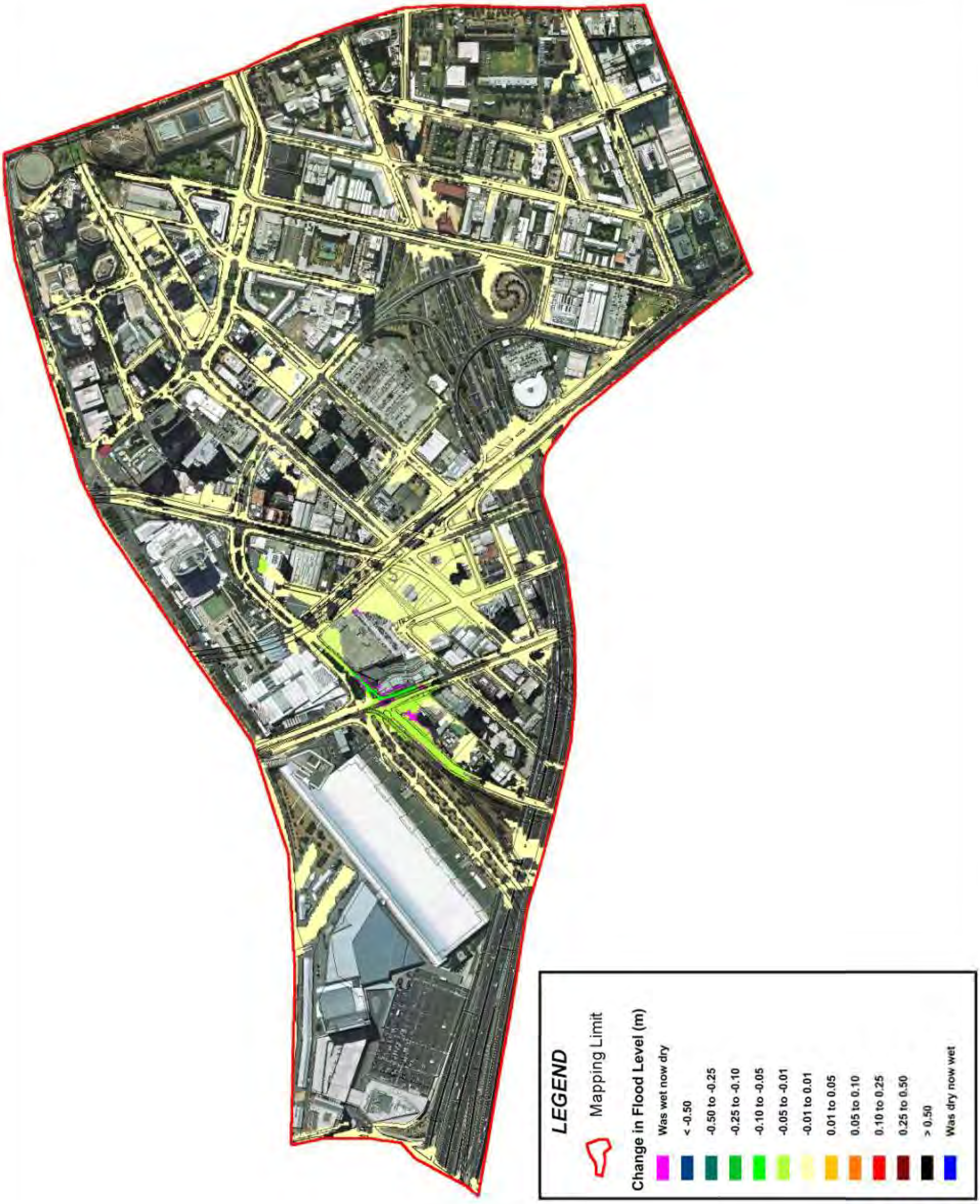
8.1.3 Pipe Augmentation

The subsequent flood impact mapping presents the impact of the construction of a duplicated pipe from the intersection of Clarendon Street and Whiteman Street to the Yarra River. The pipe duplication is the City of Melbourne pipes only and does not impact the Melbourne Water pipe network.

The inverts of the duplicated pipe are identical to the existing pipe network.

8.1.3.1 Discussion of Results

The pipe augmentation option provides minimal benefits in terms of a flood level reduction, due to the elevated water levels impacting the flood behaviour in this location (Clarendon Street and Whiteman Street). The duplicated pipe is under to discharge via gravity into the Yarra River and essentially acts as an underground storage (albeit a small one).



Title:
Southbank - Climate Change +32% - Pipe Change in 5 Year ARI Peak Flood Heights - MSL

Figure: 8-6

Rev: A

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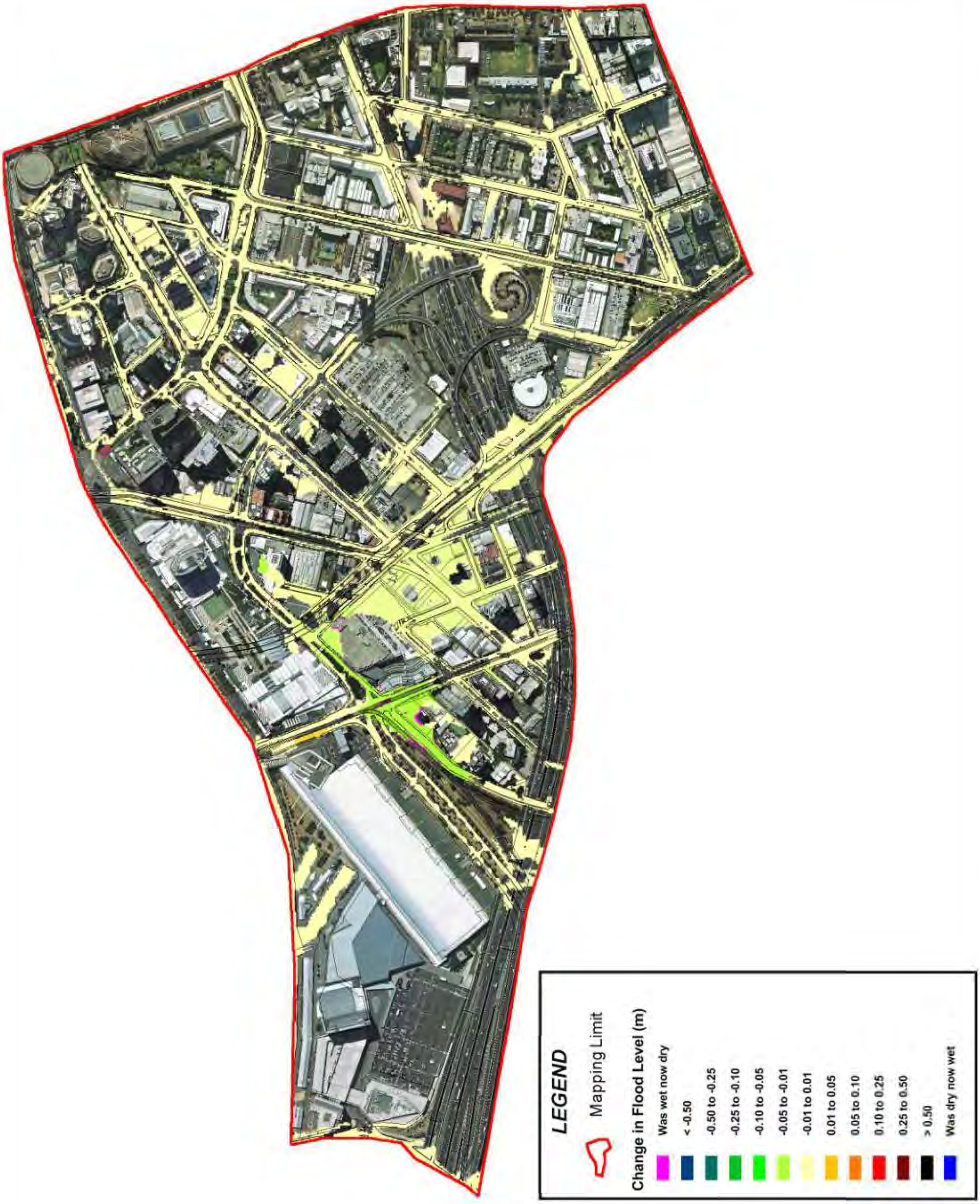

Title:

Southbank - Climate Change +32% - Pipe
Change in 10 Year ARI Peak Flood Heights - MSL

Figure: **8-7**

Rev: **A**

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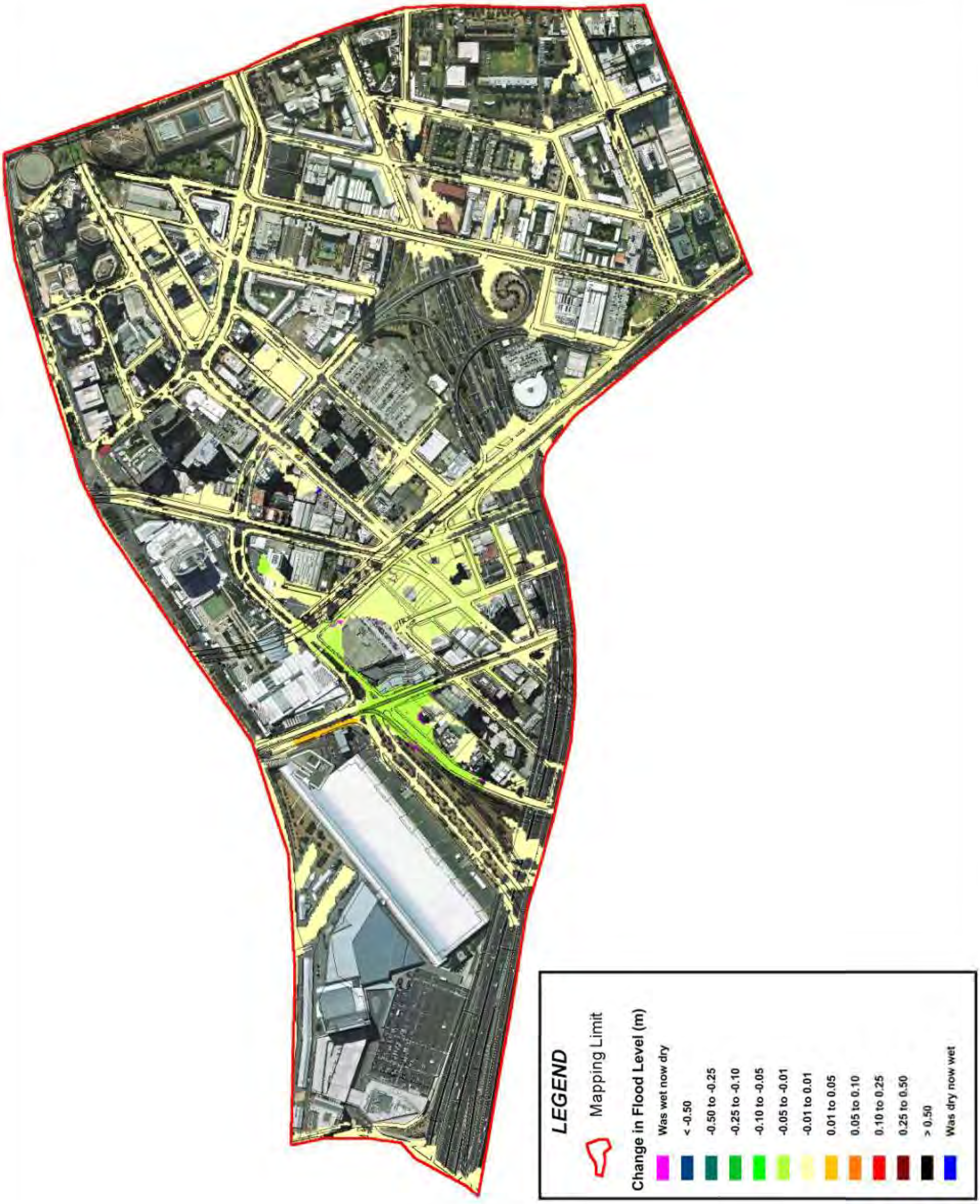

Title:

Southbank - Climate Change +32% - Pipe
Change in 20 Year ARI Peak Flood Heights - MSL

Figure: 8-8

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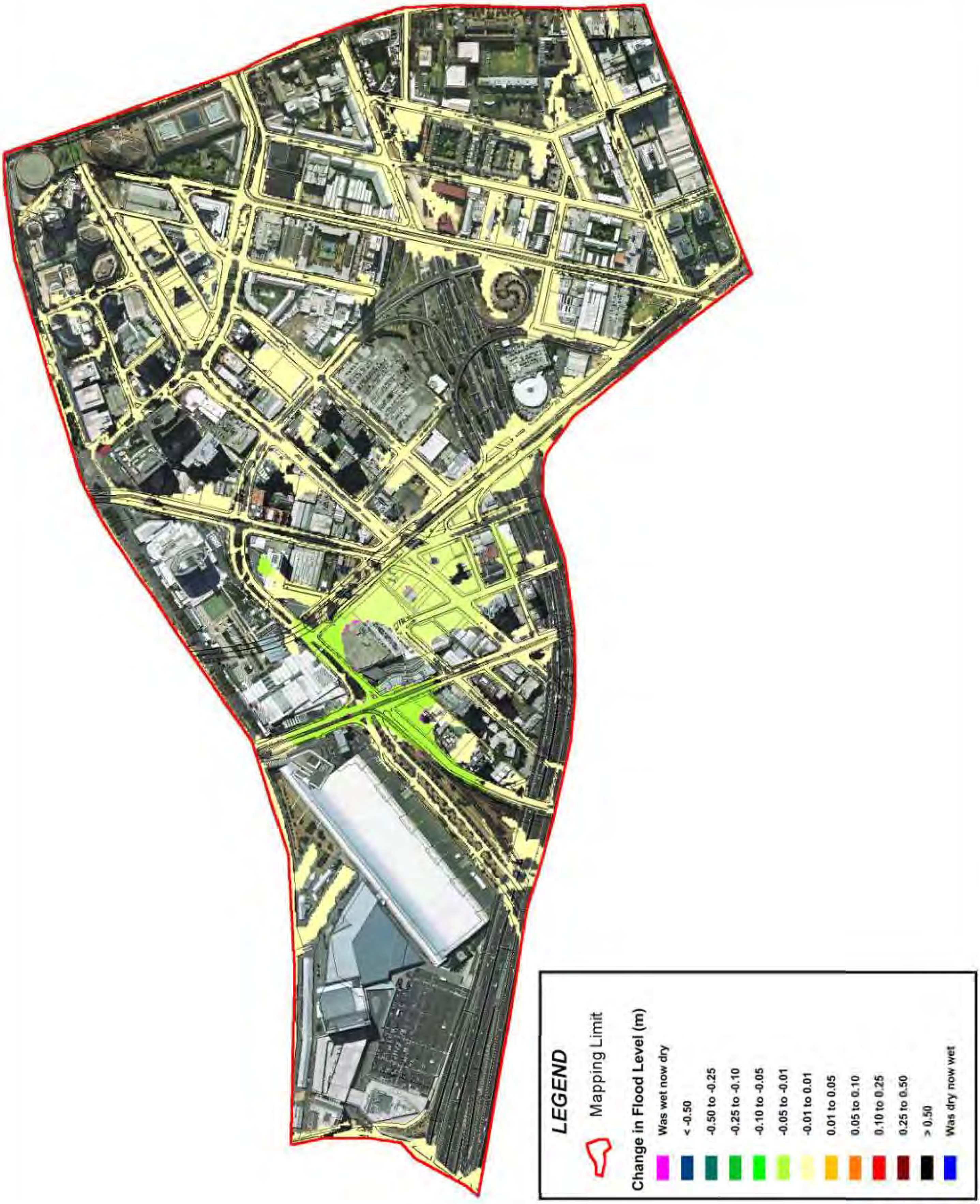

Title:

Southbank - Climate Change +32% - Pipe
Change in 50 Year ARI Peak Flood Heights - MSL

Figure: 8-9

Rev: A

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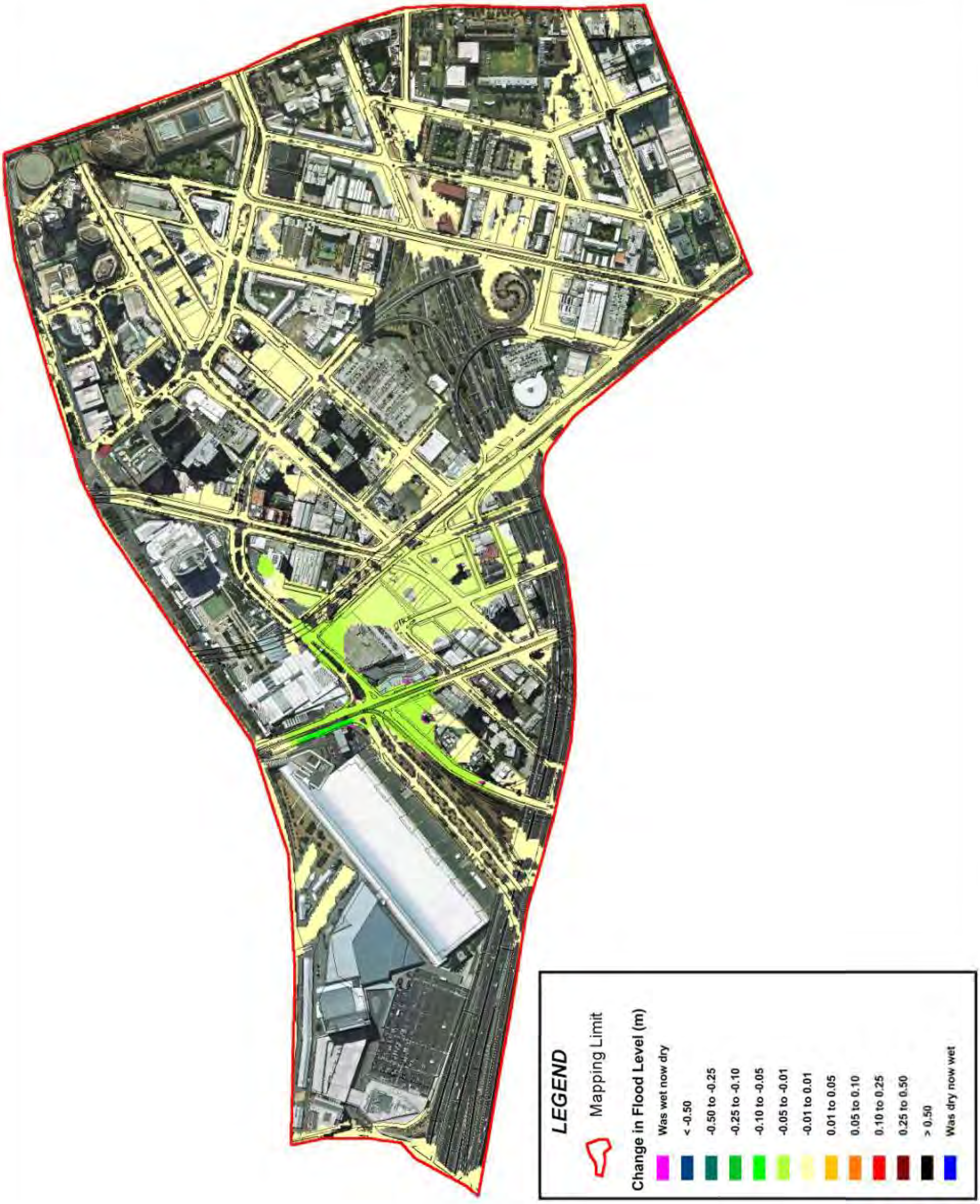

Title:

Southbank - Climate Change +32% - Pipe Change in 100 Year ARI Peak Flood Heights - MSL

Figure: **8-10**

Rev: **A**

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8.2 Summary of Modelled Opportunities (Future Climate)

The flood modelling indicates that a larger benefit (in terms of reduction of reductions in peak flood depths) occurs as a result of the implementation of WSUD treatments. However, the benefits are not as significant as those experienced under the current climate. The change is the result of the influence of the tailwater level under a future climate and the volume of water stored in WSUD treatments being insignificant when compared to the volume of floodwater ponding in the precinct.

There is also additional potential to implement WSUD treatment throughout the precinct (other than those identified in this report) as further redevelopment and road upgrades occur.

Assuming that WSUD treatments are implemented in an opportunistic manner (during road upgrades, redevelopment) rather than as a retrofit, the costs are likely to be significantly less that drainage system upgrades.

9 Recommendations

This section discusses the recommendations of the Southbank Stormwater Investigation based on the flood modelling and analysis outlined in previous sections of this report. This work has shown that there is a significant flood risk to the Southbank precinct currently and this risk will increase into the future due to the expected impacts of climate change on both extreme rainfall intensity and sea level rise. This means that the level of risk and also the predominant source of risk to Southbank will change over time. For these reasons the recommendations are considered over three time horizons;

- The current period (0 to 15 years);
- The medium term (15 to 50 years); and,
- The long term (50 years and beyond).

These time horizons are largely dependent on the quantum and timing of the impacts of climate change. If the impacts of climate change are realised sooner than current projections the time horizons will contract, that is, recommendations in the medium and long term will need to be brought forward. Conversely, if the expected impacts of climate change occur slower than predicted the time horizons will extend further into the future.

Recommendations for each time horizon are set out below.

9.1 Current time horizon (0 to 15 years)

As discussed in Section 3.3.3, the main source of flood risk to Southbank is flooding from the rainfall and in inefficiencies in the drainage system. The secondary source of flooding is the tidal levels in Yarra River, either infiltrating the drainage system and inundating low lying areas or tide-locking outfalls.

The recommendations for the current time horizon focus around these sources of risk, with the main measures being:

- WSUD treatments
- Planning controls
- Maintenance - in particular Yarra River outlets
- Traditional drainage measures
- Augment Pipe along Clarendon Street

9.1.1 WSUD Treatments

WSUD treatments broadly refer to measures such as on-site detention, stormwater harvesting ponds, wetland and the like that have been designed to accommodate flood water. These measures can be effective at reducing flooding locally and also regional scale in catchments such as Southbank where there are areas that are volume dominated. This has been demonstrated in Section 6.6.2 though the incorporation of the Wells Street WSUD treatments (see for instance

Figure 6-5). In addition, WSUD treatments have the potential to provide co-benefits, such as harvestable water and pollutant reductions.

WSUD treatments can be incorporated into public space or private land. While public space in Southbank is limited there are opportunities, such as:

- The Power Street Loop in the Wells Street catchment
- The redevelopment of Southbank Boulevard

These opportunities should be actively sought and incorporated into CoM works where feasible. Opportunities with external organisation, such as TransUrban (Power Street Loop) should also be sought. The opportunities compatible with public space could be of the form of:

- Stormwater harvesting
- Detention ponds or wetlands
- Raingardens and infiltration

The bulk of the land in Southbank is not in the control of the CoM; however, this does not preclude the use of WSUD treatments. As part of this report the following opportunities have been identified onsite not in the control of the CoM:

- Victoria Barracks
- 93 – 115 Kavanagh Street
- Crown Entertainment and Melbourne Convention and Exhibition Centre
- 1 – 25 Queens Bridge Street

The opportunities to-date have been opportunistic and it is recommended that planning control are put in place to ensure that development and redevelopment trigger a referral (see discussion below). The use of WSUD treatments in these situations could take the form of:

- Storage and reuse tanks (collecting water from the site)
- Harvesting of off-site water from the drainage system
- Raingardens and infiltration systems

Site Integrated Water Cycle Management (IWCM) are recommended as a means of assessing and incorporating WSUD treatments into site. In addition, a Site IWCM plan will also provide guidance and recommendations on how to contribute to the CoM overall water management strategy.

Recommendations

- Opportunities to work with land holders and developers are actively sought
- New development and significant redevelopments are required to produce a site Integrated Water Cycle Management Plan that incorporate WSUD treatments where practical
- When public land is redeveloped WSUD treatments are incorporated

- Tools within the planning scheme are amended to ensure referrals are directed to the appropriate area within the CoM

9.1.2 Planning controls

Planning controls such as overlays can be used to ensure development and significant redevelopments are referred to the appropriate area within Council. These Planning Controls could be used to implement recommendations such as site IWCM plans.

Recommendation

- Planning Controls are developed to ensure referrals are triggered and IWCM plans are required.

9.1.3 Management and maintenance

On-going maintenance of any drainage system is required to ensure it is functioning. In Southbank this must include the drainage outfalls to the Yarra River. Further, maintenance will be required of WSUD treatments.

The modelling presented in Section 4 clearly demonstrates the importance of drainage outfalls to the Yarra River, with Figure 4-1 and Figure 4-2, highlighting the consequence of the failure of these outfalls. As a minimum these outfalls should be inspected regularly, every three months or when there are reports of daily flooding during high tides. A preferable system would be to install telemetry to monitor the system and send alerts when the outfalls are failing. It is recommended that a feasibility study of this is undertaken.

With the installation of distributed WSUD treatments throughout the precinct there will be a need for on-going maintenance. Given, that many of the likely sites are occur on land not in the control of the CoM clear roles and responsibilities in terms of maintenance will need to be agreed. It is recommended that this is in the planning phase of the project or the required Site IWCM plan.

Recommendations

- Ongoing maintenance of the drainage system to ensure its continuing functioning
- Inspection of the Yarra River outfalls every 3 months or when reports of daily flooding at high tide occur
- Feasibility study into a telemetered system to monitor the status of the outfalls
- Agreed roles and responsibilities for the ongoing maintenance of WSUD treatments in the Site IWCM plans

9.2 Medium term time horizon (15 to 50 years)

Implementation of the measures recommended in the current period will have continuing benefit into the future time horizons. At this stage it is difficult to predict with any certainty what opportunities to work with land owners and developers will exist this far into the future; however opportunities should be continuously sought after. The more specific recommendations in this section are therefore, aimed a large scale capital works to allow the drainage system to function effectively.

During the medium time horizon, it is expected that the tidal source of flooding will become increasing dominant. The recommendations for the medium term time horizon is to continue with WSUD treatments and to implement a drainage system that is able to discharge to higher water levels in the Yarra River.

9.2.1 WSUD Treatments

While there is a reasonably high turnover of building stock in the Southbank precinct it is envisaged that there will continue to be opportunities to work with land holders and developers to install WSUD treatments. Furthermore, it is likely that new technologies for water management will continue to be developed.

Recommendations

- Continued investment in WSUD treatments and Site IWMC plans

9.2.2 Fully Pumped Drainage System

As the mean sea level rises throughout this century, drainage outfall to the Yarra River will increasingly be tide-locked. At some point this will become regular event. The drainage system will not be able to drain under gravity and it will become necessary to actively drain the system, this will require a pumped system. Eventually, the Southbank drainage system will be fully pumped.

Given the lack of available land in the Southbank precinct it will be necessary to begin planning for a fully pumped system will need to commence well before its delivery. Sites will need to be identified and agreements reached to house pumping stations and other infrastructure.

One advantage of a fully pumped drainage system is that the size of the existing pipes will not have to be upgraded, although they may need to be replaced to cope with the additional pressure. This means that any required relocation of existing services will be kept to a minimum.

Recommendation

- Feasibility studies and implementation of a fully pumped drainage system

9.3 Long Term Time Horizon (50 years and beyond)

As discussed in Section 6.7, during the Long Term time horizon, tidal flood levels will be the dominant driver of flood risk. To manage this flood risk significant drainage works will be required. As for the Medium Term time horizon, the exact timing of the required improvements is not possible to predict; however, given future prediction of sea level and low lying land in Southbank it is clear significant works will be required to ensure that Southbank continues to function effectively.

It is envisaged that during this time horizon a fully pumped drainage system for Southbank will be completed. It will therefore be necessary to investigate other measure to defend against the expected rise in sea level and hence Port Phillip Bay levels. These options will be extensive and expensive.

It is recommended that hard defences against increasing tidal levels are investigated. This would include sea walls along the river frontage; however, the low lying land extends beyond the Southbank precinct into Fishermans Bend and beyond. Therefore this option becomes a multicouncil issue that will require co-ordination not only across Local Government Areas, but also across State Government agencies. Consideration will also need to be given to the impacts of increased water levels due to hard defences.

An alternative or supplement to the sea wall option is the construction of a tidal barrage along the lower reaches of the Yarra River. This option involves the construction of a tidal barrier that is operated to exclude high tides and tidal surges. It would be designed to allow the passage of river traffic.

It is recommended that a feasibility study that investigates options to manage the impacts of sea level rise for not only Southbank but all areas impacted by increased tidal levels in the Yarra River. Importantly, this is a multi-agency issue with a number of stakeholders including the City of Melbourne, City of Port Phillip, Hobsons Bay, Maribyrnong City Council, Melbourne Water and various State Government Agencies.

These recommendations represent significant investments and significant saving can be made by considering the timing and phasing of capital works. To investigate this it is recommended that an economic assessment is undertaken, such as a Real Options Analysis.

Recommendations

- A feasibility study into options for Melbourne to adapt to climate change focusing on tidal flood risk from Port Phillip Bay; and,
- Economic assessment to investigate the phasing and timing of significant capital works.

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Appendix A Existing Condition Mapping

Title:
Southbank
5 Year ARI Peak Flood Depth - MSL

Figure: A-1

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigA-1_5y_MSL_dMax_RevA.WOR

Title:

Southbank
10 Year ARI Peak Flood Depth - MSL

Figure: A-2

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigA-2_10y_MSL_dMax_RevA.WOR

Title:

Southbank

20 Year ARI Peak Flood Depth - MSL

Figure: **A-3**

Rev: **A**

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N

0 125 250m
Approx. Scale

BMT WBM
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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigA-3_20y_MSL_dMax_RevA.WOR

Title:
Southbank
50 Year ARI Peak Flood Depth - MSL

Figure: A-4

Rev: A

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Approx. Scale

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Title:
Southbank
100 Year ARI Peak Flood Depth - MSL

Figure: A-5

Rev: A

N

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Approx. Scale

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigA-5_100y_MSL_dMax_RevA.WOR

Title:

Southbank

5 Year ARI Peak Flood Depth - HAT

Figure: **A-6**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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Title:

Southbank
10 Year ARI Peak Flood Depth - HAT

Figure: A-7

Rev: A

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Approx. Scale

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Title:

Southbank
20 Year ARI Peak Flood Depth - HAT

Figure: A-8

Rev: A

BMT WBM

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Title:

Southbank
50 Year ARI Peak Flood Depth - HAT

Figure: A-9

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
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Title:

Southbank

100 Year ARI Peak Flood Depth - HAT

Figure: **A-10**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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Title:

Southbank
5 Year ARI Peak Flood Depth - Storm Surge

Figure: A-11

Rev: A

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Approx. Scale

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigA-11_5y_Storm_dMax_RevA.WOR

Title:

Southbank
10 Year ARI Peak Flood Depth - Storm Surge

Figure: A-12

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigA-12_10y_Storm_dMax_RevA.WOR

Title:
Southbank
20 Year ARI Peak Flood Depth - Storm Surge

Figure: A-13

Rev: A

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Approx. Scale

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Title:

Southbank
50 Year ARI Peak Flood Depth - Storm Surge

Figure: A-14

Rev: A

N

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Approx. Scale

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Title:
Southbank
100 Year ARI Peak Flood Depth - Storm Surge

Figure: A-15

Rev: A

N

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Approx. Scale

BMT WBM
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Title:

Southbank

5 Year ARI Peak Flood Depth - Yarra 100y

Figure: **A-16**

Rev: **A**

N

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Approx. Scale

BMT WBM

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigA-16_5y_Yarra100y_dMax_RevA.WOR

Title:

Southbank

10 Year ARI Peak Flood Depth - Yarra 100y

Figure: **A-17**

Rev: **A**

N

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Approx. Scale

BMT WBM
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Title:

Southbank
20 Year ARI Peak Flood Depth - Yarra 100y

Figure: A-18

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigA-18_20y_Yarra100y_dMax_RevA.WOR

Title:

Southbank
50 Year ARI Peak Flood Depth - Yarra 100y

Figure: **A-19**

Rev: **A**

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Approx. Scale

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Title:

Southbank
100 Year ARI Peak Flood Depth - Yarra 100y

Figure: A-20

Rev: A

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Approx. Scale

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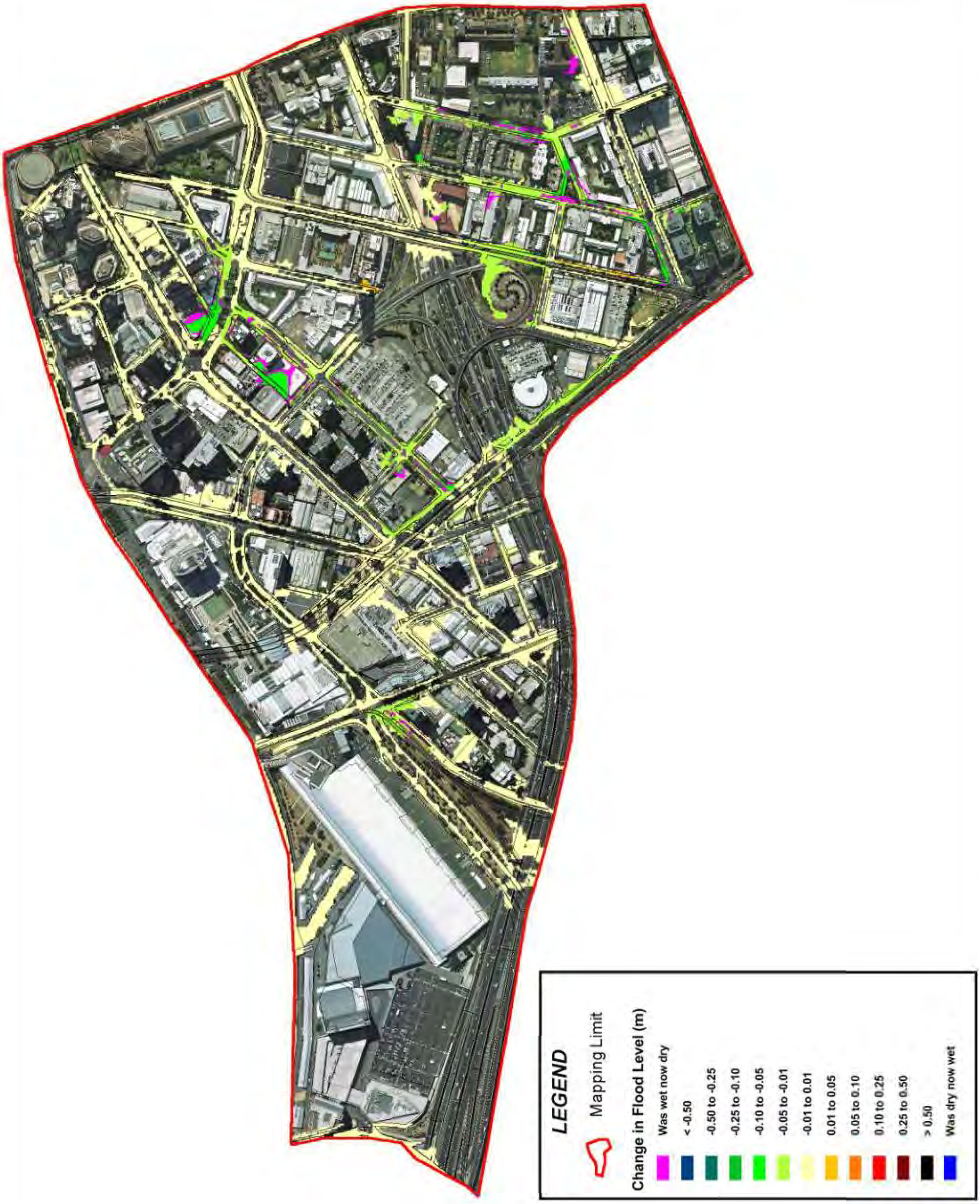
Appendix B Opportunities Mapping (Current Climate)



Title:

Southbank - WSUD
Change in 5 Year ARI Peak Flood Heights - MSL

Figure: B-1

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
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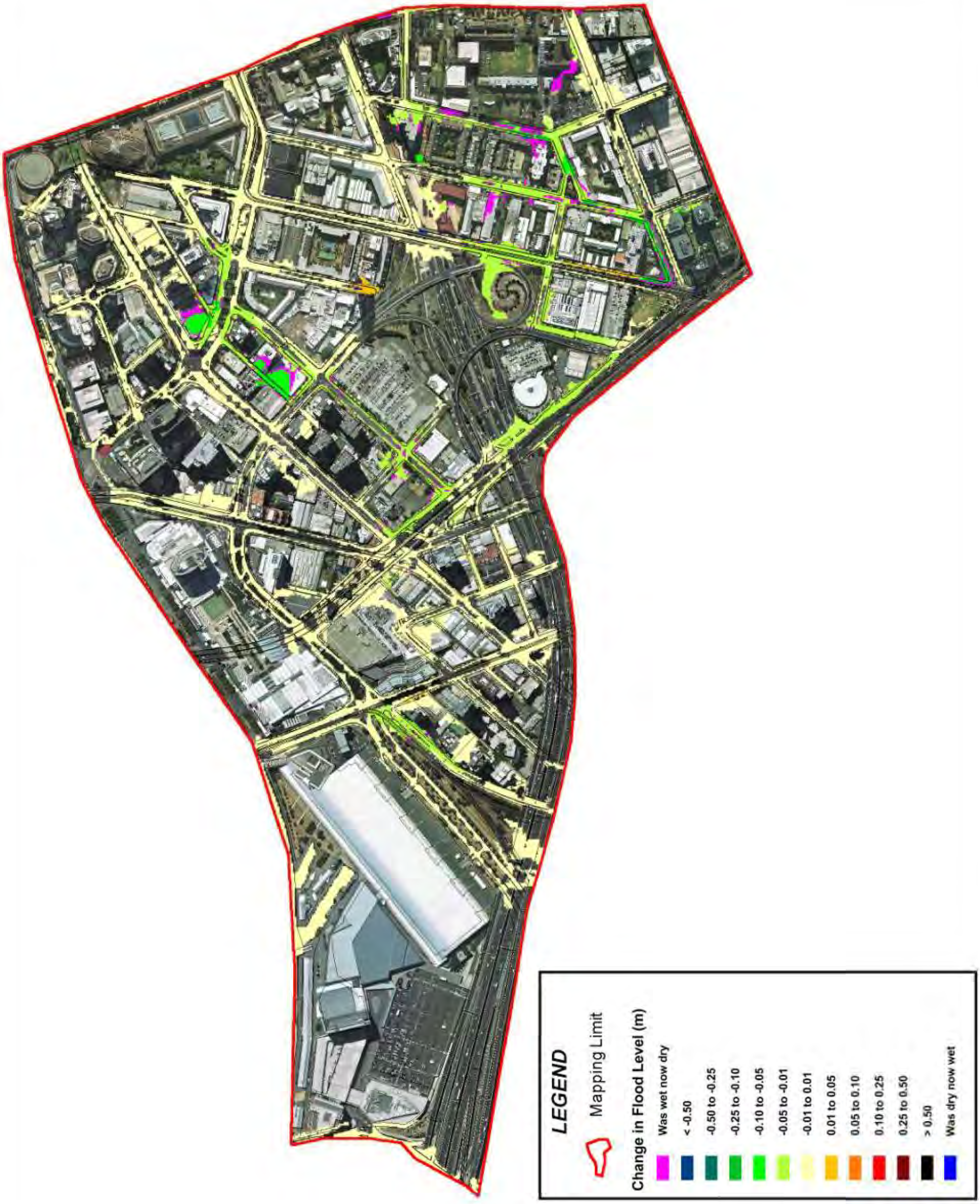
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-1_FldDif_D01_E01_5y_MSL_RevA.WOR



Title:

Southbank - WSUD

Change in 10 Year ARI Peak Flood Heights - MSL

Figure: **B-2**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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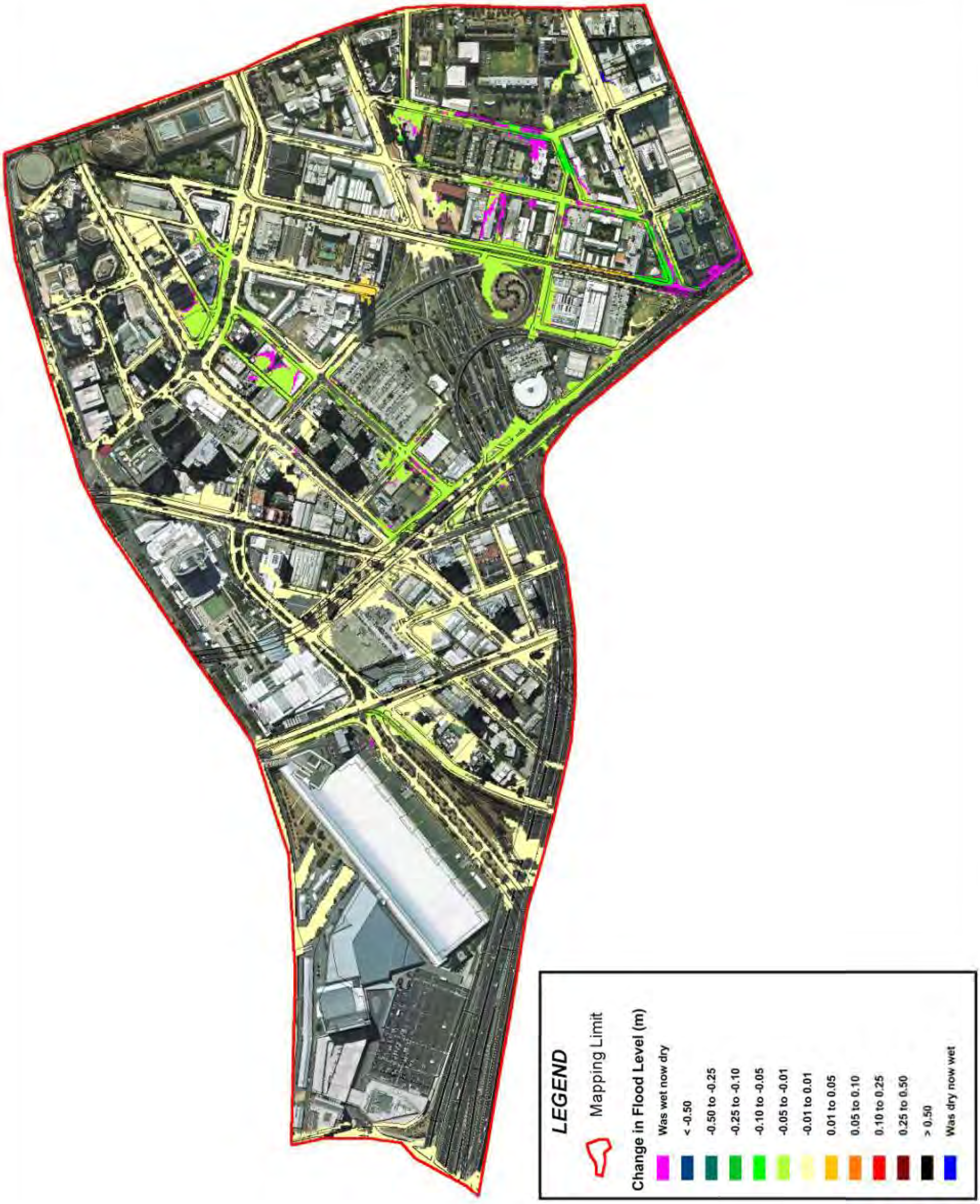
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-2_FldDif_D01_E01_10y_MSL_RevA.WOR



Title:

Southbank - WSUD
Change in 20 Year ARI Peak Flood Heights - MSL

Figure: **B-3**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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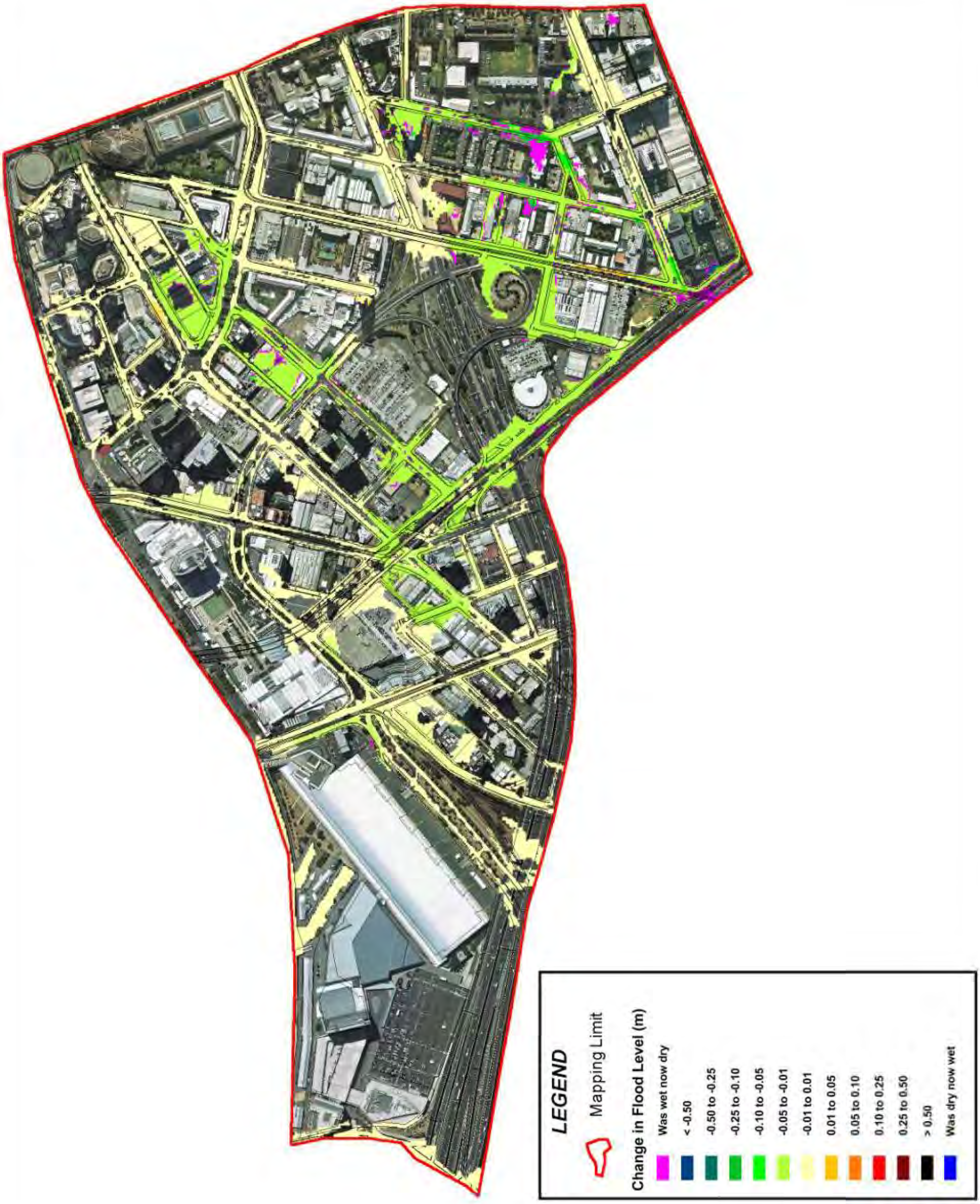
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-3_FldDif_D01_E01_20y_MSL_RevA.WOR



Title:

Southbank - WSUD
Change in 50 Year ARI Peak Flood Heights - MSL

Figure: B-4

Rev: A

N

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Approx. Scale

BMT WBM
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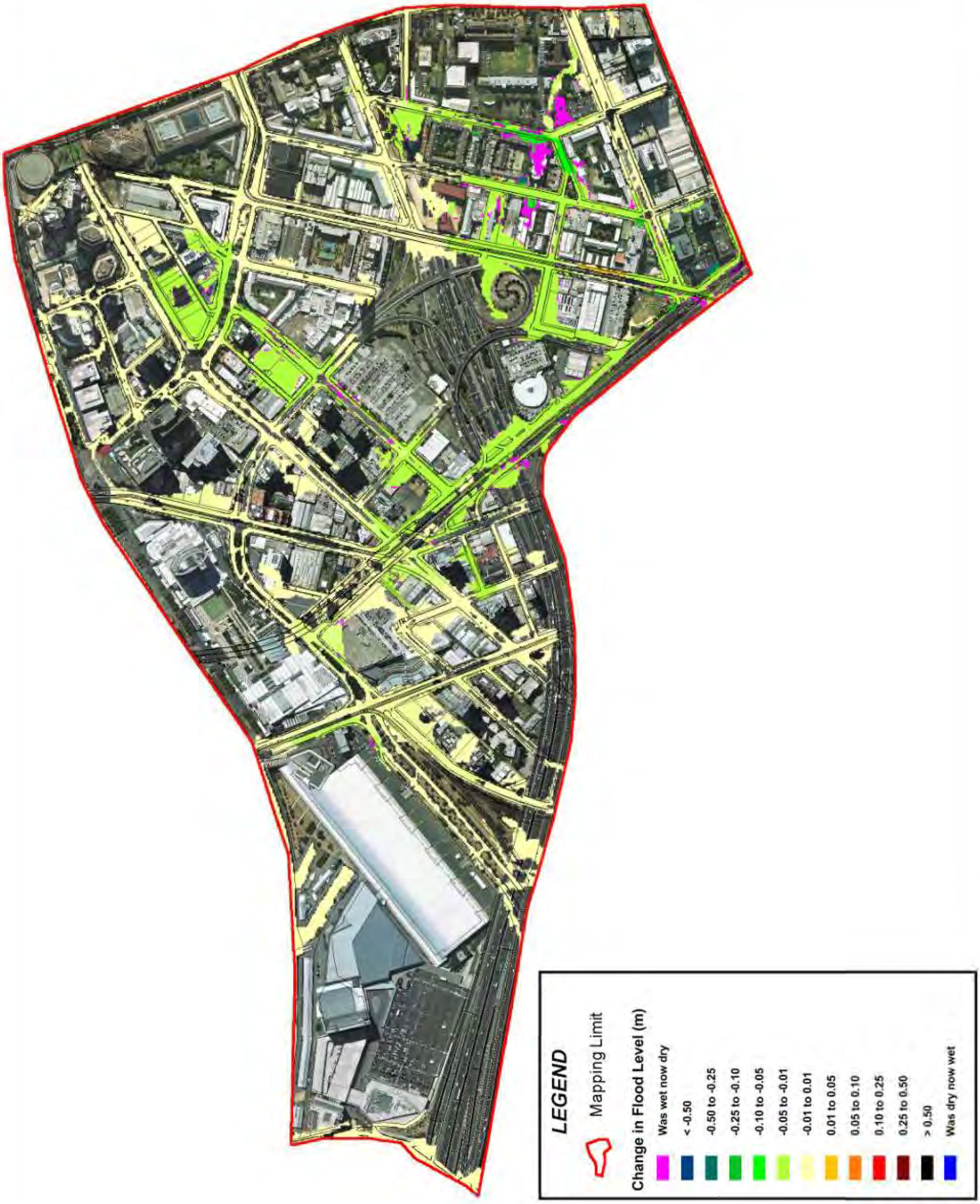
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-4_FldDif_D01_E01_50y_MSL_RevA.WOR



Title:

Southbank - WSUD
Change in 100 Year ARI Peak Flood Heights - MSL

Figure: **B-5**

Rev: **A**

BMT WBM
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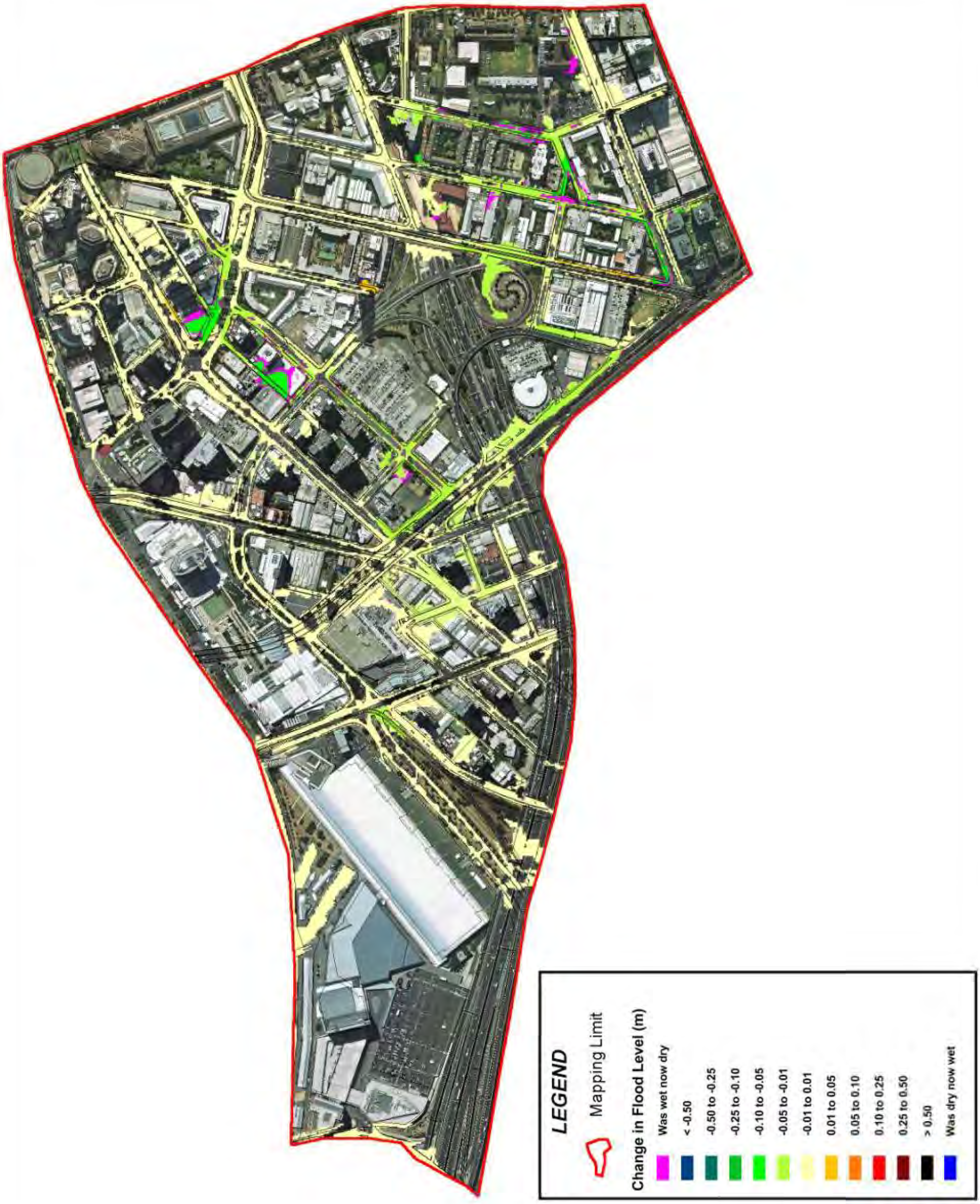

Title:
Southbank - WSUD
Change in 5 Year ARI Peak Flood Heights - HAT

Figure: **B-6**

Rev: **A**

BMT WBM
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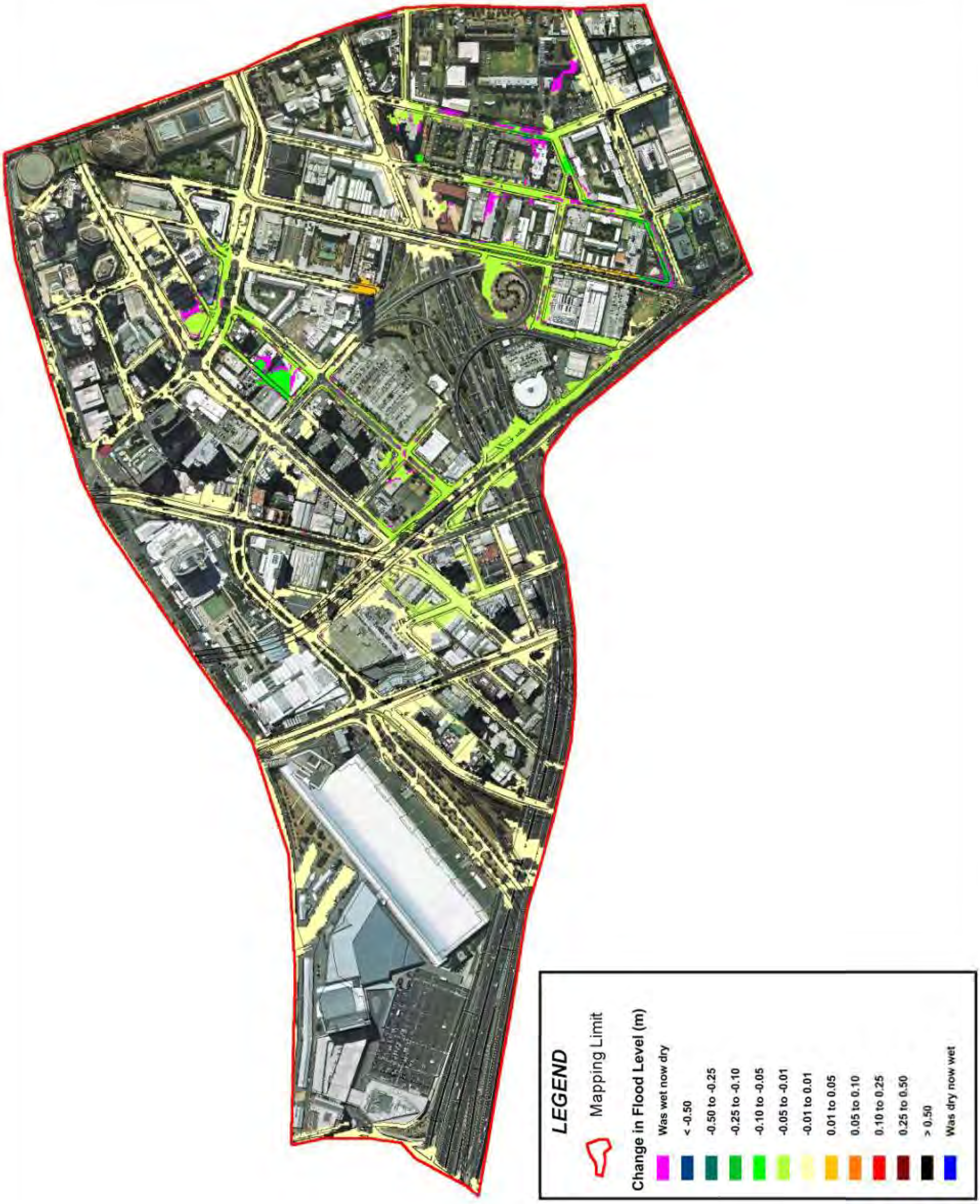


Title:

Southbank - WSUD

Change in 10 Year ARI Peak Flood Heights - HAT

Figure: **B-7**

Rev: **A**

N

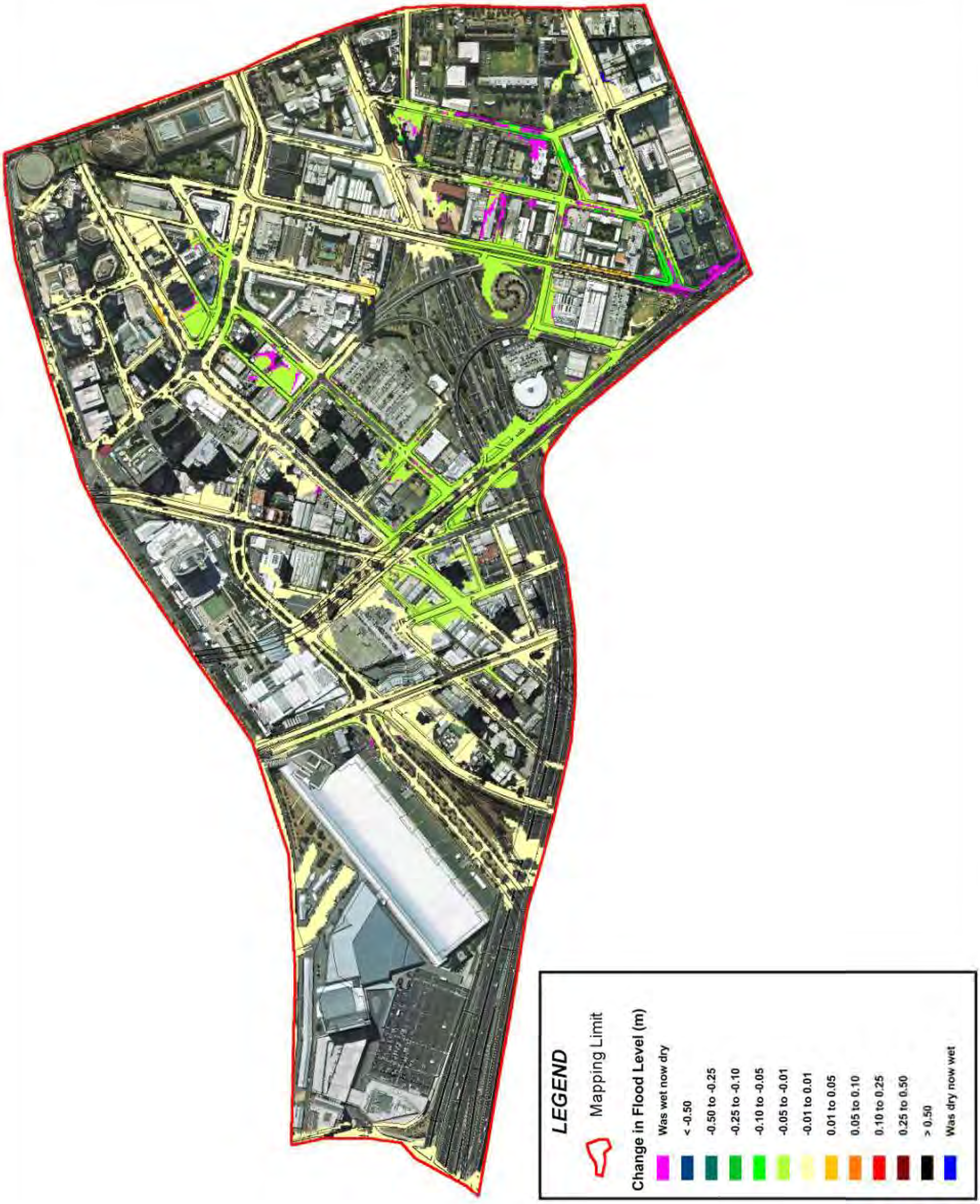
0 125 250m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-7_FldDif_D01_E01_10y_Storm_RevA.WOR



Title:

Southbank - WSUD
Change in 20 Year ARI Peak Flood Heights - HAT

Figure: **B-8**

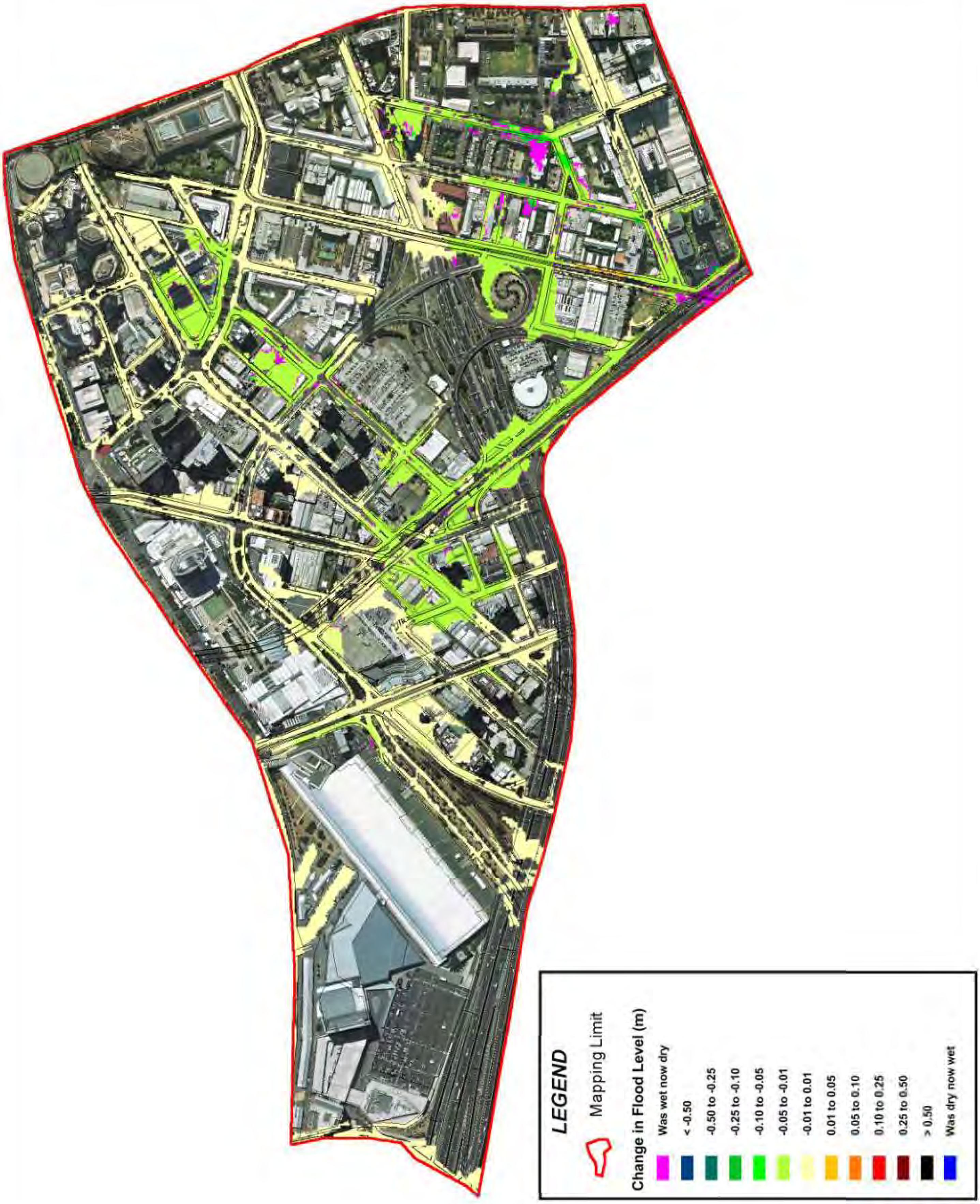
Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-8_FldDif_D01_E01_20y_Storm_RevA.WOR



Title:

Southbank - WSUD

Change in 50 Year ARI Peak Flood Heights - HAT

Figure: **B-9**

Rev: **A**

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N

0 125 250m

Approx. Scale

BMT WBM

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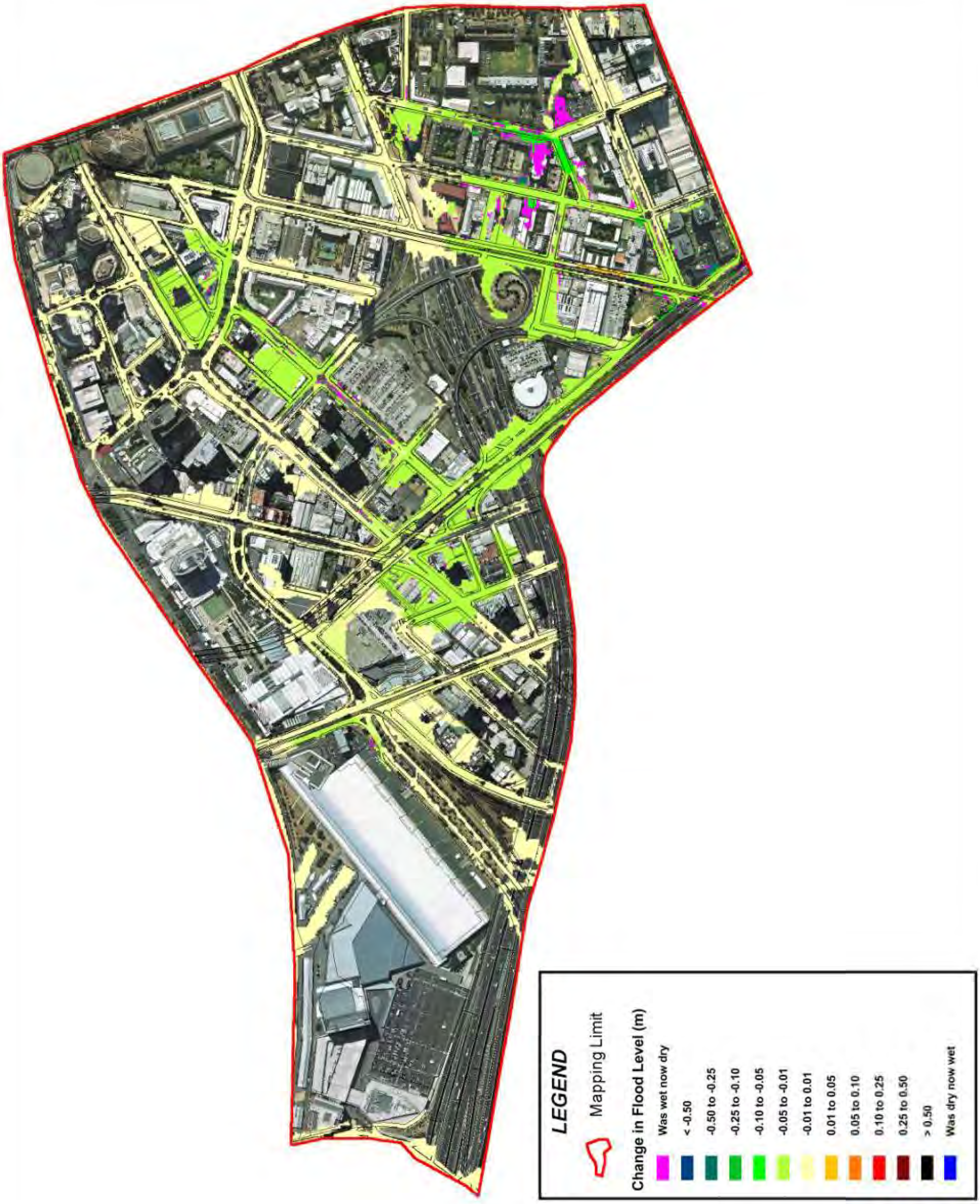
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-9_FldDif_D01_E01_50y_Storm_RevA.WOR



Title:

Southbank - WSUD

Change in 100 Year ARI Peak Flood Heights - HAT

Figure: **B-10**

Rev: **A**

BMT WBM

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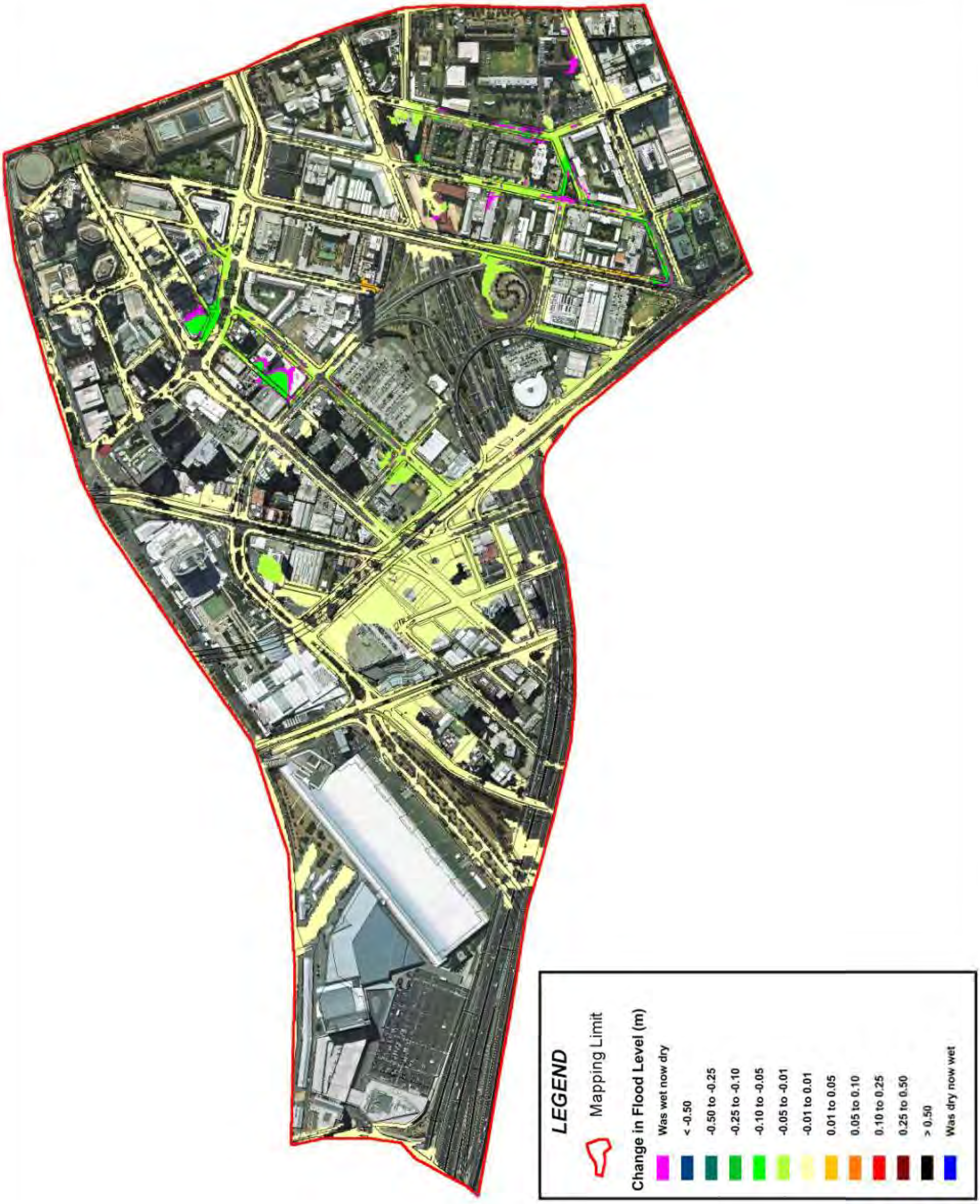
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-10_FldDif_D01_E01_100y_Storm_RevA.WOR



Title:

Southbank - WSUD

Change in 5 Year ARI Peak Flood Heights - Storm

Figure: **B-11**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-11_FldDif_D01_E01_5y_Storm_RevA.WOR

LEGEND

Mapping Limit

Change in Flood Level (m)

- Was wet now dry
- < -0.50
- -0.50 to -0.25
- -0.25 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- > 0.50
- Was dry now wet

Title: Southbank - WSUD Change in 10 Year ARI Peak Flood Heights - Storm	Figure: B-12	Rev: A

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N

0 125 250m
Approx. Scale

BMT WBM
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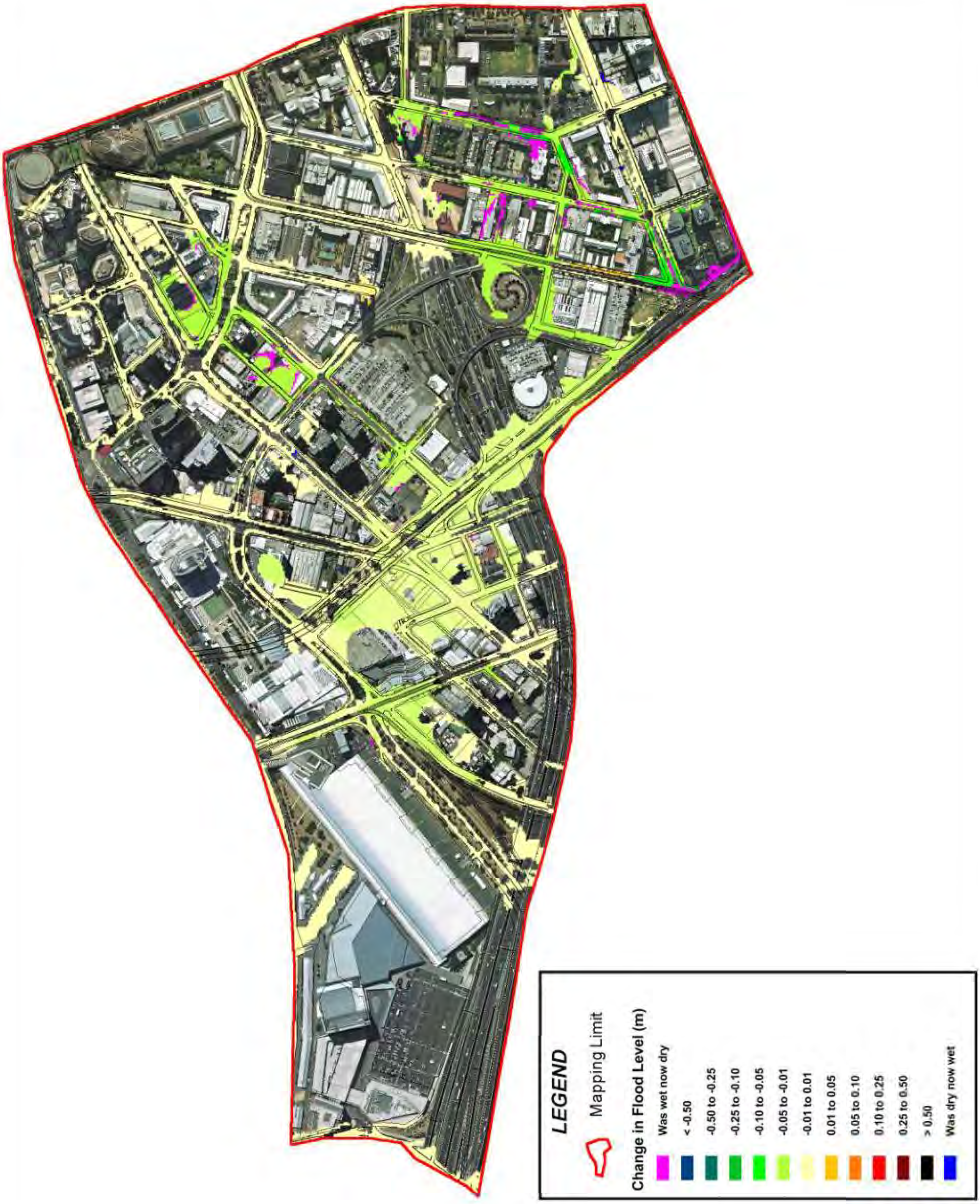
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-12_FldDif_D01_E01_10y_Storm_RevA.WOR



Title:

Southbank - WSUD

Change in 20 Year ARI Peak Flood Heights - Storm

Figure: **B-13**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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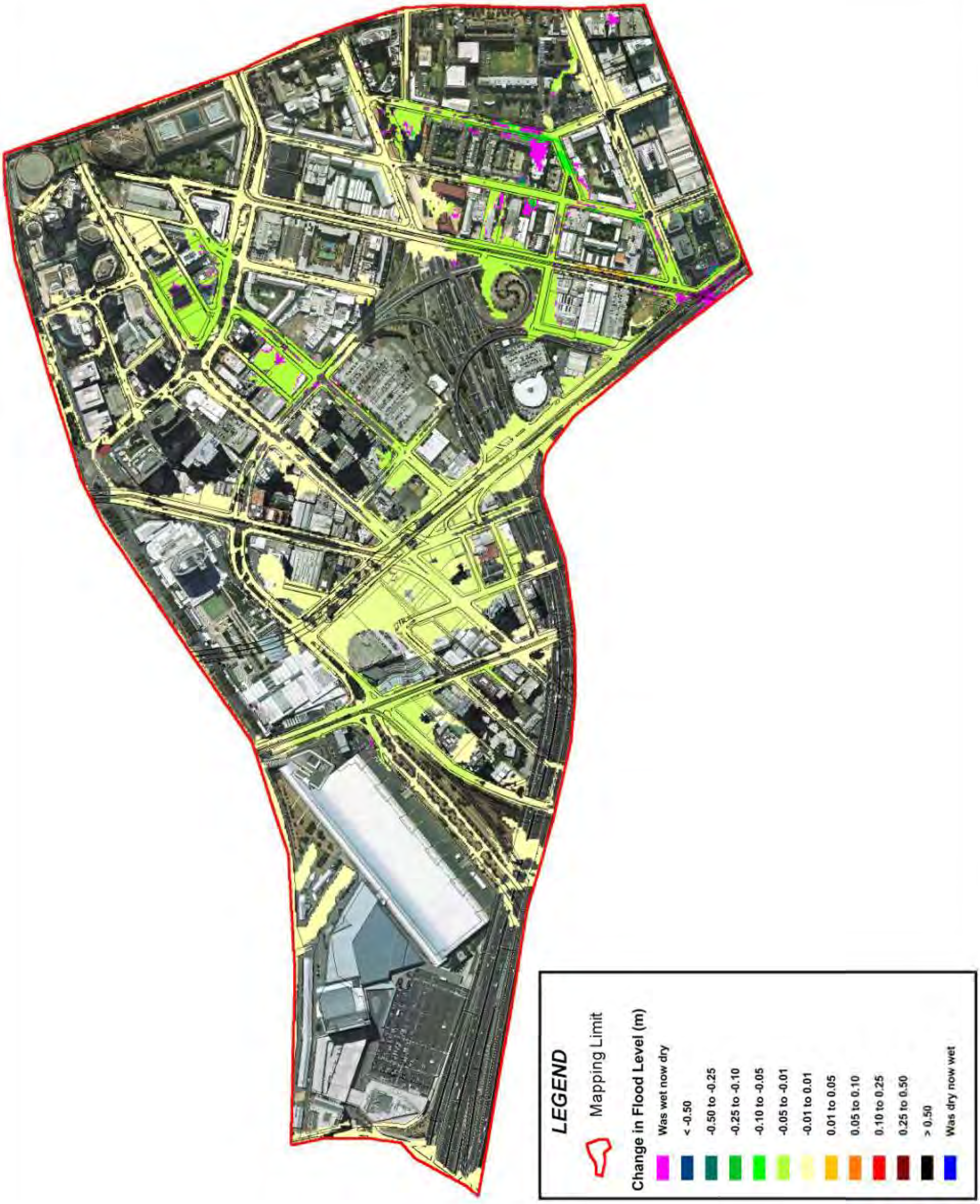
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-13_FldDif_D01_E01_20y_Storm_RevA.WOR



Title:

Southbank - WSUD
Change in 50 Year ARI Peak Flood Heights - Storm

Figure: **B-14**

Rev: **A**

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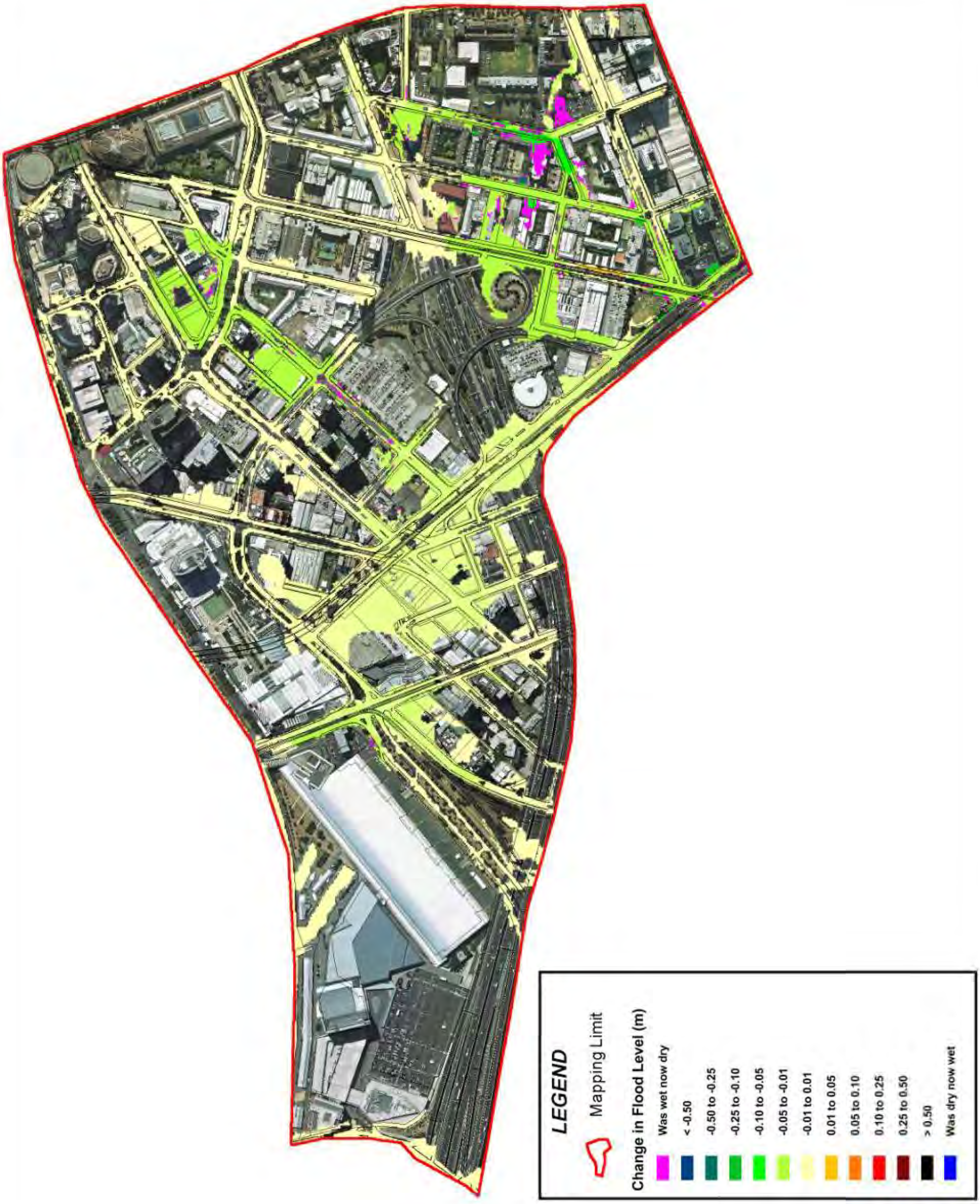
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-14_FldDif_D01_E01_50y_Storm_RevA.WOR



Title:
Southbank - WSUD
Change in 100 Year ARI Peak Flood Heights - Storm

Figure: **B-15**

Rev: **A**

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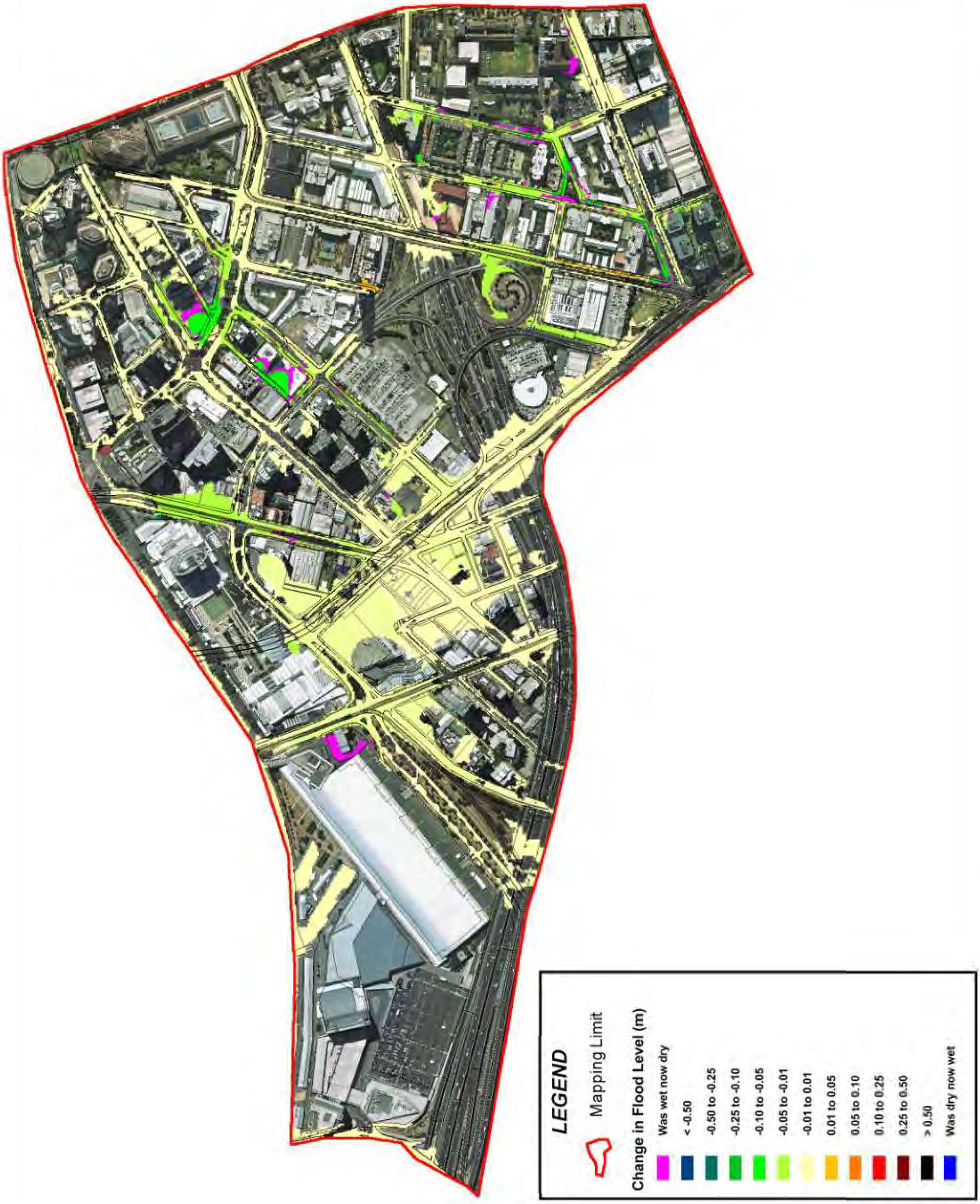
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-15_FldDif_D01_E01_100y_Storm_RevA.WOR



Title:

Southbank - WSUD
Change in 5 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-16**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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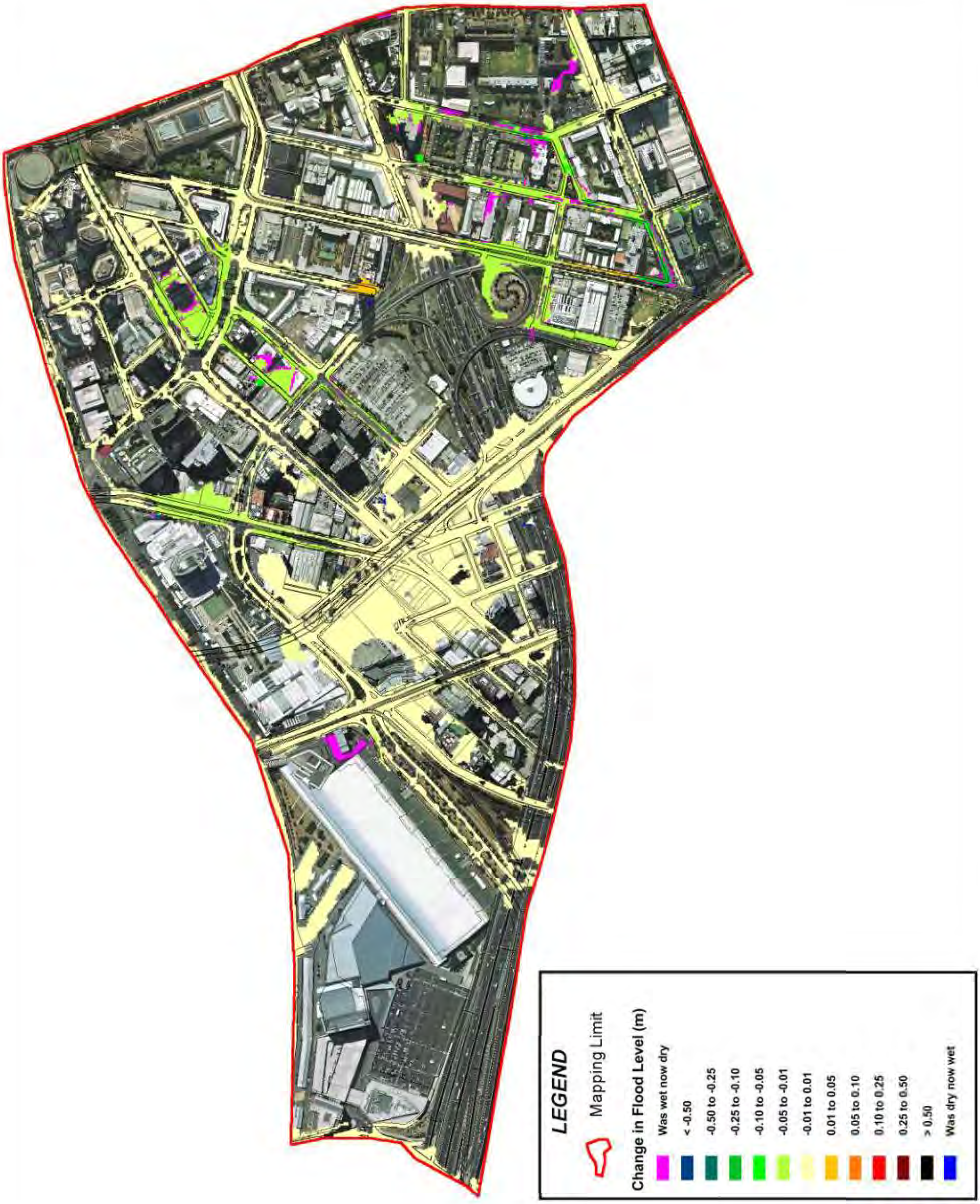
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-16_FldDif_D01_E01_5y_Yarra100y_RevA.WOR



Title:

Southbank - WSUD

Change in 10 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-17**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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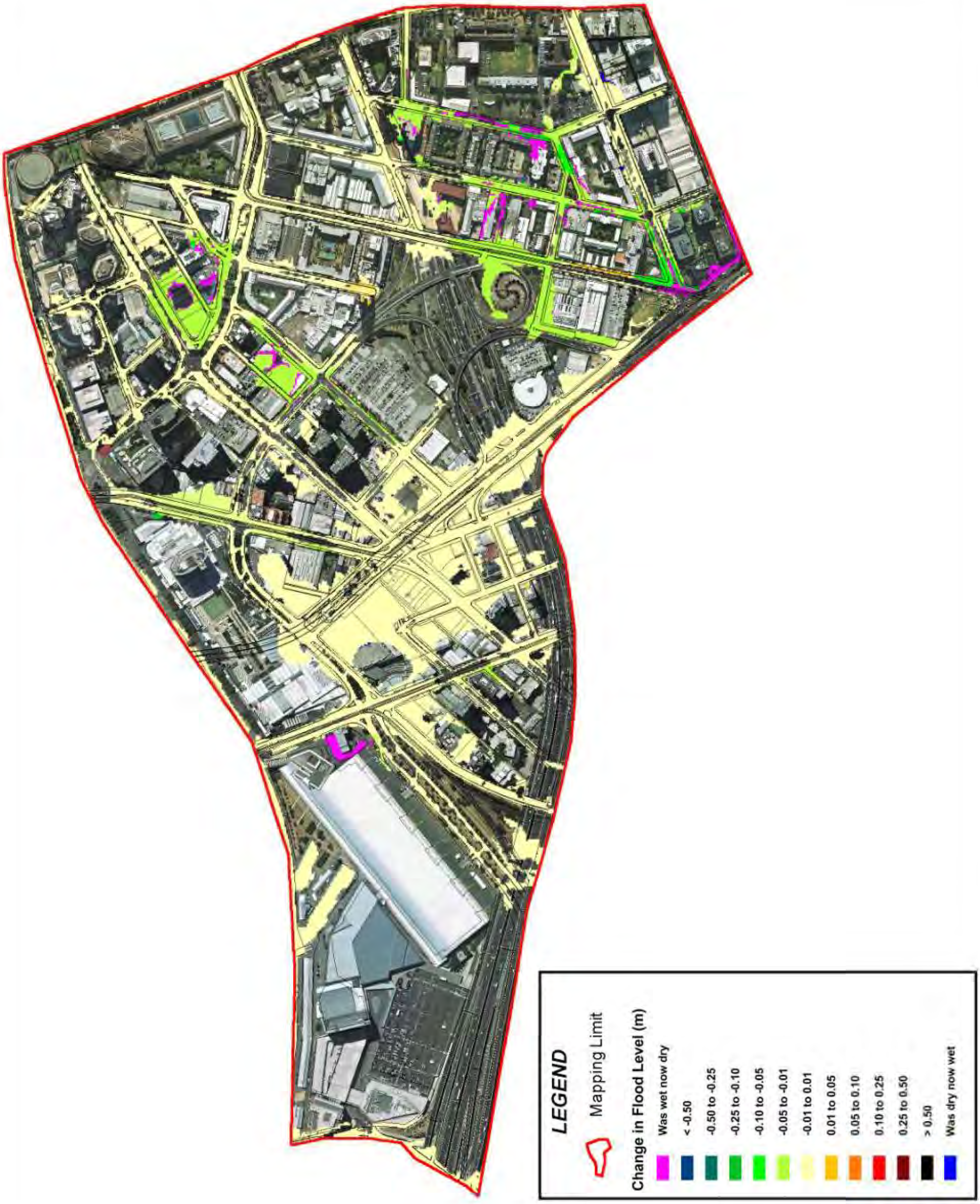
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-17_FldDif_D01_E01_10y_Yarra100y_RevA.WOR



Title:

Southbank - WSUD
Change in 20 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-18**

Rev: **A**

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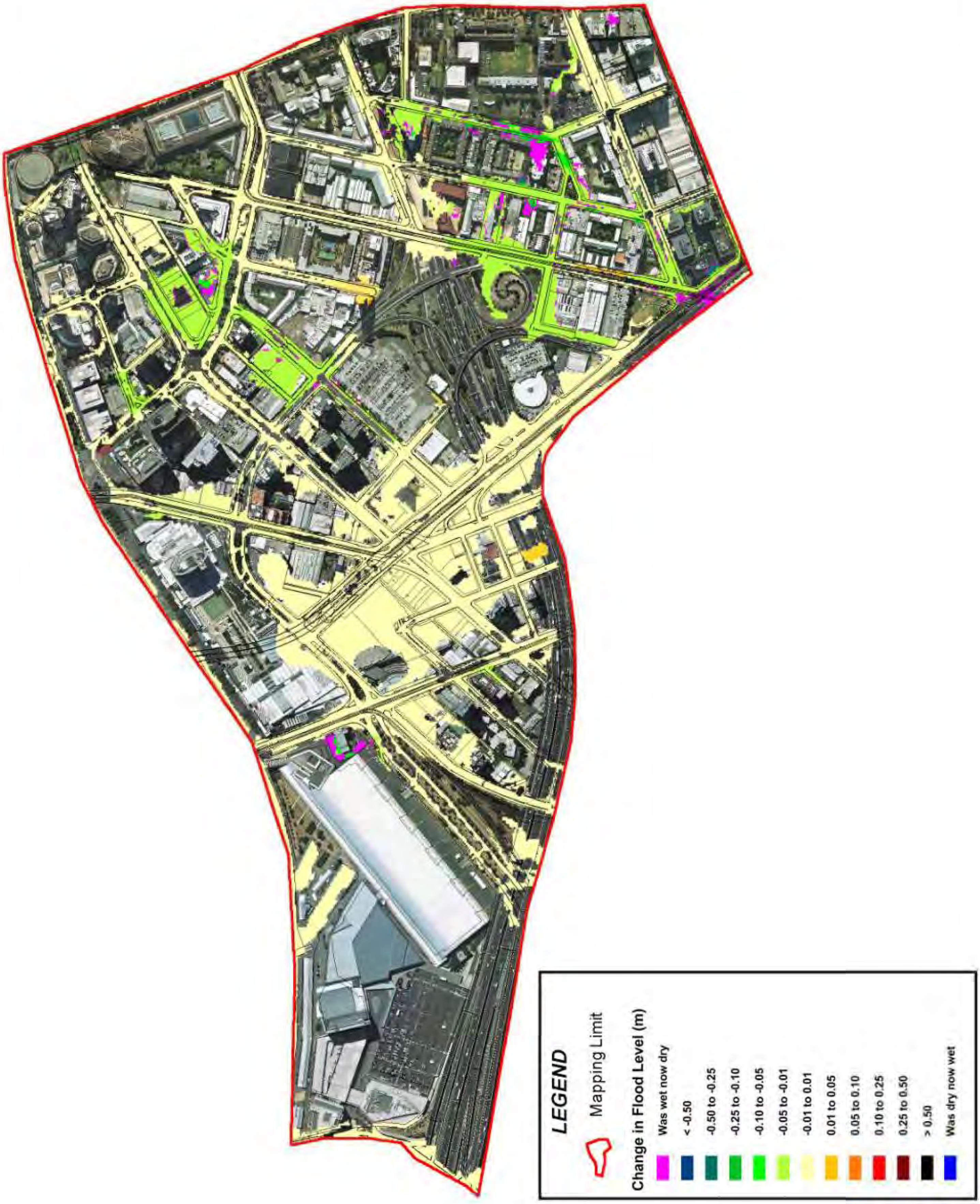
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-18_FldDif_D01_E01_20y_Yarra100y_RevA.WOR



Title:

Southbank - WSUD

Change in 50 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-19**

Rev: **A**

BMT WBM

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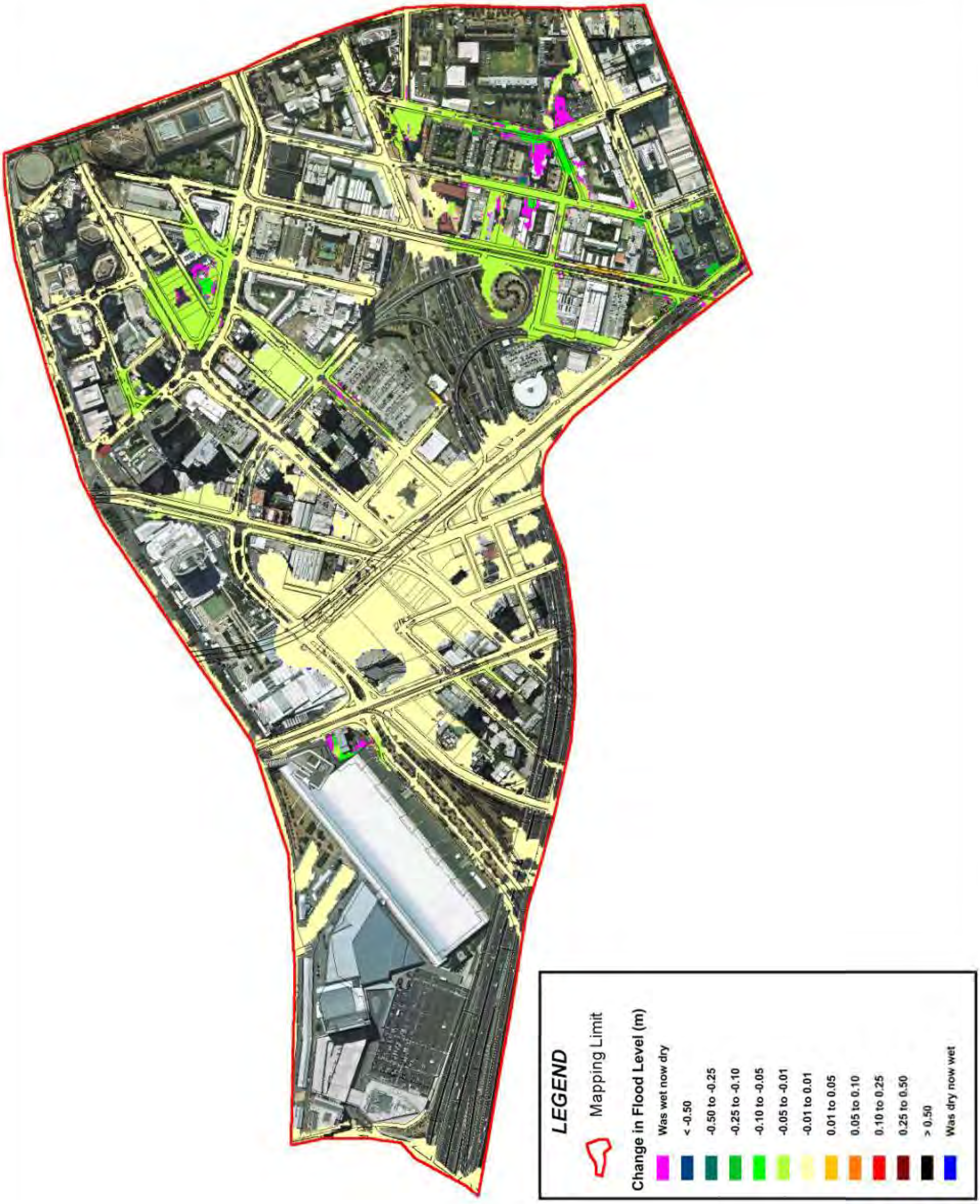
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-19_FldDif_D01_E01_50y_Yarra100y_RevA.WOR



Title:

Southbank - WSUD

Change in 100 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-20**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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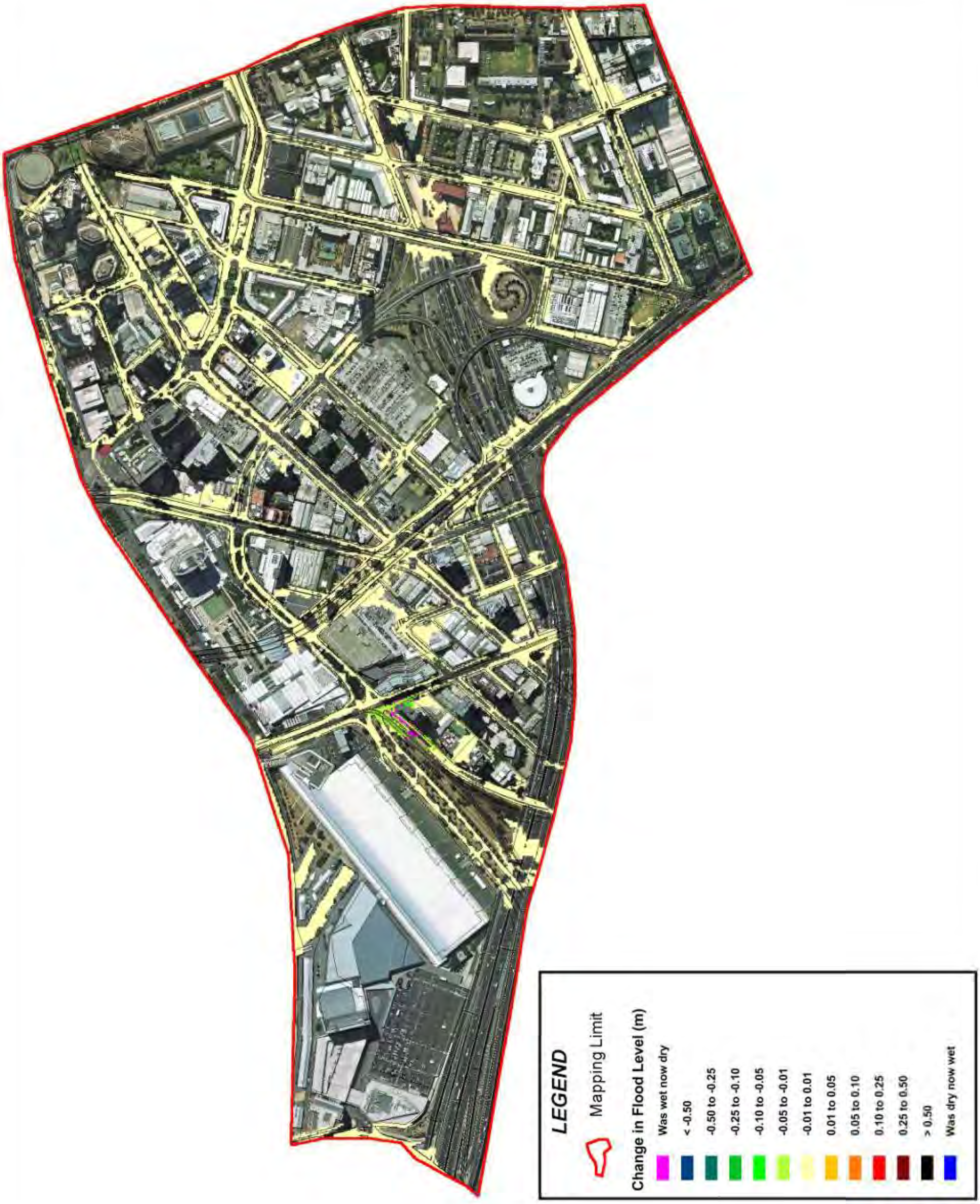
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-20_FldDif_D01_E01_100y_Yarra100y_RevA.WOR



Title:
Southbank - Pipe
Change in 5 Year ARI Peak Flood Heights - MSL

Figure: B-1

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
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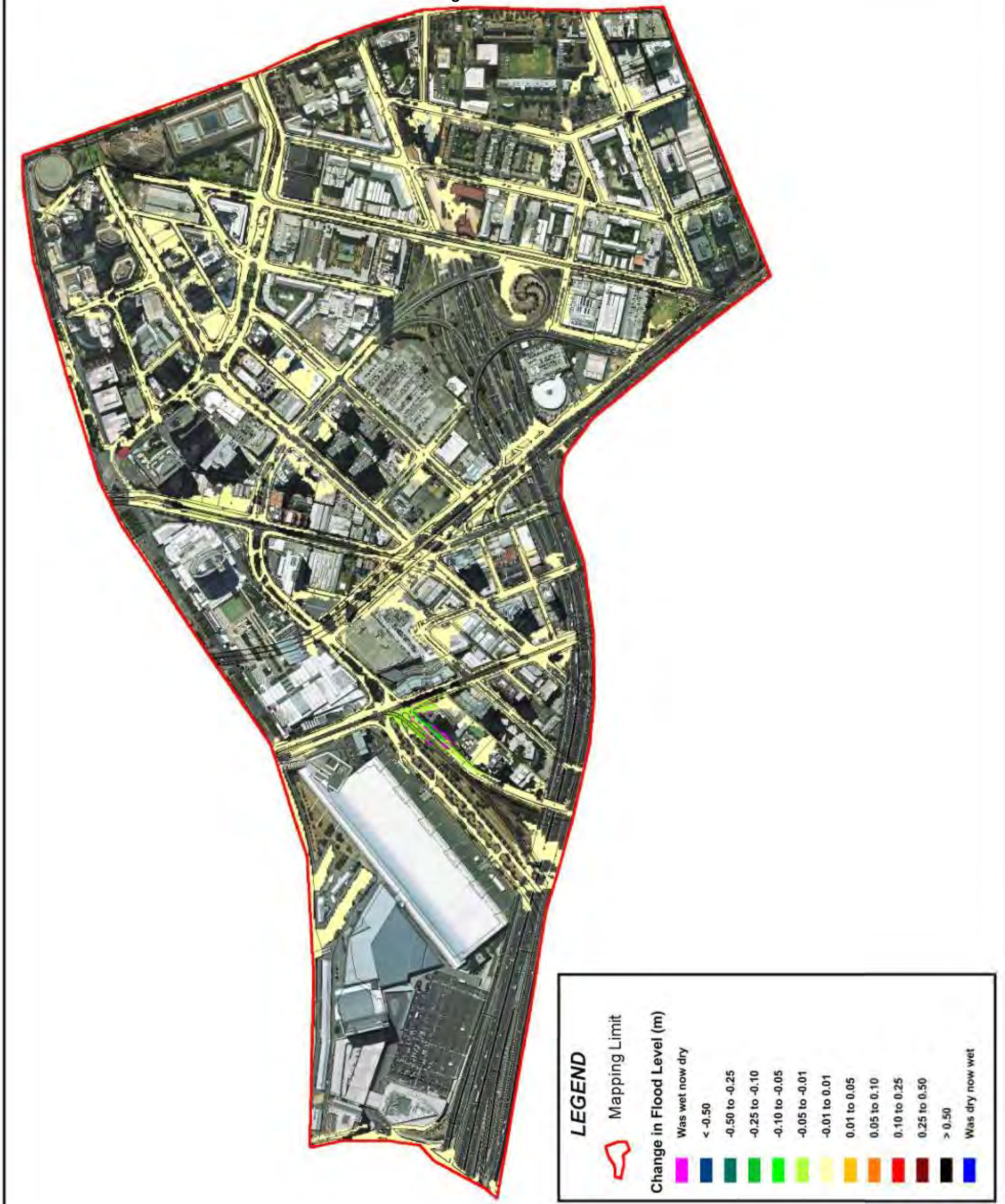
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-1_FldDif_D02_E01_5y_MSL_RevA.WOR



Title:

Southbank - Pipe
Change in 10 Year ARI Peak Flood Heights - MSL

Figure: **B-22**

Rev: **A**

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-22_FldDif_D02_E01_10y_MSL_RevA.WOR

LEGEND

Mapping Limit

Change in Flood Level (m)

- Was wet now dry
- < -0.50
- -0.50 to -0.25
- -0.25 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- > 0.50
- Was dry now wet

Title:

Southbank - Pipe
Change in 20 Year ARI Peak Flood Heights - MSL

Figure: **B-23**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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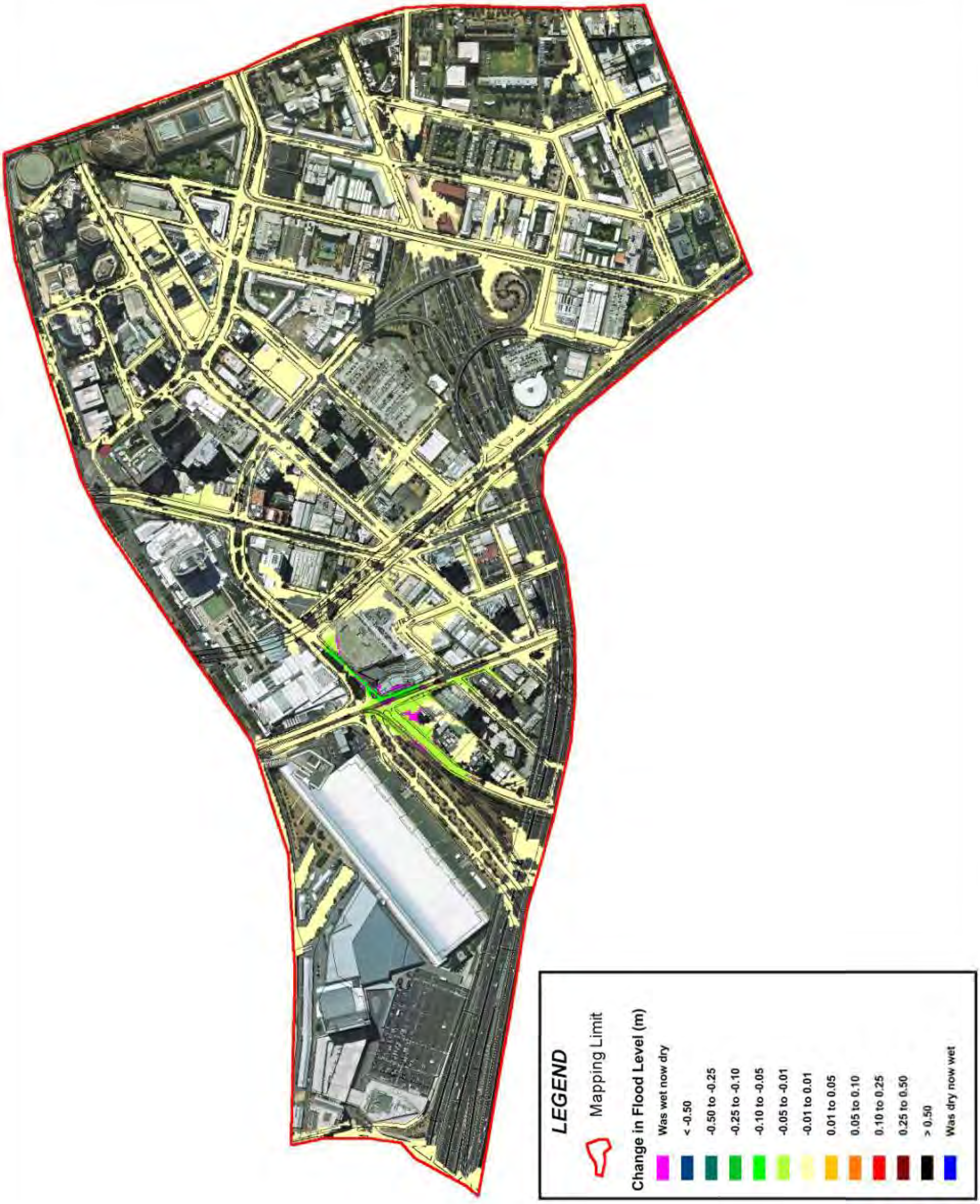
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-23_FldDif_D02_E01_20y_MSL_RevA.WOR



Title:
Southbank - Pipe
Change in 50 Year ARI Peak Flood Heights - MSL

Figure: B-24

Rev: A

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N

0 125 250m
Approx. Scale

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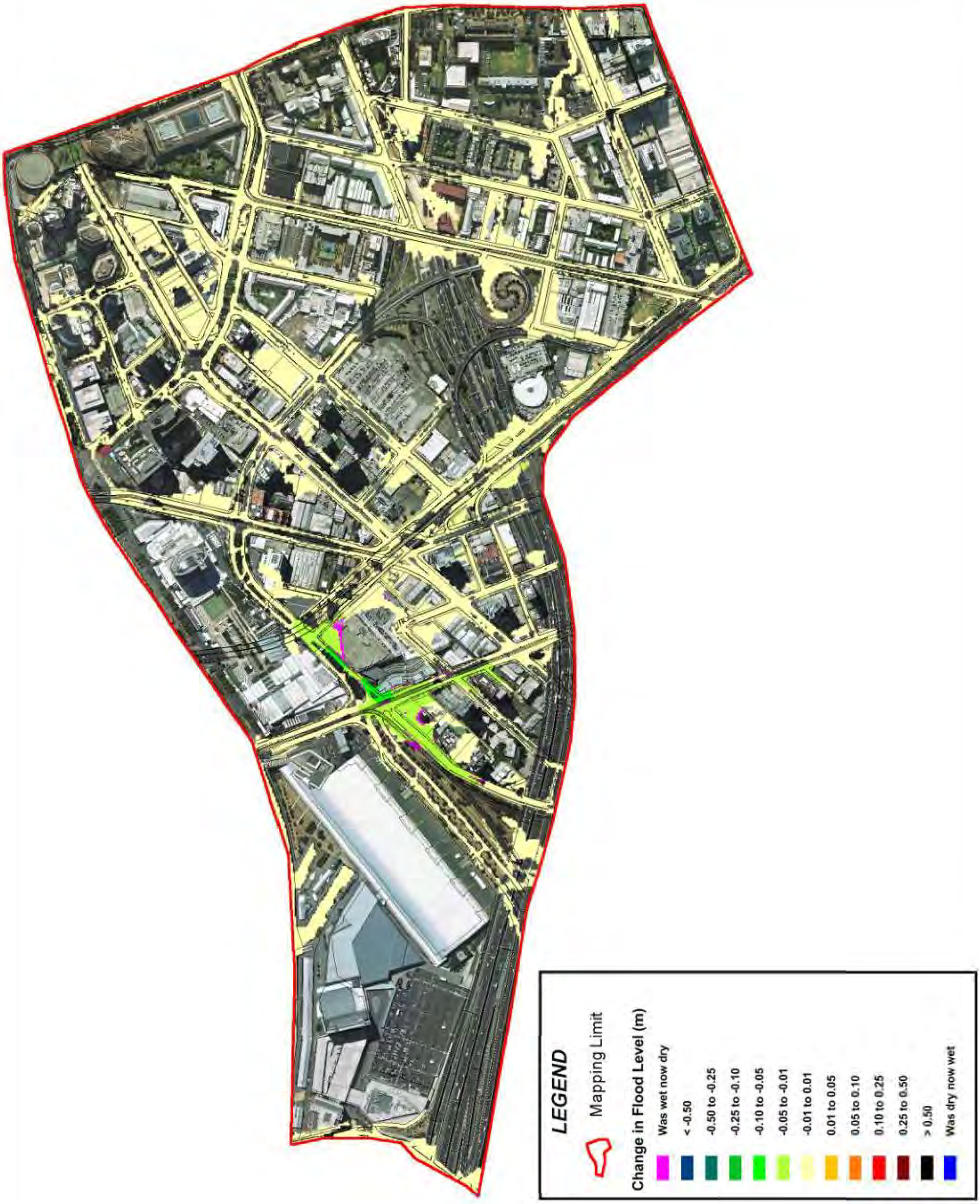
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-24_FldDif_D02_E01_50y_MSL_RevA.WOR



Title:
Southbank - Pipe
Change in 100 Year ARI Peak Flood Heights - MSL

Figure: **B-25**

Rev: **A**

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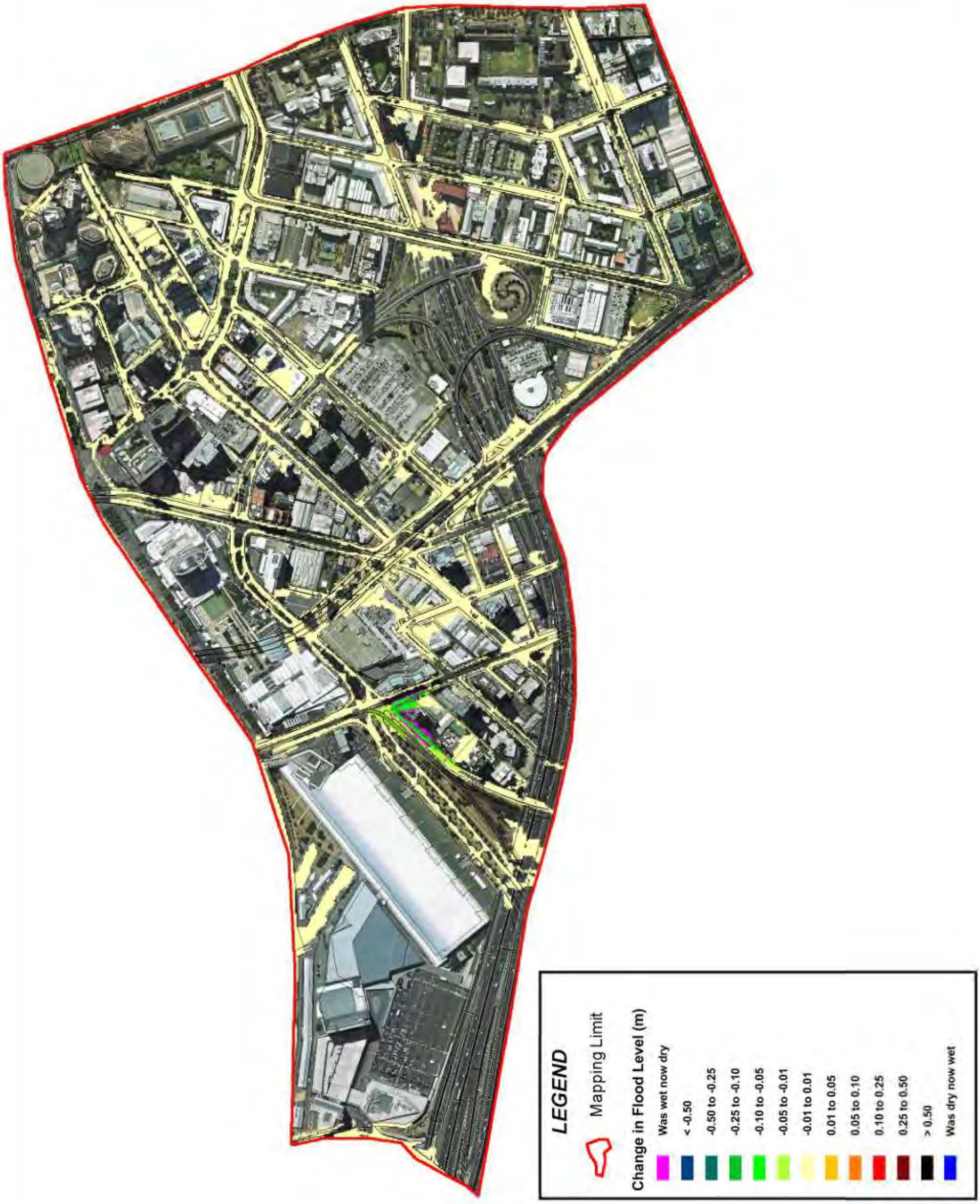
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-25_FldDif_D02_E01_100y_MSL_RevA.WOR



Title:

Southbank - Pipe
Change in 5 Year ARI Peak Flood Heights - HAT

Figure: **B-26**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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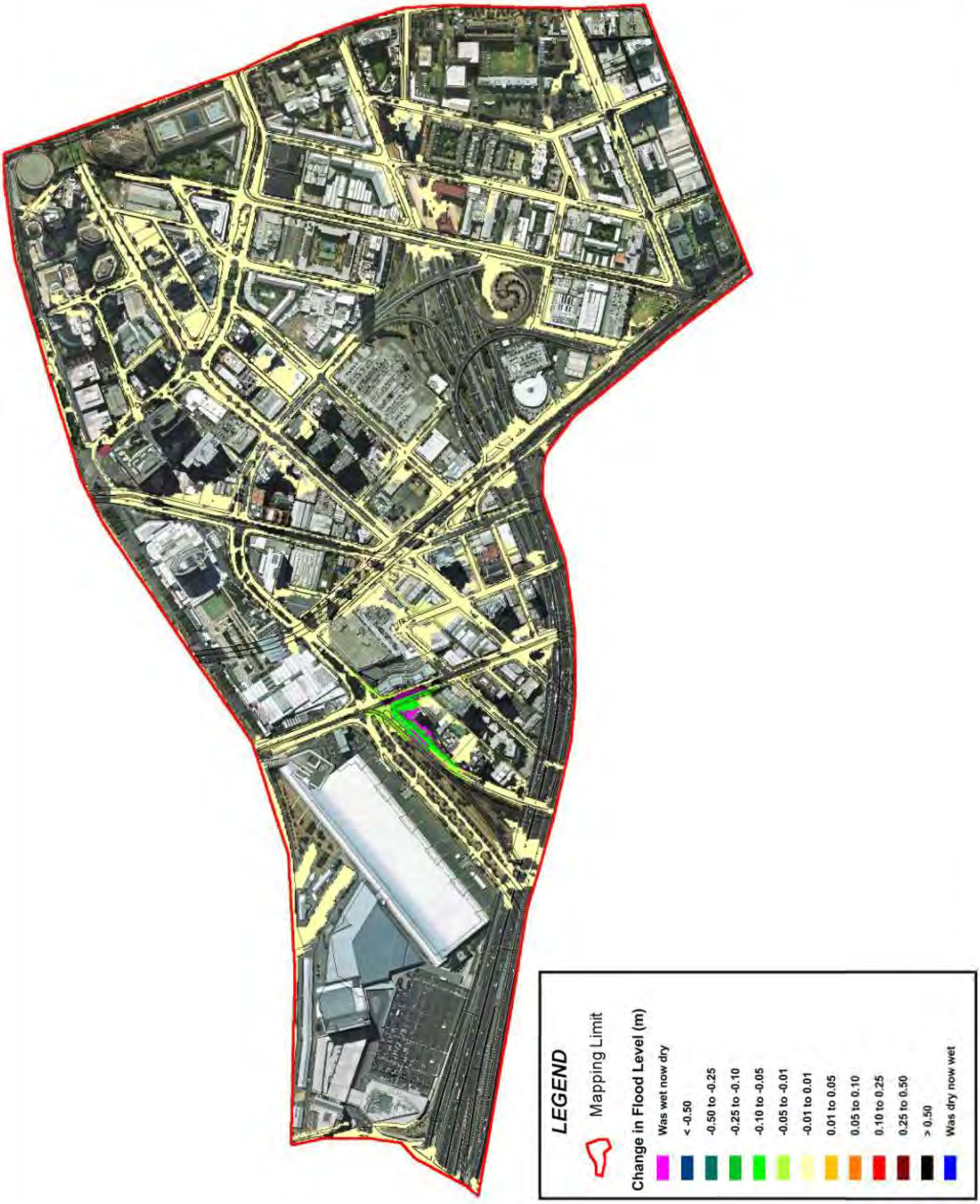
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-26_FldDif_D02_E01_5y_Storm_RevA.WOR



Title:
Southbank - Pipe
Change in 10 Year ARI Peak Flood Heights - HAT

Figure: **B-27**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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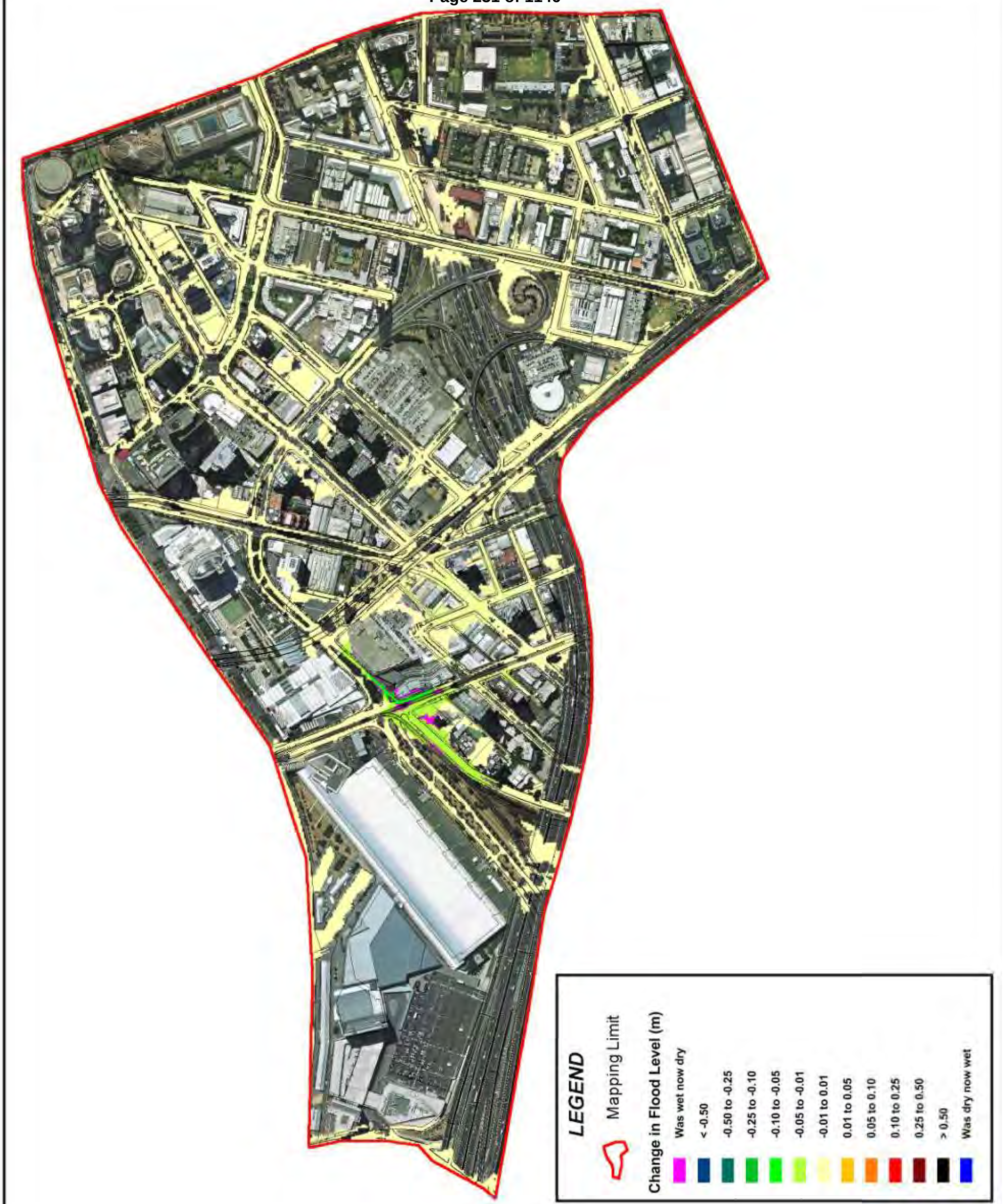
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-27_FldDif_D02_E01_10y_Storm_RevA.WOR



Title:
Southbank - Pipe
Change in 20 Year ARI Peak Flood Heights - HAT

Figure: **B-28**

Rev: **A**

BMT WBM
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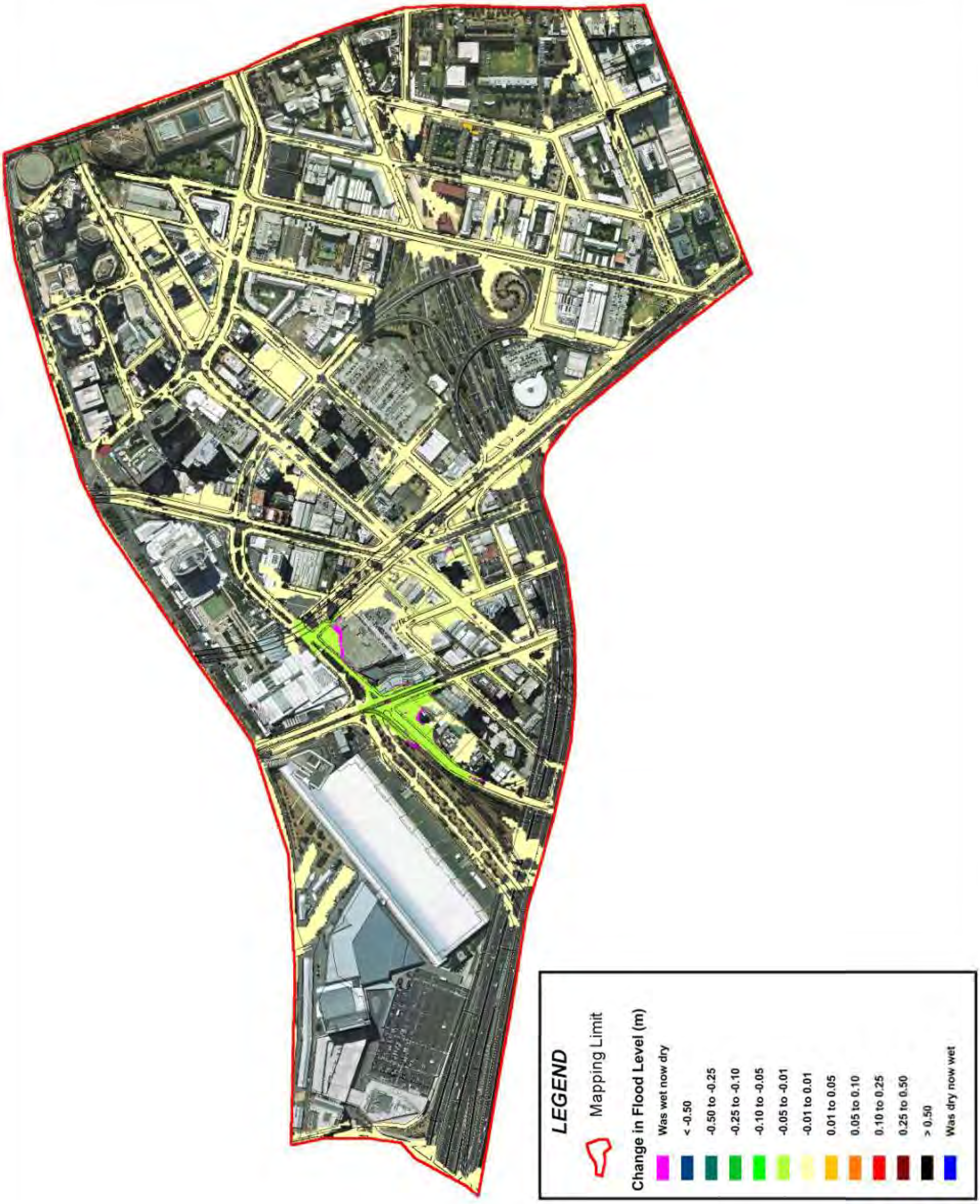
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-28_FldDif_D02_E01_20y_Storm_RevA.WOR



Title:

Southbank - Pipe
Change in 50 Year ARI Peak Flood Heights - HAT

Figure: B-29

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
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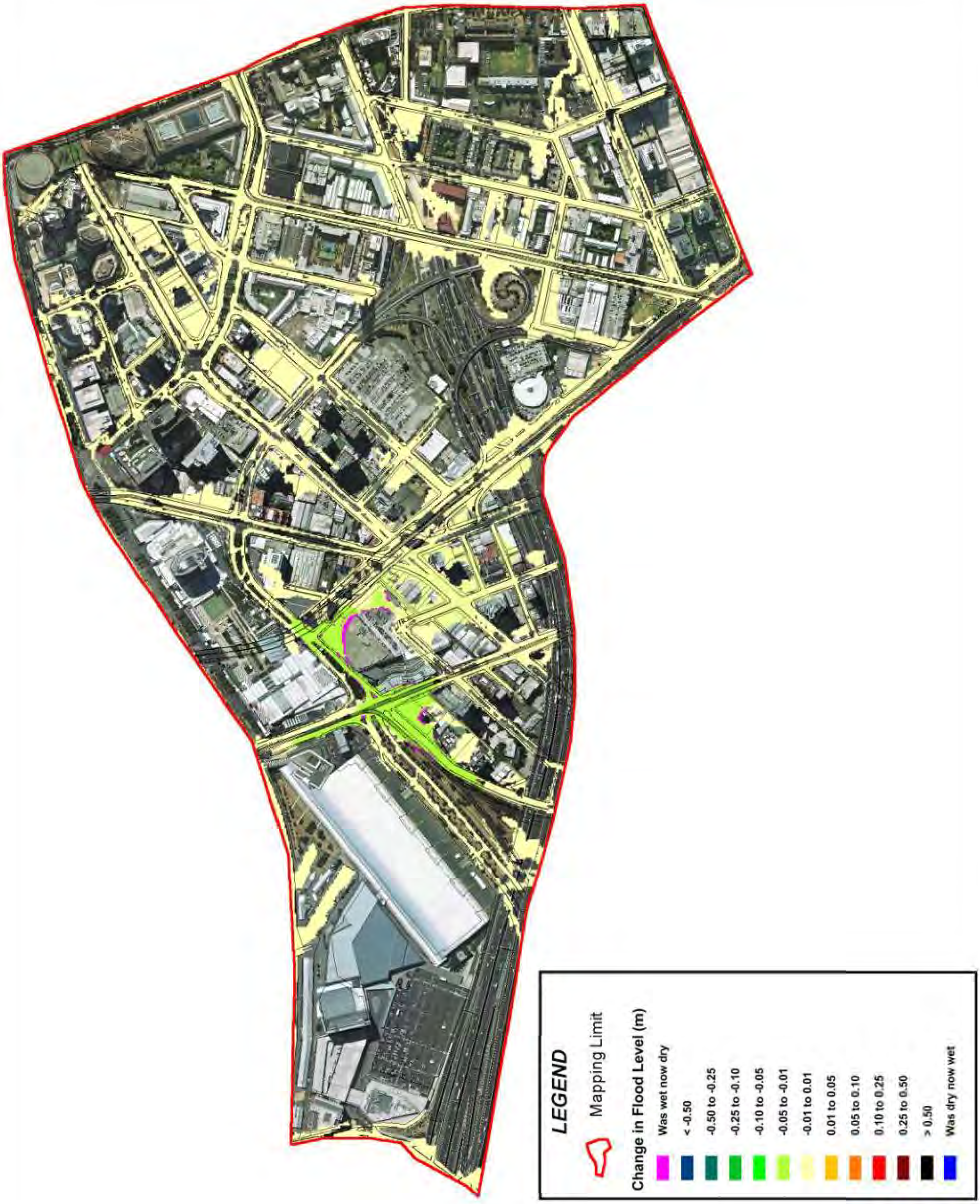
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-29_FldDif_D02_E01_50y_Storm_RevA.WOR



Title:

Southbank - Pipe

Change in 100 Year ARI Peak Flood Heights - HAT

Figure: **B-30**

Rev: **A**

BMT WBM

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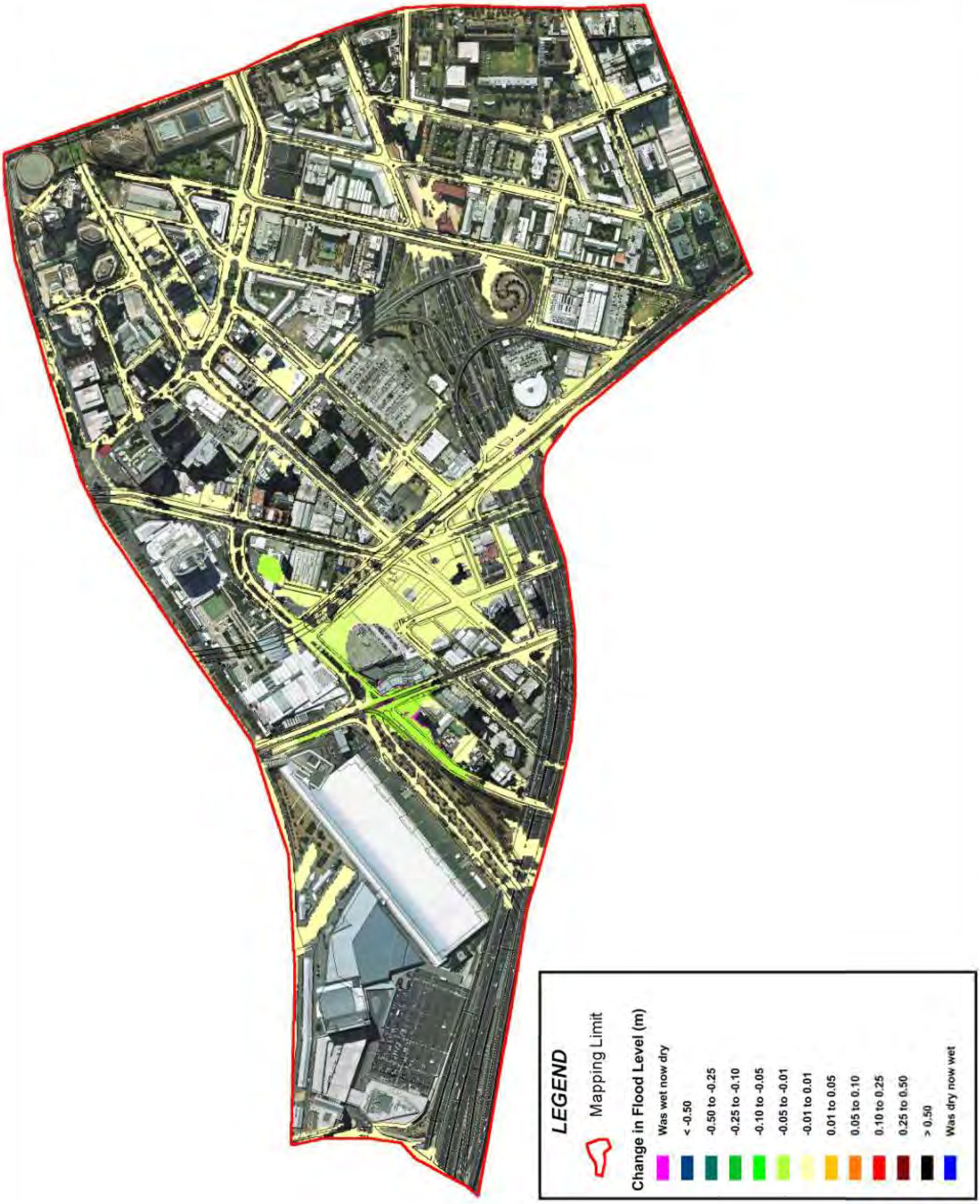
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-30_FldDif_D02_E01_100y_Storm_RevA.WOR



Title:

Southbank - Pipe
Change in 5 Year ARI Peak Flood Heights - Storm

Figure: **B-31**

Rev: **A**

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N

0 125 250m
Approx. Scale

BMT WBM
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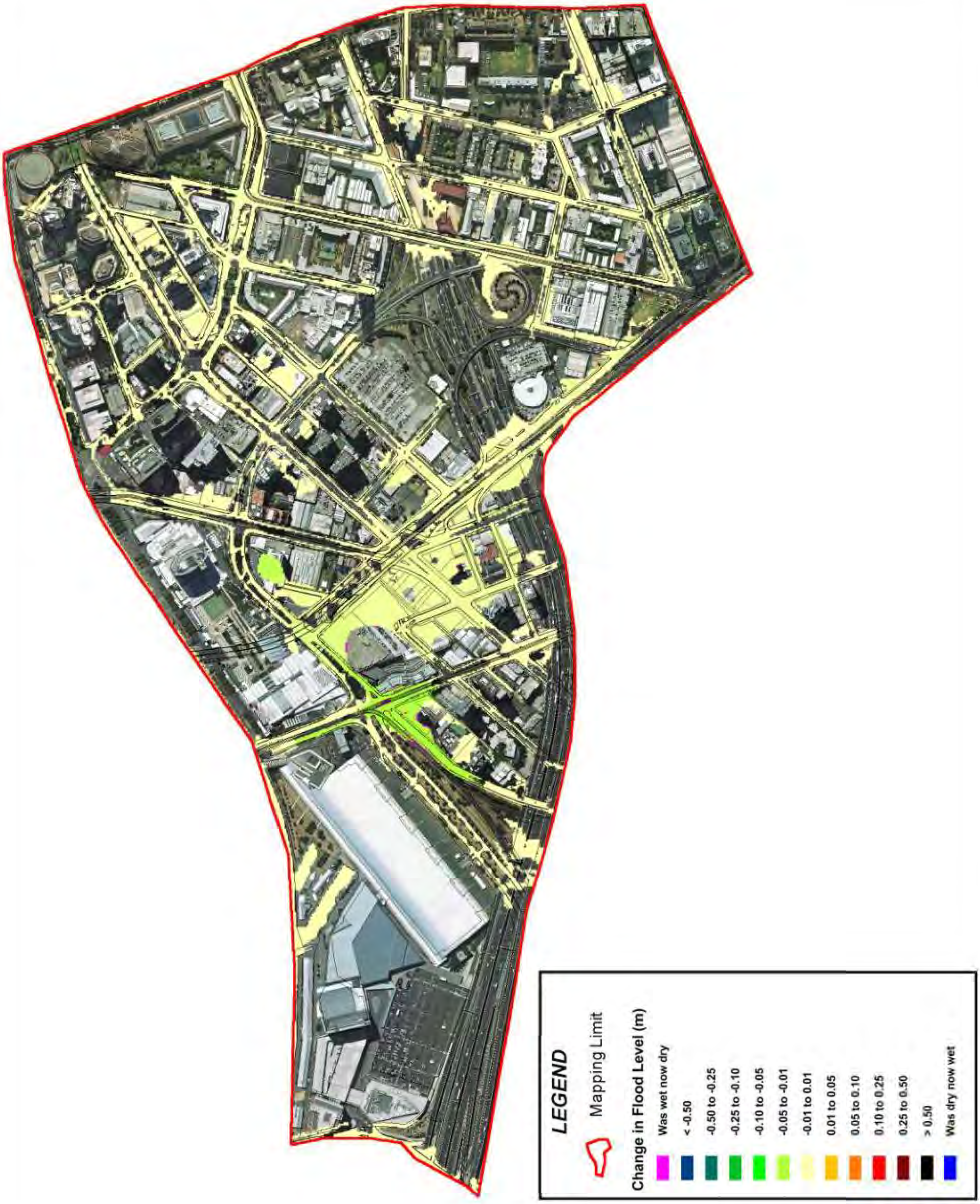
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-31_FldDif_D02_E01_5y_Storm_RevA.WOR



Title:

Southbank - Pipe
Change in 10 Year ARI Peak Flood Heights - Storm

Figure: **B-32**

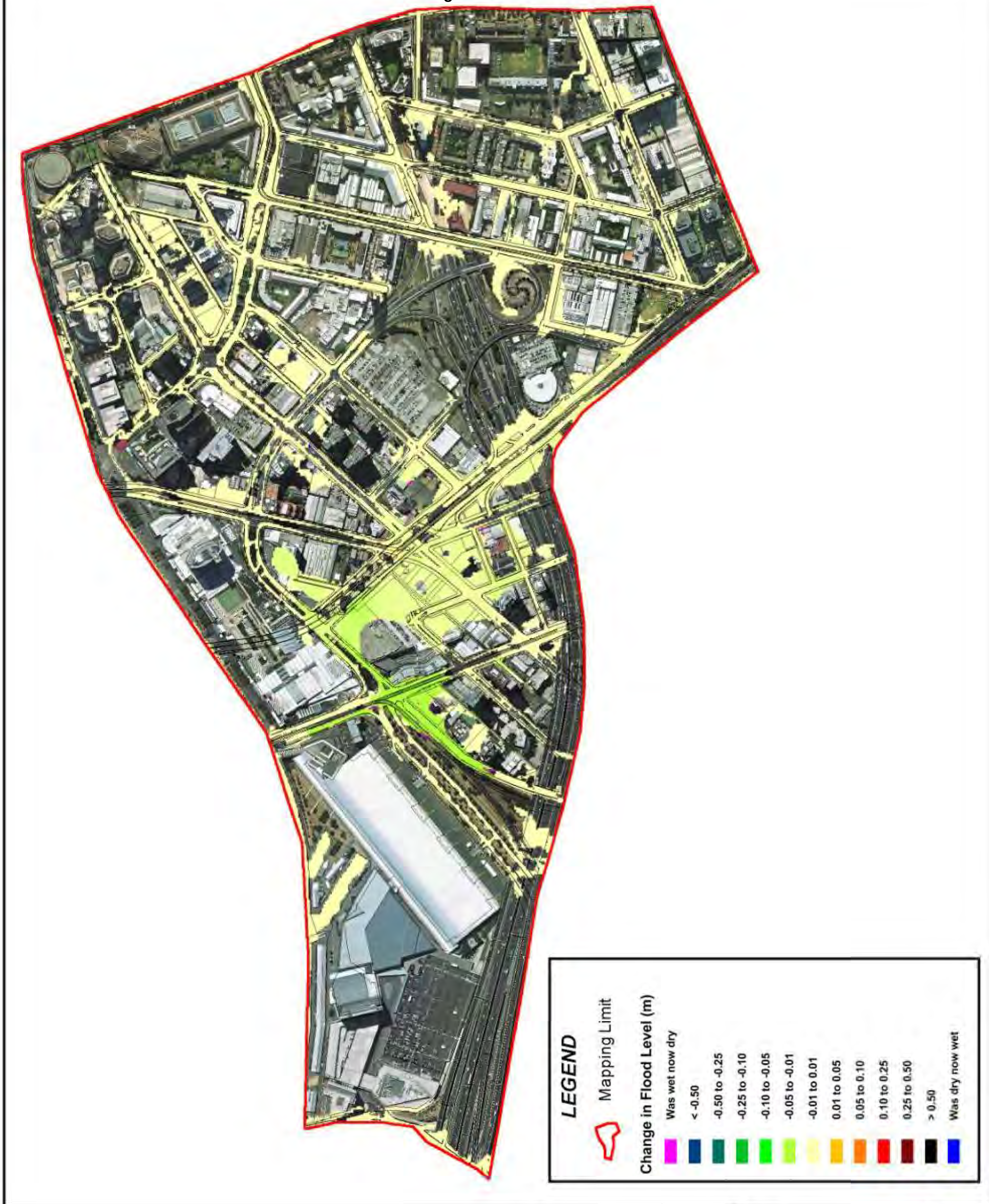
Rev: **A**

N

0 125 250m
Approx. Scale

www.bmtwbm.com.au

Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-32_FldDif_D02_E01_10y_Storm_RevA.WOR



Title:
Southbank - Pipe
Change in 20 Year ARI Peak Flood Heights - Storm

Figure: **B-33**

Rev: **A**

BMT WBM
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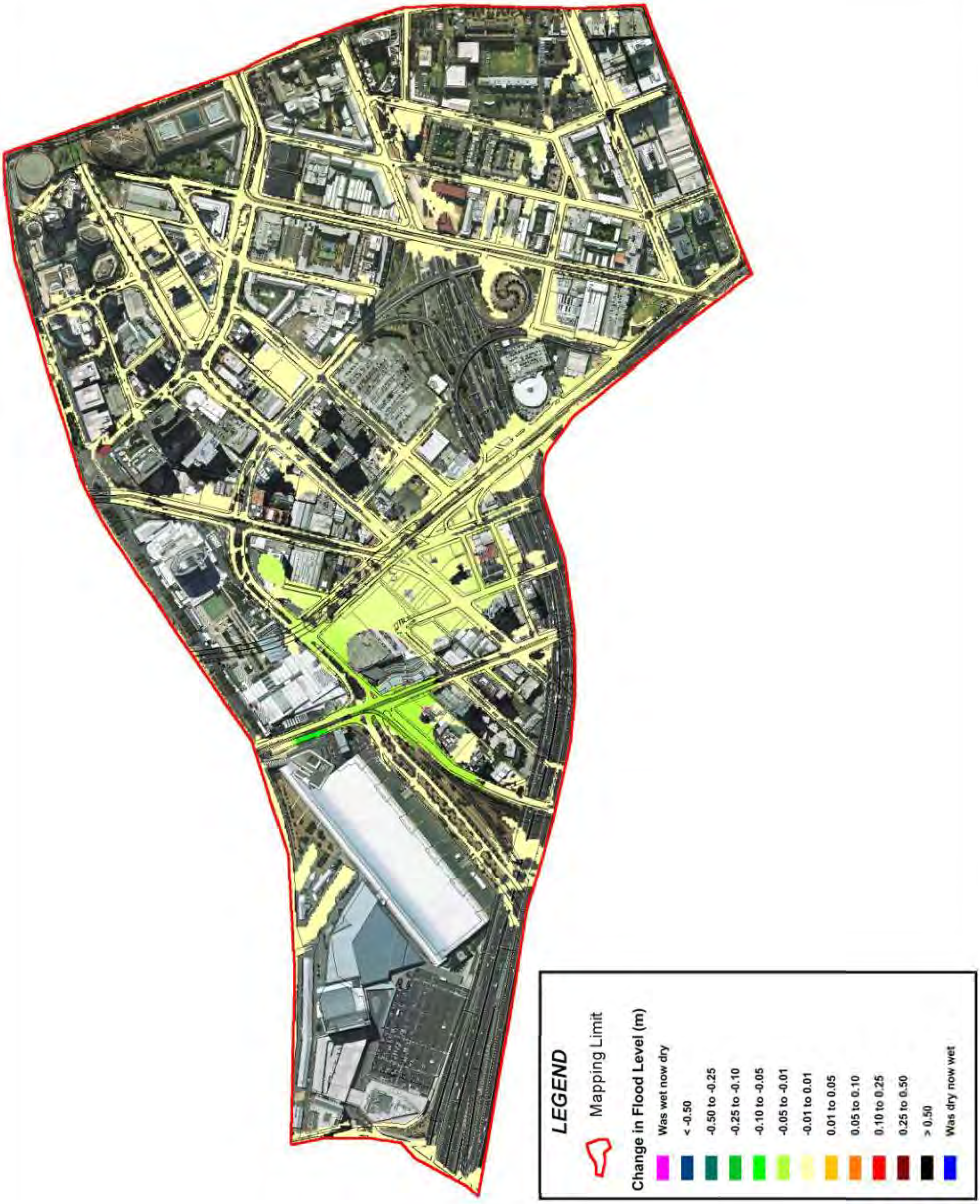
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-33_FldDif_D02_E01_20y_Storm_RevA.WOR



Title:

Southbank - Pipe

Change in 50 Year ARI Peak Flood Heights - Storm

Figure: **B-34**

Rev: **A**

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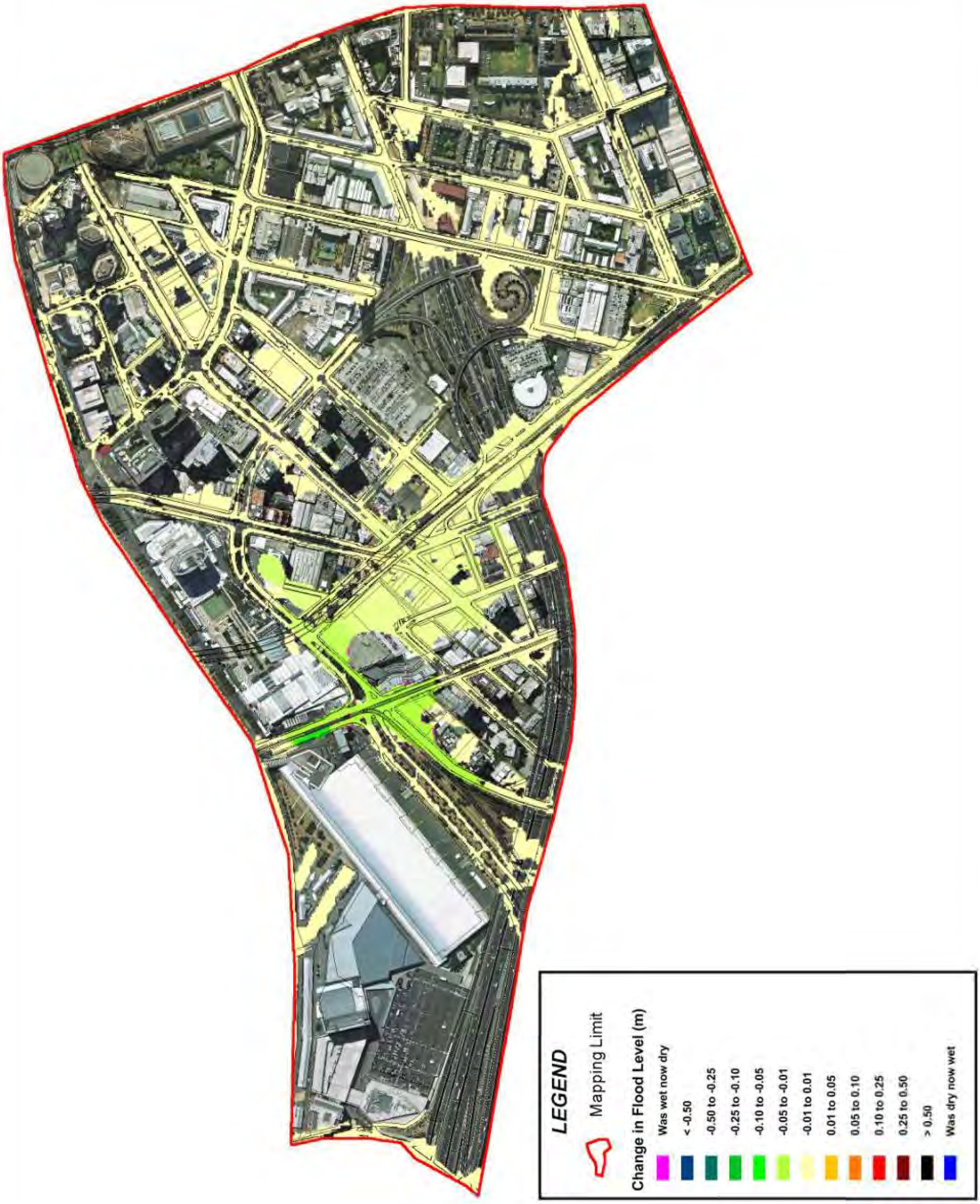
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-34_FldDif_D02_E01_50y_Storm_RevA.WOR



Title:

Southbank - Pipe
Change in 100 Year ARI Peak Flood Heights - Storm

Figure: **B-35**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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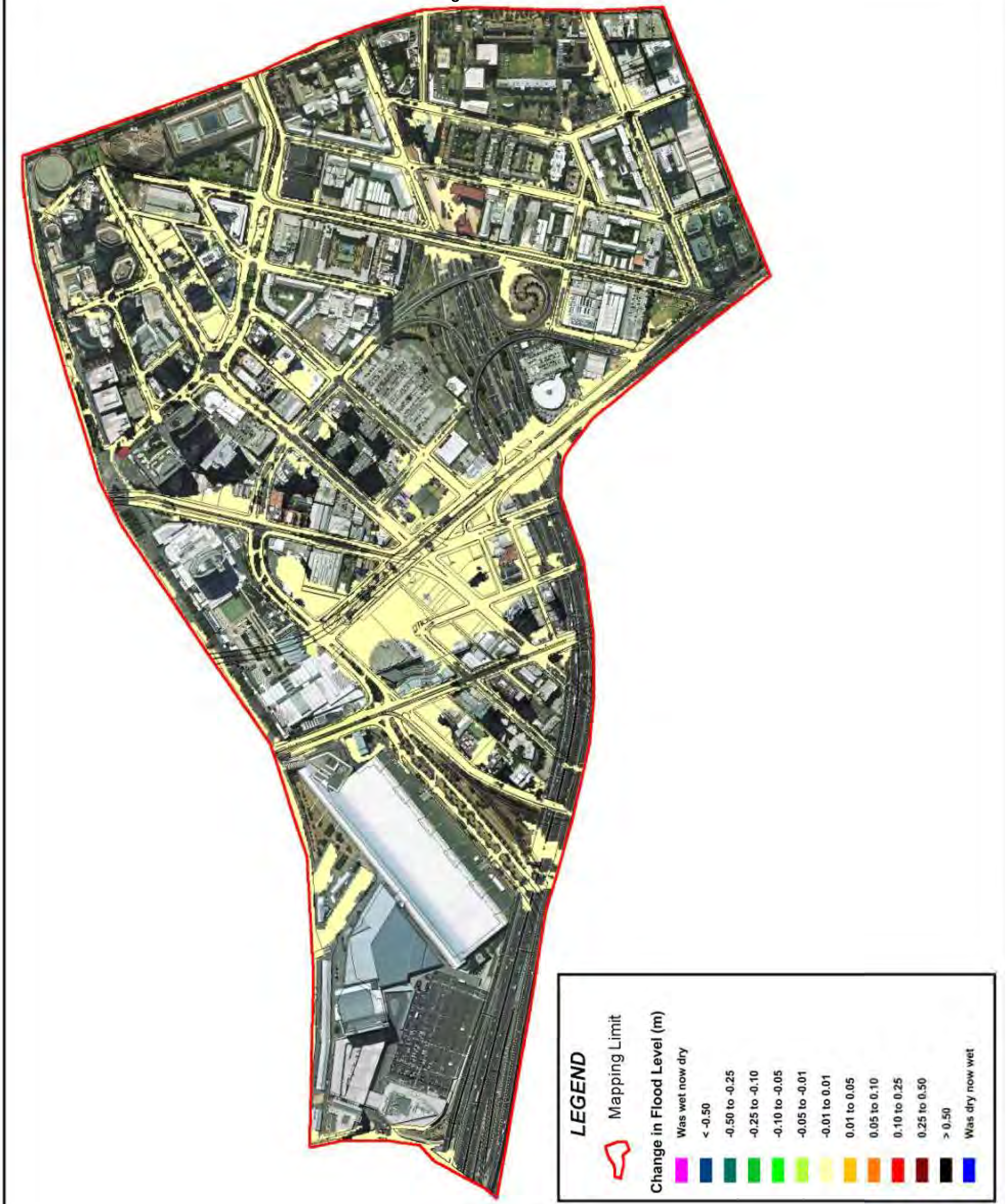
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-35_FldDif_D02_E01_100y_Storm_RevA.WOR



Title:
Southbank - Pipe
Change in 5 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-36**

Rev: **A**

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-36_FldDif_D02_E01_5y_Yarra100y_RevA.WOR

LEGEND

Mapping Limit

Change in Flood Level (m)

- Was wet now dry
- < -0.50
- -0.50 to -0.25
- -0.25 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- > 0.50
- Was dry now wet

Title:

Southbank - Pipe
Change in 10 Year ARI Peak Flood Heights - Yarra 100y

Figure: B-37

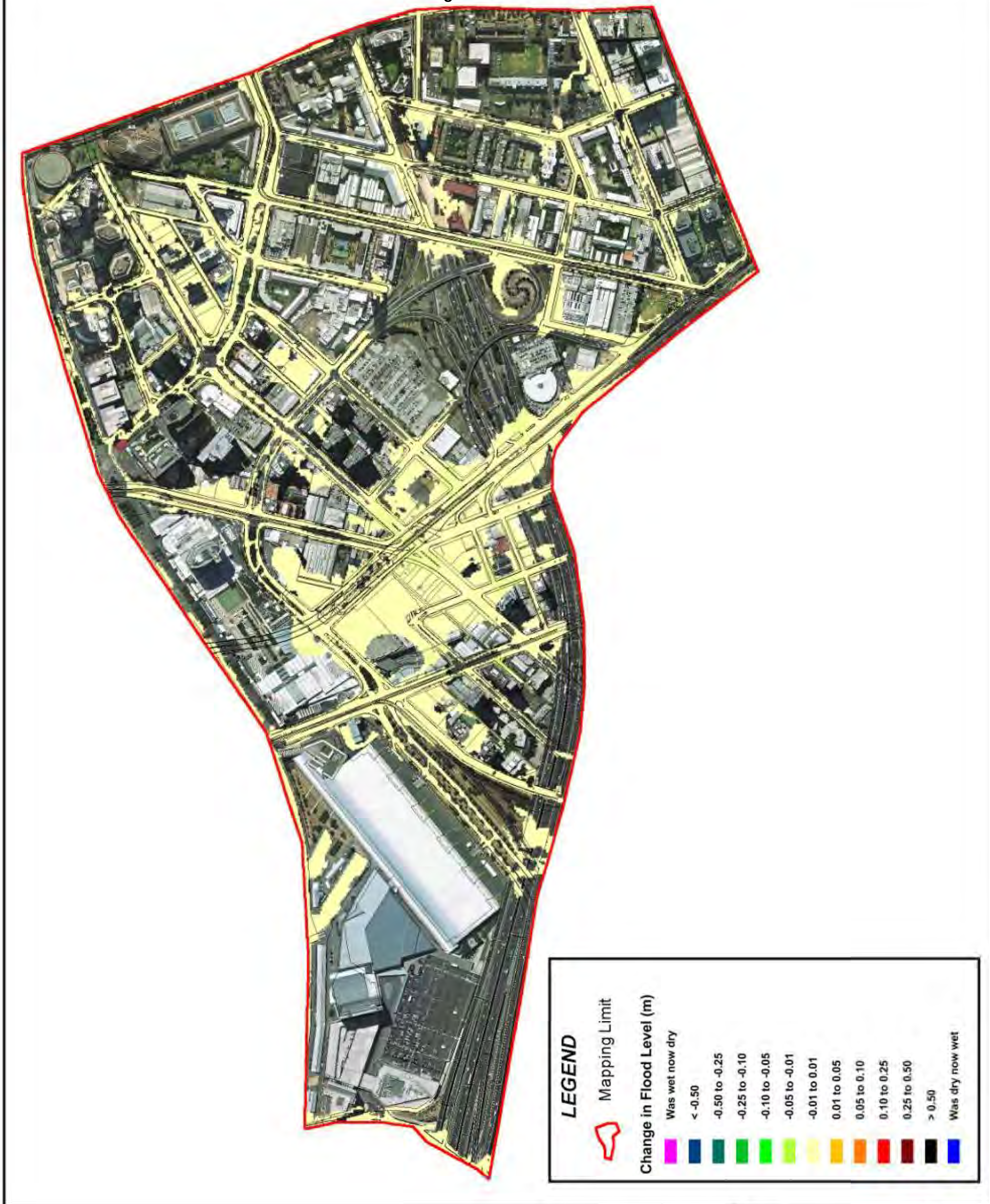
Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-37_FldDif_D02_E01_10y_Yarra100y_RevA.WOR



Title:

Southbank - Pipe

Change in 20 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-38**

Rev: **A**

BMT WBM

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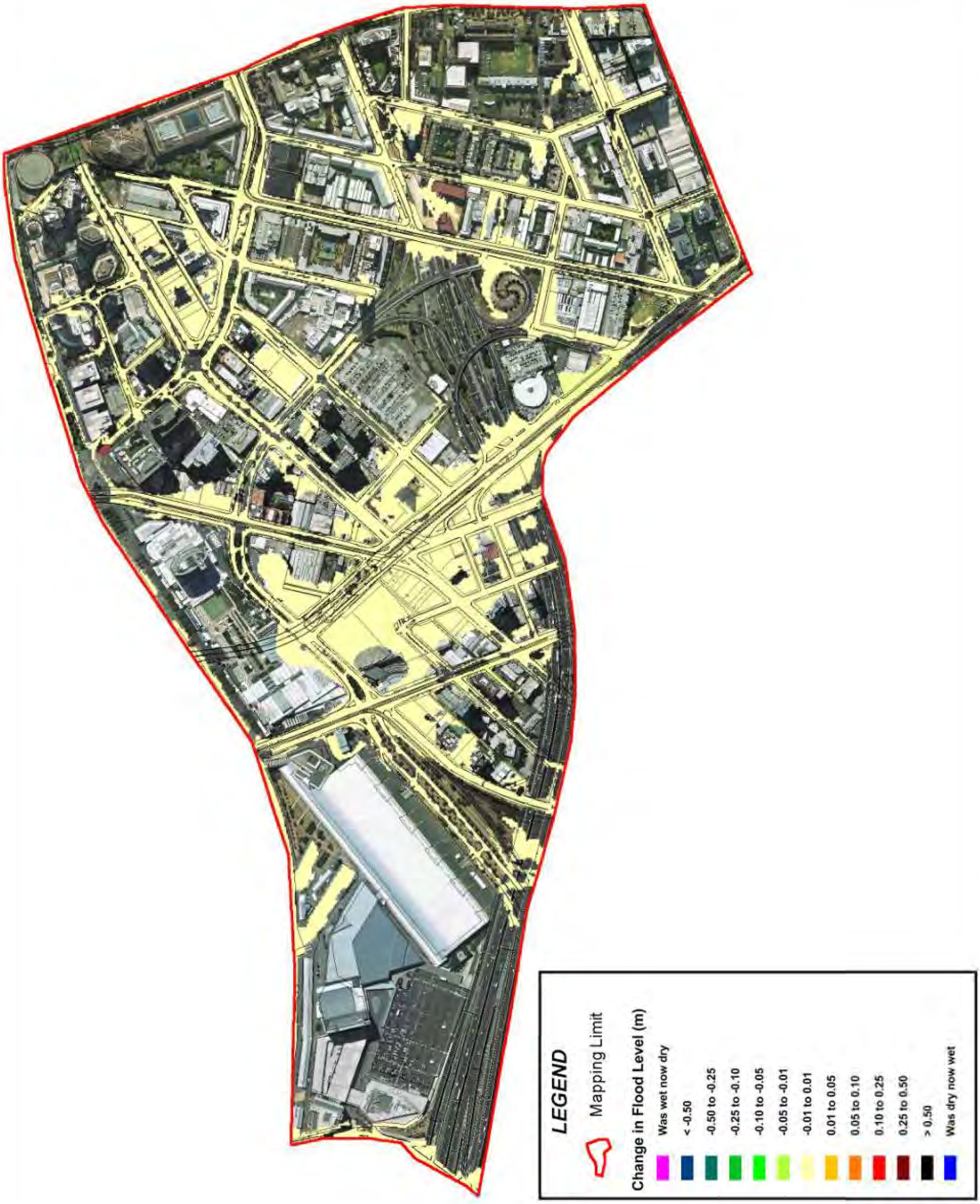
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-38_FldDif_D02_E01_20y_Yarra100y_RevA.WOR



Title:
Southbank - Pipe
Change in 50 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-39**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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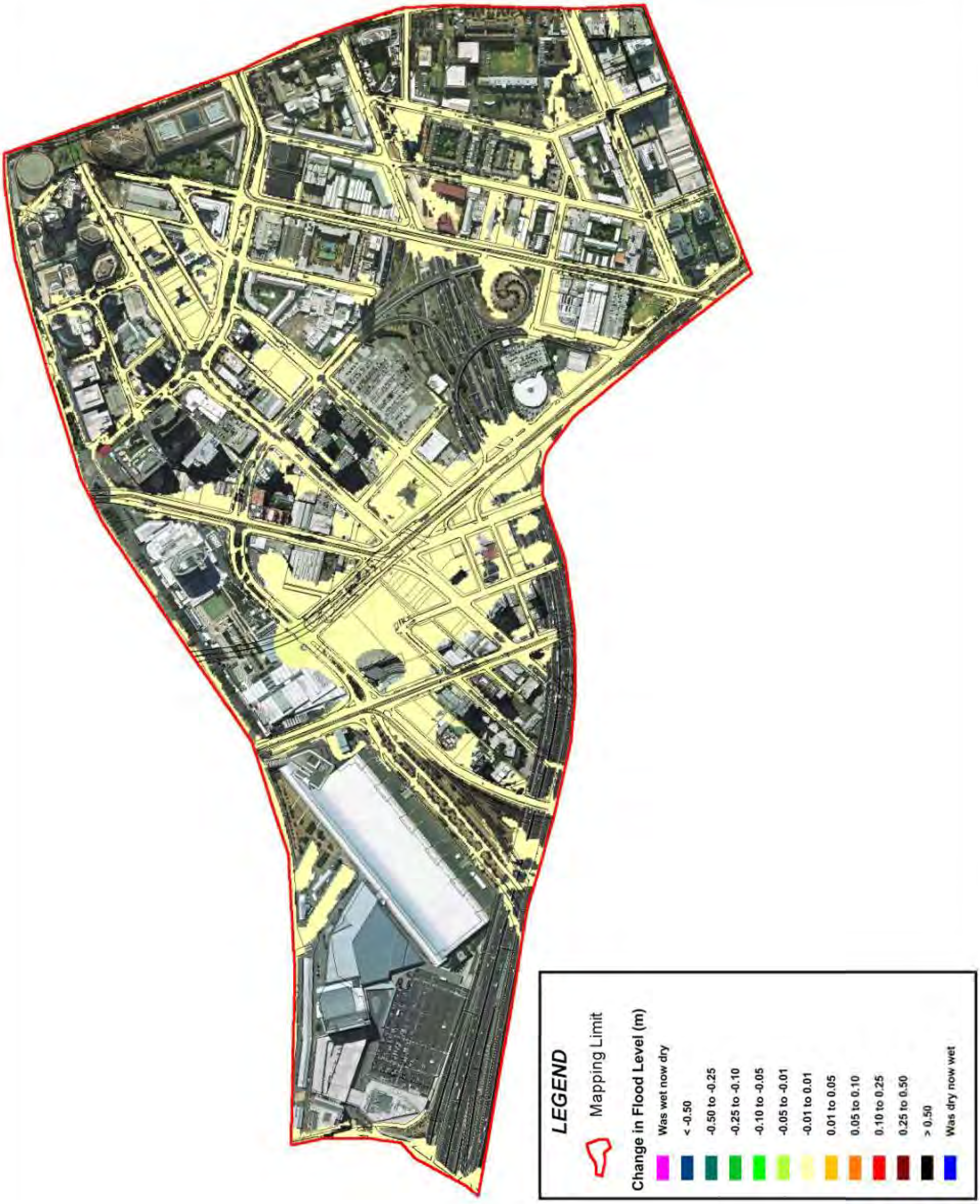
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-39_FldDif_D02_E01_50y_Yarra100y_RevA.WOR



Title:

Southbank - Pipe
Change in 100 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-40**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-40_FldDif_D02_E01_100y_Yarra100y_RevA.WOR

Appendix C Future Climate Mapping (Depth)

Title:

Southbank - Climate Change +15%
5 Year ARI Peak Flood Depth - MSL

Figure: C-1

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigC-1_5y_MSL_C01+15%_dmax_RevA.WOR

Title:

Southbank - Climate Change +15%
10 Year ARI Peak Flood Depth - MSL

Figure: C-2

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigC-2_10y_MSL_C01+15%_dmax_RevA.WOR

Title:

Southbank - Climate Change +15%
20 Year ARI Peak Flood Depth - MSL

Figure: C-3

Rev: A

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N

0 125 250m
Approx. Scale

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Title:

Southbank - Climate Change +15%
50 Year ARI Peak Flood Depth - MSL

Figure: C-4

Rev: A

N

0 125 250m
Approx. Scale

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigC-4_50y_MSL_C01+15%_dmax_RevA.WOR

Title:

Southbank - Climate Change +15%
100 Year ARI Peak Flood Depth - MSL

Figure: **C-5**

Rev: **A**

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Title:

Southbank - Climate Change +15%
5 Year ARI Peak Flood Depth - HAT

Figure: C-6

Rev: A

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Title:

Southbank - Climate Change +15%
10 Year ARI Peak Flood Depth - HAT

Figure: C-7

Rev: A

N

0 125 250m
Approx. Scale

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Title:

Southbank - Climate Change +15%
20 Year ARI Peak Flood Depth - HAT

Figure: C-8

Rev: A

N

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Approx. Scale

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigC-8_20y_HAT_C01+15%_dmax_RevA.WOR

Title:

Southbank - Climate Change +15% 50 Year ARI Peak Flood Depth - HAT

Figure: C-9

Rev: A

N

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Approx. Scale

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigC-9_50y_HAT_C01+15%_dmax_RevA.WOR

Title:

Southbank - Climate Change +15% 100 Year ARI Peak Flood Depth - HAT

Figure: C-10

Rev: A

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Title:

Southbank - Climate Change +15%
5 Year ARI Peak Flood Depth - Storm Surge

Figure: C-11

Rev: A

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Title:

Southbank - Climate Change +15%
10 Year ARI Peak Flood Depth - Storm Surge

Figure: C-12

Rev: A

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Title:

Southbank - Climate Change +15%
20 Year ARI Peak Flood Depth - Storm Surge

Figure: C-13

Rev: A

N

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Approx. Scale

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-13_20y_Storm_C01+15%_dmax_RevA.WOR

Title:

Southbank - Climate Change +15%
50 Year ARI Peak Flood Depth - Storm Surge

Figure: C-14

Rev: A

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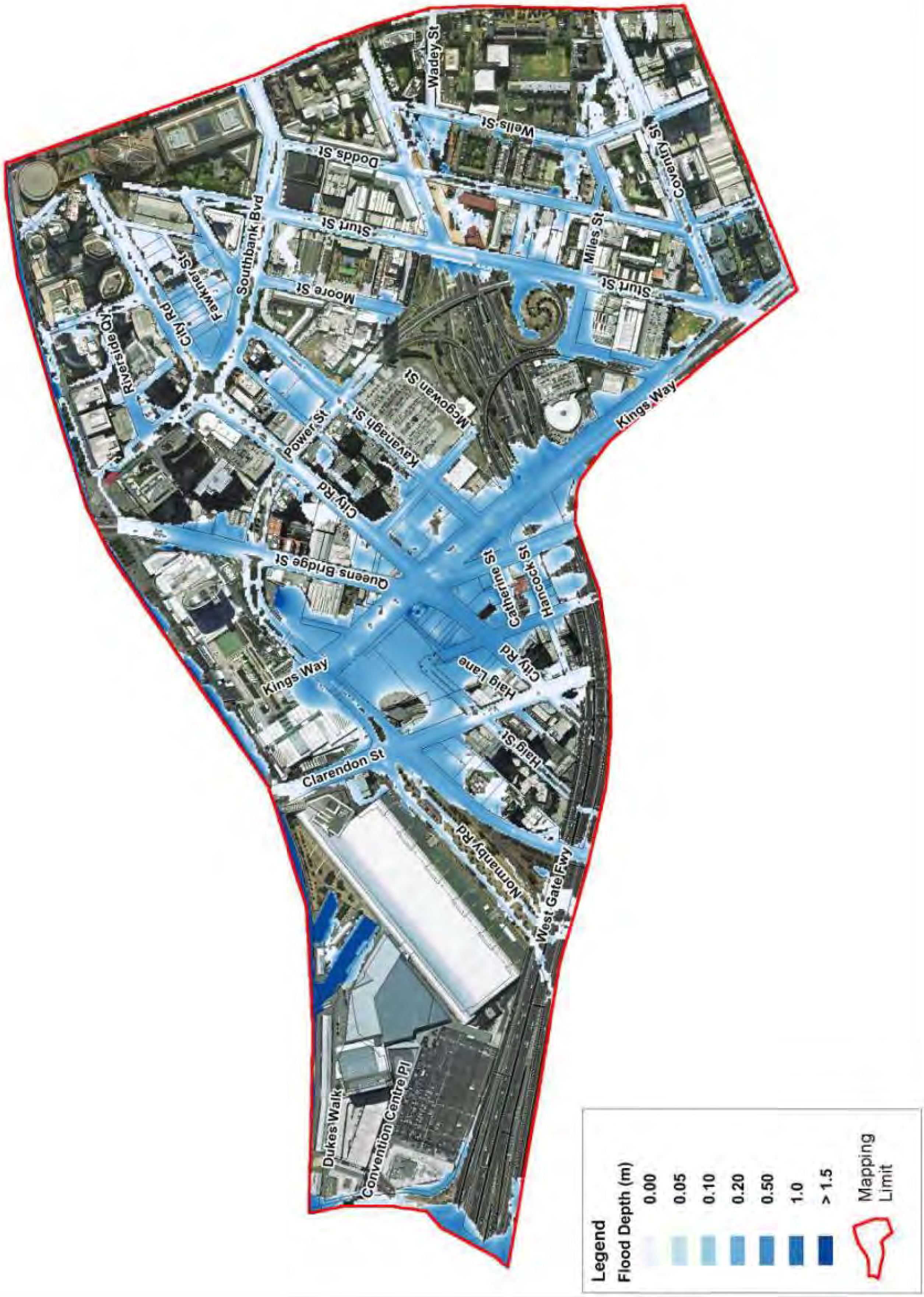

Title:

Southbank - Climate Change +15%
100 Year ARI Peak Flood Depth - Storm Surge

Figure: C-15

Rev: A

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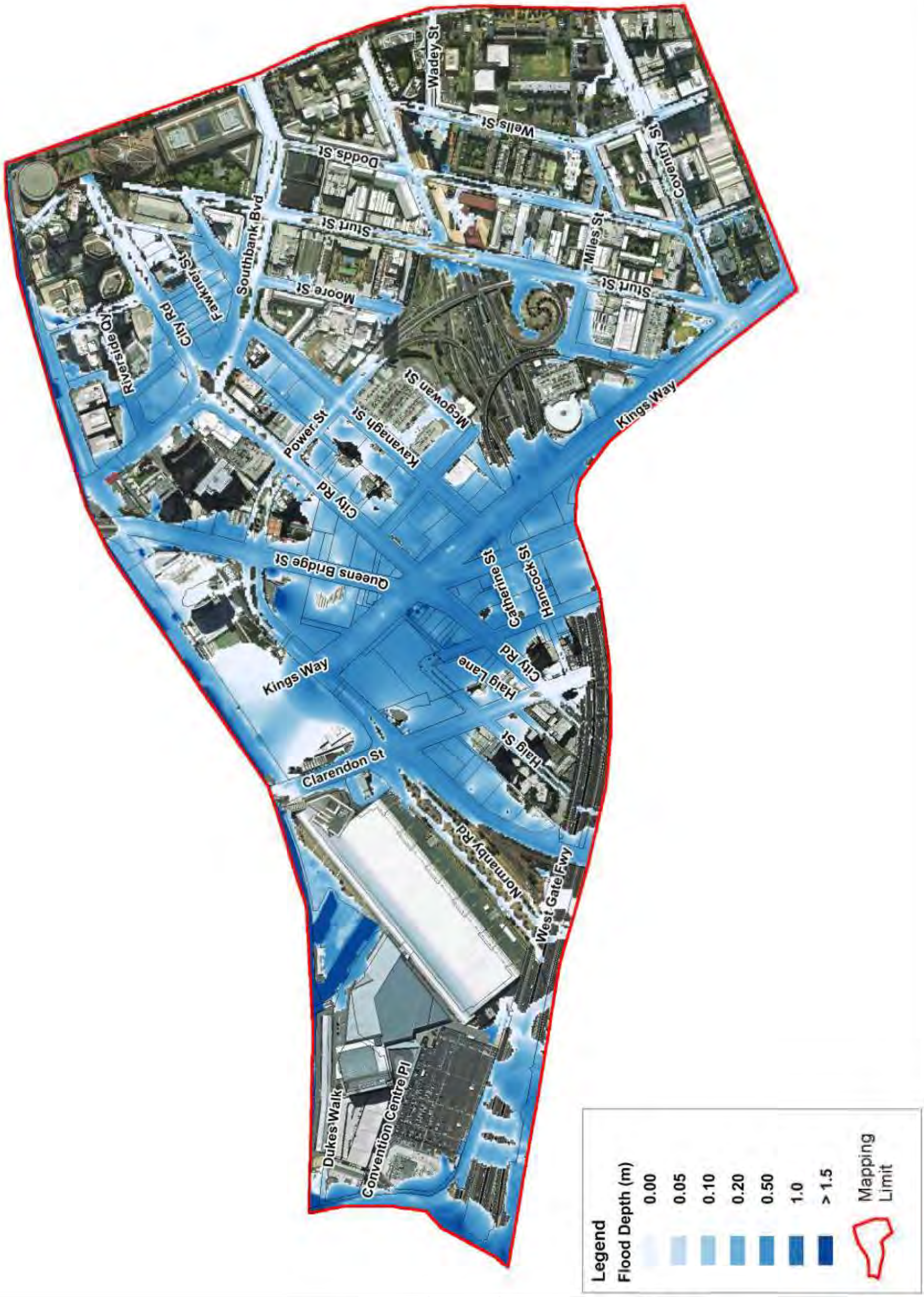

Title:

Southbank - Climate Change +15%
5 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-16

Rev: A

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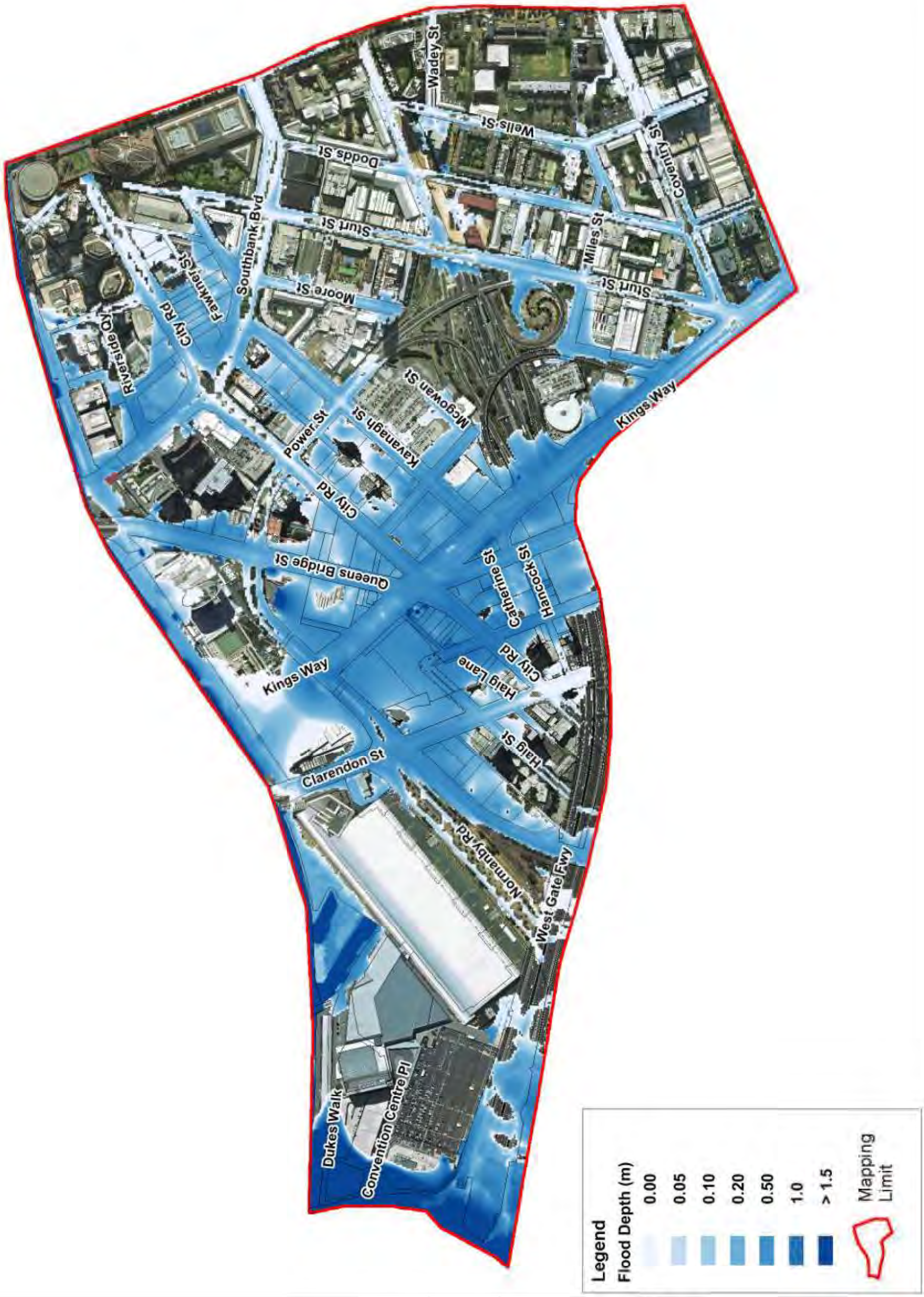

Title:

Southbank - Climate Change +15%
10 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-17

Rev: A

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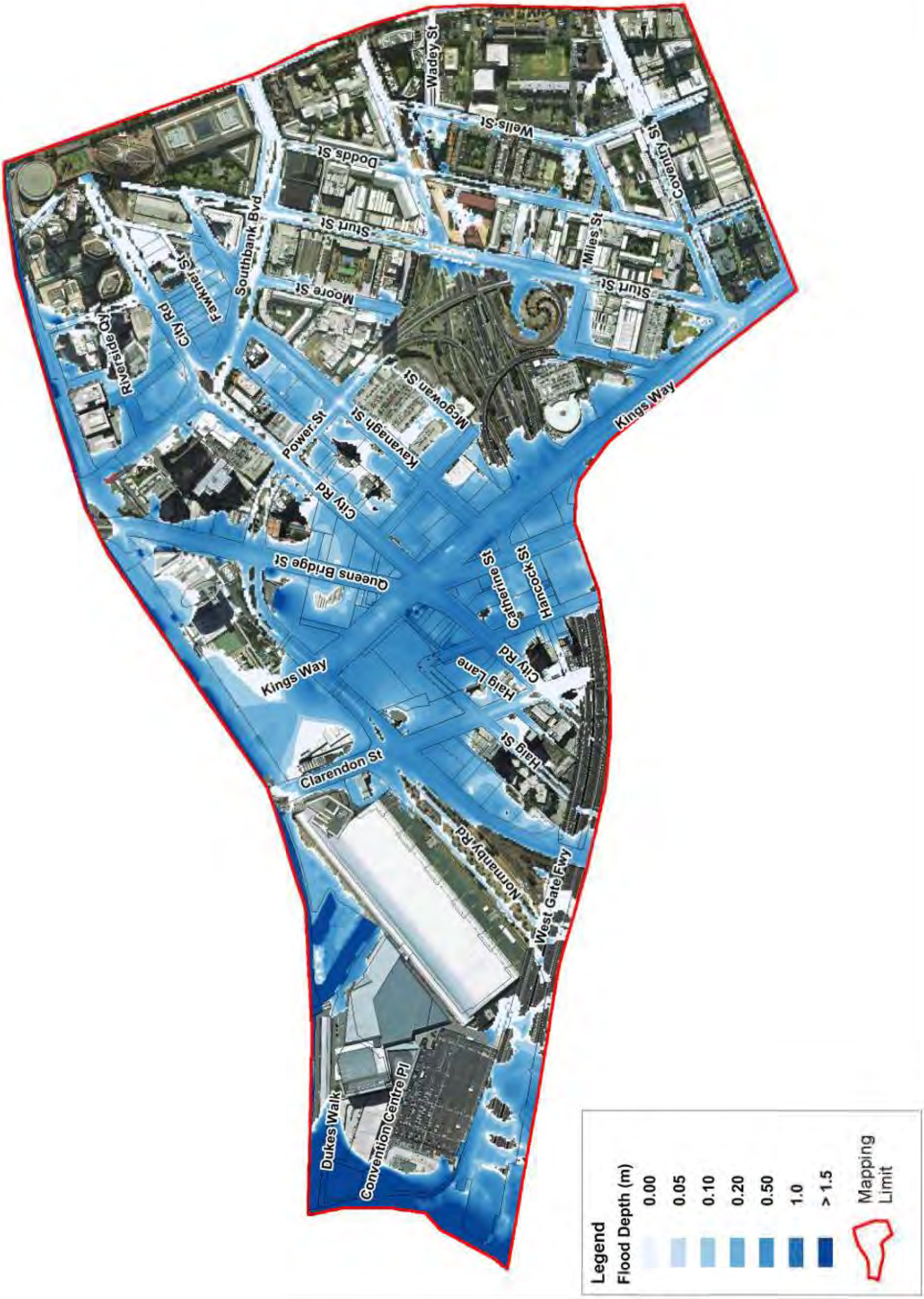

Title:

Southbank - Climate Change +15%
20 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-18

Rev: A

N

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Approx. Scale

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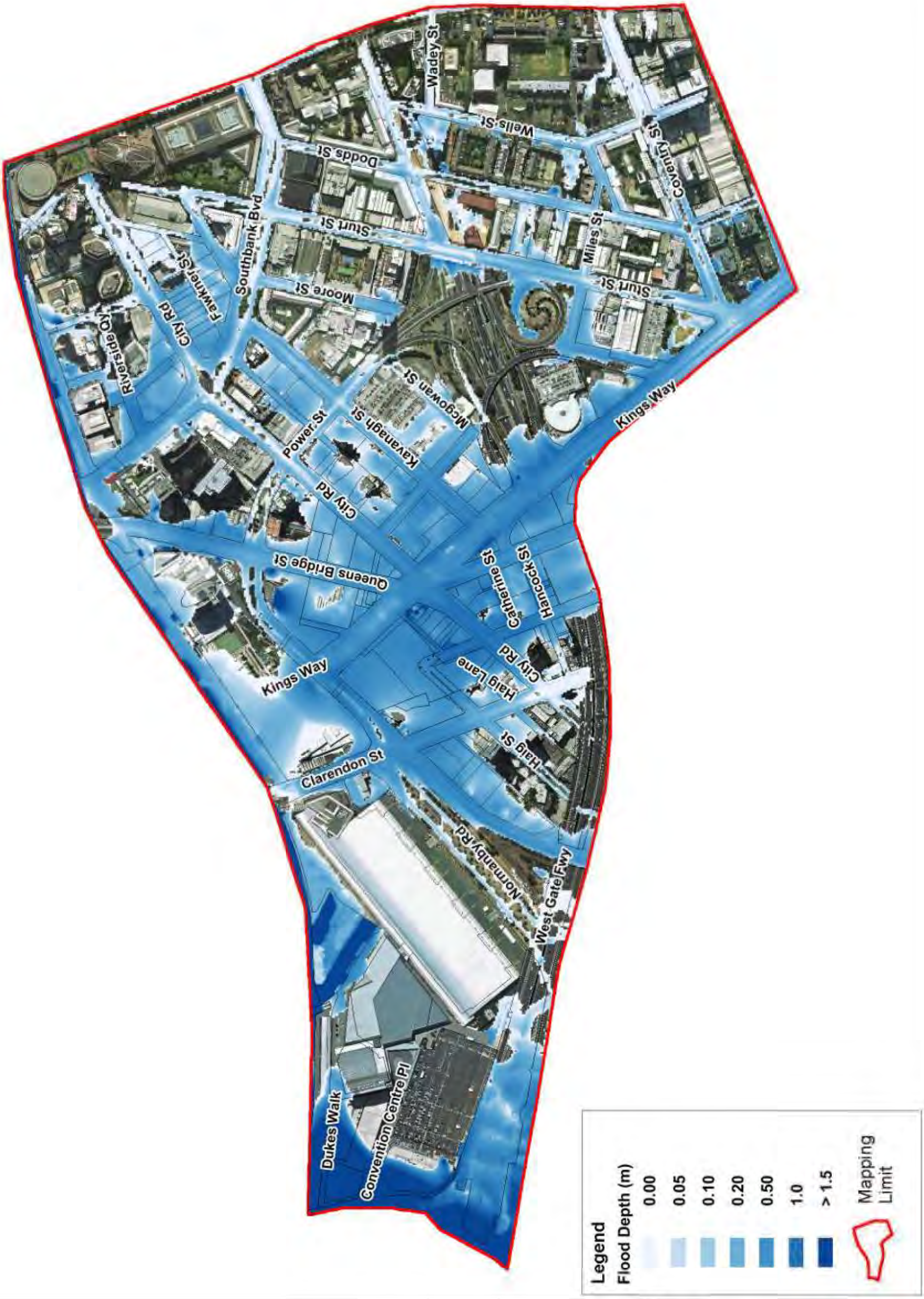
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-18_20y_Yarra100y_C01+15%_dmax_RevA.WOR



Title:

Southbank - Climate Change +15%
50 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-19

Rev: A

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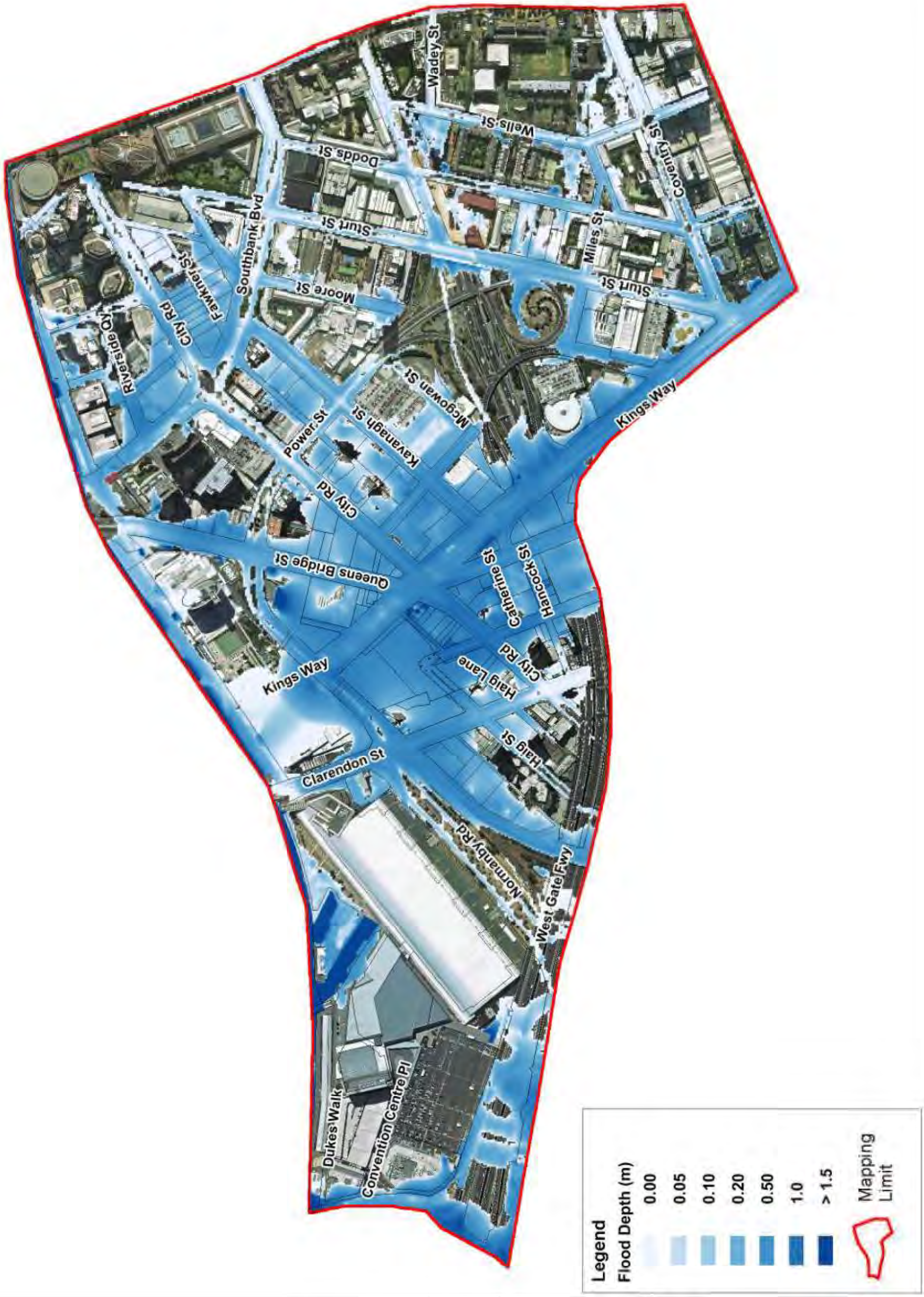

Title:

Southbank - Climate Change +15%
100 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-20

Rev: A

N

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Approx. Scale

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Title:

Southbank - Climate Change +32%
5 Year ARI Peak Flood Depth - MSL

Figure: C-21

Rev: A

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Title:

Southbank - Climate Change +32%
10 Year ARI Peak Flood Depth - MSL

Figure: C-22

Rev: A

N

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Approx. Scale

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Title:

Southbank - Climate Change +32%
20 Year ARI Peak Flood Depth - MSL

Figure: C-23

Rev: A

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Approx. Scale

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Title:

Southbank - Climate Change +32%
50 Year ARI Peak Flood Depth - MSL

Figure: C-24

Rev: A

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Title:

Southbank - Climate Change +32%
100 Year ARI Peak Flood Depth - MSL

Figure: C-25

Rev: A

N

0 125 250m
Approx. Scale

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Title:

Southbank - Climate Change +32%
5 Year ARI Peak Flood Depth - HAT

Figure: C-26

Rev: A

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Title:

Southbank - Climate Change +32% 10 Year ARI Peak Flood Depth - HAT

Figure: C-27

Rev: A

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Title:

Southbank - Climate Change +32% 20 Year ARI Peak Flood Depth - HAT

Figure: C-28

Rev: A

N

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Approx. Scale

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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigC-28_20y_HAT_C02+32%_dmax_RevA.WOR

Title:

Southbank - Climate Change +32%
50 Year ARI Peak Flood Depth - HAT

Figure: C-29

Rev: A

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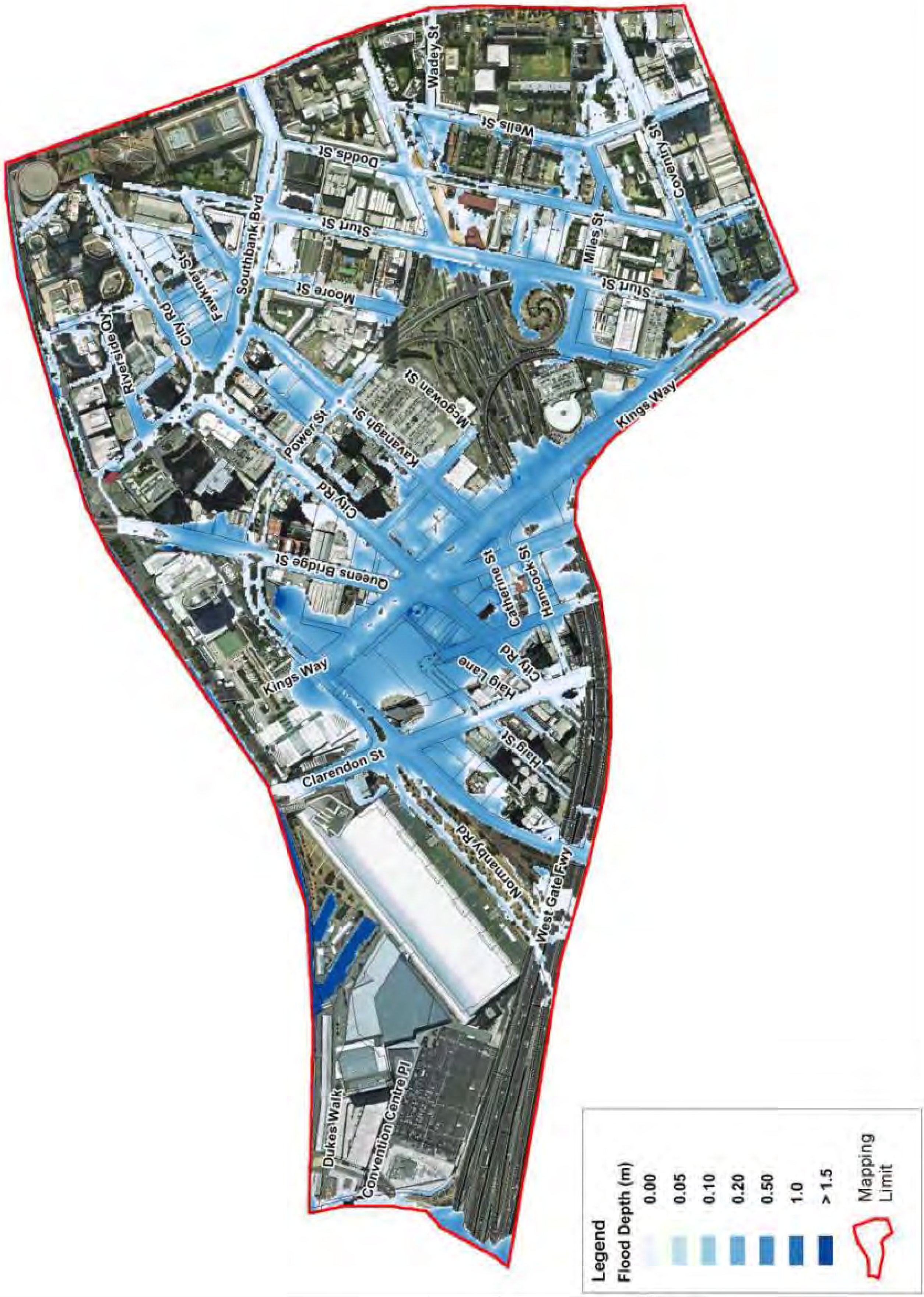

Title:

Southbank - Climate Change +32%
100 Year ARI Peak Flood Depth - HAT

Figure: C-30

Rev: A

N

0 125 250m
Approx. Scale

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Title:

Southbank - Climate Change +32%
5 Year ARI Peak Flood Depth - Storm Surge

Figure: C-31

Rev: A

N

0 125 250m
Approx. Scale

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Title:

Southbank - Climate Change +32%
10 Year ARI Peak Flood Depth - Storm Surge

Figure: C-32

Rev: A

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Title:

Southbank - Climate Change +32%
20 Year ARI Peak Flood Depth - Storm Surge

Figure: **C-33**

Rev: **A**

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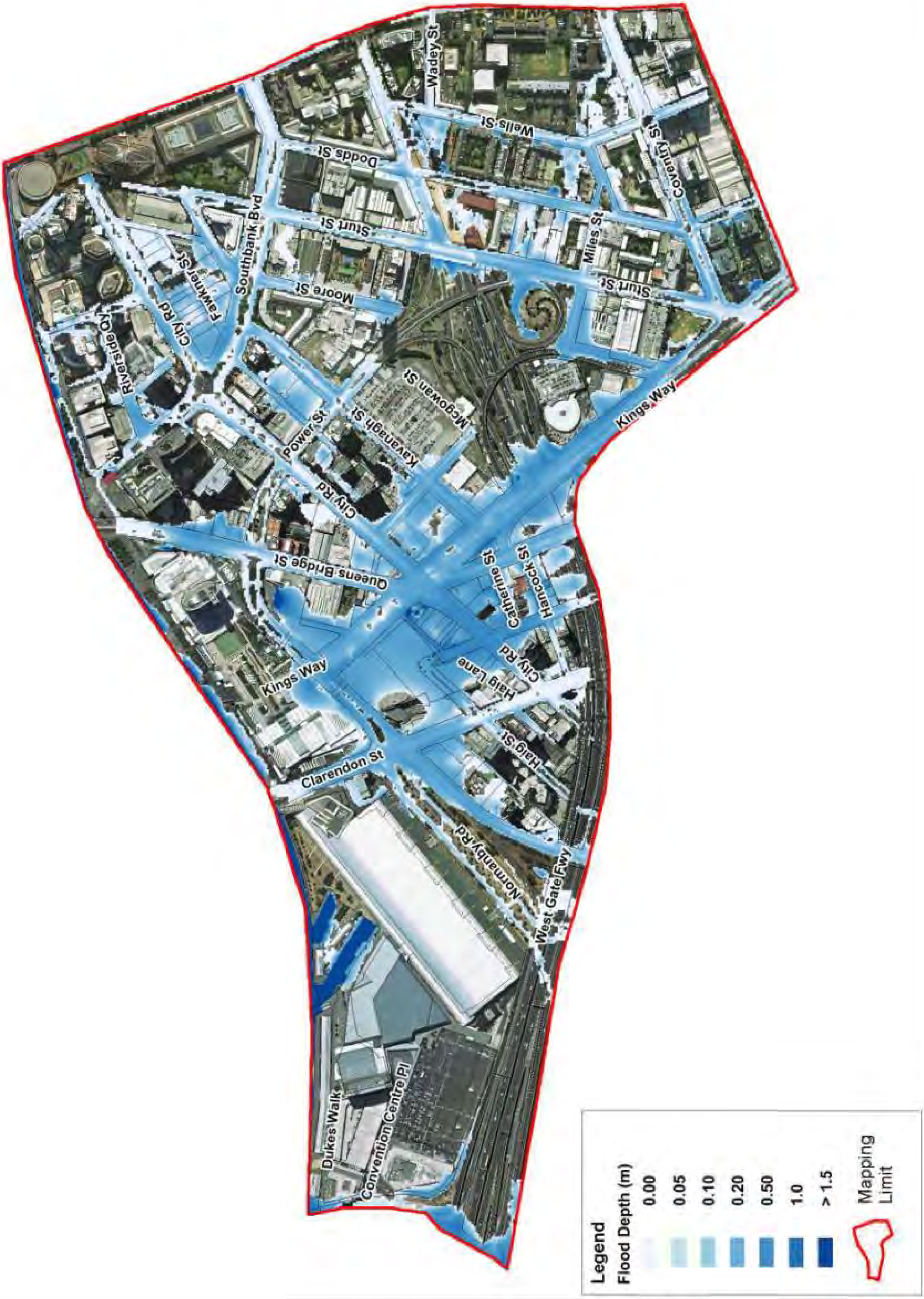

Title:

Southbank - Climate Change +32%
50 Year ARI Peak Flood Depth - Storm Surge

Figure: C-34

Rev: A

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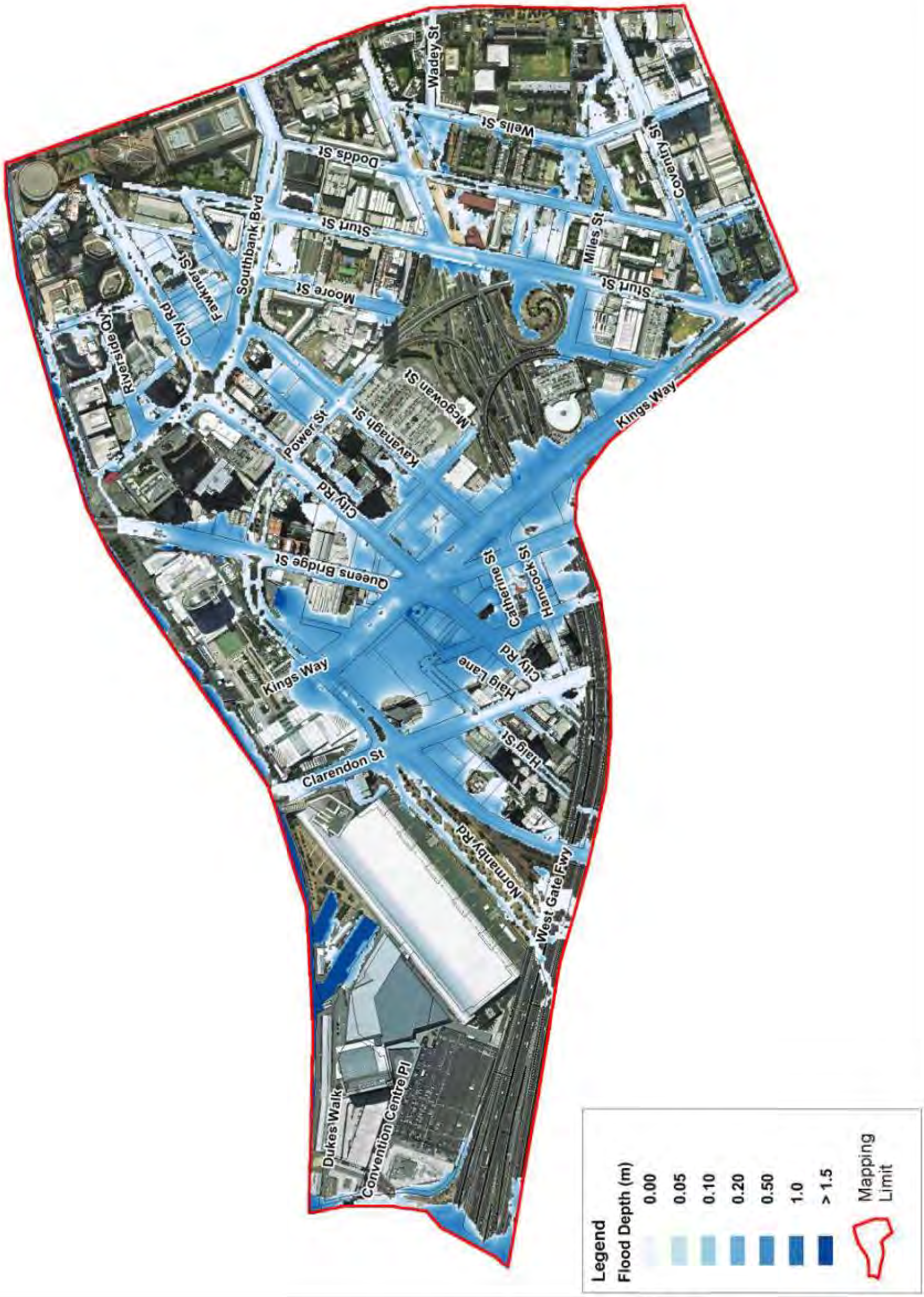

Title:

Southbank - Climate Change +32%
100 Year ARI Peak Flood Depth - Storm Surge

Figure: C-35

Rev: A

N

0 125 250m
Approx. Scale

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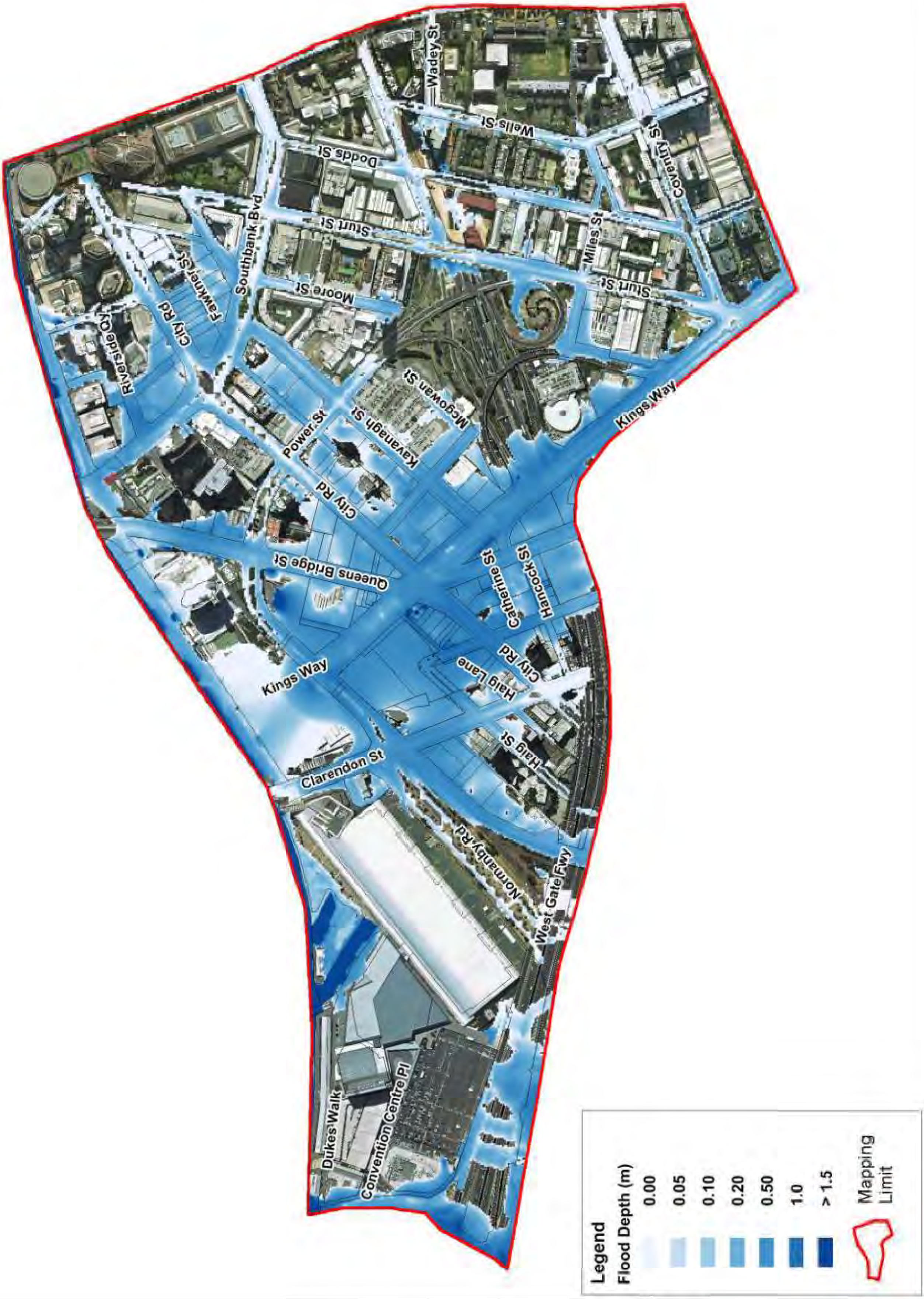
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-35_100y_Storm_C02+32%_dmax_RevA.WOR



Title:

Southbank - Climate Change +32%
5 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-36

Rev: A

N

0 125 250m
Approx. Scale

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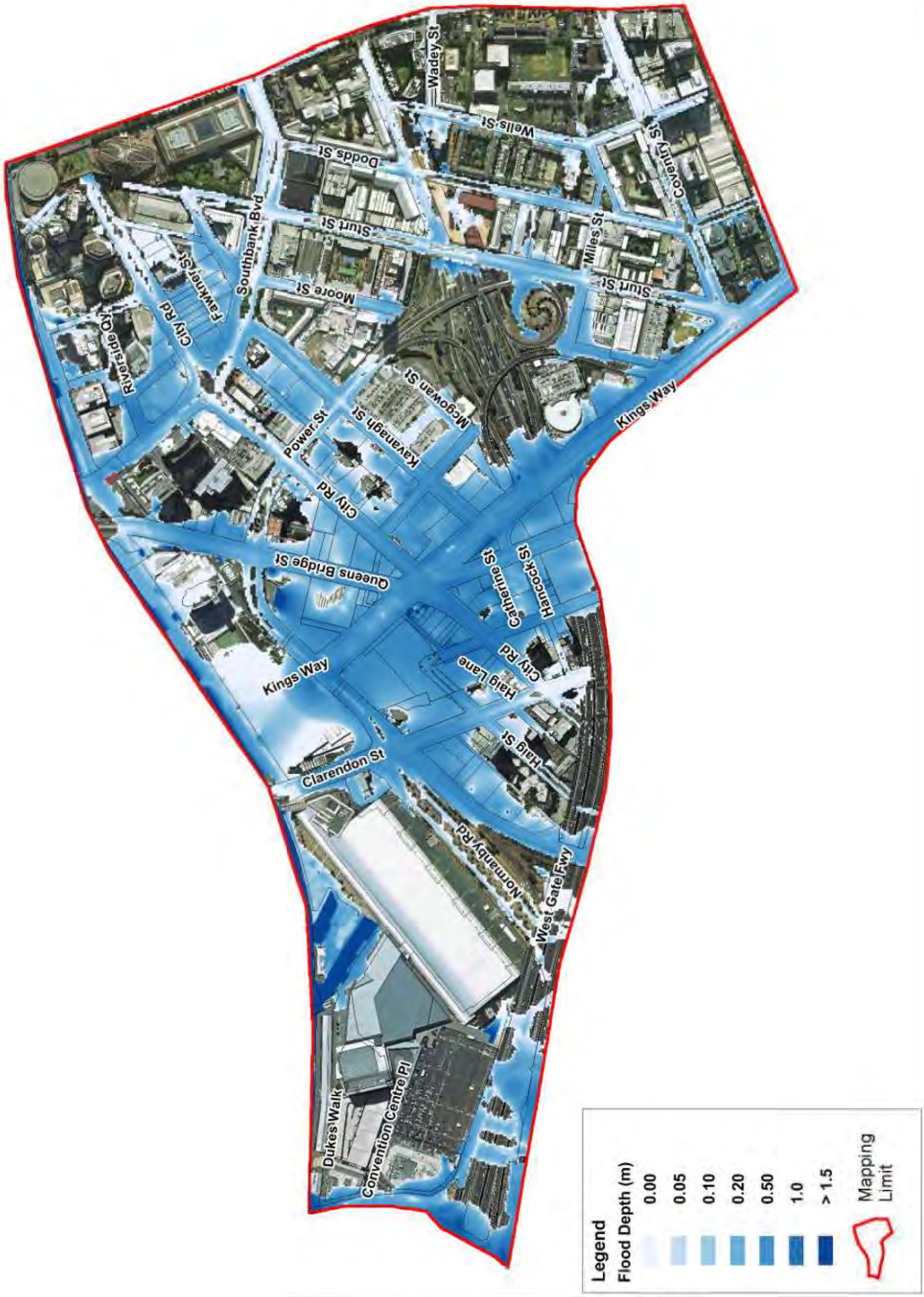
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-36_5y_Yarra100y_C02+32%_dmax_RevA.WOR



Title:

Southbank - Climate Change +32%
10 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-37

Rev: A

N

0 125 250m
Approx. Scale

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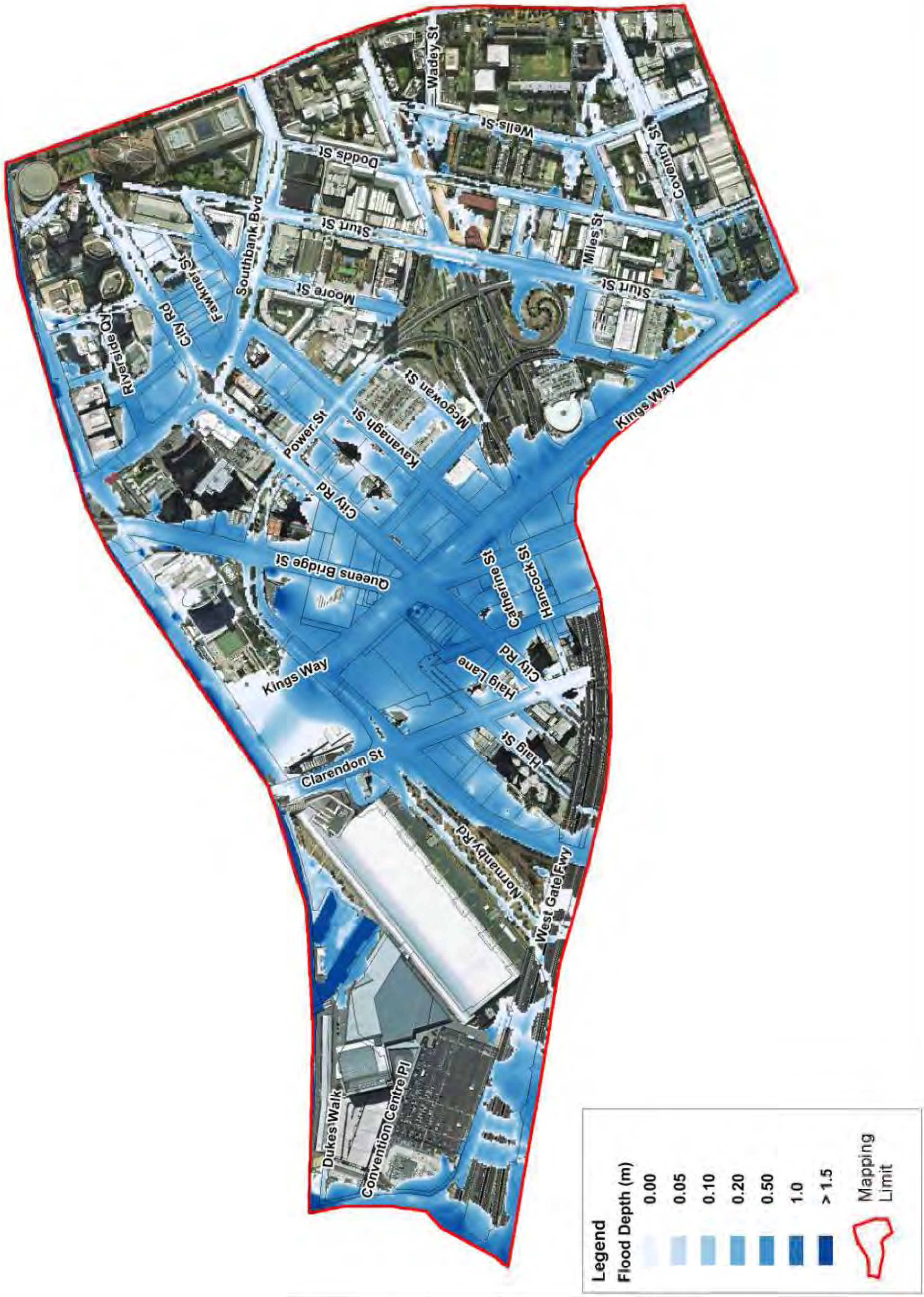

Title:

Southbank - Climate Change +32%
20 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-38

Rev: A

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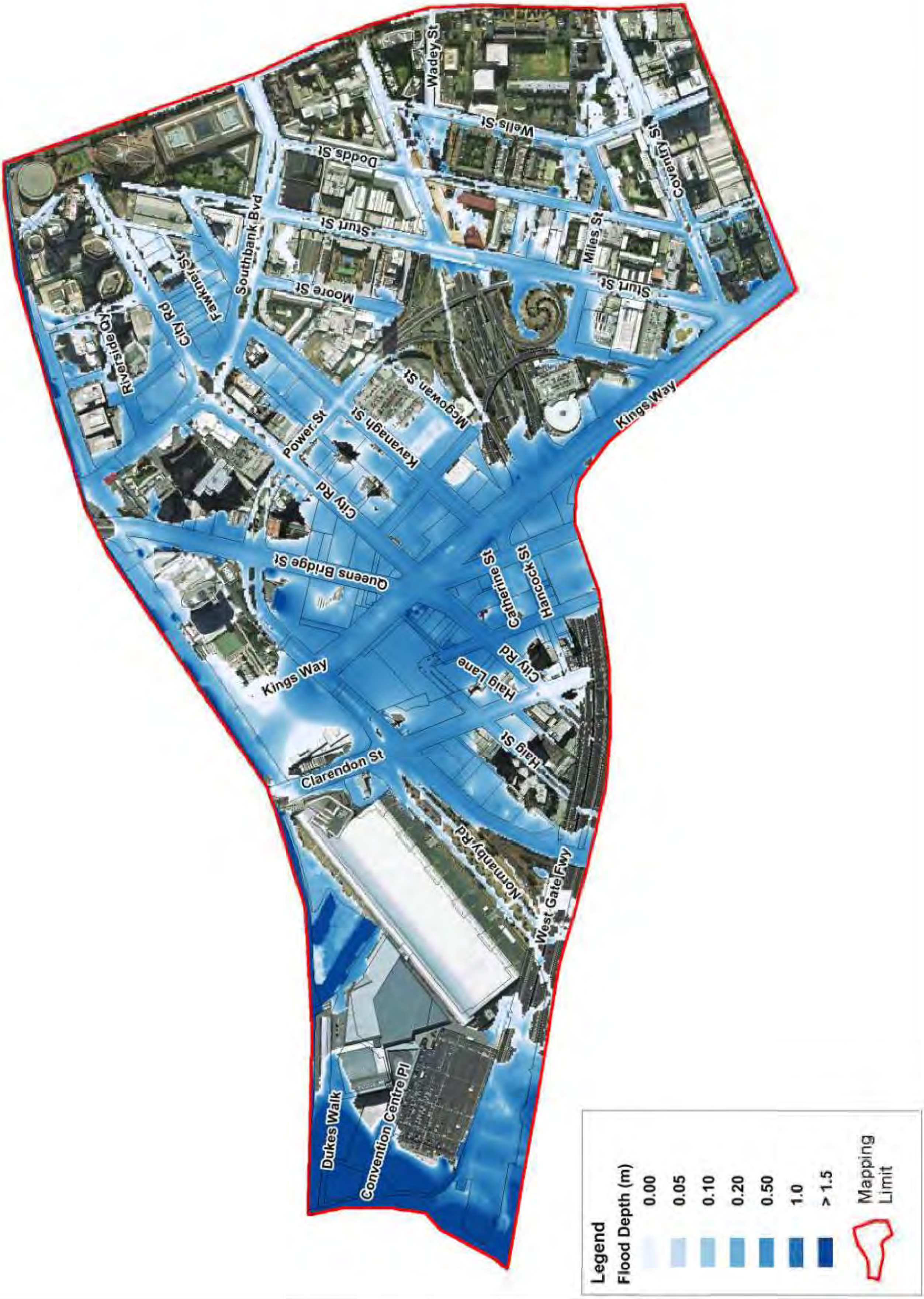

Title:

Southbank - Climate Change +32%
50 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-39

Rev: A

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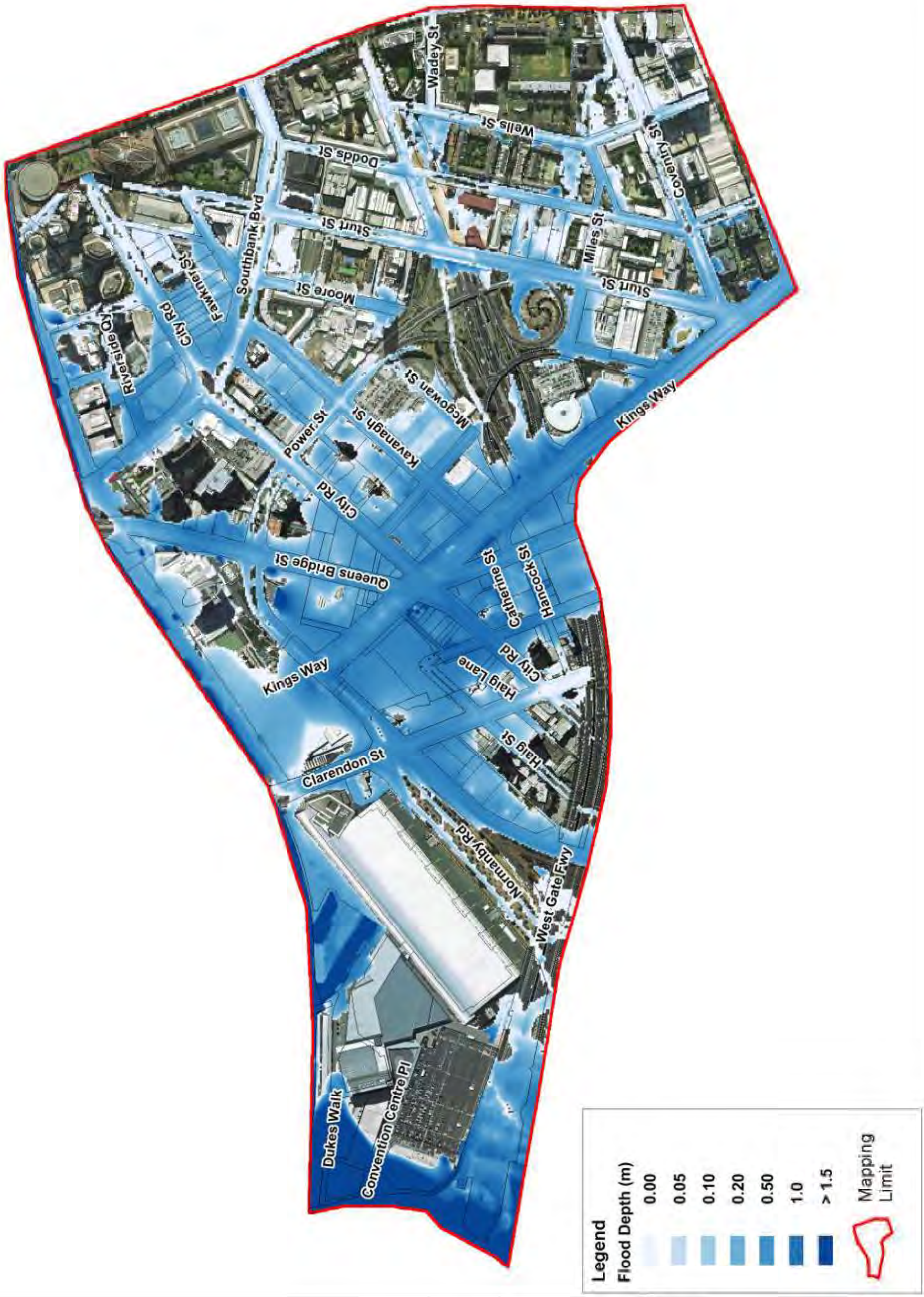

Title:

Southbank - Climate Change +32% 100 Year ARI Peak Flood Depth - Yarra 100y

Figure: C-40

Rev: A

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