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Southbank Stormwater Infrastructure Assessment: Final Report

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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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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

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

Figure: 2

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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

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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

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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

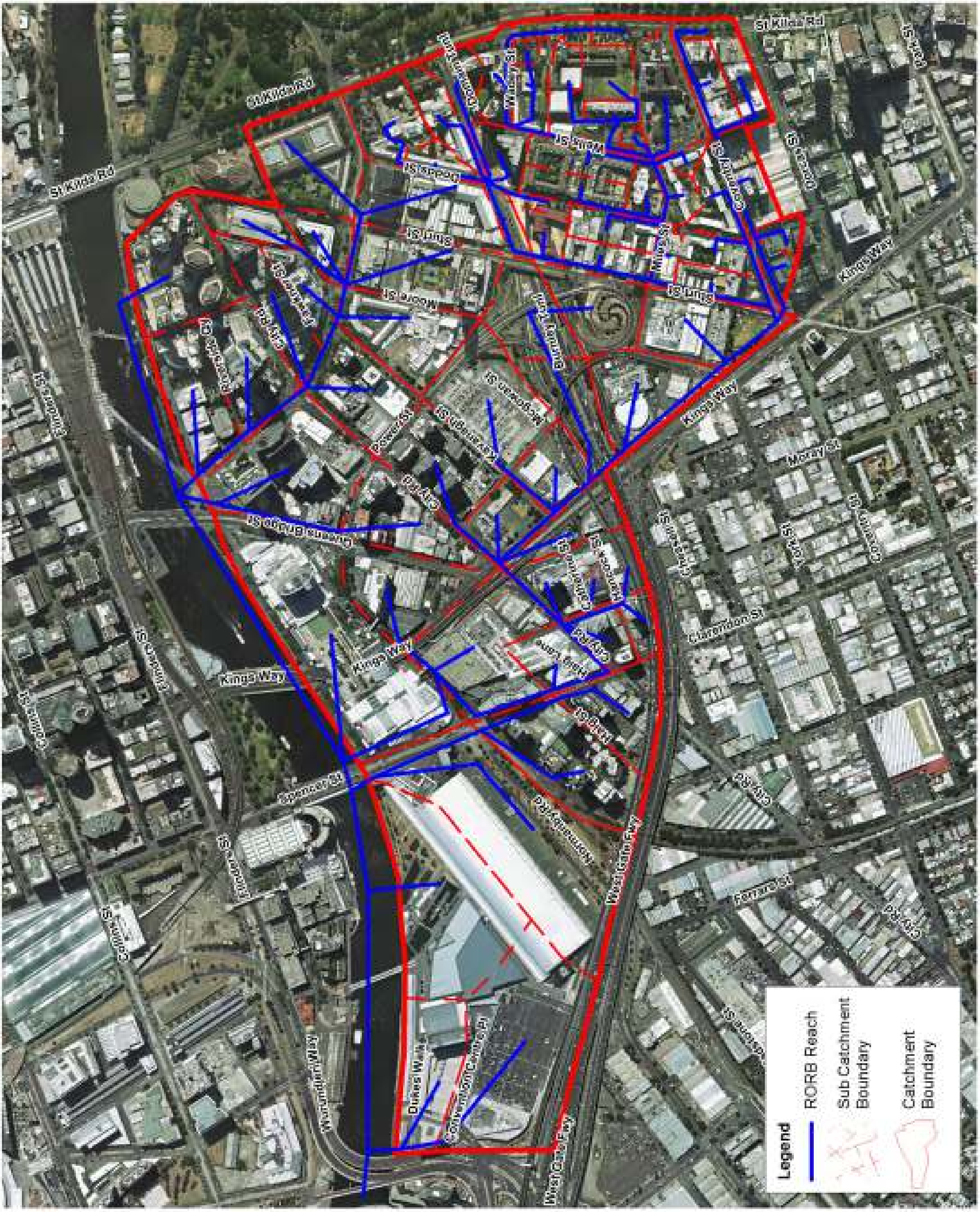
	Clarendon Street Outlet*	Southbank Boulevard Outlet	Queens Bridge Street Outlet
Critical Duration	2 hour	1 hour	25 minute

* 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**

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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.

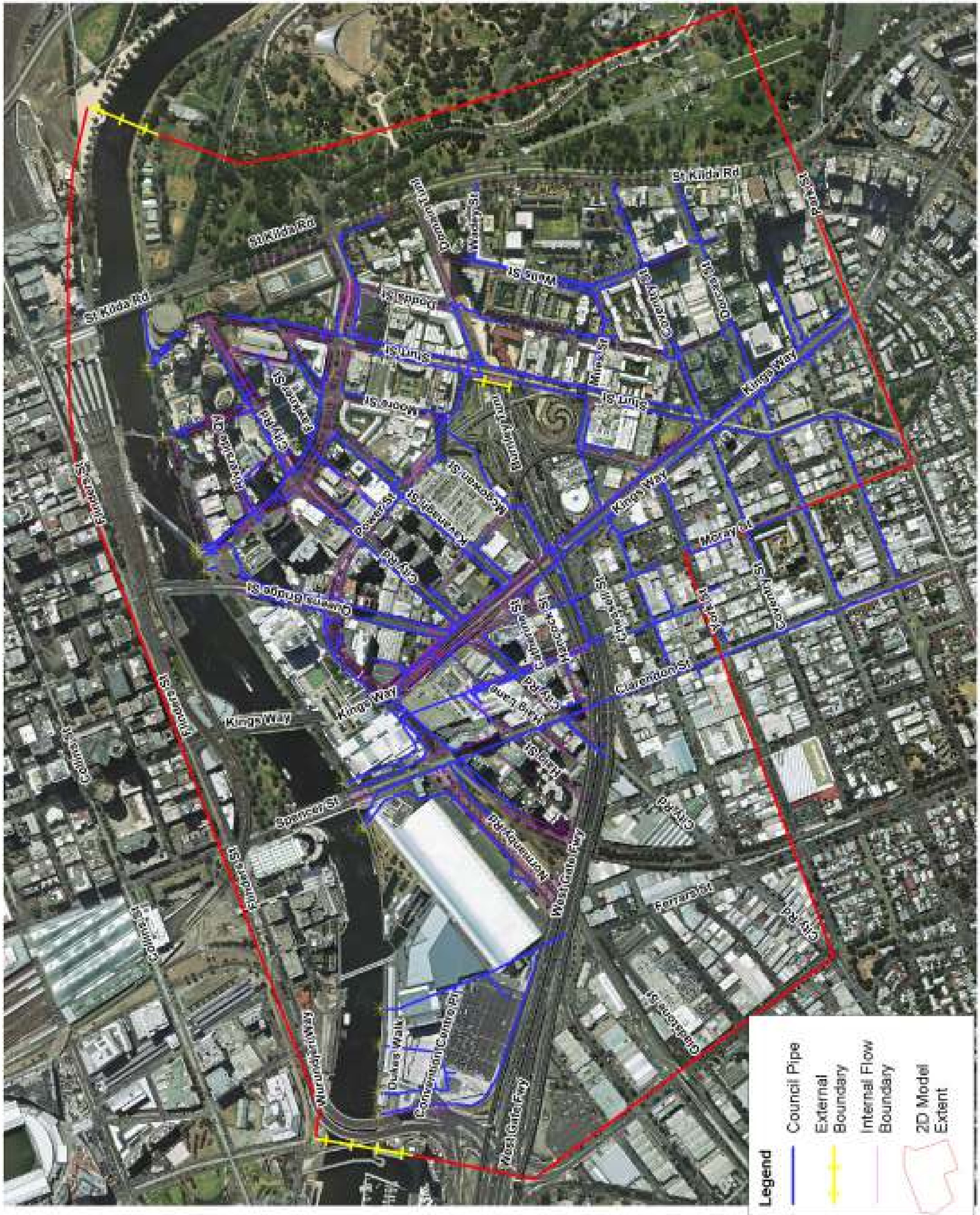
3.3.1 TUFLOW model description

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

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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

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Title:

Southbank

10 Year ARI Peak Flood Depth - MSL

Figure: **3-4**

Rev: **A**

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Title:

Southbank

20 Year ARI Peak Flood Depth - MSL

Figure:

3-5

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Title:
Southbank
50 Year ARI Peak Flood Depth - MSL

Figure:
3-6

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Title:

Southbank

100 Year ARI Peak Flood Depth - MSL

Figure: **3-7**

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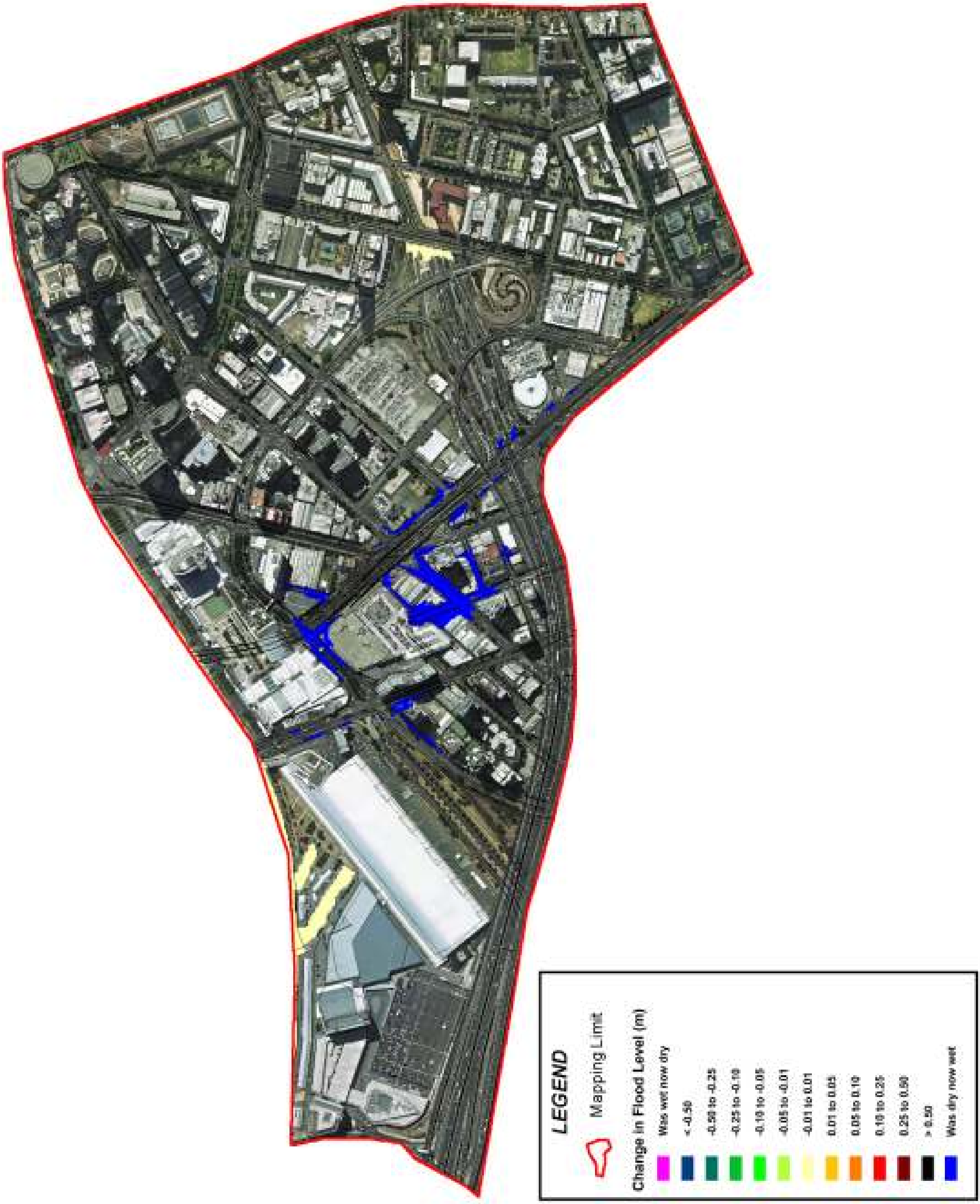
4 Impact of Back Flow Preventers (Tide Valves)

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

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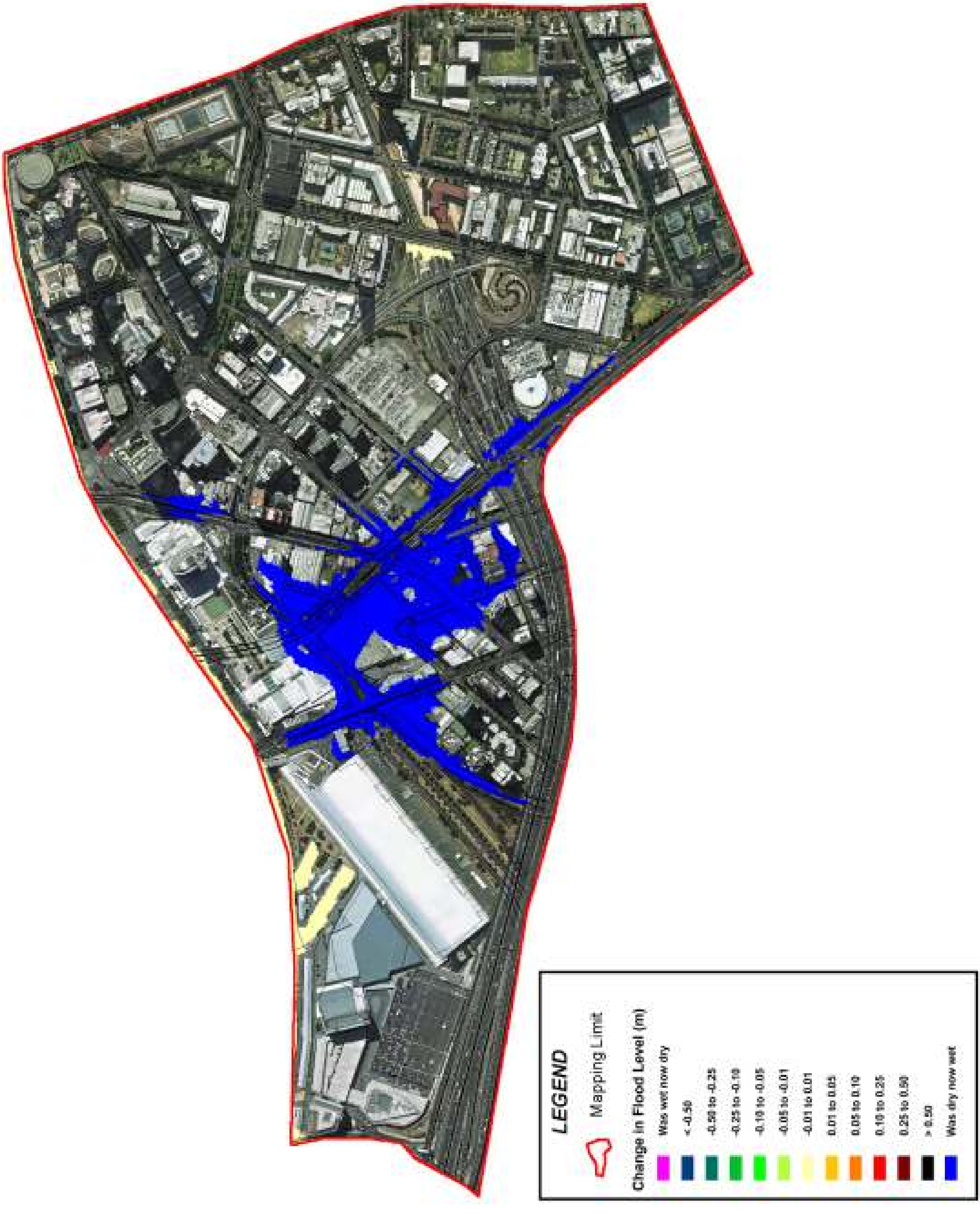

Title:

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

Figure: **4-2**

Rev: **A**

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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.

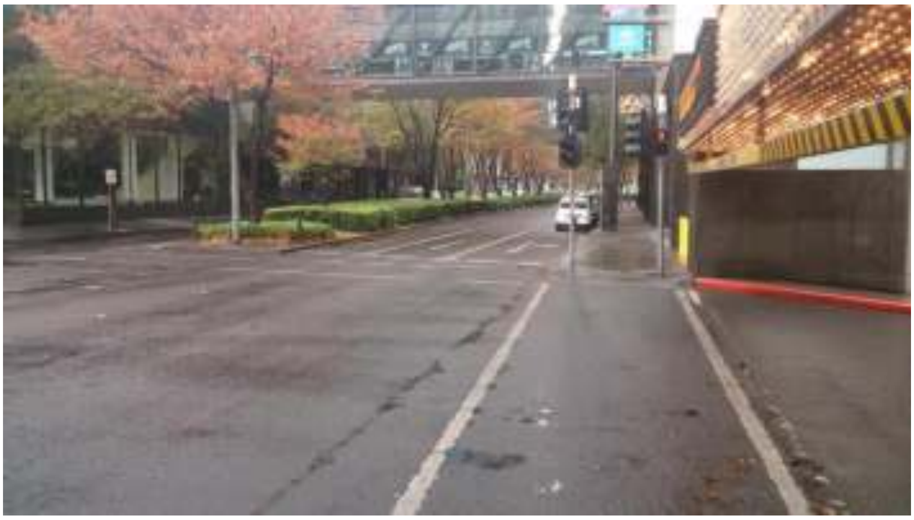


Figure 5-4 Whiteman Street

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

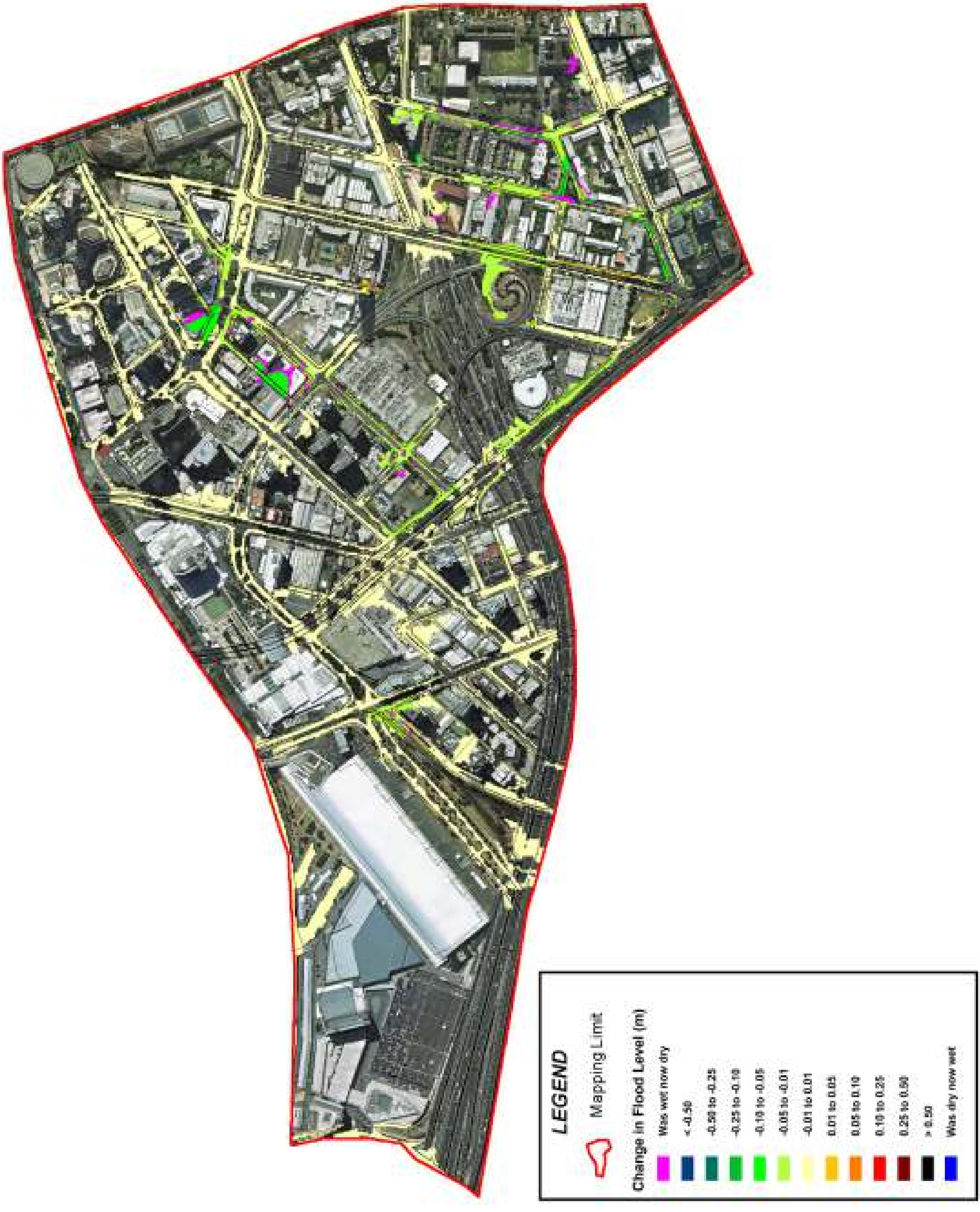
Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	42	2	37	4	33	5	27	1	19	0
0.02 – 0.05 m	42	0	43	-3	42	1	45	2	38	2
0.05 – 0.10 m	33	3	35	4	38	-3	33	1	30	0
0.10 – 0.25 m	53	-4	51	-6	58	-2	69	-1	73	-2
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

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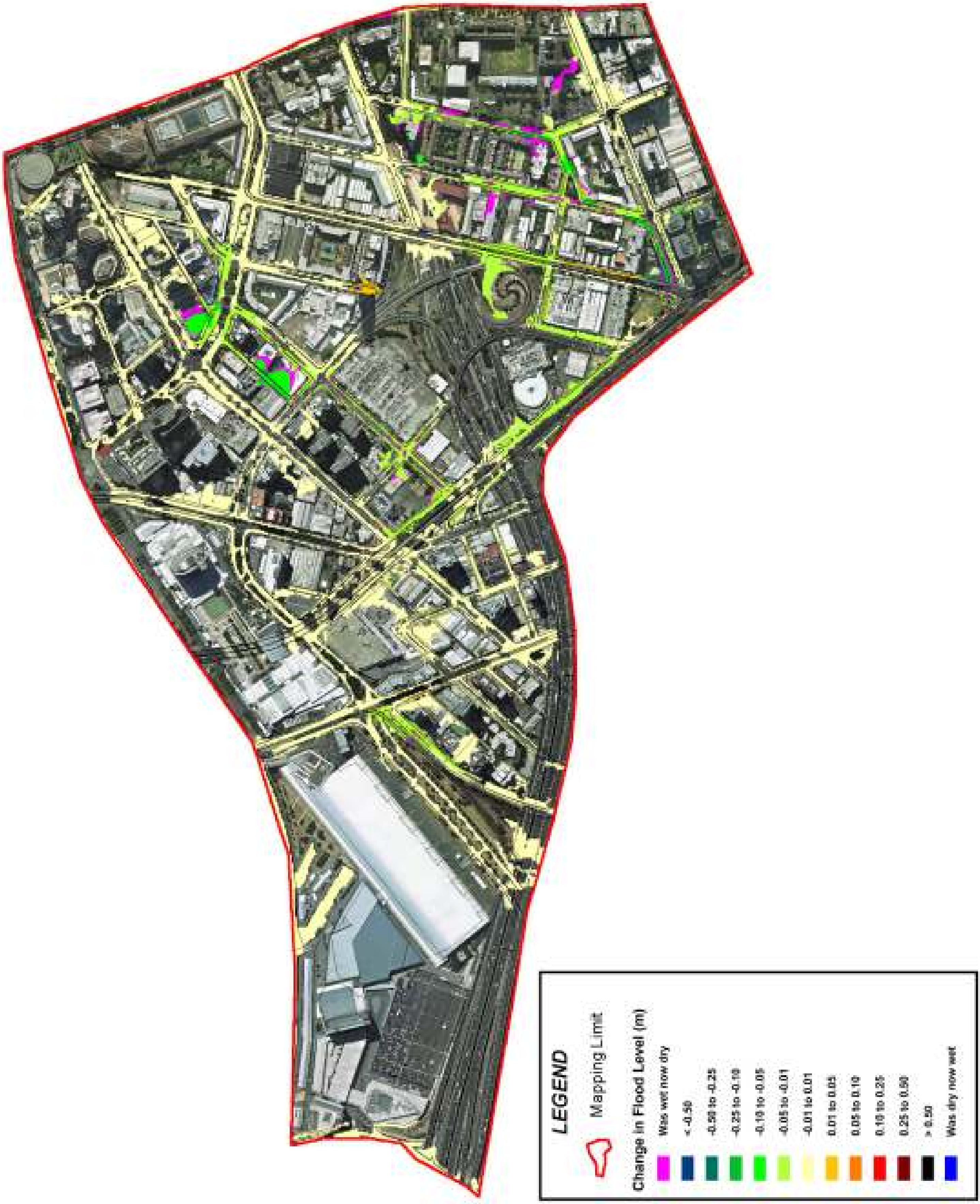

Title:

Southbank - WSUD

Change in 10 Year ARI Peak Flood Heights - MSL

Figure: **6-2**

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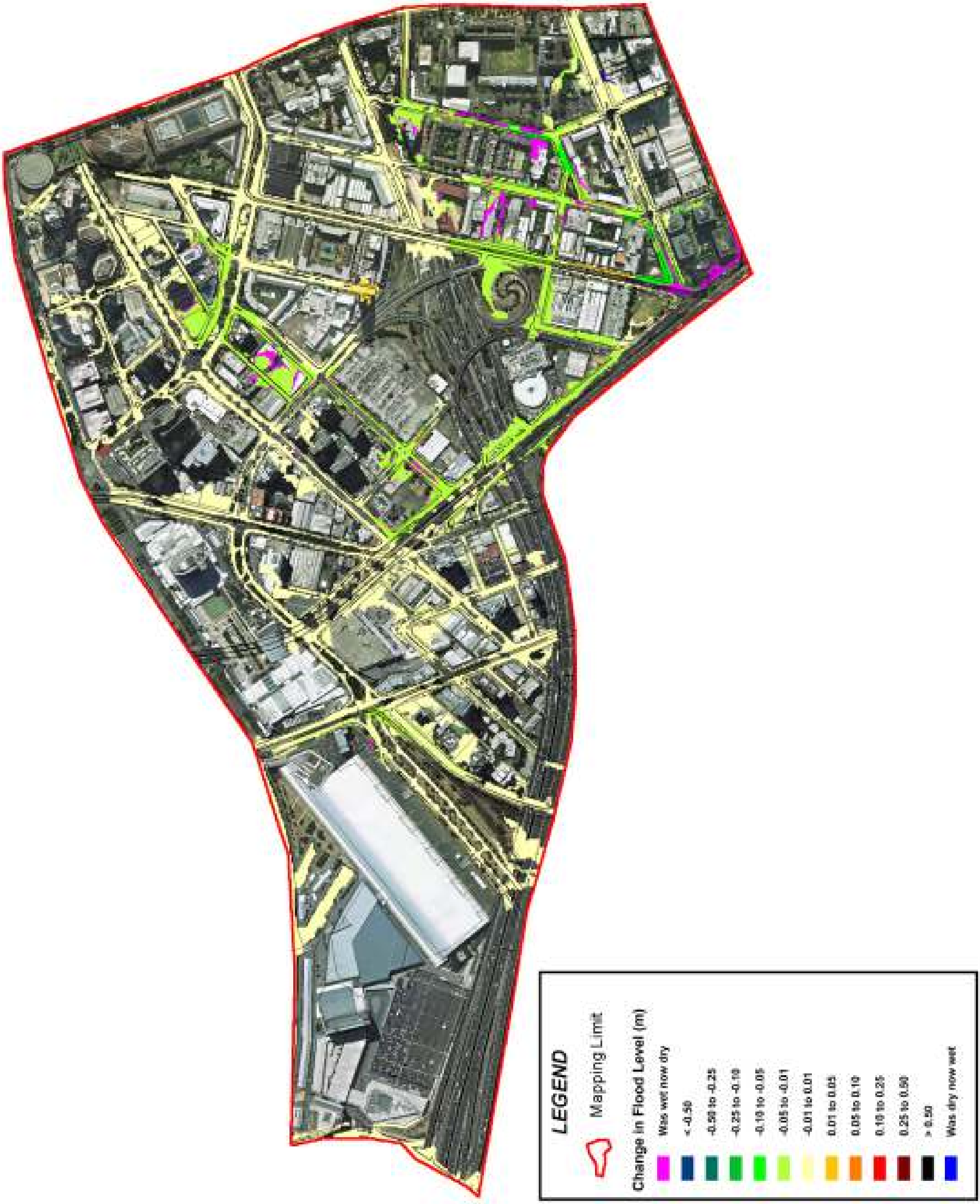

Title:
Southbank - WSUD
Change in 20 Year ARI Peak Flood Heights - MSL

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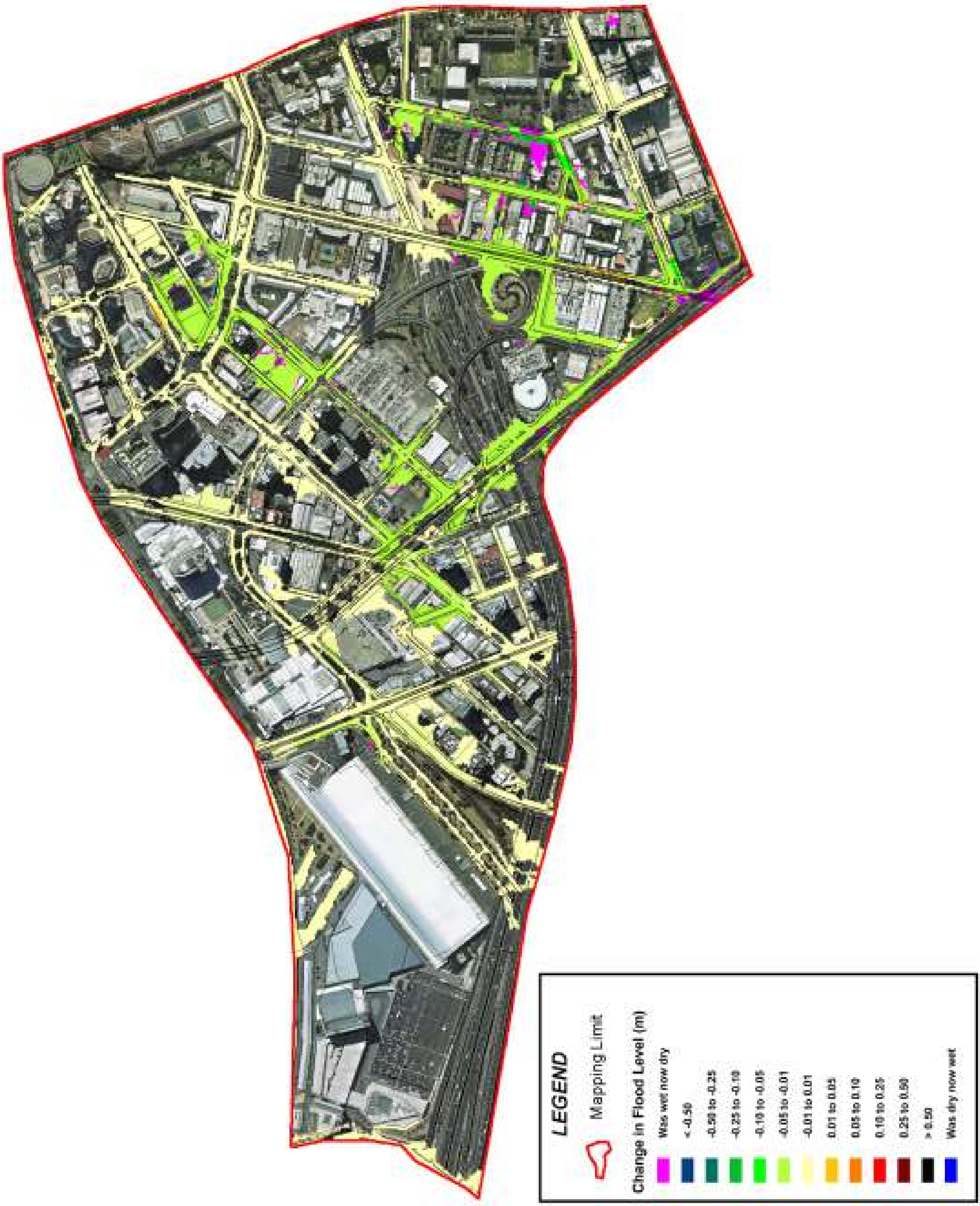

Title:

Southbank - WSUD

Change in 50 Year ARI Peak Flood Heights - MSL

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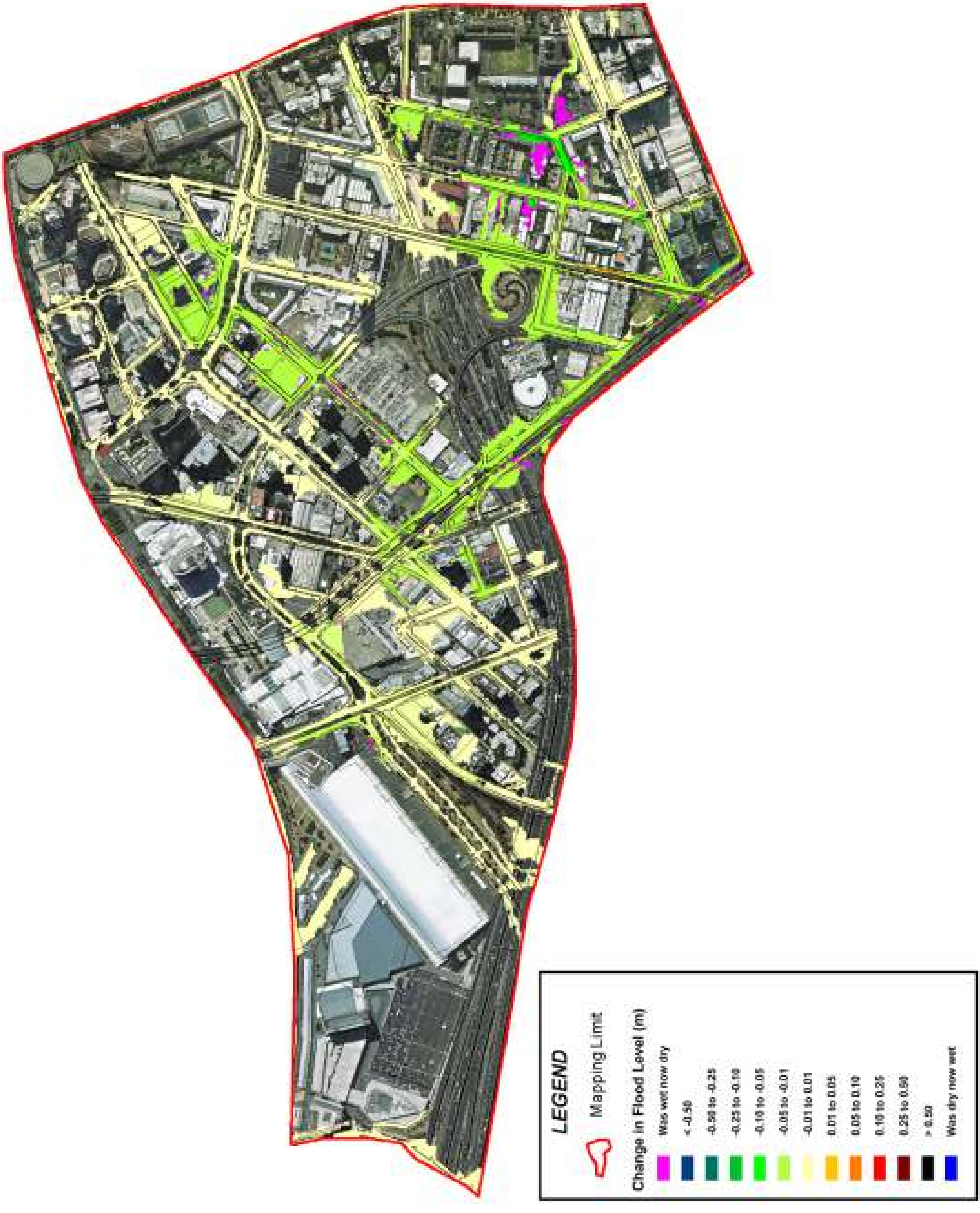

Title:

Southbank - WSUD

Change in 100 Year ARI Peak Flood Heights - MSL

Figure: **6-5**

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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

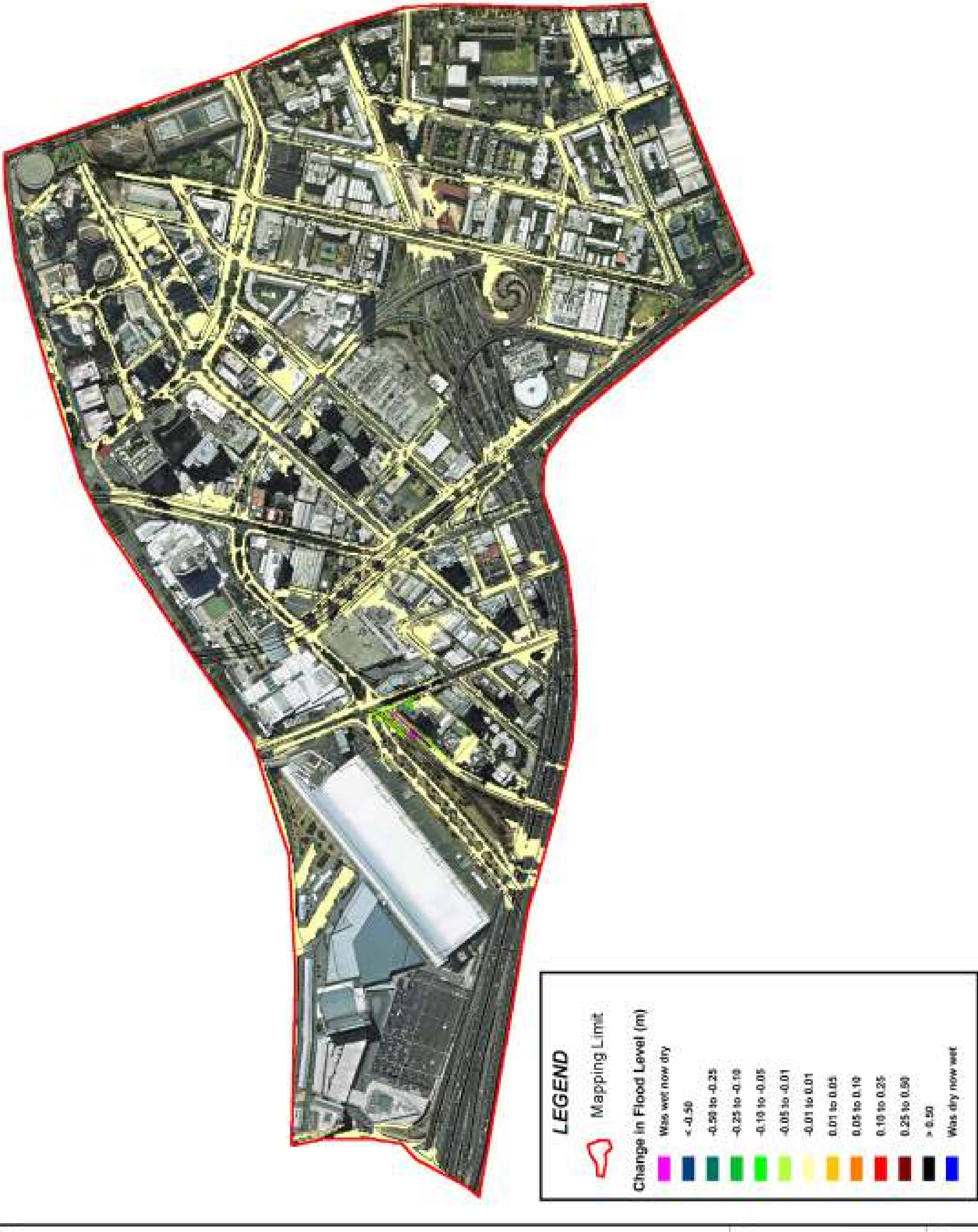
Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	40	0	33	0	28	0	26	0	19	0
0.02 – 0.05 m	42	0	46	0	41	0	43	0	37	1
0.05 – 0.10 m	31	1	32	1	41	0	32	0	29	-1
0.10 – 0.25 m	57	0	57	0	60	0	70	0	75	0
0.25 – 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**

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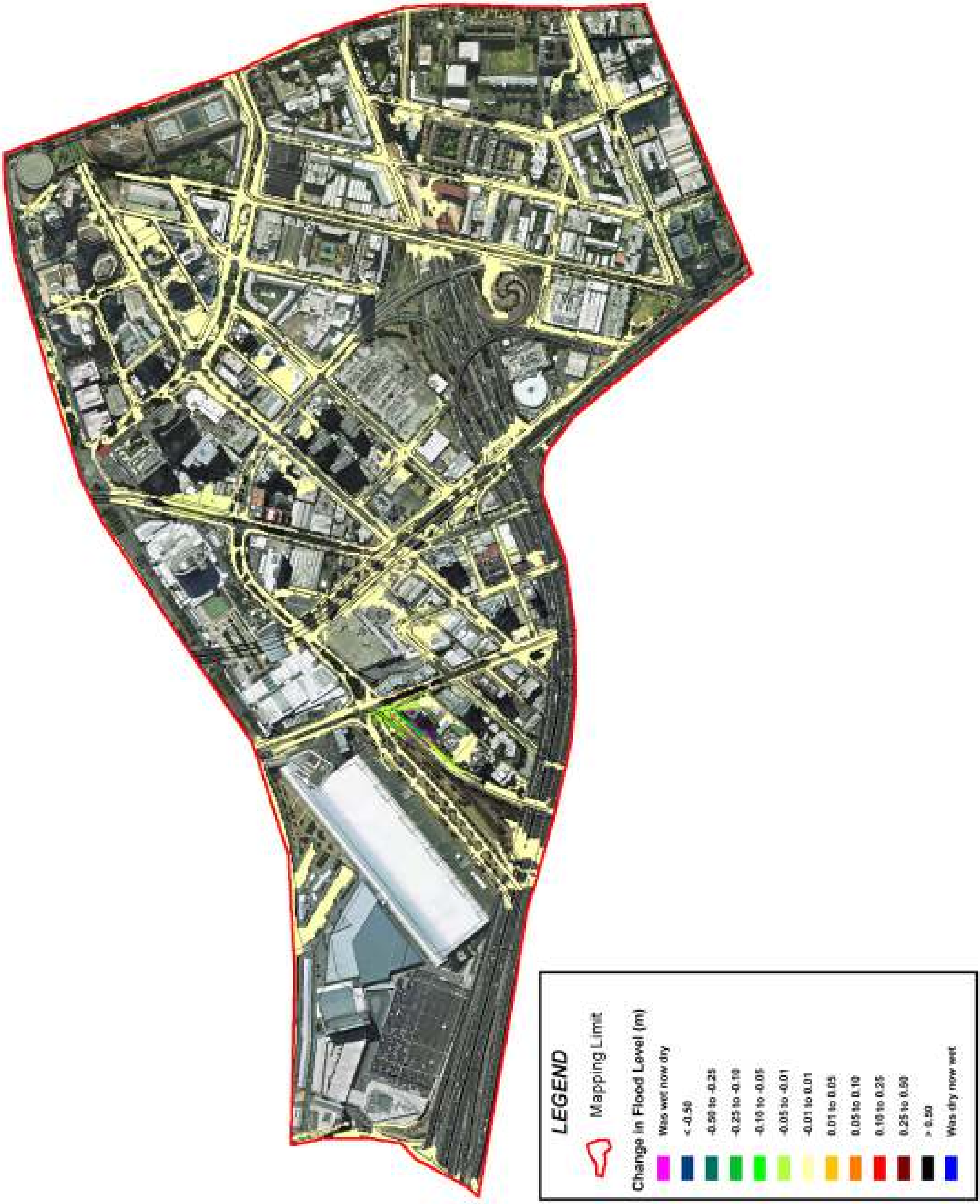

Title:
Southbank - Pipe
Change in 10 Year ARI Peak Flood Heights - MSL

Figure:
6-7

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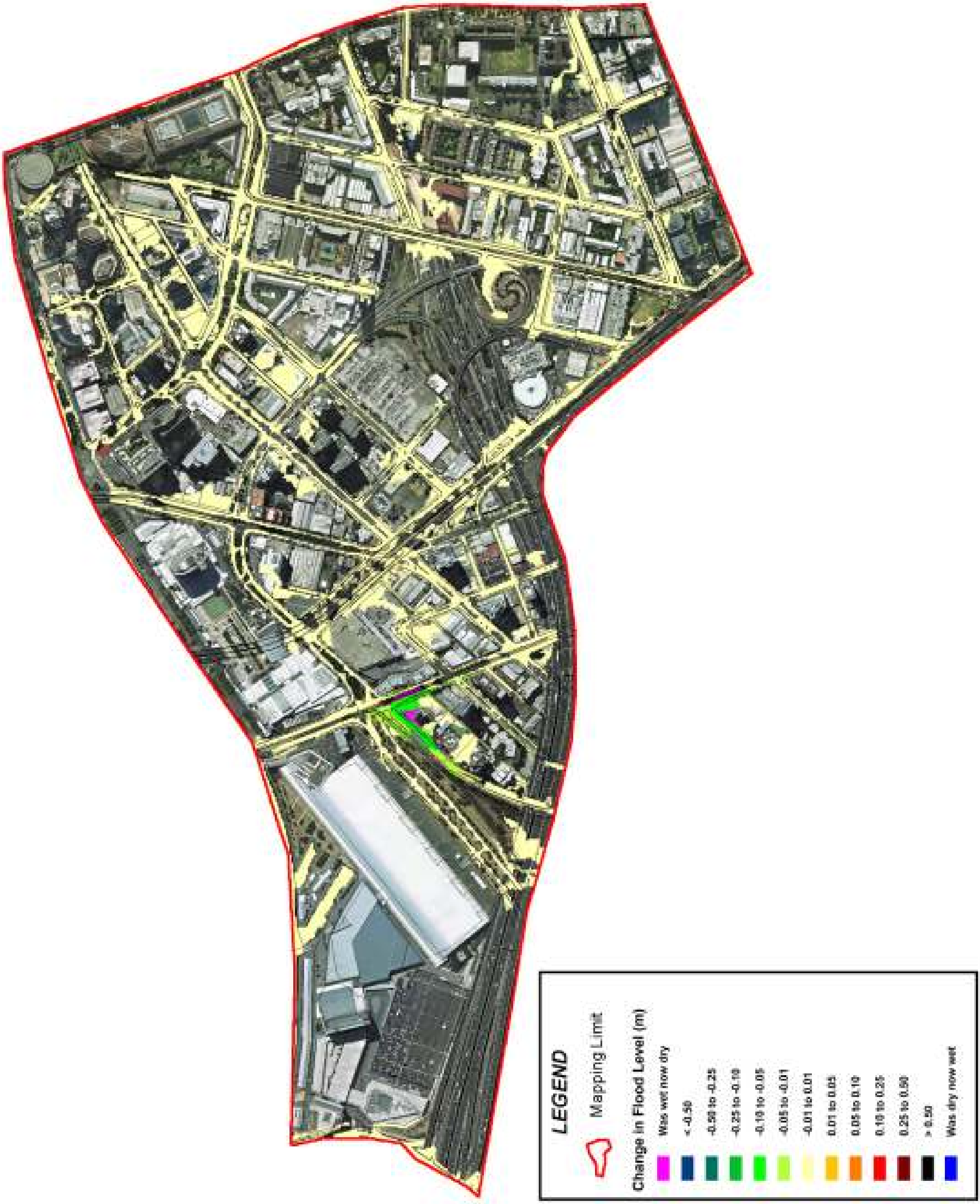

Title:

Southbank - Pipe

Change in 20 Year ARI Peak Flood Heights - MSL

Figure: **6-8**

Rev: **A**

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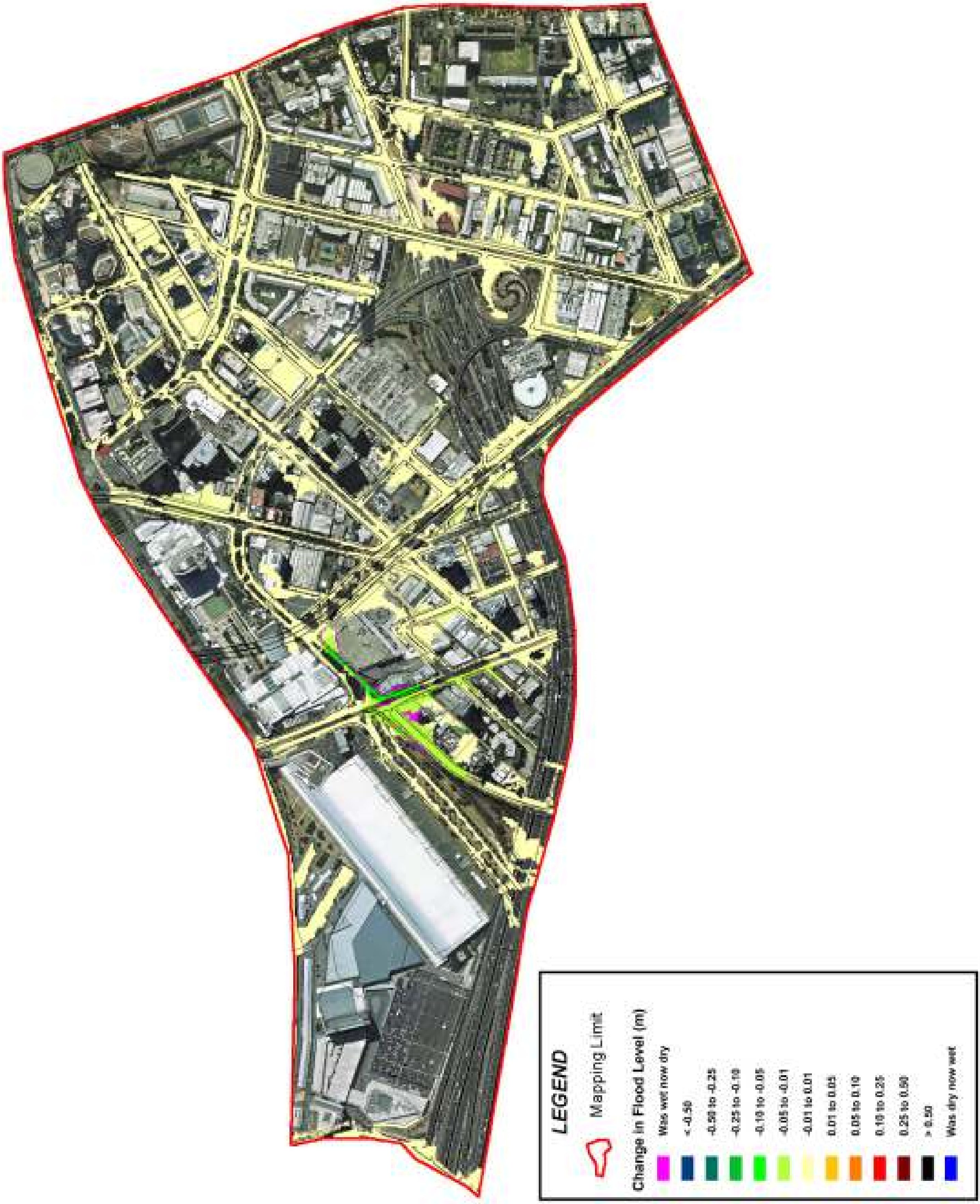

Title:

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

Figure: **6-9**

Rev: **A**

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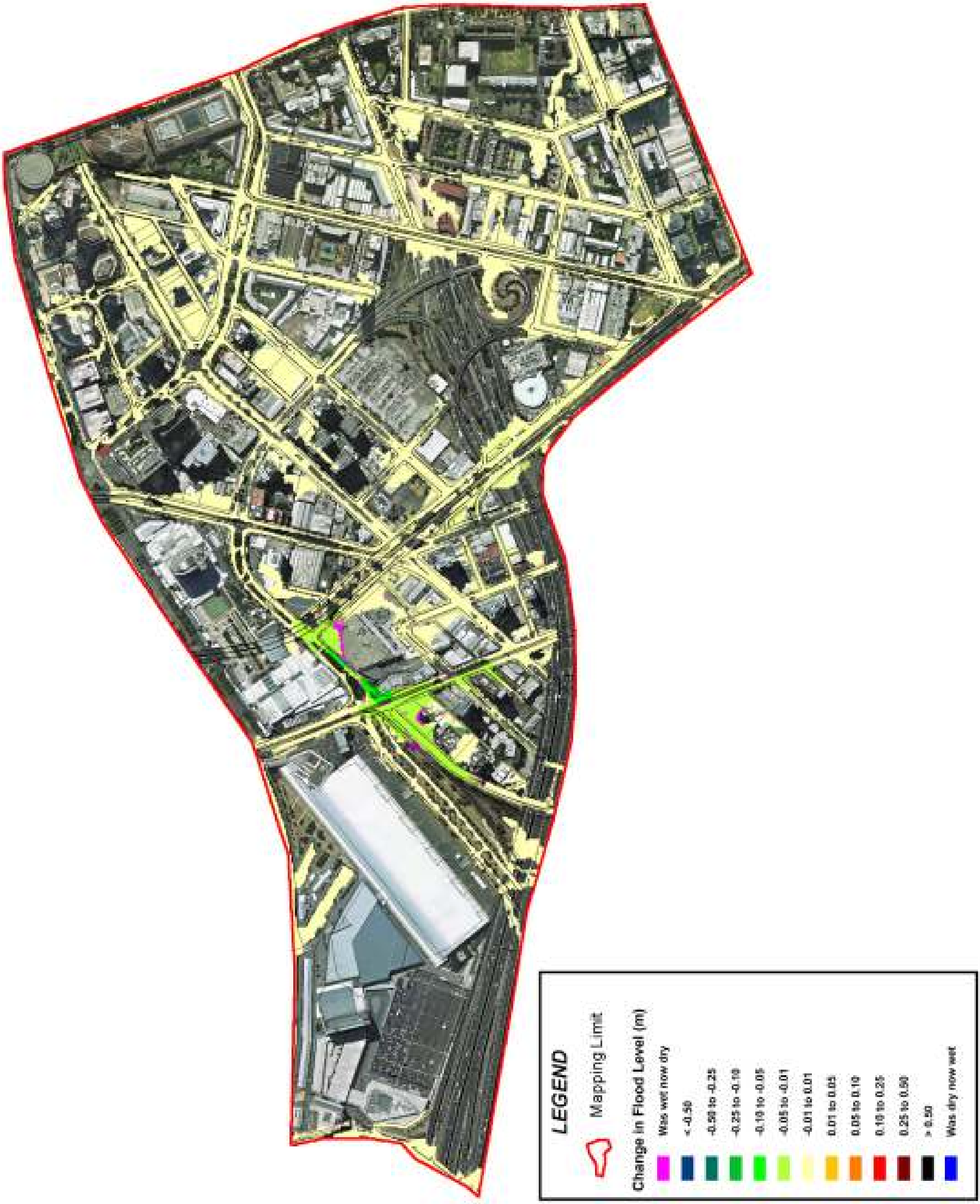

Title:

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

Figure: 6-10

Rev: A

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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.

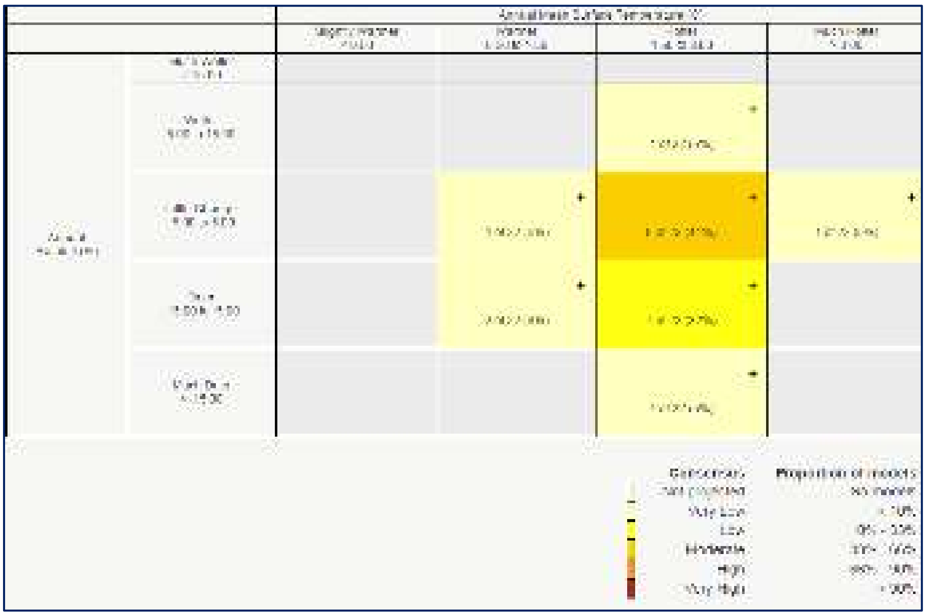


Figure 7-1 CSIRO 2090 Climate Futures (RCP6.0)

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

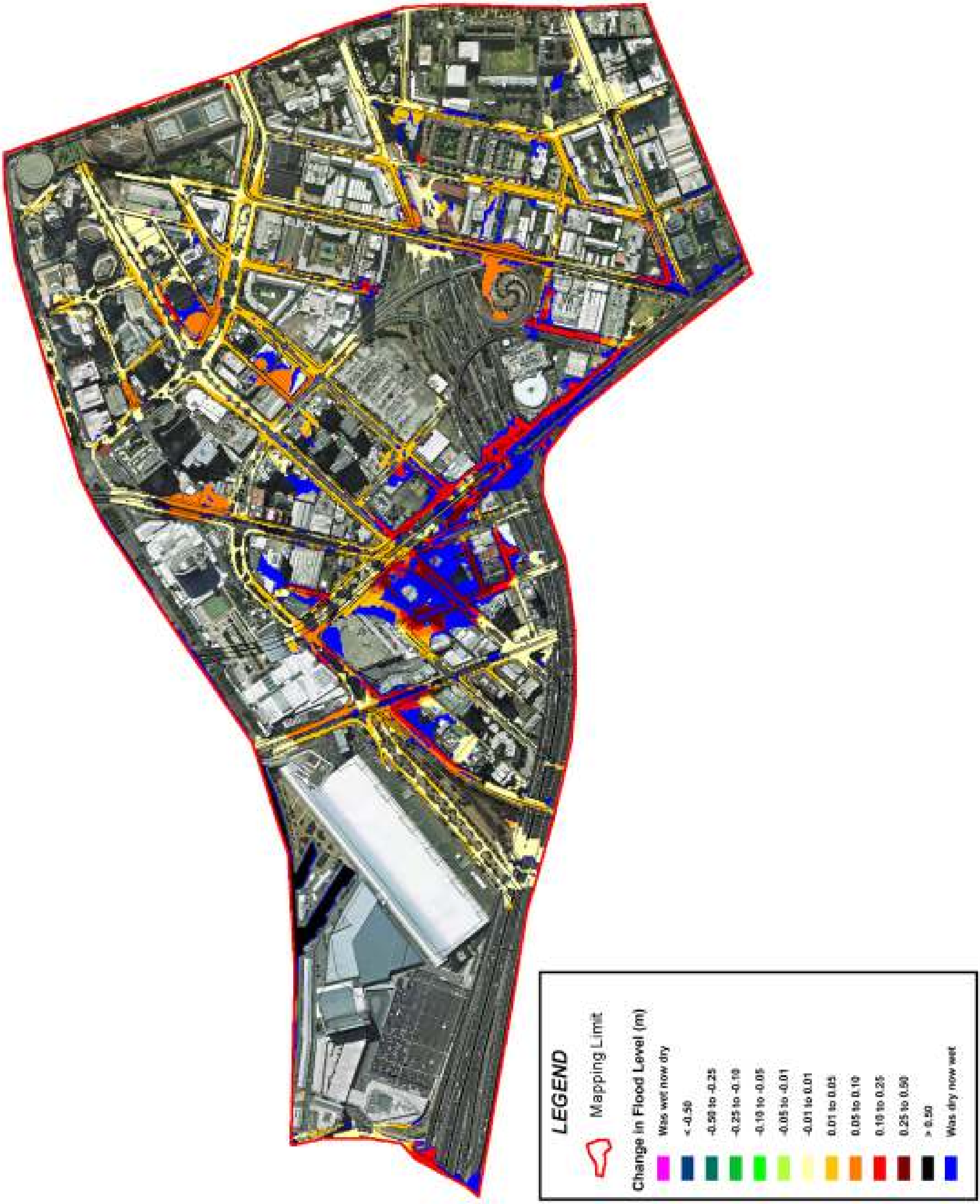
Properties Inundated	5 Year ARI		10 Year ARI		20 Year ARI		50 Year ARI		100 Year ARI	
	No.	Change	No.	Change	No.	Change	No.	Change	No.	Change
0 – 0.02 m	27	-13	24	-9	18	-10	22	-4	20	1
0.02 – 0.05 m	29	-13	29	-17	29	-12	25	-18	14	-22
0.05 – 0.10 m	31	1	24	-7	25	-16	29	-3	29	-1
0.10 – 0.25 m	54	-3	57	0	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

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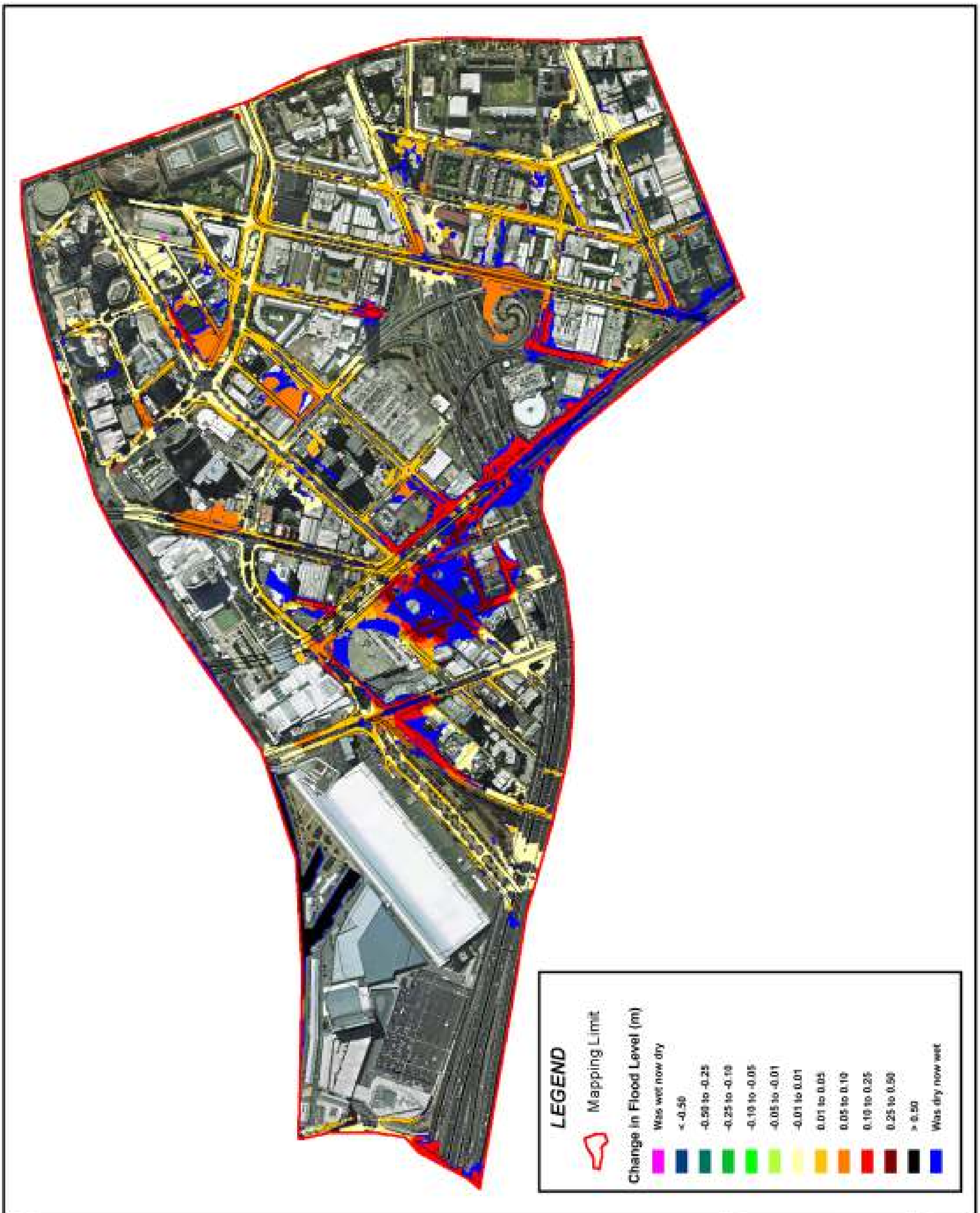

Title:

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

Figure: 7-3

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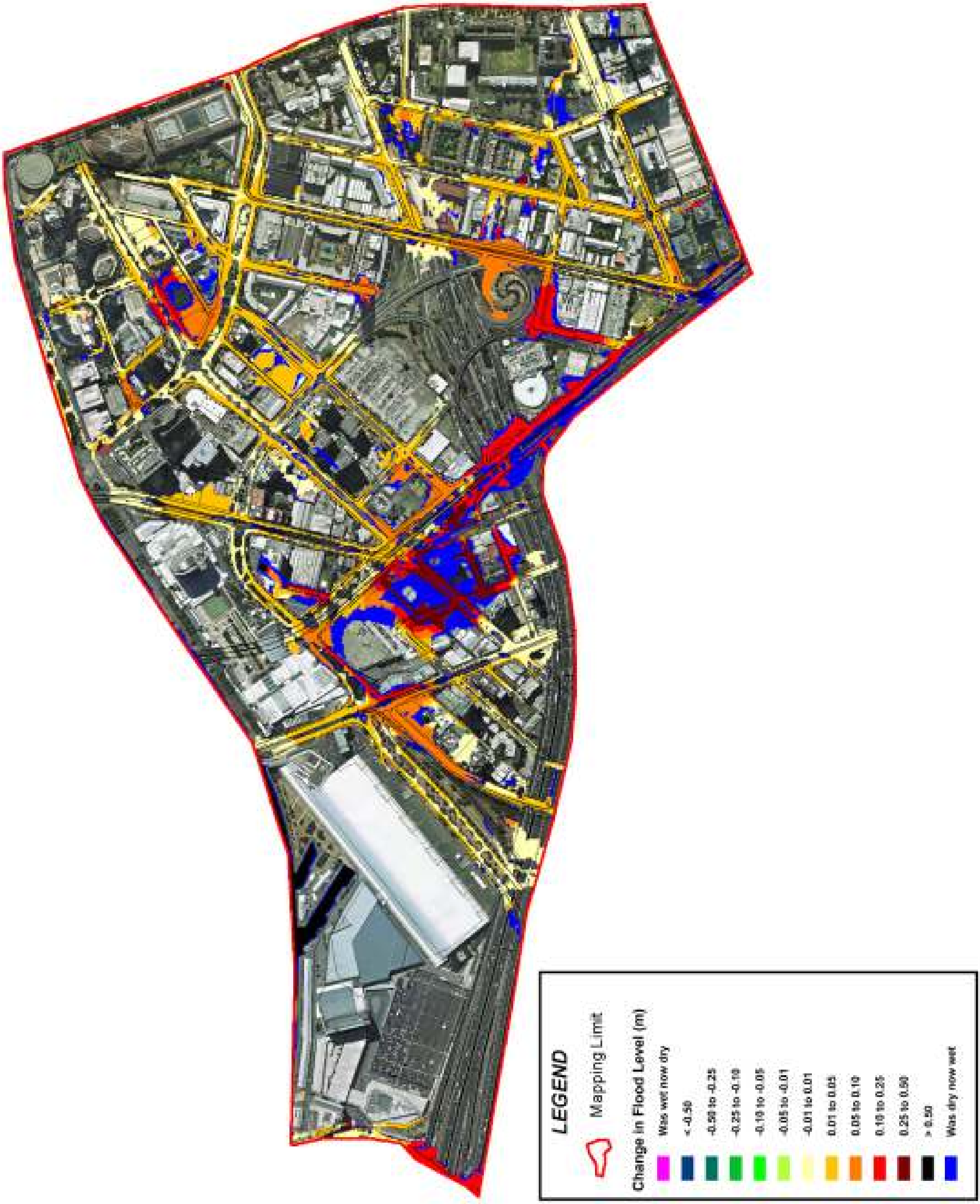

Title:

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

Figure: **7-4**

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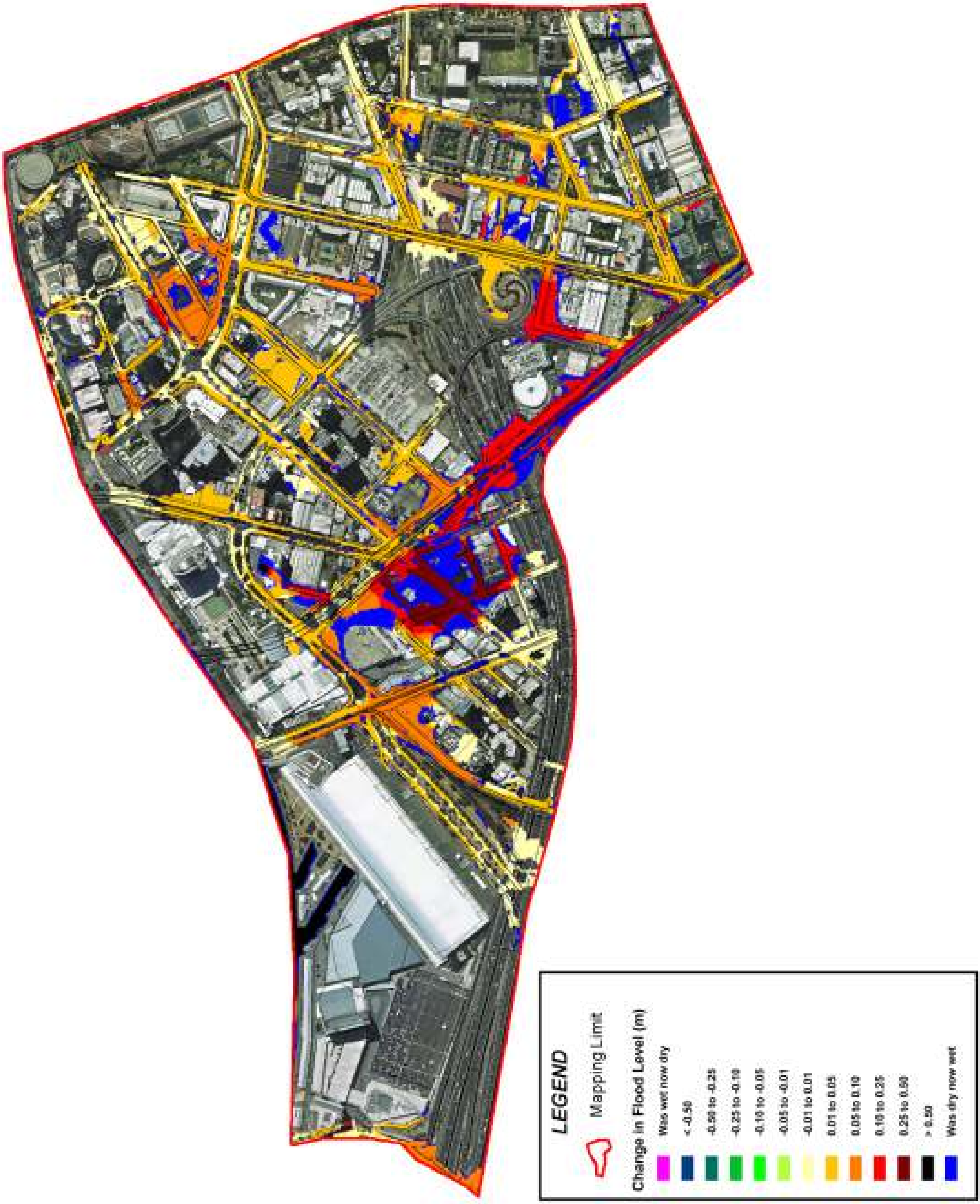

Title:
Southbank - Climate Change +32%
Change in 50 Year ARI Peak Flood Heights - MSL

Figure:
7-5

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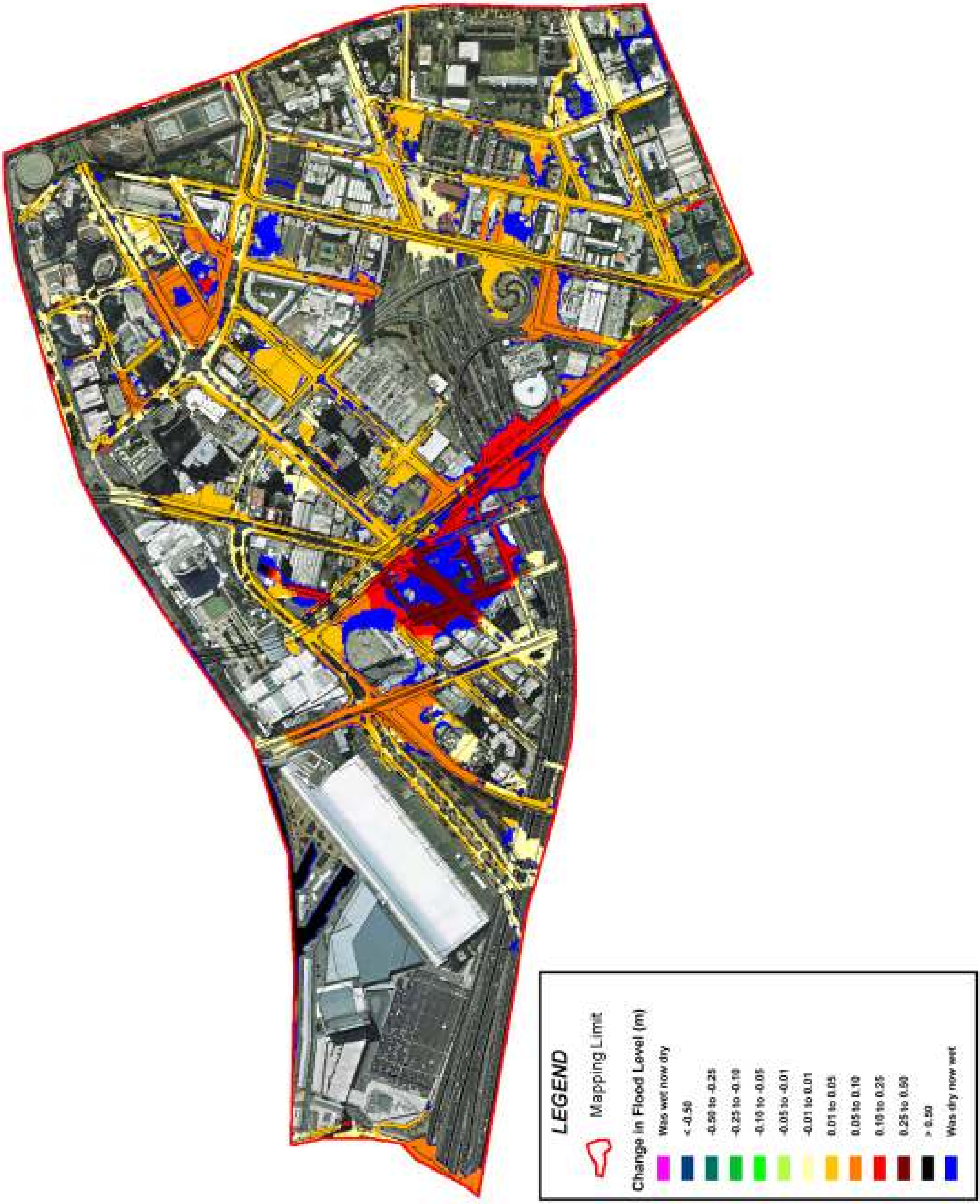

Title:

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

Figure: **7-6**

Rev: **A**

N

0 125 250m
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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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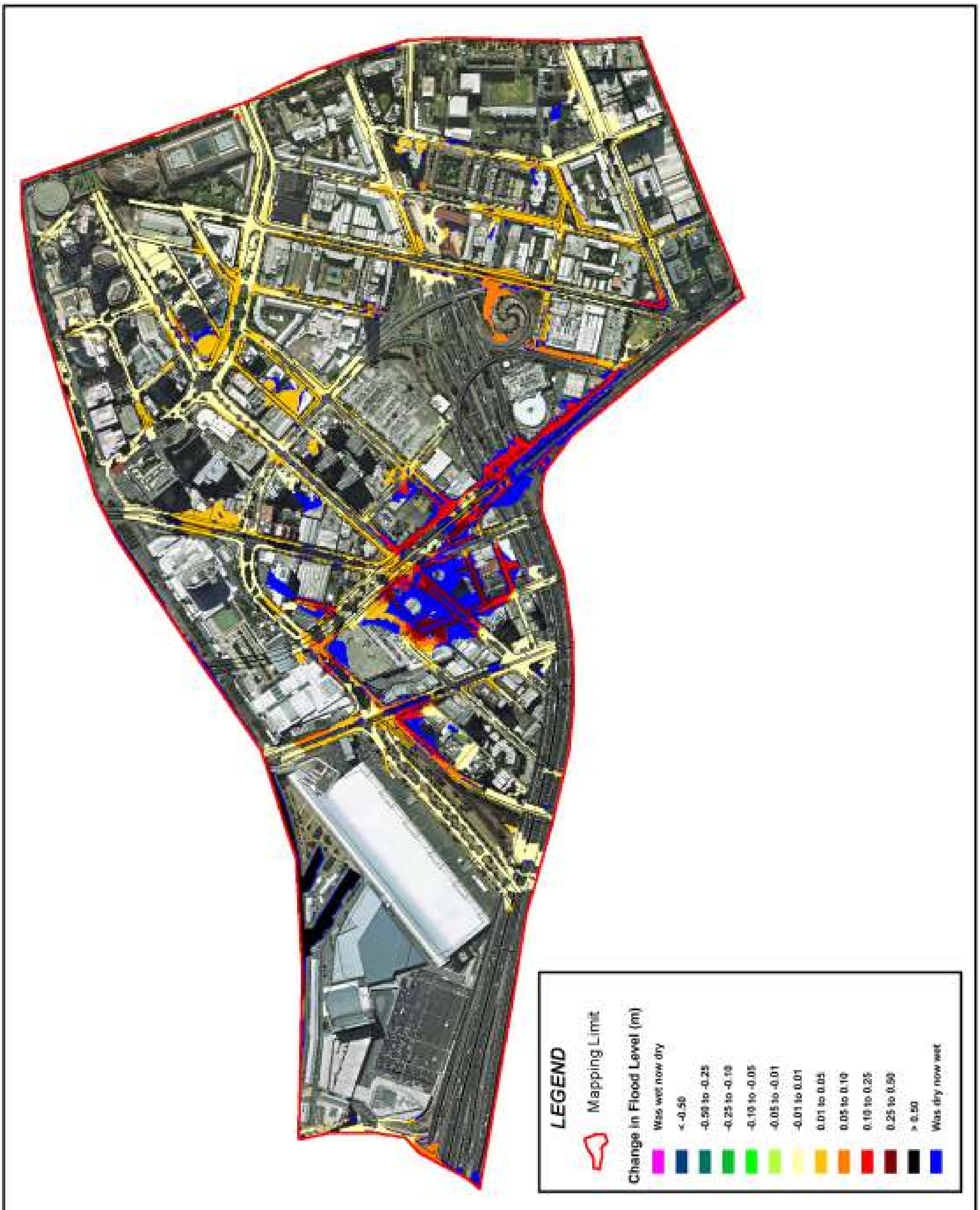

Title:

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

Figure: 7-7

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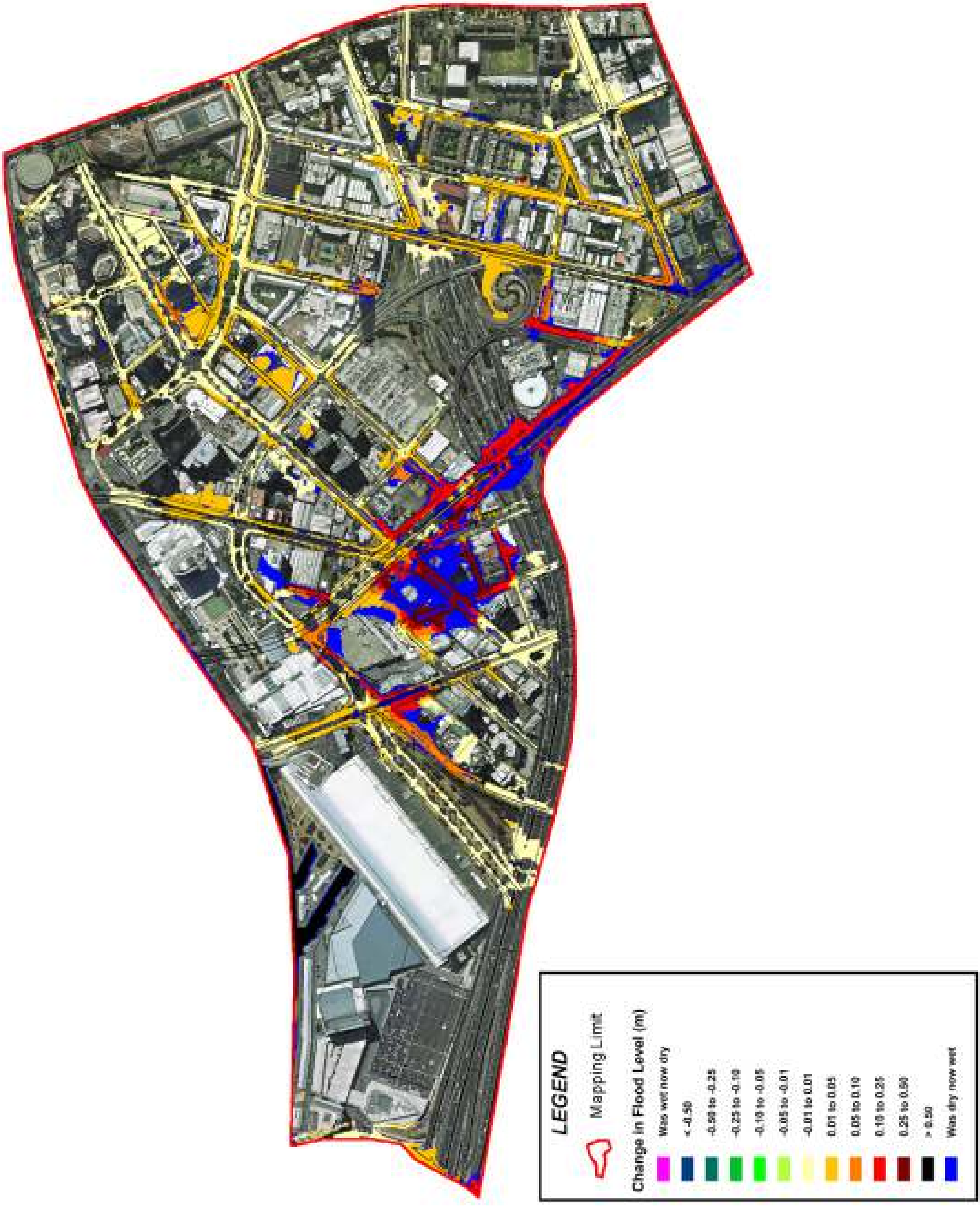

Title:
Southbank - Climate Change +15%
Change in 10 Year ARI Peak Flood Heights - MSL

Figure: **7-8**

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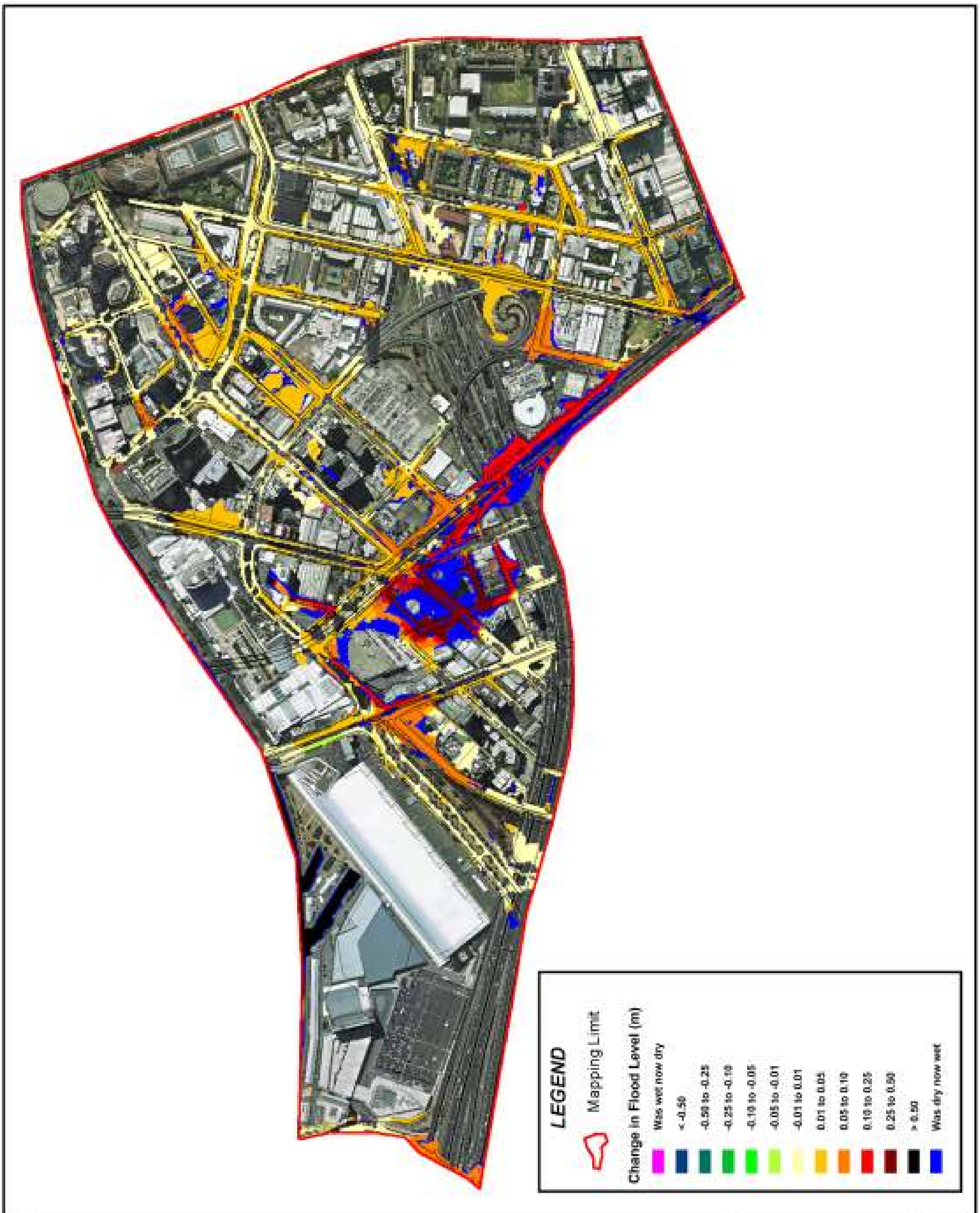

Title:

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

Figure: 7-9

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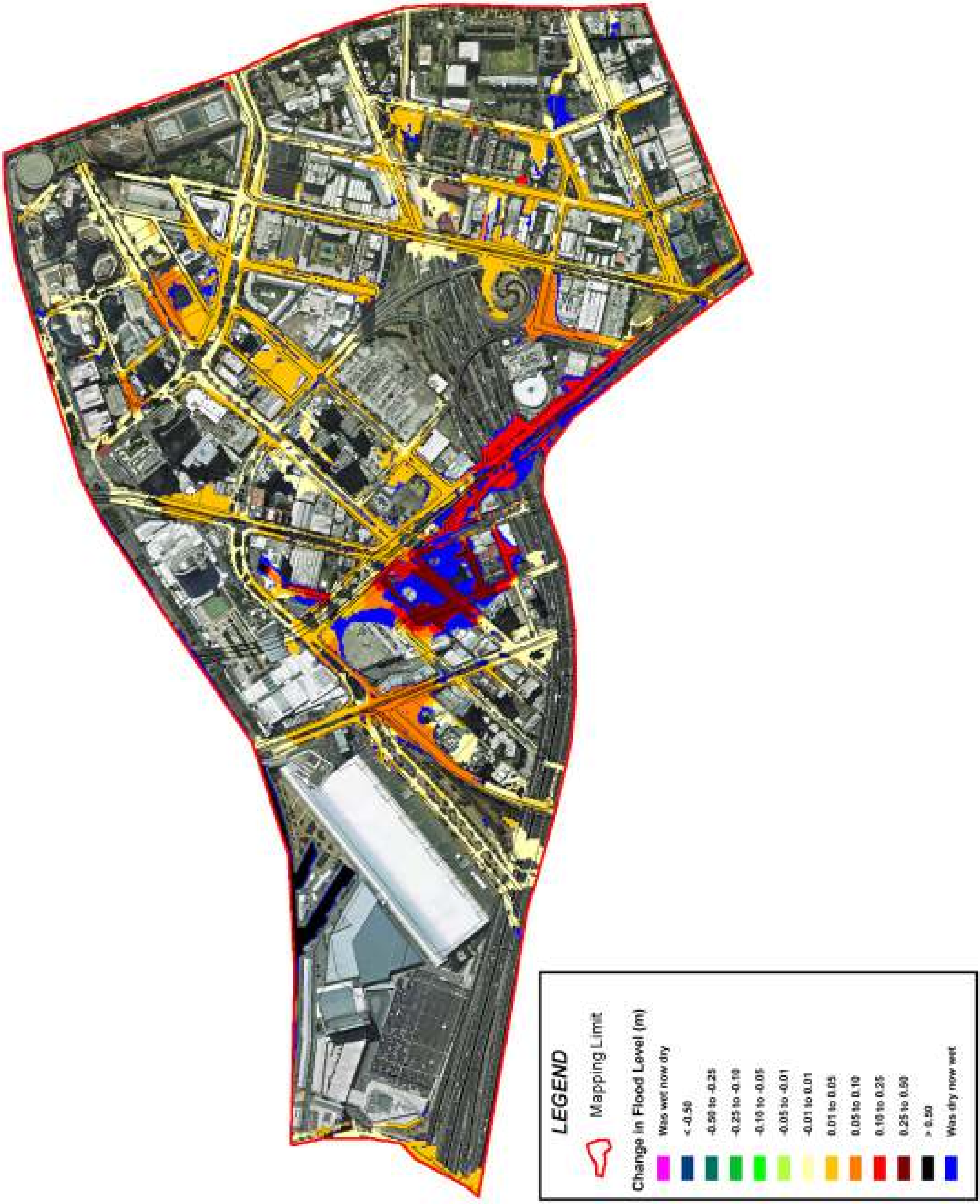

Title:

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

Figure: **7-10**

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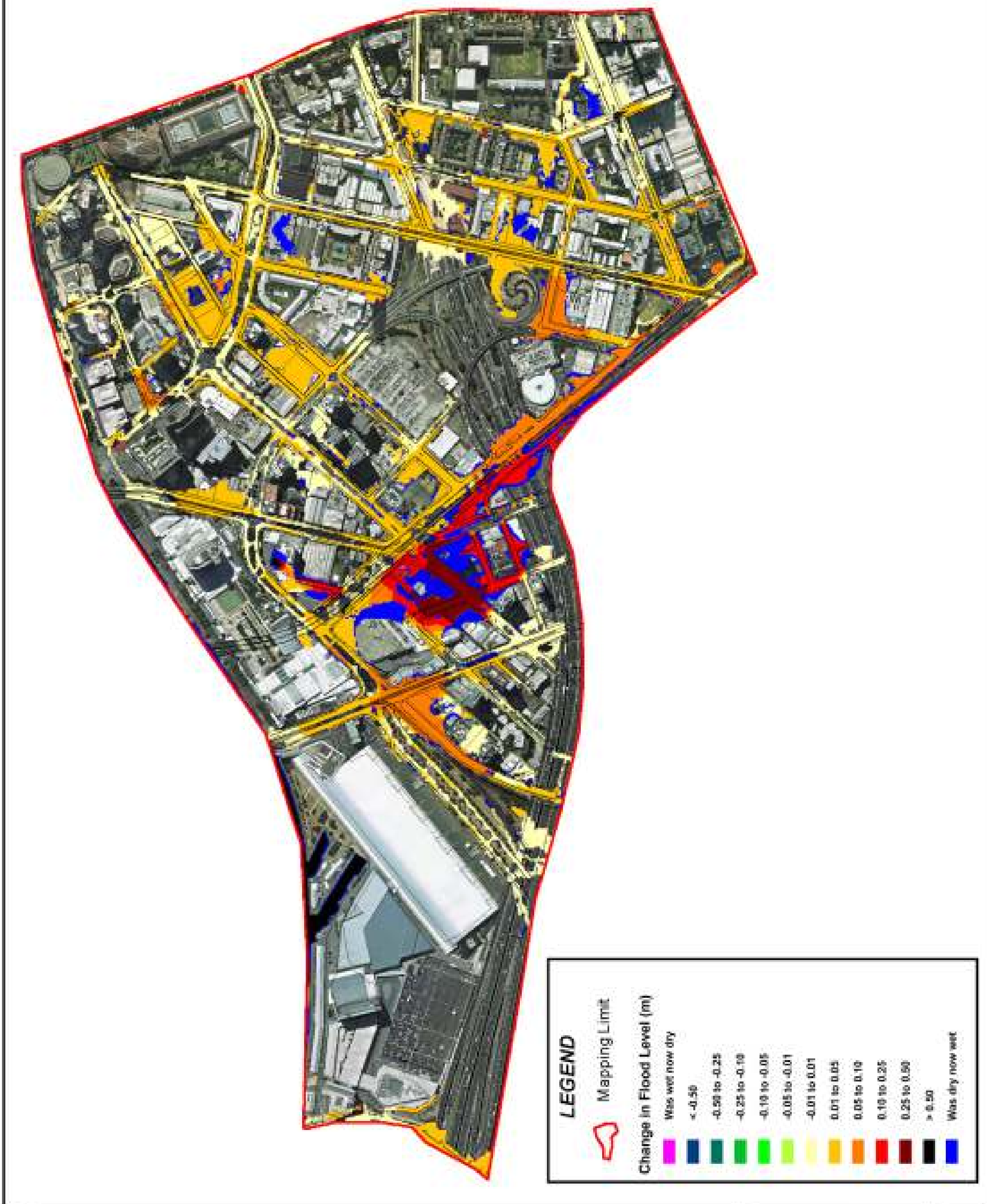

Title:

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

Figure: **7-11**

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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:

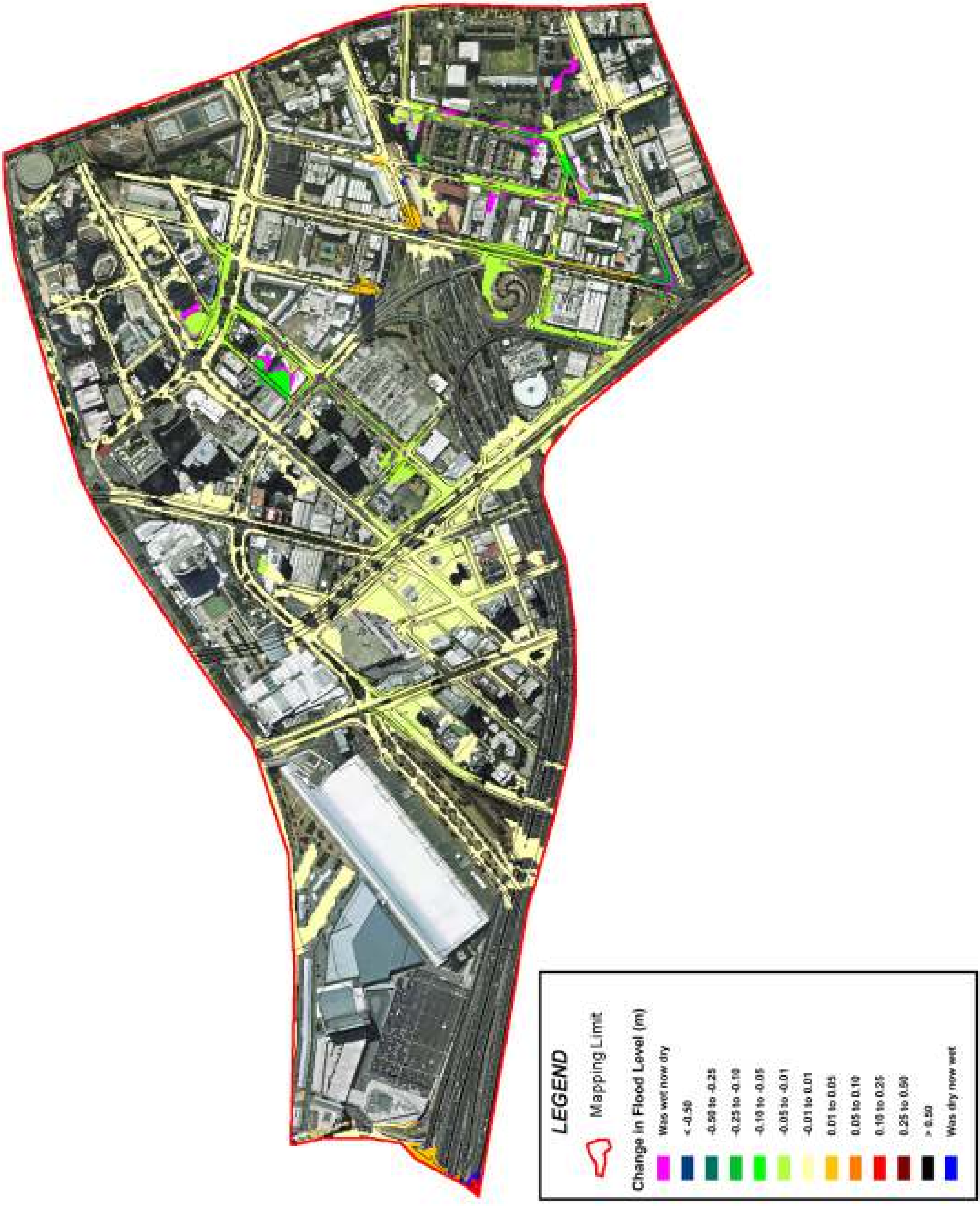
- WSUD measures along Southbank Boulevard, Whiteman Street and Normanby Road;
- All proposed WSUD measures from the Wells Street Study;
- Storage tanks at MCEC and Crown Casino; and,
- Storage tanks at the proposed development of Kavanagh Street.

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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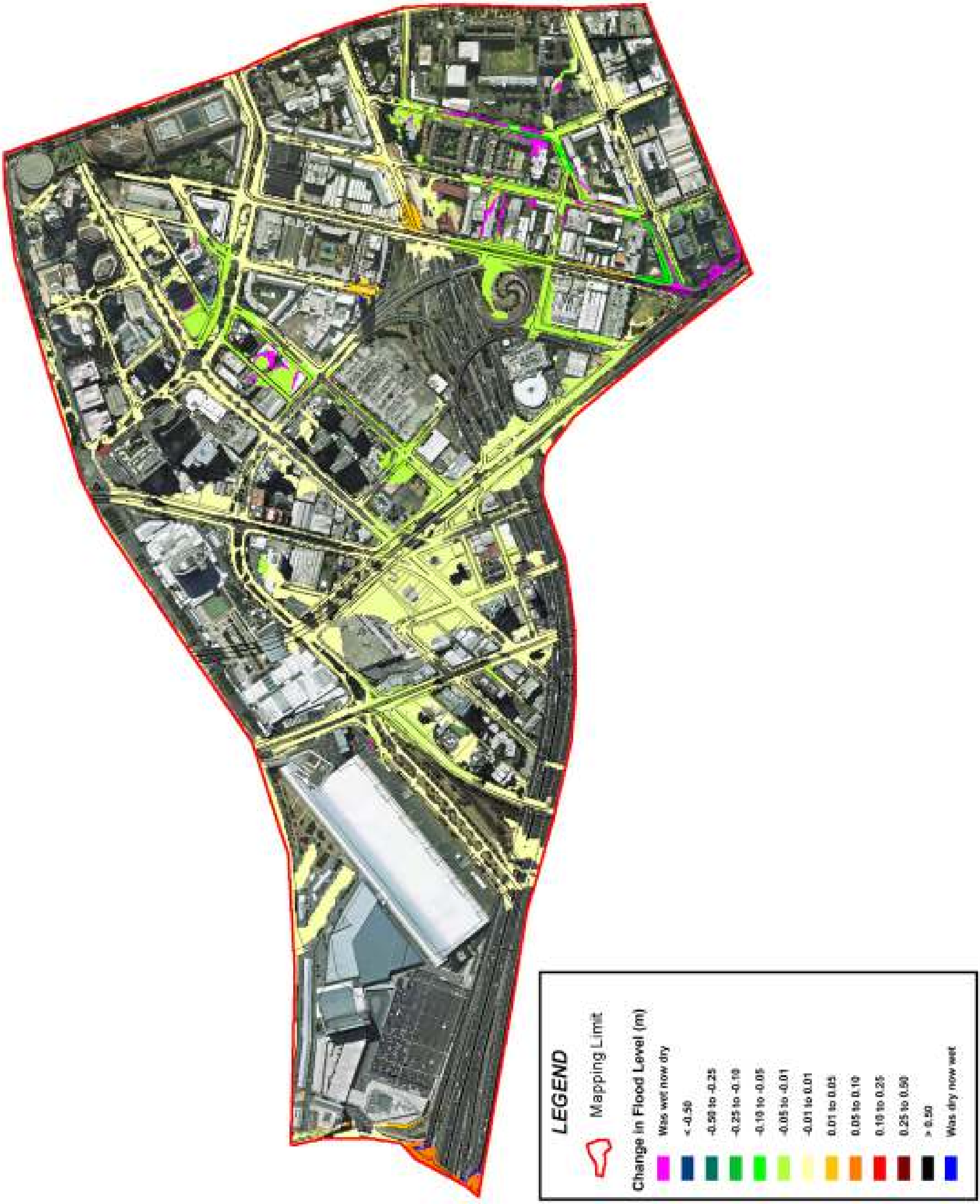

Title:

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

Figure: **8-2**

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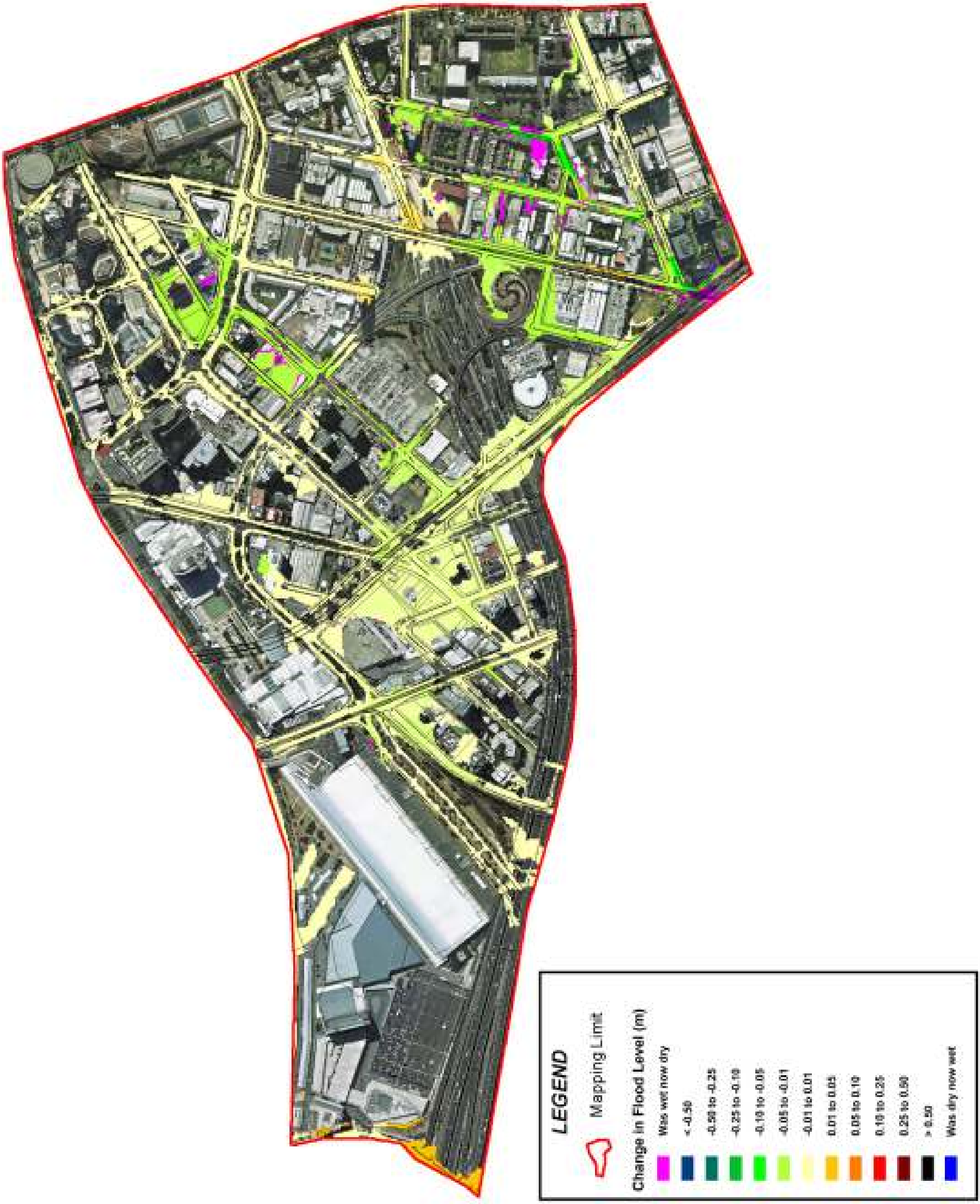

Title:

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

Figure: **8-3**

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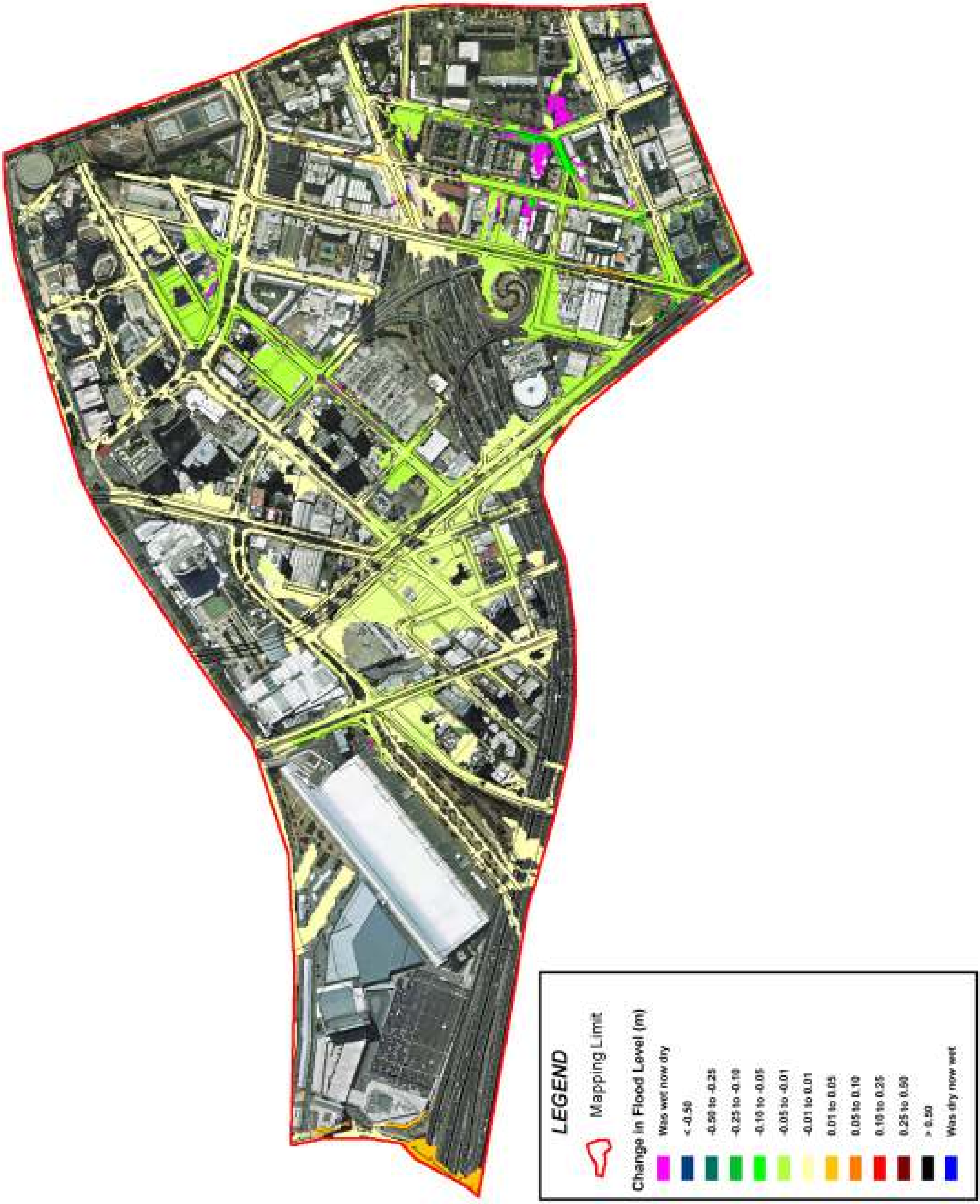

Title:

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

Figure: 8-4

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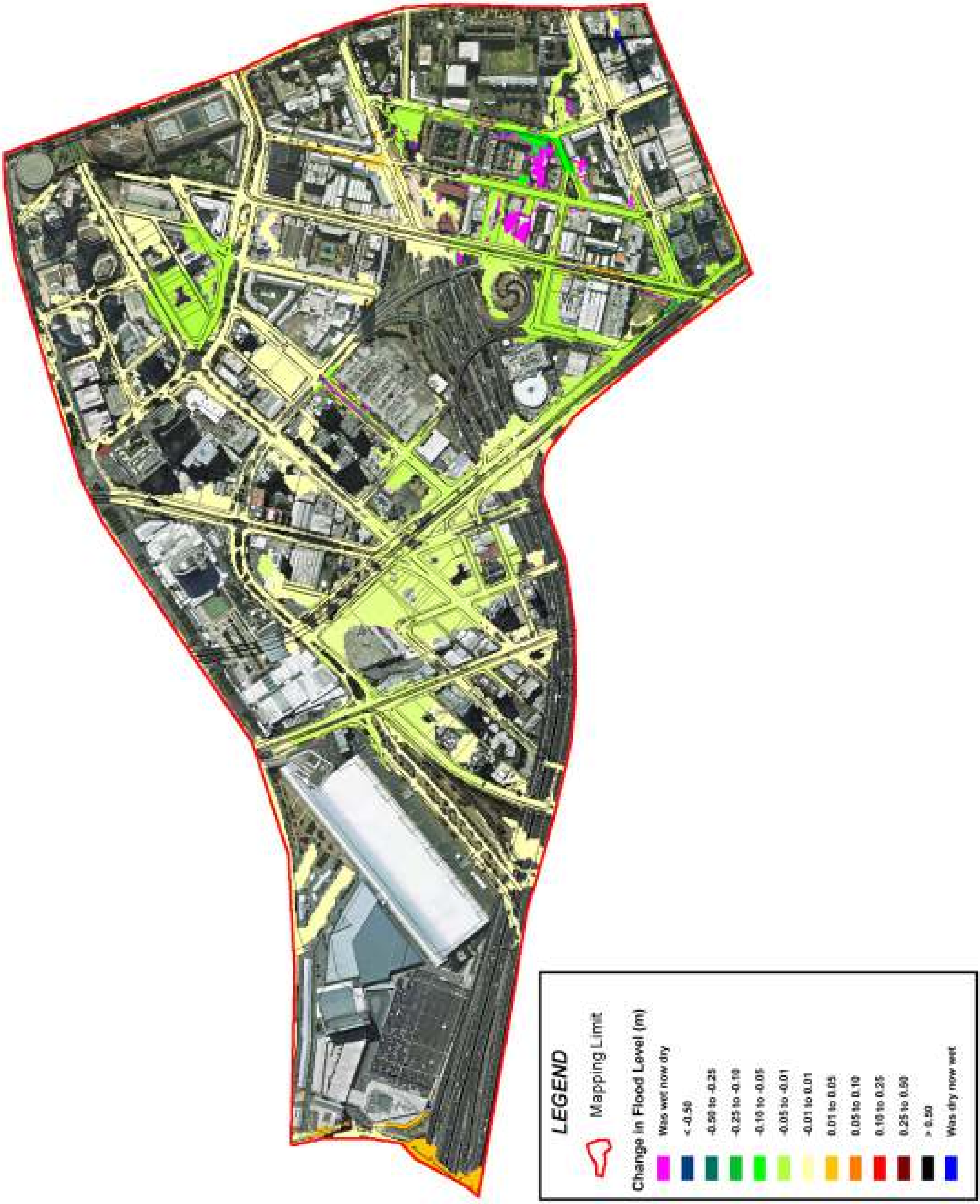

Title:

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

Figure: 8-5

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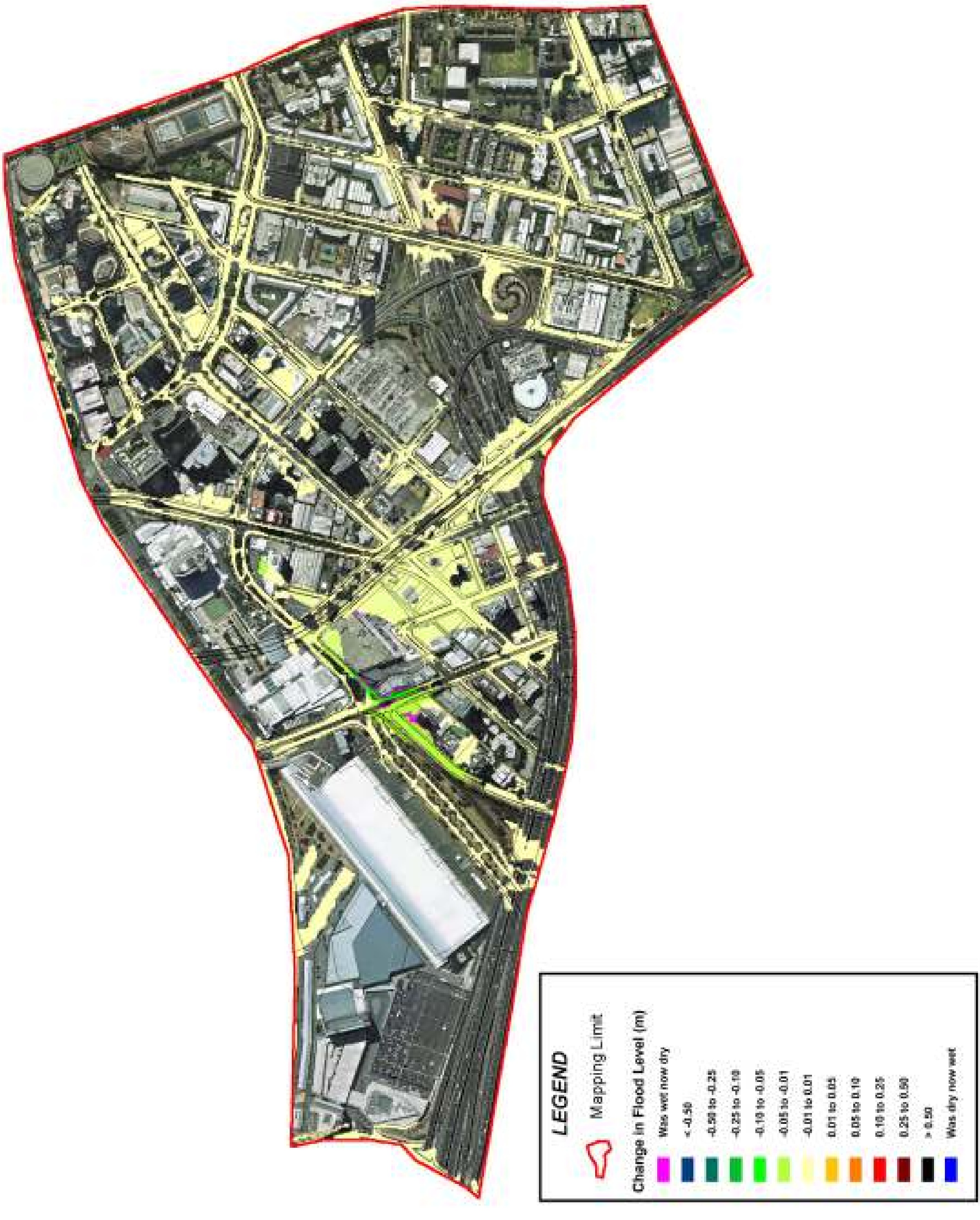
8.1.3 Pipe Augmentation

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

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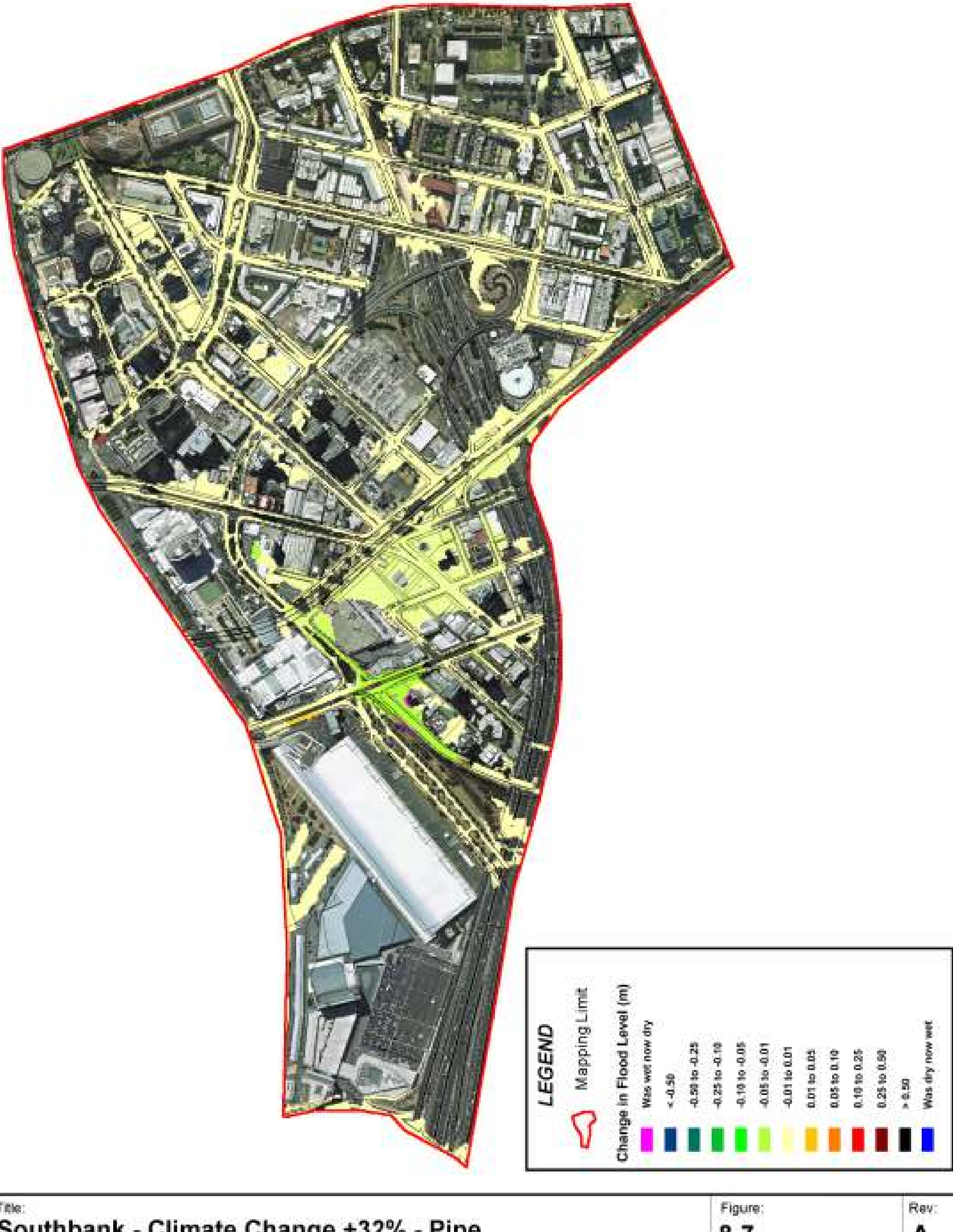

Title:

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

Figure: 8-7

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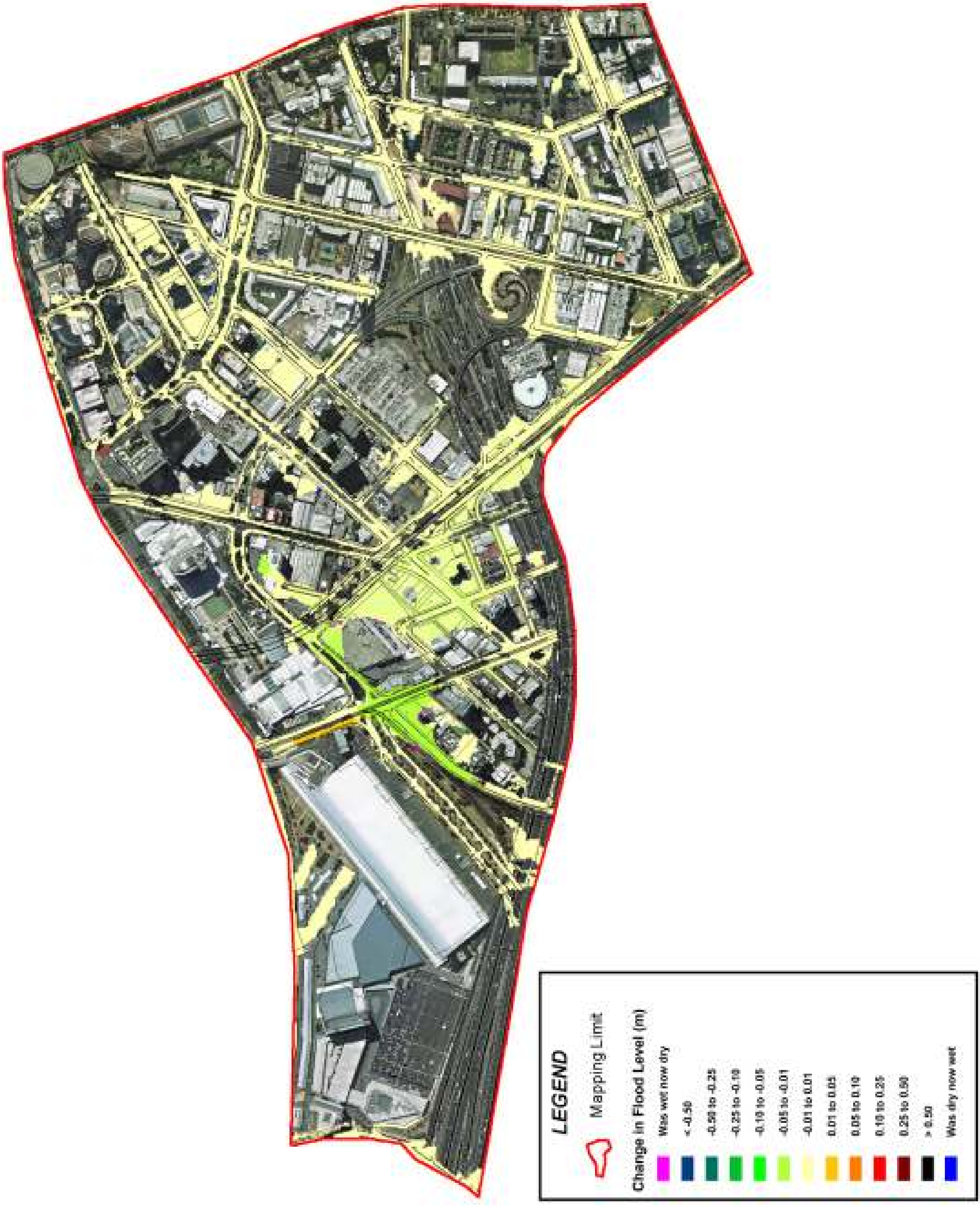

Title:

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

Figure: **8-8**

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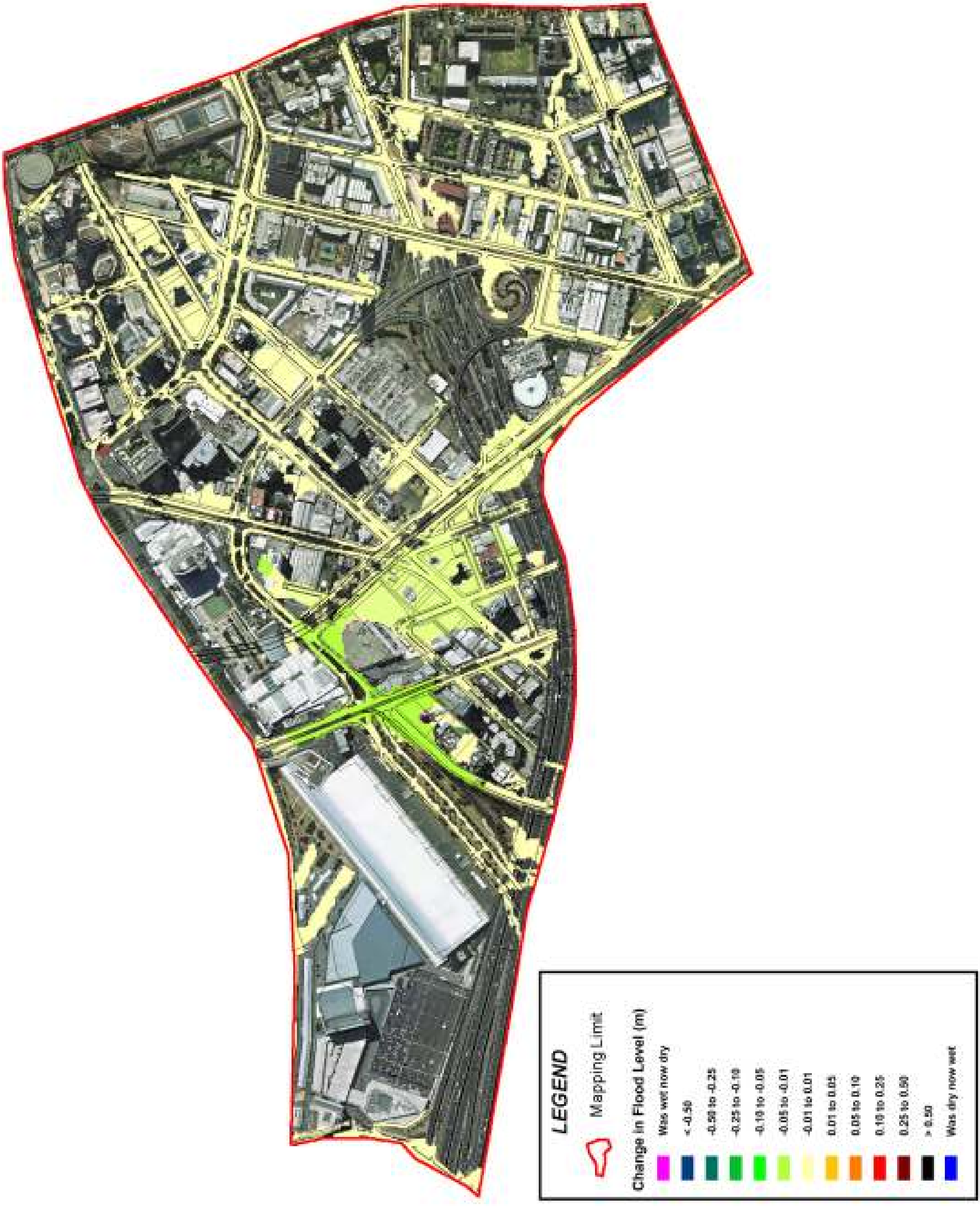

Title:

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

Figure: 8-9

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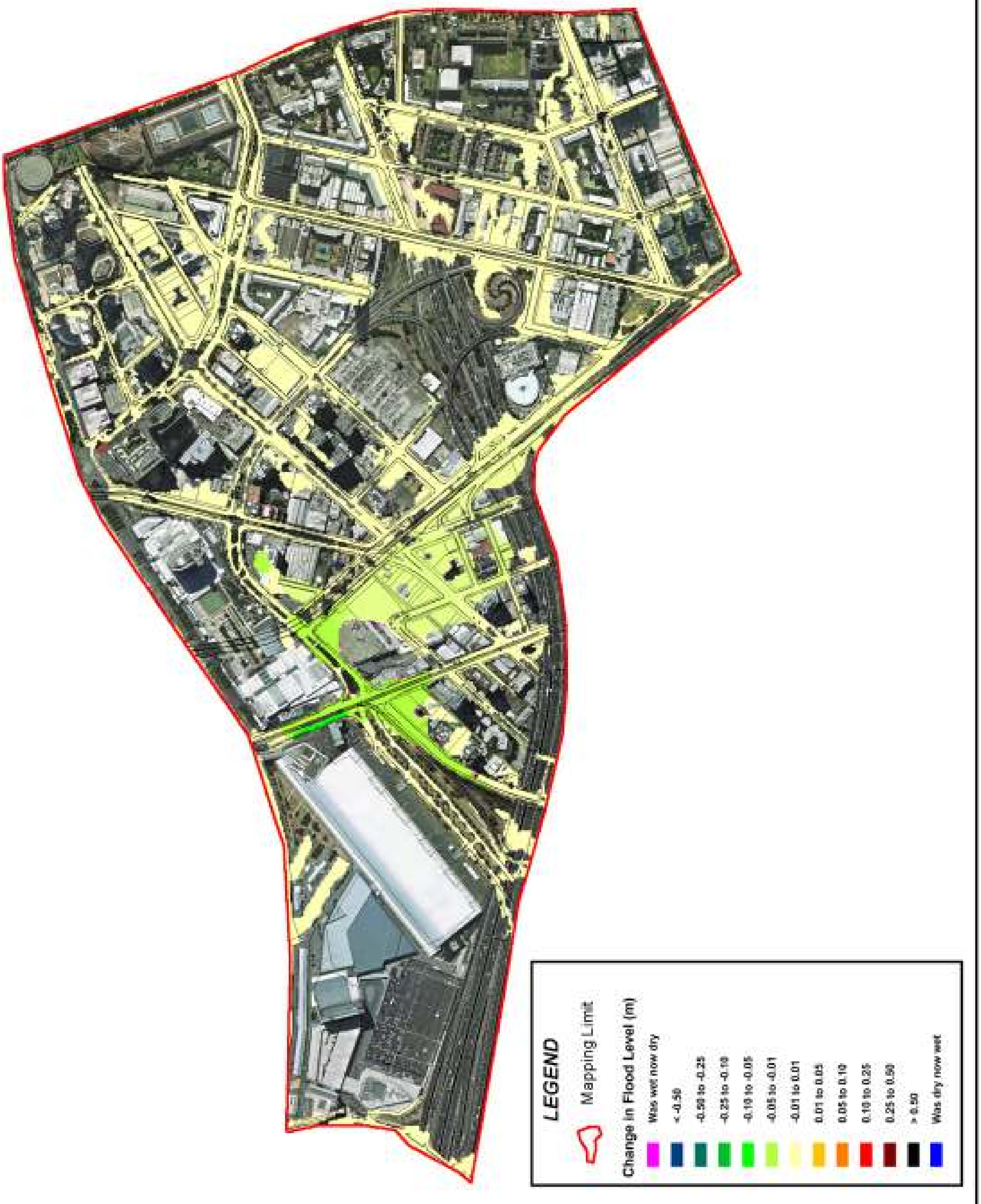

Title:
Southbank - Climate Change +32% - Pipe
Change in 100 Year ARI Peak Flood Heights - MSL

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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.

10 References

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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

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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**

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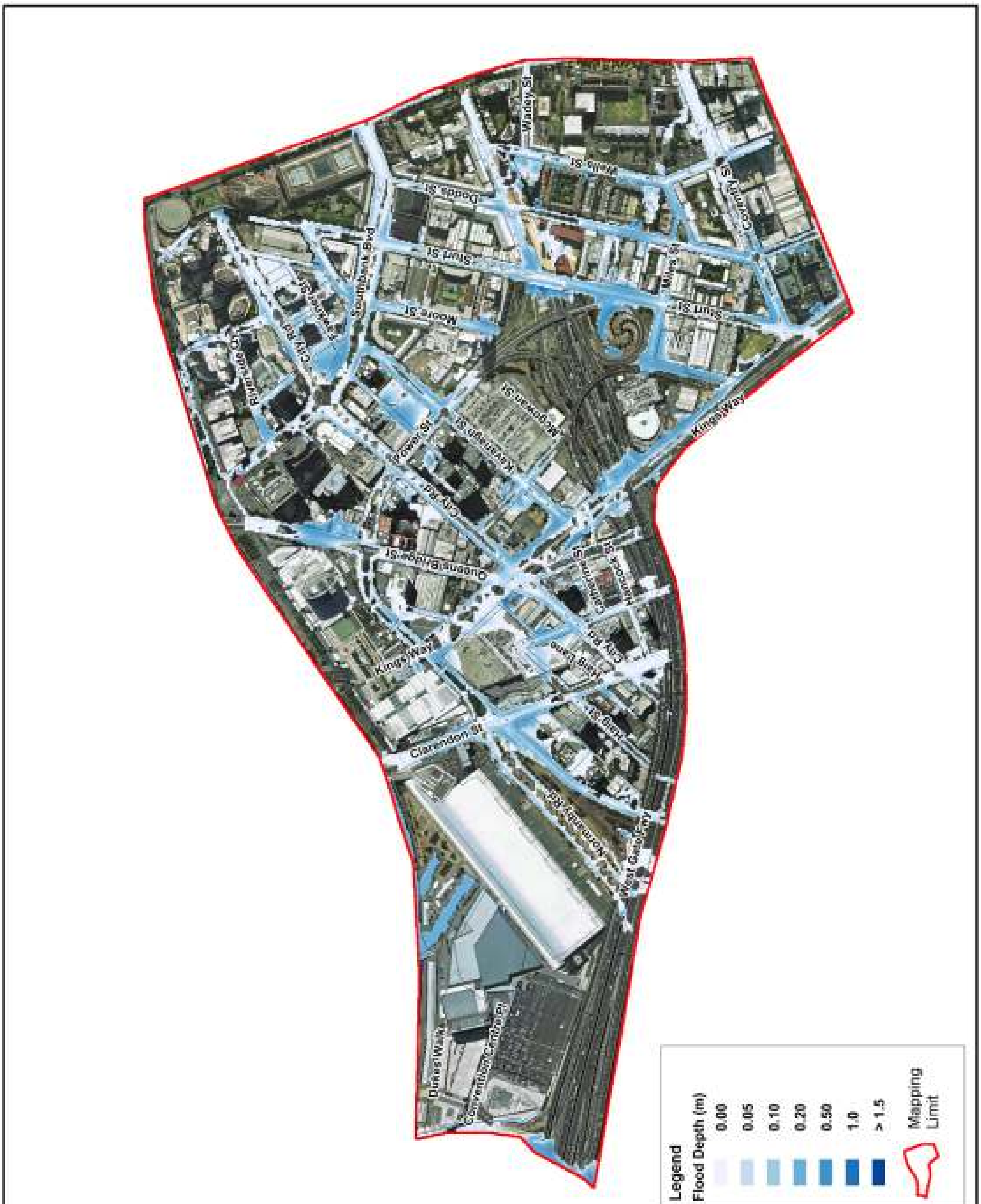
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigA-3_20y_MSL_dMax_RevA.WOR



Title:

Southbank

50 Year ARI Peak Flood Depth - MSL

Figure: **A-4**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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Title:

Southbank

100 Year ARI Peak Flood Depth - MSL

Figure: **A-5**

Rev: **A**

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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-5_100y_MSL_dMax_RevA.WOR

Title:

Southbank
5 Year ARI Peak Flood Depth - HAT

Figure: **A-6**

Rev: **A**

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N

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Approx. Scale

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Title:

Southbank

10 Year ARI Peak Flood Depth - HAT

Figure: **A-7**

Rev: **A**

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N

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Approx. Scale

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Title:

Southbank

20 Year ARI Peak Flood Depth - HAT

Figure: **A-8**

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-8_20y_HAT_dMax_RevA.WOR

Title:

Southbank

50 Year ARI Peak Flood Depth - HAT

Figure:

A-9

Rev:

A

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N

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Approx. Scale

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Title:

Southbank
100 Year ARI Peak Flood Depth - HAT

Figure: **A-10**

Rev: **A**

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0 125 250m

Approx. Scale

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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

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Approx. Scale

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Title:

Southbank

20 Year ARI Peak Flood Depth - Storm Surge

Figure: **A-13**

Rev: **A**

N

0 125 250m

Approx. Scale

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

Figure: **A-14**

Rev: **A**

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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**

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Title:
Southbank
5 Year ARI Peak Flood Depth - Yarra 100y

Figure: **A-16**

Rev: **A**

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Approx. Scale

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Title:

Southbank

10 Year ARI Peak Flood Depth - Yarra 100y

Figure: **A-17**

Rev: **A**

N

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Approx. Scale

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Title:
Southbank
20 Year ARI Peak Flood Depth - Yarra 100y

Figure: **A-18**

Rev: **A**

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Approx. Scale

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Title:

Southbank
50 Year ARI Peak Flood Depth - Yarra 100y

Figure: **A-19**

Rev: **A**

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Title:

Southbank
100 Year ARI Peak Flood Depth - Yarra 100y

Figure: **A-20**

Rev: **A**

N

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Approx. Scale

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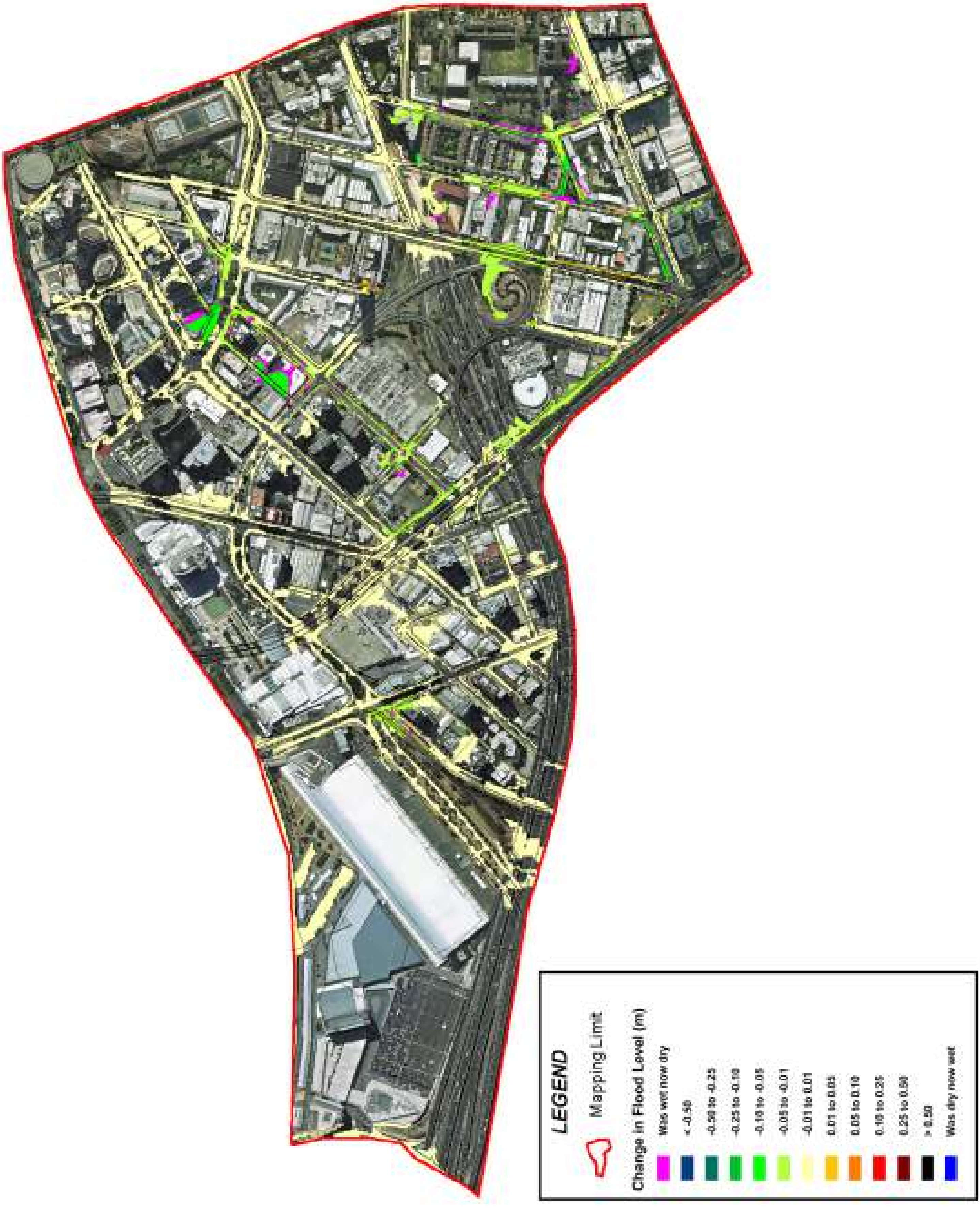
Appendix B Opportunities Mapping (Current Climate)



Title:

Southbank - WSUD

Change in 5 Year ARI Peak Flood Heights - MSL

Figure: **B-1**

Rev: **A**

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Approx. Scale

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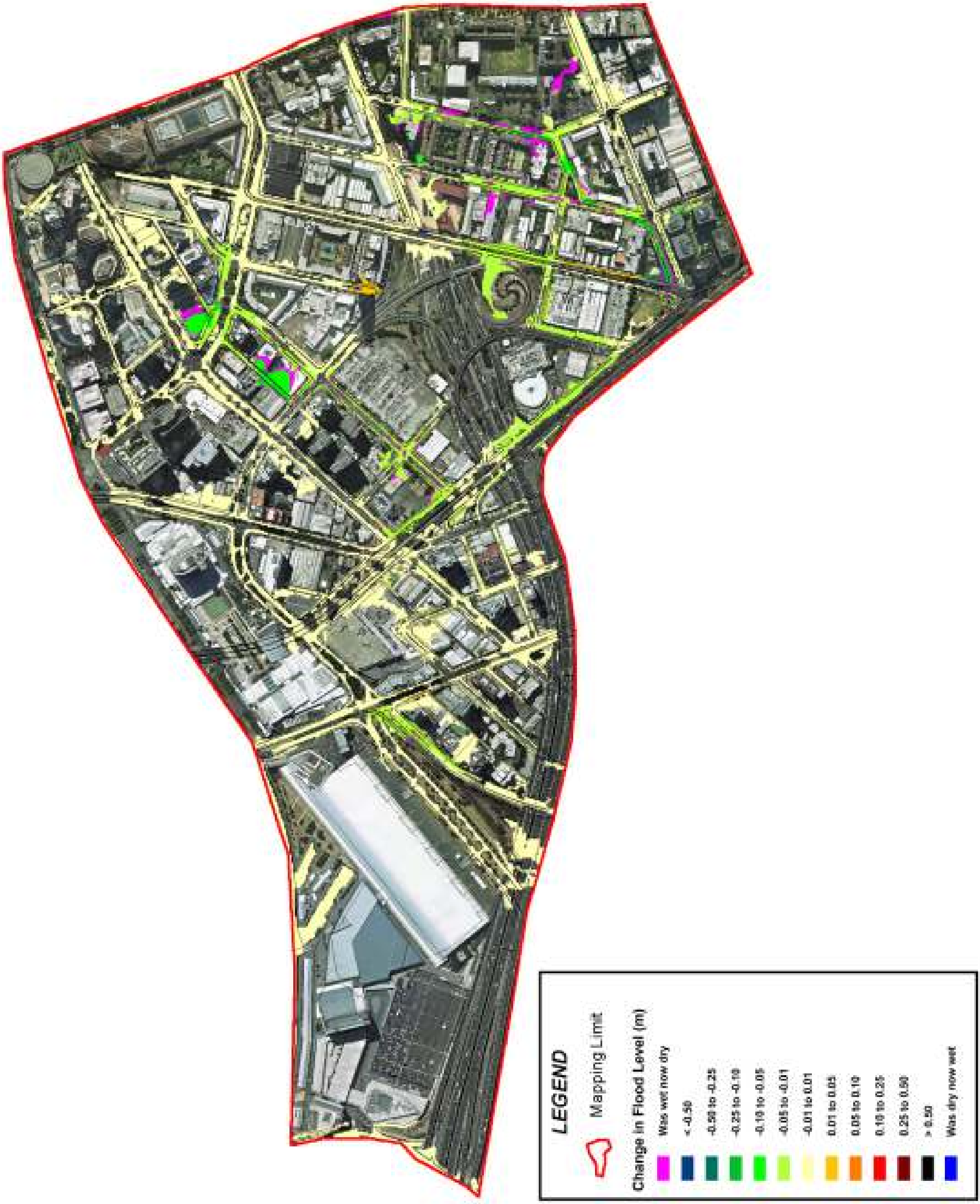

Title:

Southbank - WSUD

Change in 10 Year ARI Peak Flood Heights - MSL

Figure: **B-2**

Rev: **A**

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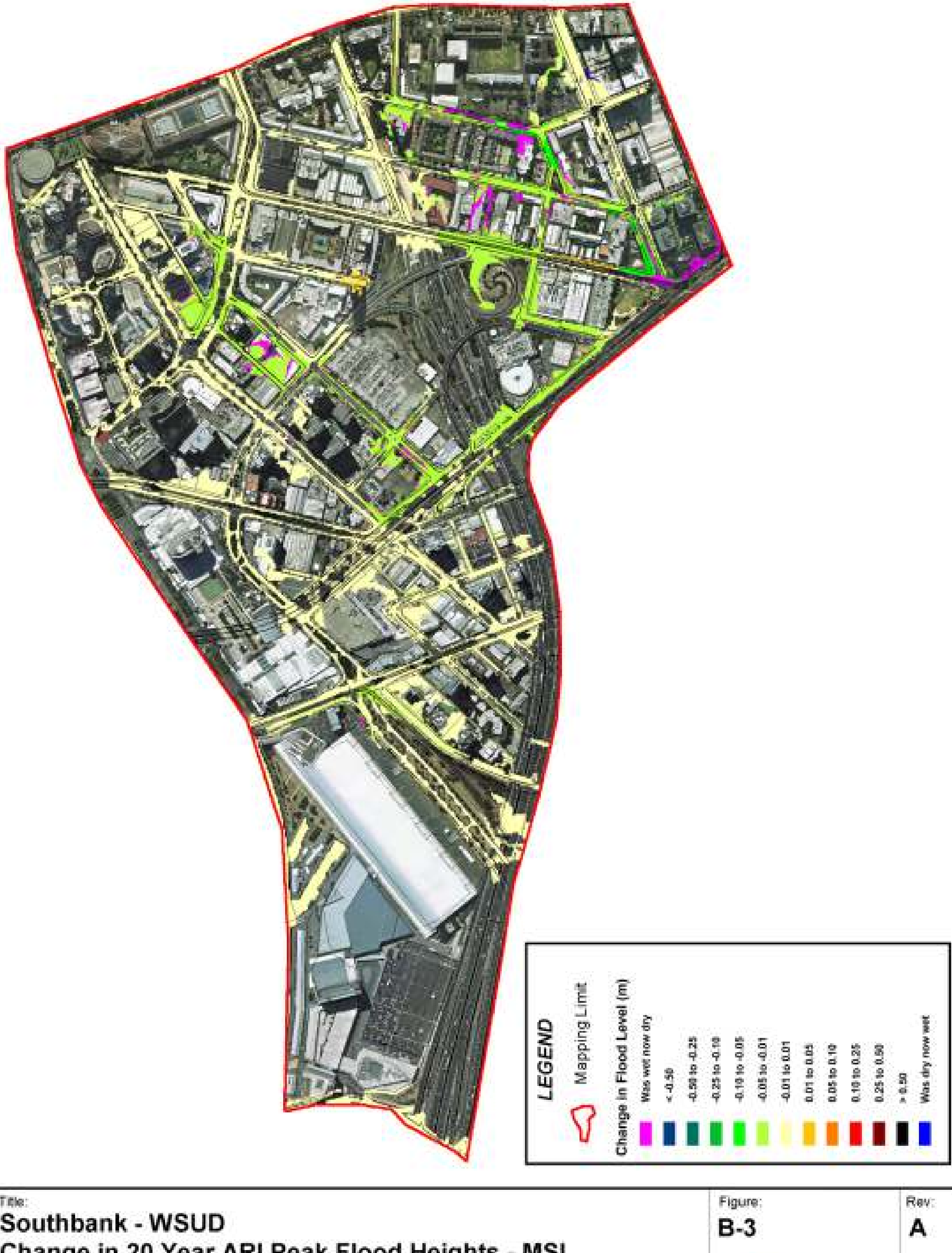

Title:
Southbank - WSUD
Change in 20 Year ARI Peak Flood Heights - MSL

Figure:
B-3

Rev:
A

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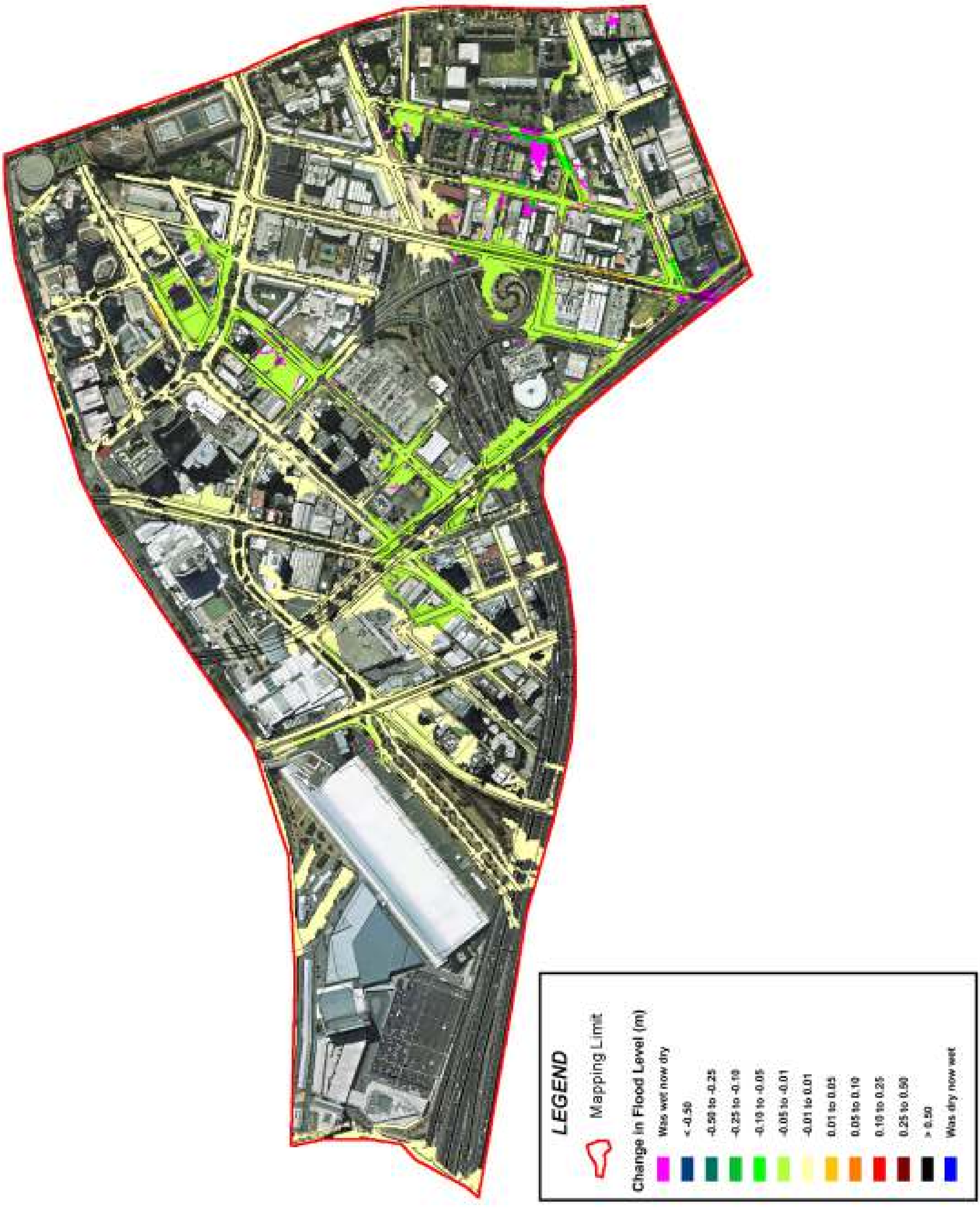

Title:

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

Figure: **B-4**

Rev: **A**

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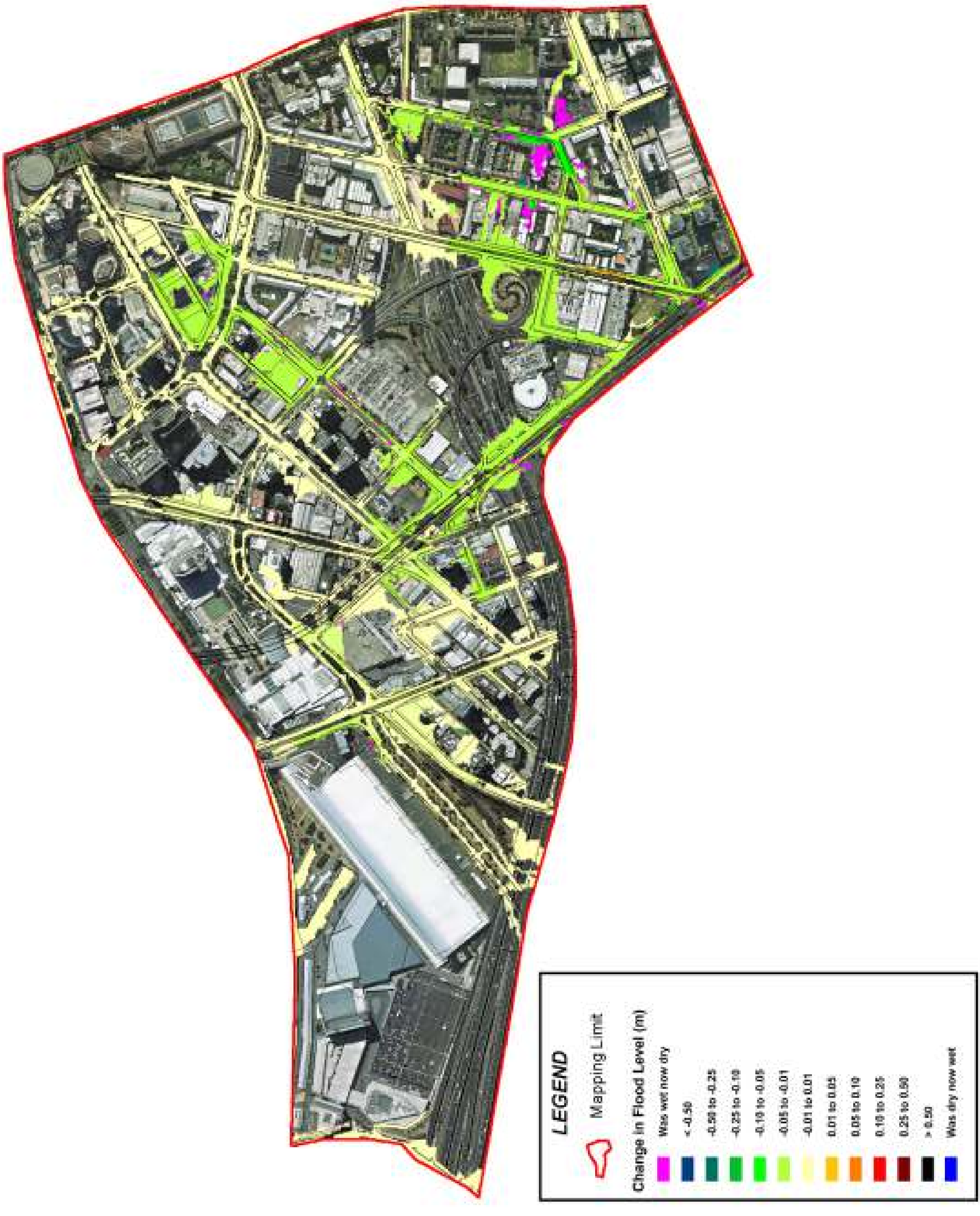

Title:
Southbank - WSUD
Change in 100 Year ARI Peak Flood Heights - MSL

Figure: **B-5**

Rev: **A**

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N

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Approx. Scale

BMT WBM
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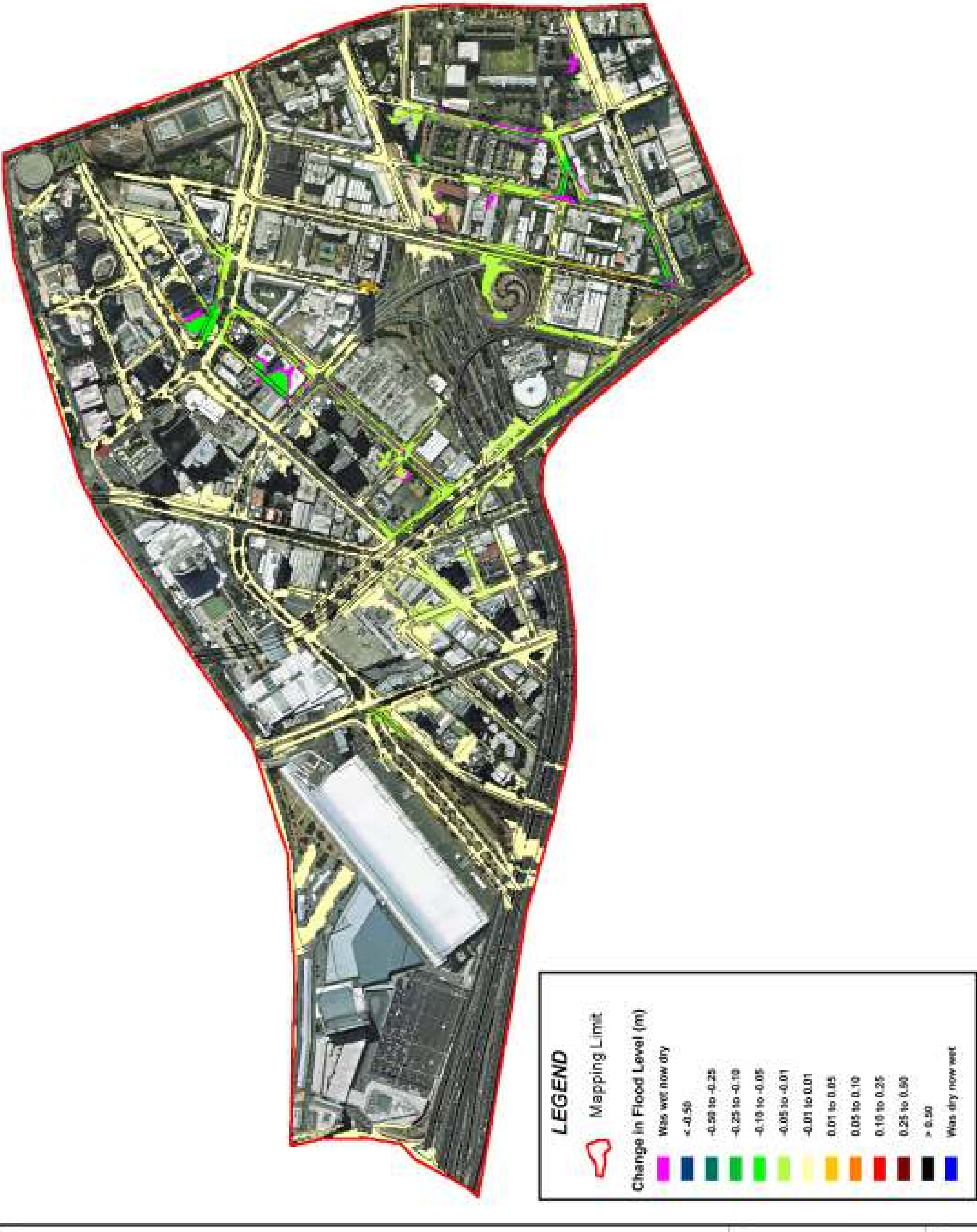

Title:

Southbank - WSUD

Change in 5 Year ARI Peak Flood Heights - HAT

Figure: **B-6**

Rev: **A**

N

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Approx. Scale

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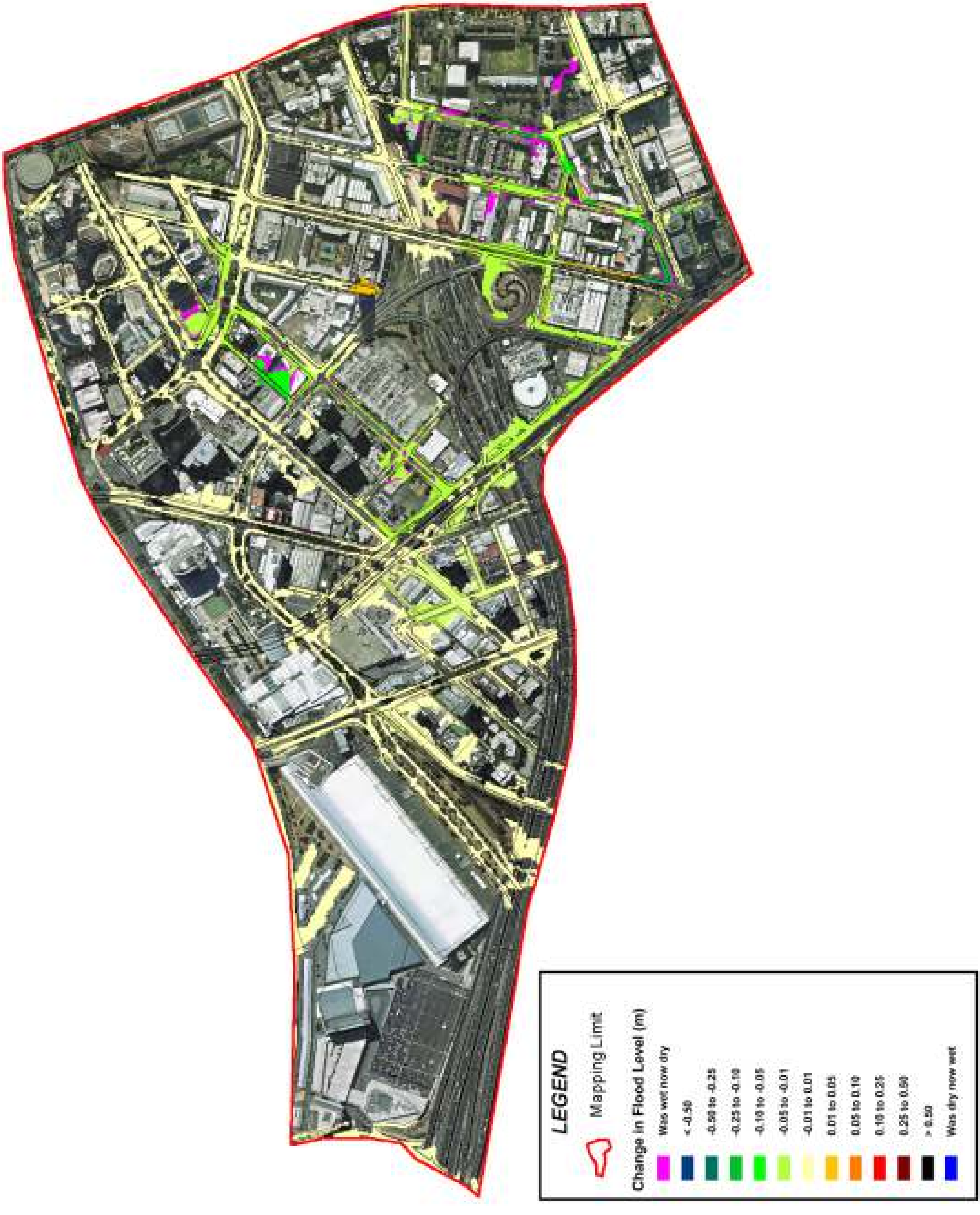
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-6_FldDif_D01_E01_5y_Storm_RevA.WOR



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

Figure: **B-7**

Rev: **A**

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N

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Approx. Scale

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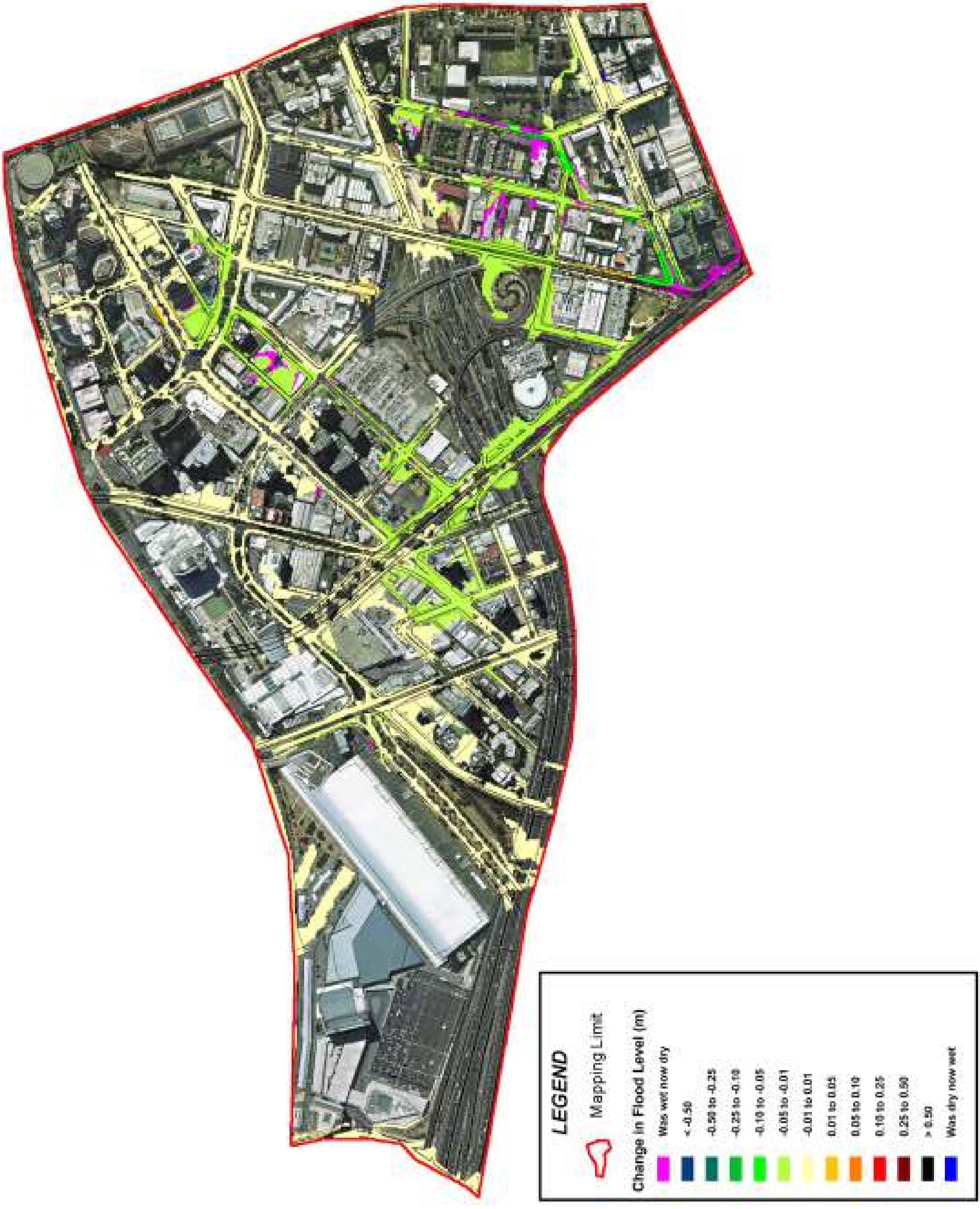

Title:
Southbank - WSUD
Change in 20 Year ARI Peak Flood Heights - HAT

Figure:
B-8

Rev:
A

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N

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Approx. Scale

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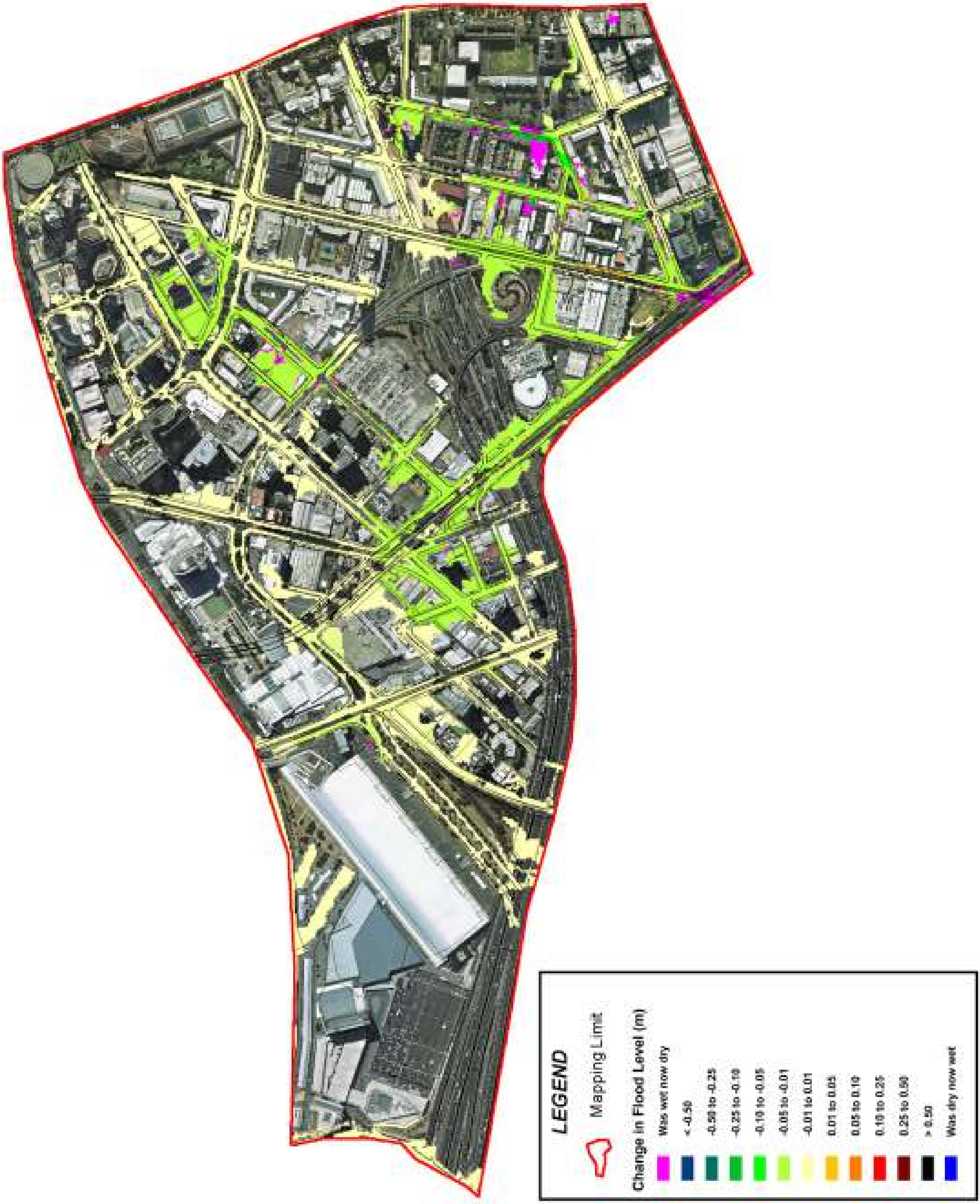

Title:

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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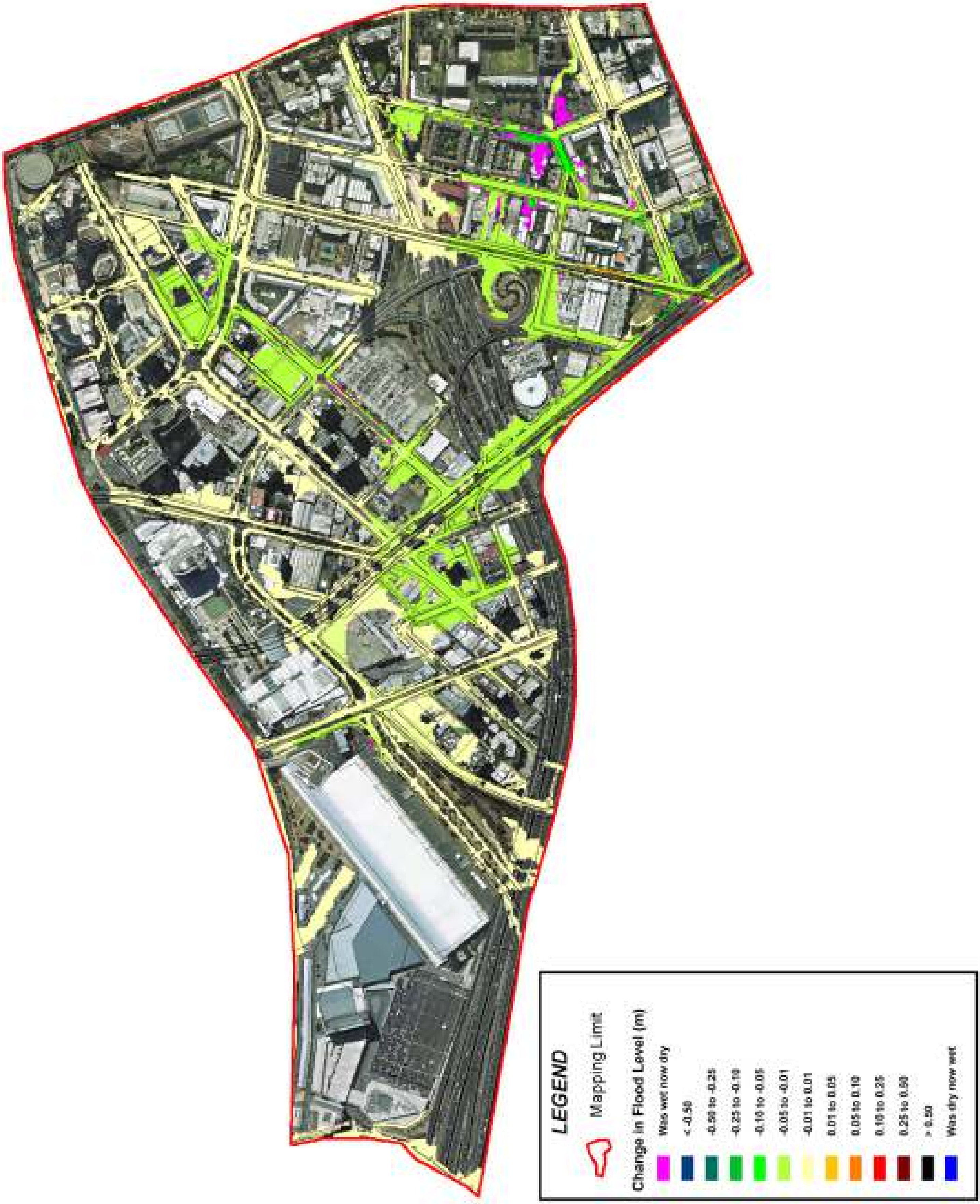

Title:

Southbank - WSUD

Change in 100 Year ARI Peak Flood Heights - HAT

Figure: **B-10**

Rev: **A**

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N

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Approx. Scale

BMT WBM

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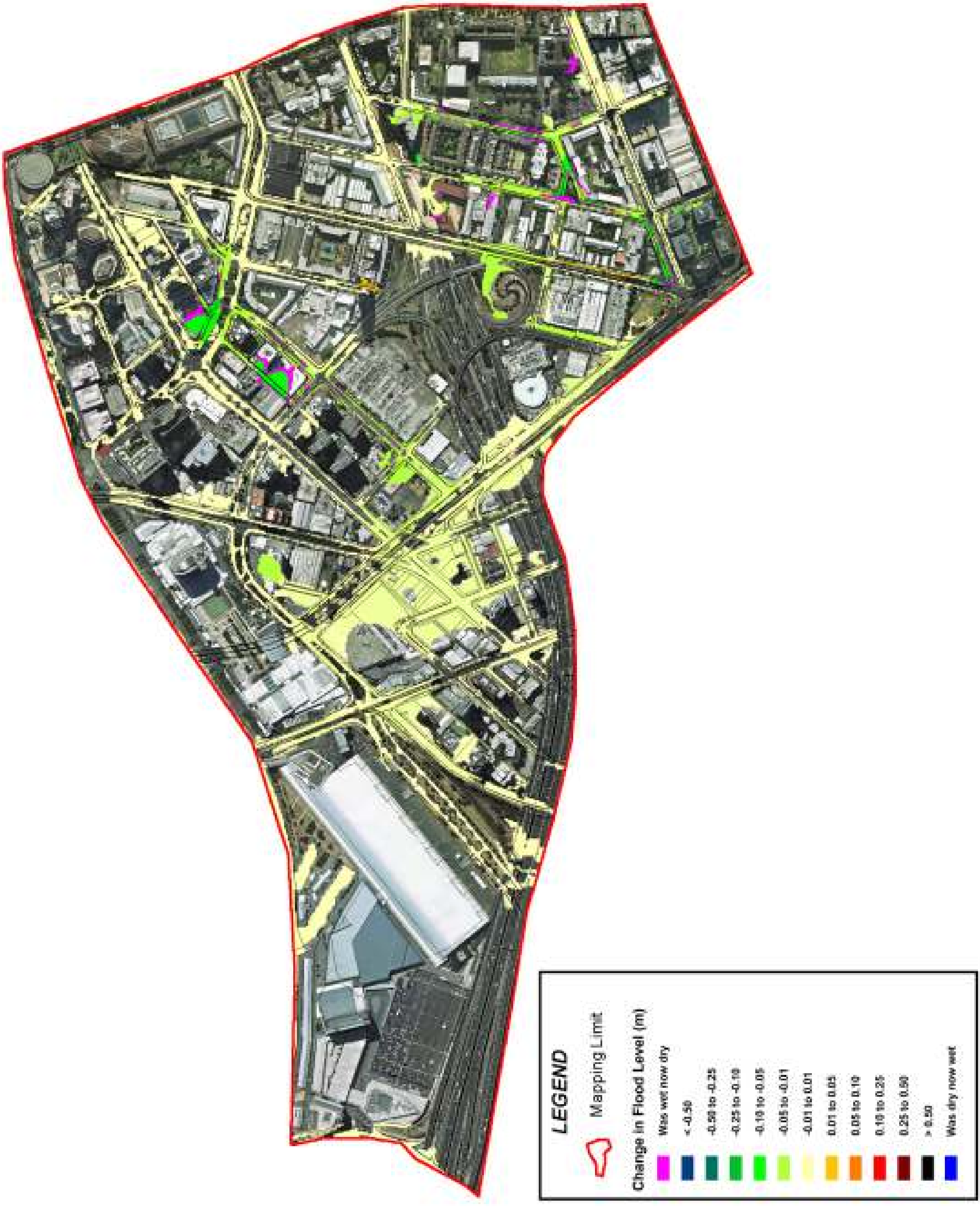
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-10_FldDif_D01_E01_100y_Storm_RevA.WOR



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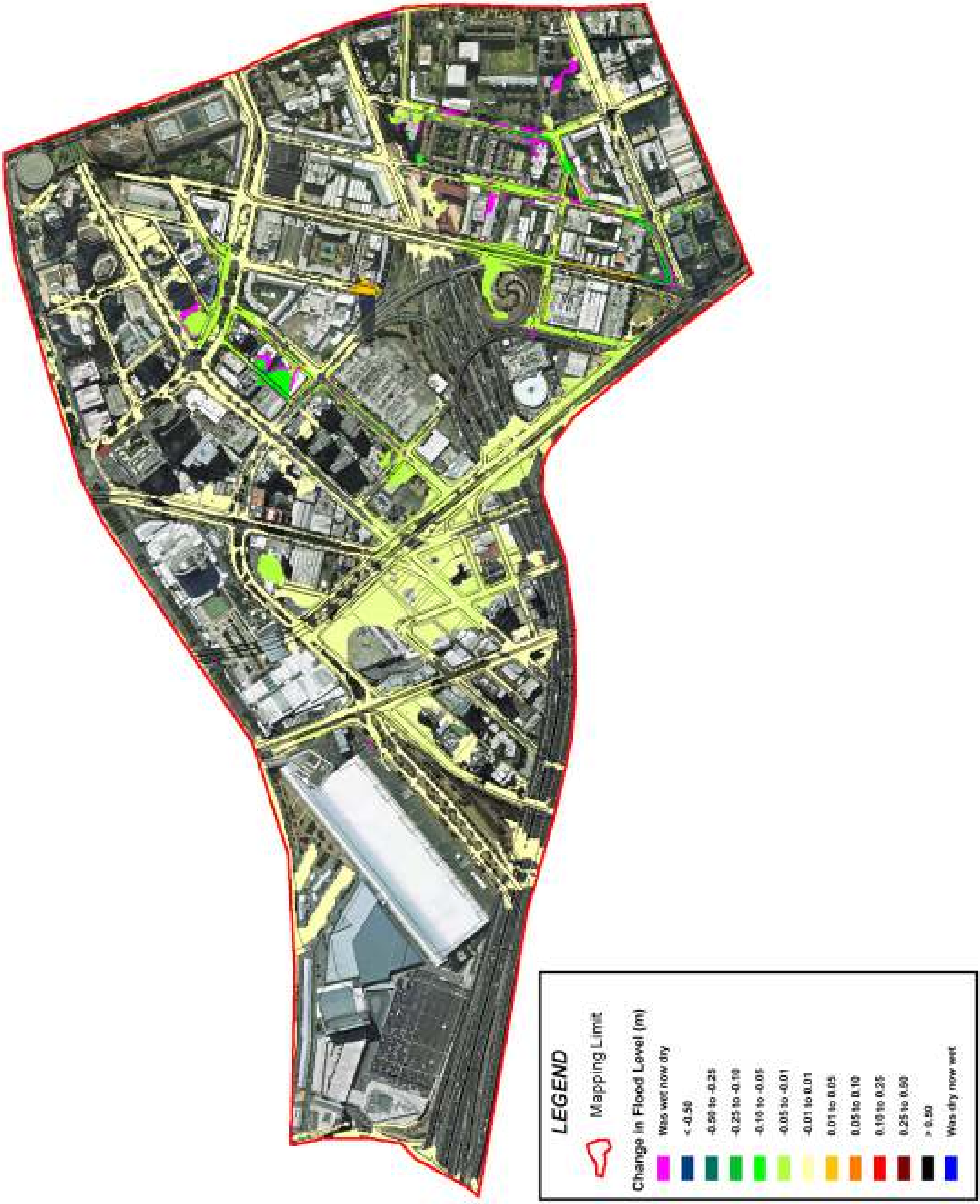
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-11_FldDif_D01_E01_5y_Storm_RevA.WOR



Title:

Southbank - WSUD

Change in 10 Year ARI Peak Flood Heights - Storm

Figure: **B-12**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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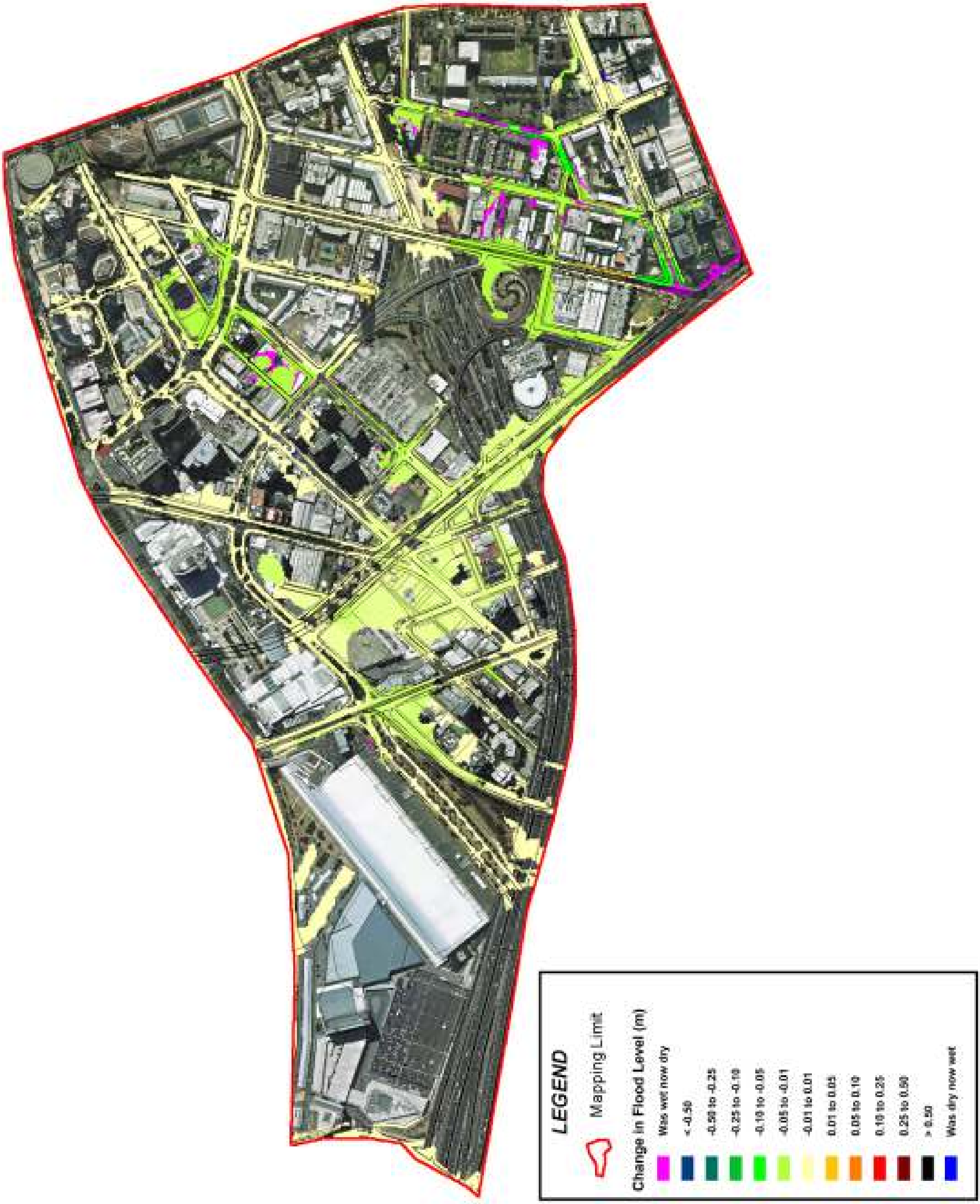
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-12_FldDif_D01_E01_10y_Storm_RevA.WOR



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

Figure: **B-13**

Rev: **A**

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

0 125 250m
Approx. Scale

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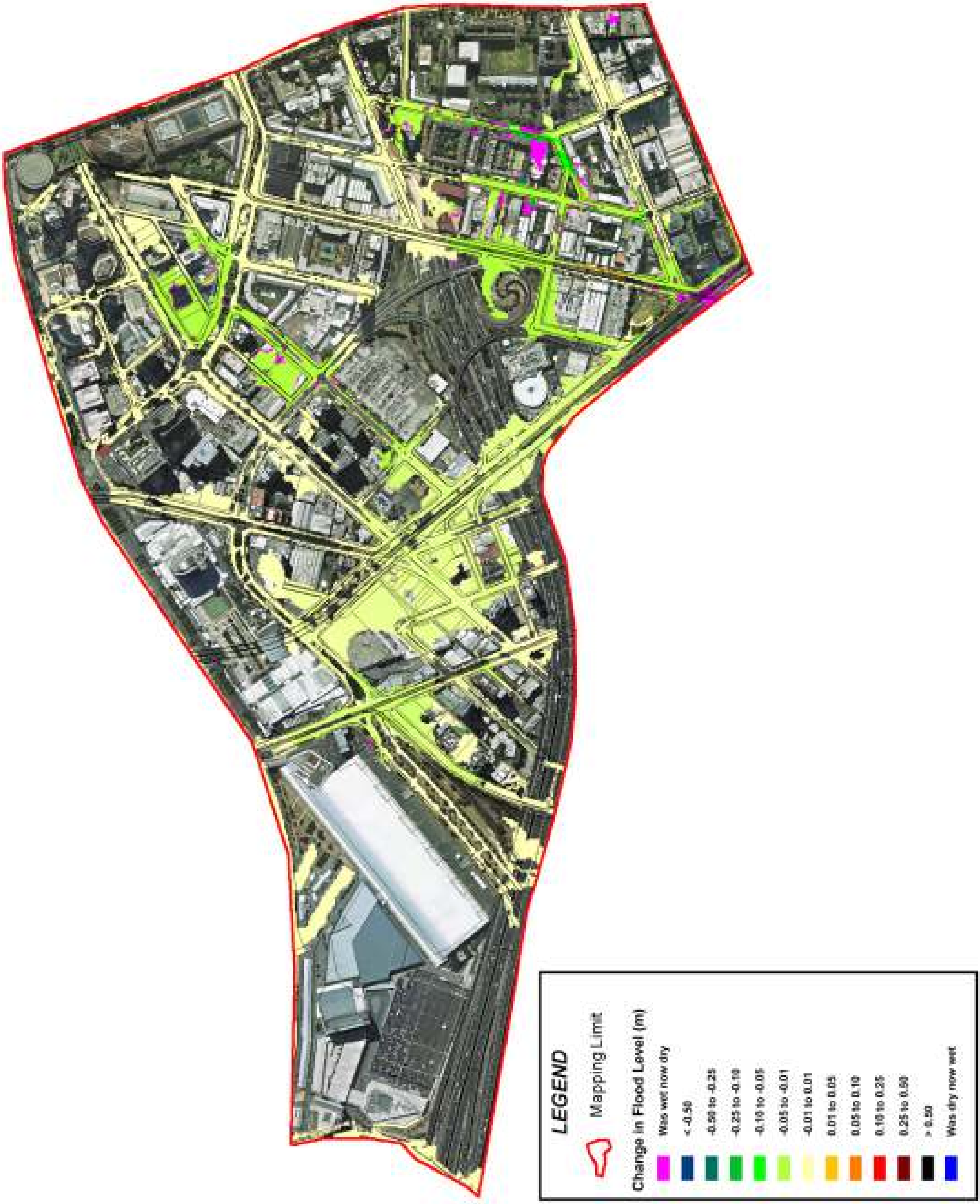
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-13_FldDif_D01_E01_20y_Storm_RevA.WOR



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

Figure:
B-14

Rev:
A

N

0 125 250m
Approx. Scale

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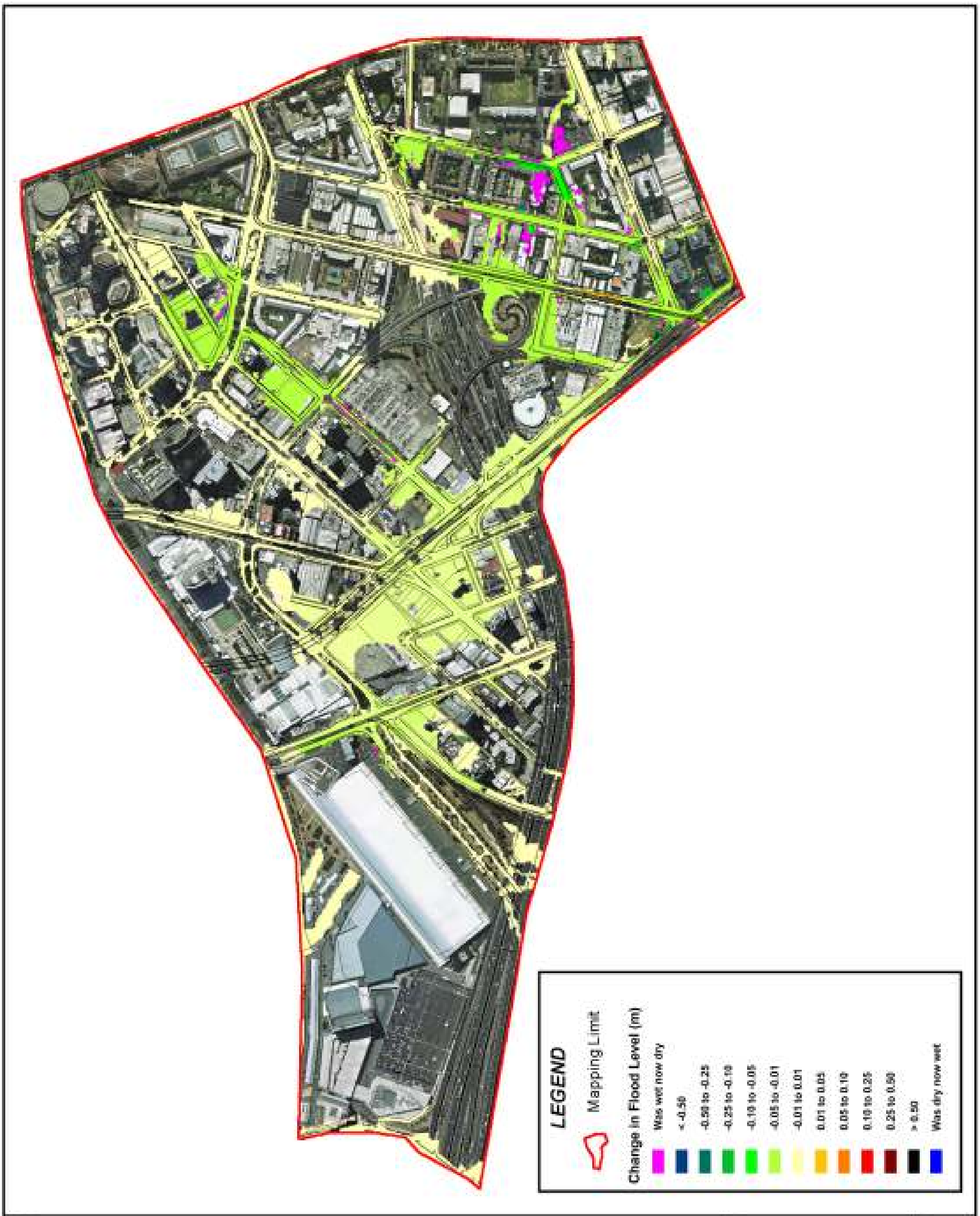
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-14_FldDif_D01_E01_50y_Storm_RevA.WOR



Title:

Southbank - WSUD

Change in 100 Year ARI Peak Flood Heights - Storm

Figure: **B-15**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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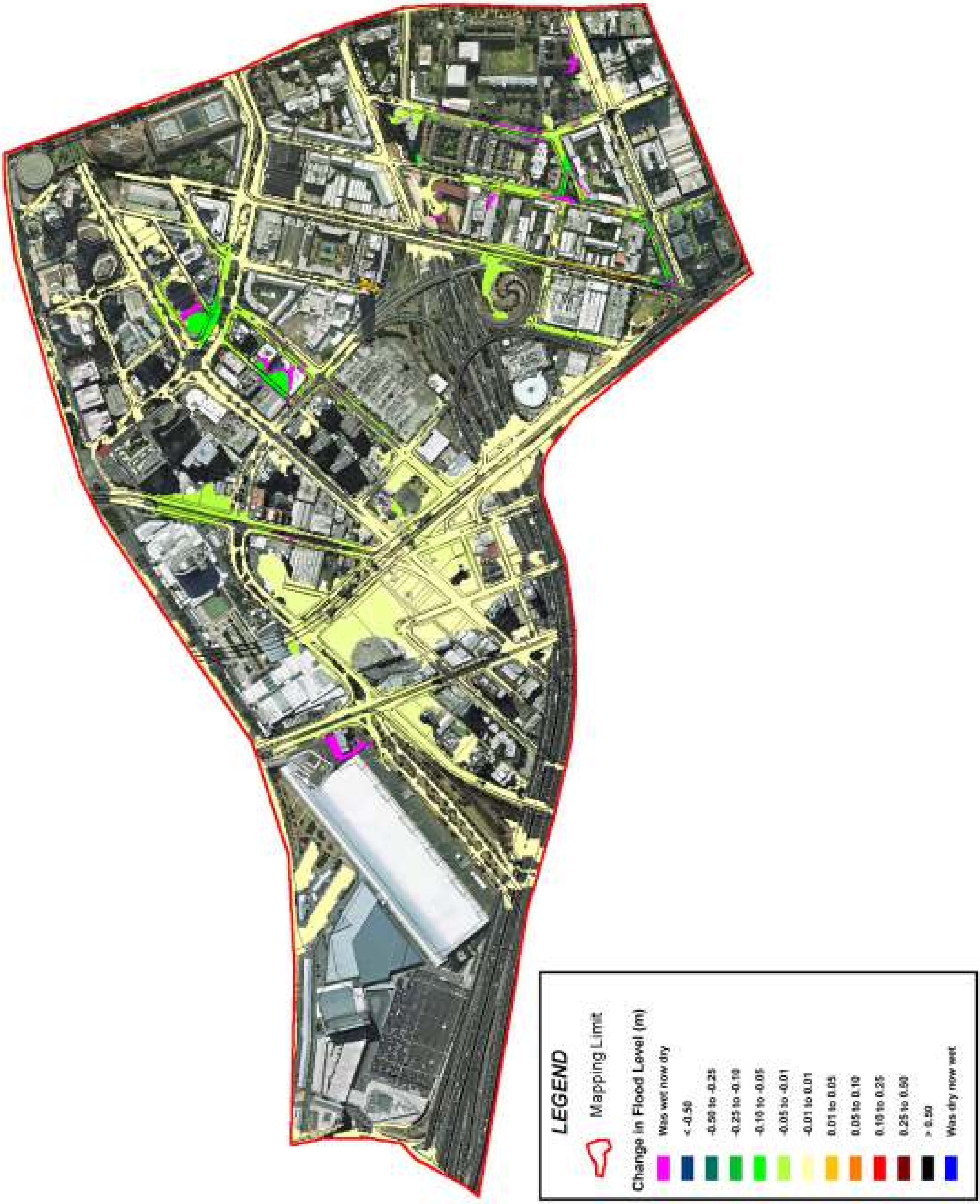
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-15_FldDif_D01_E01_100y_Storm_RevA.WOR



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

Figure: **B-16**

Rev: **A**

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

0 125 250m
Approx. Scale

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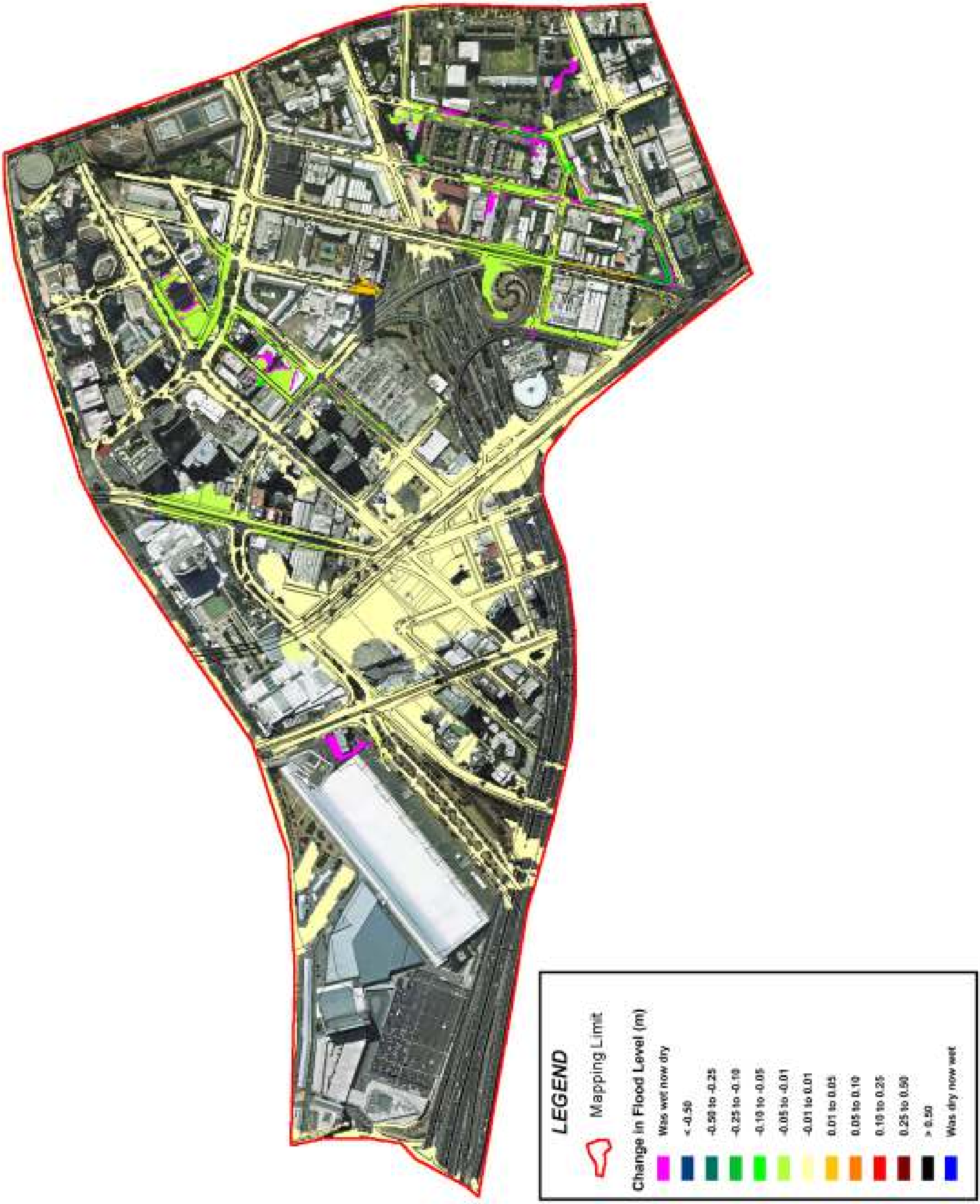
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-16_FldDif_D01_E01_5y_Yarra100y_RevA.WOR



Title:
Southbank - WSUD
Change in 10 Year ARI Peak Flood Heights - Yarra 100y

Figure: **B-17**

Rev: **A**

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

0 125 250m
Approx. Scale

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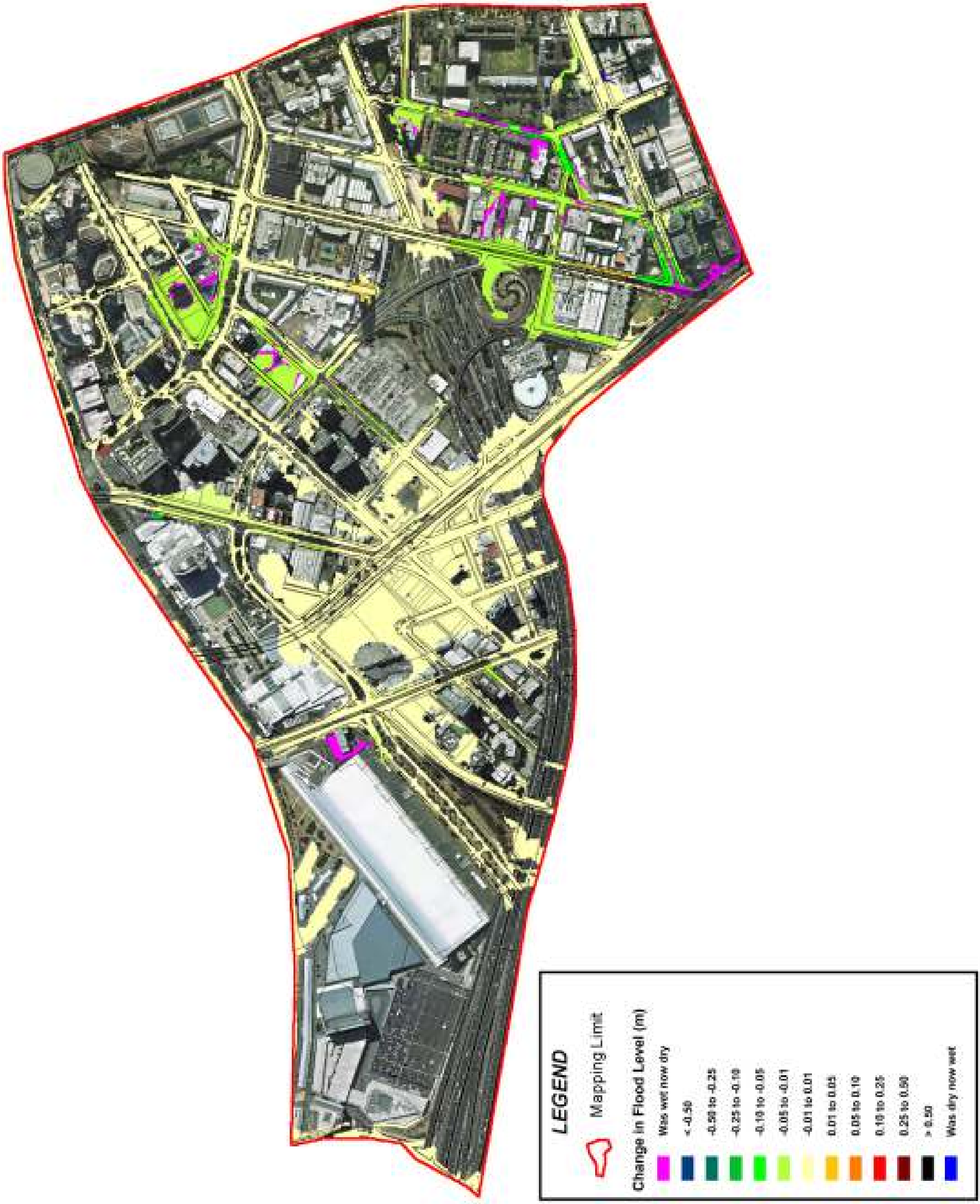
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-17_FldDif_D01_E01_10y_Yarra100y_RevA.WOR



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

Figure: **B-18**

Rev: **A**

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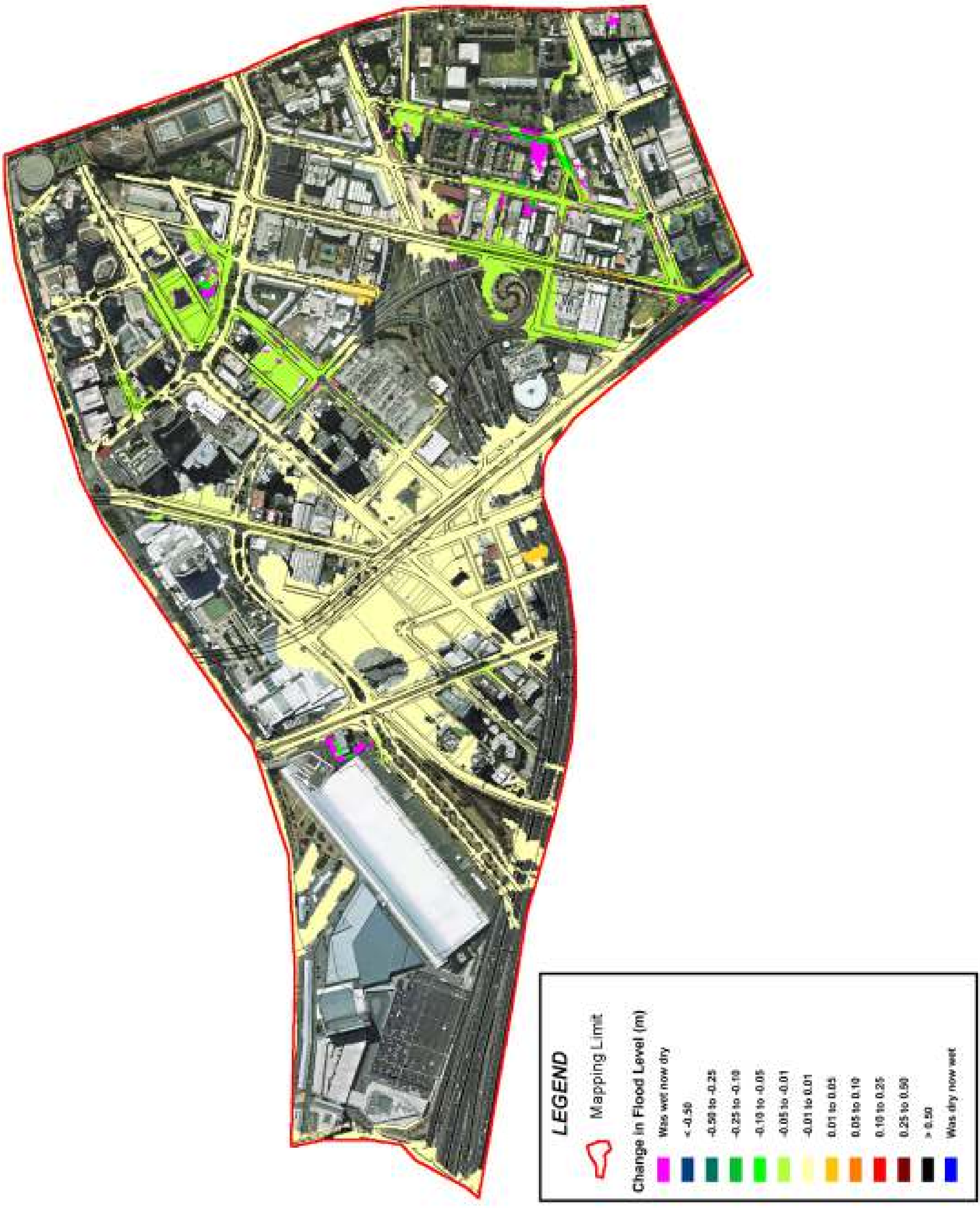
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-18_FldDif_D01_E01_20y_Yarra100y_RevA.WOR



Title:

Southbank - WSUD

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

Figure: **B-19**

Rev: **A**

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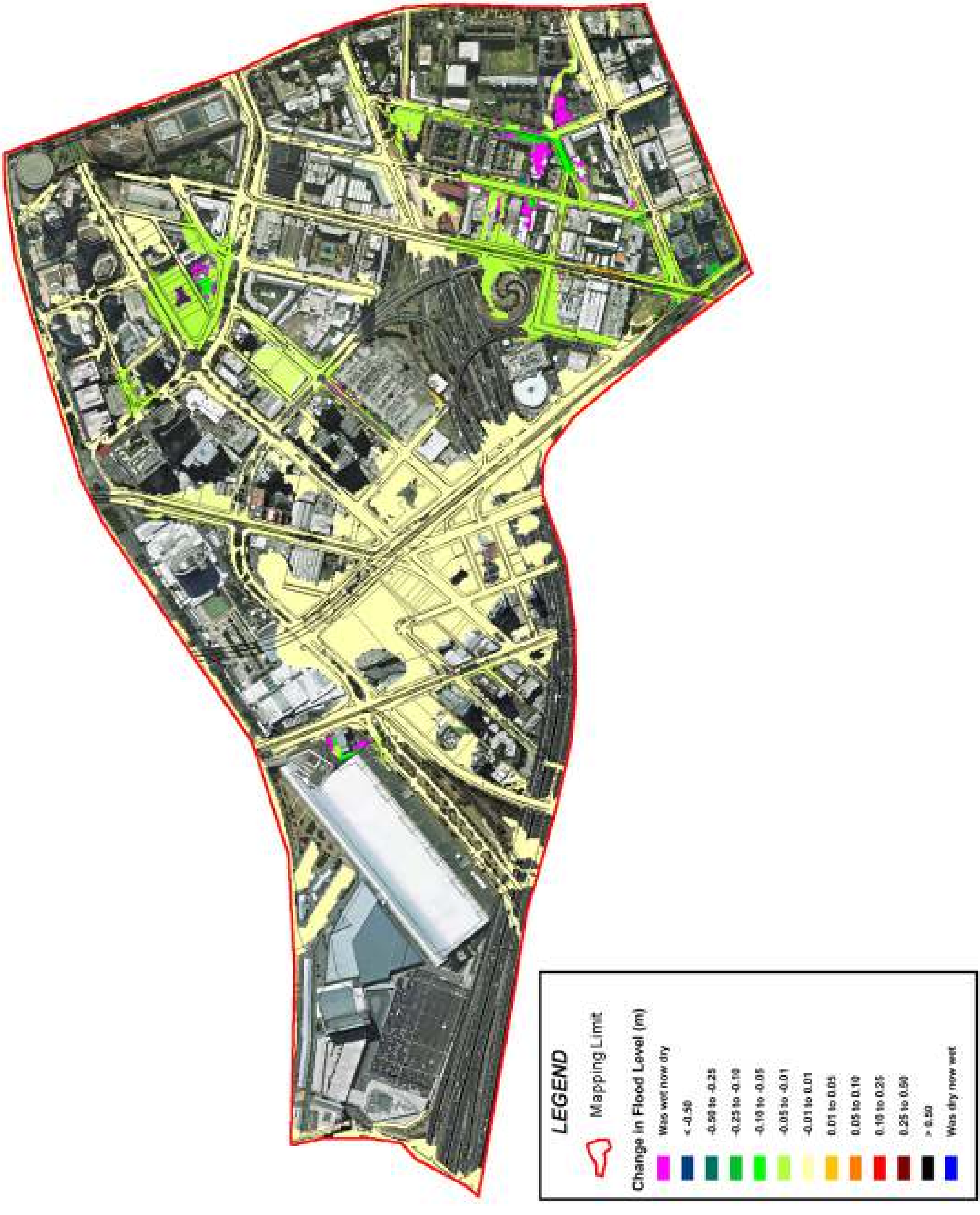
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-19_FldDif_D01_E01_50y_Yarra100y_RevA.WOR



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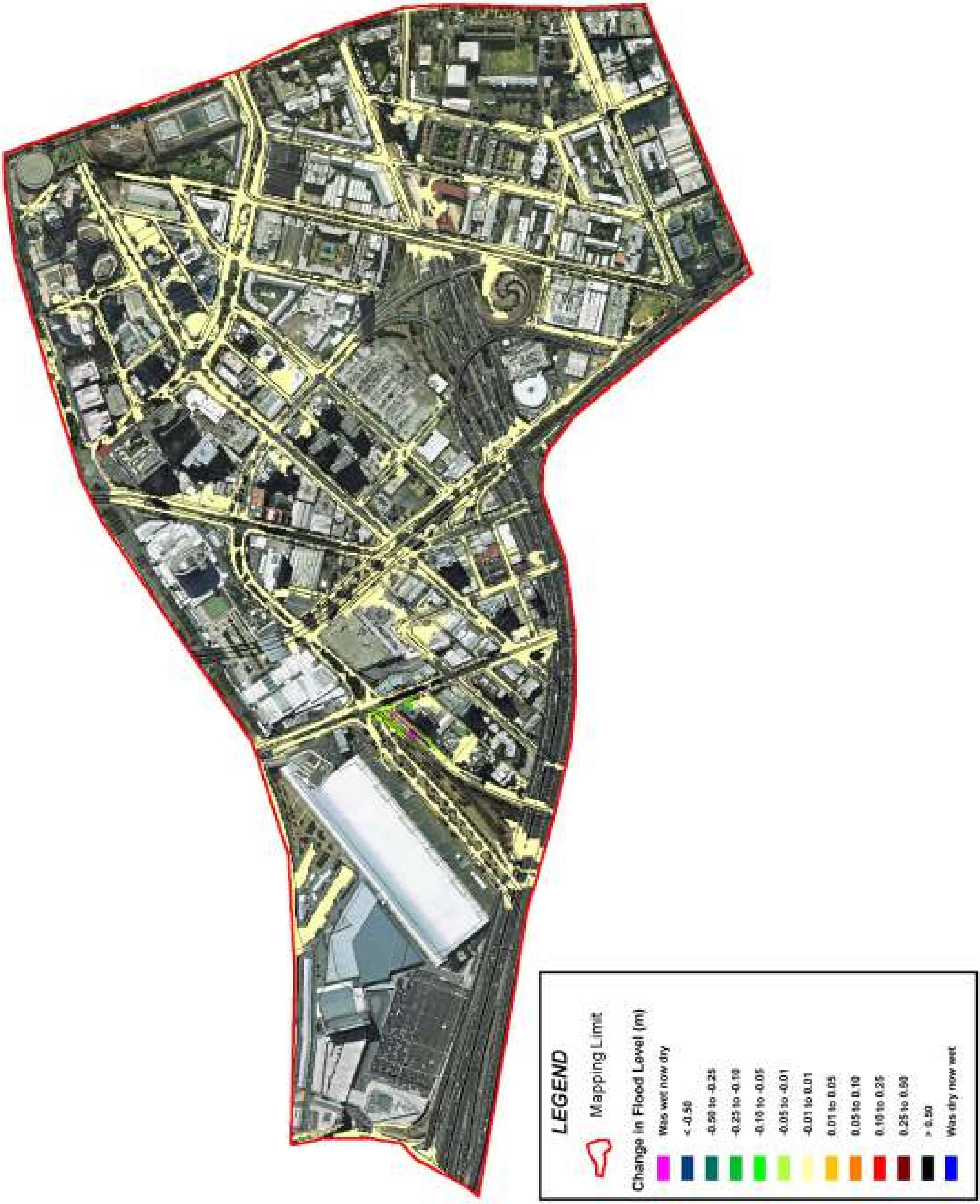
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-20_FldDif_D01_E01_100y_Yarra100y_RevA.WOR



Title:

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

Figure:
B-1

Rev:
A

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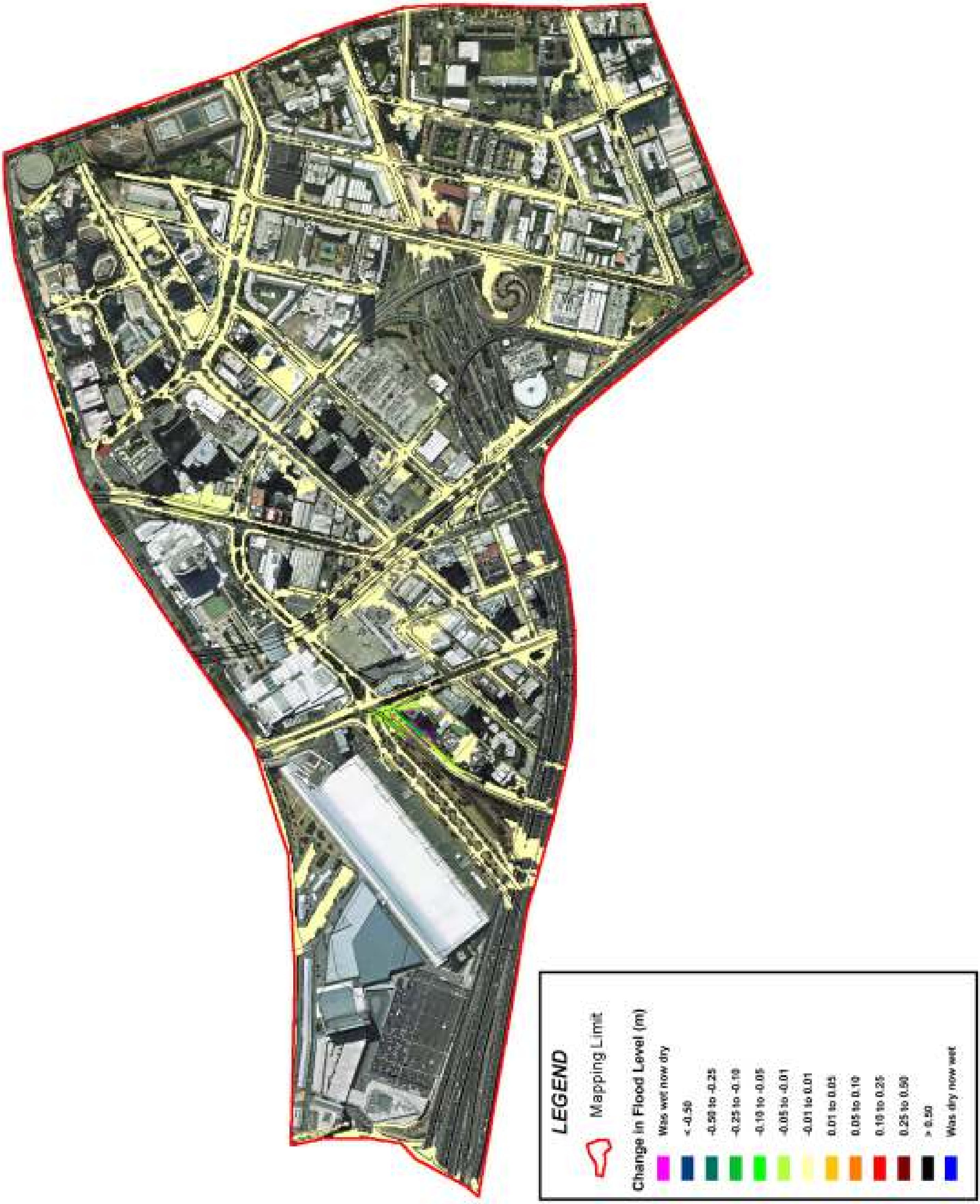
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-1_FldDif_D02_E01_5y_MSL_RevA.WOR



Title:

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

Figure: **B-22**

Rev: **A**

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N

0 125 250m
Approx. Scale

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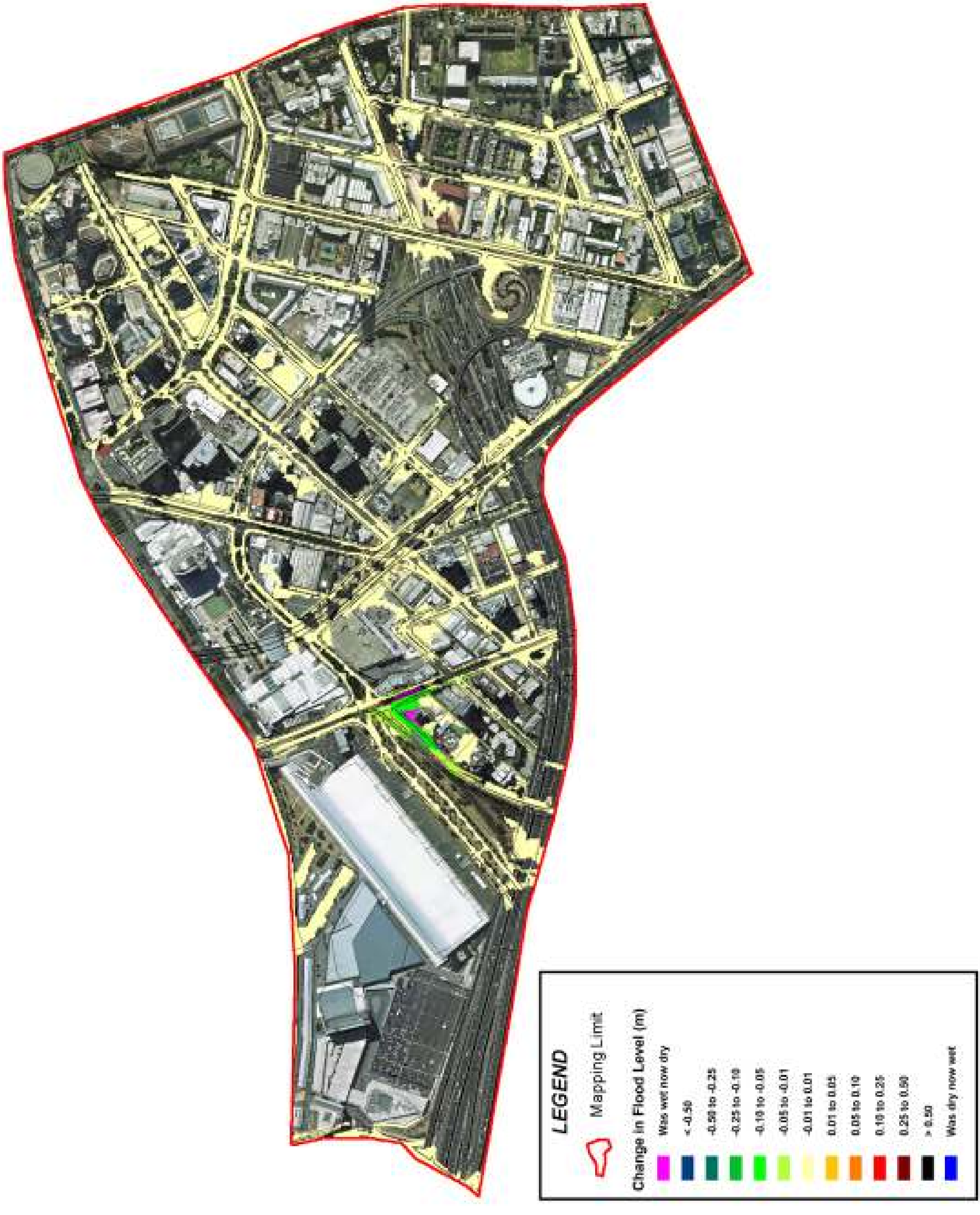
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-22_FldDif_D02_E01_10y_MSL_RevA.WOR



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

Figure:
B-23

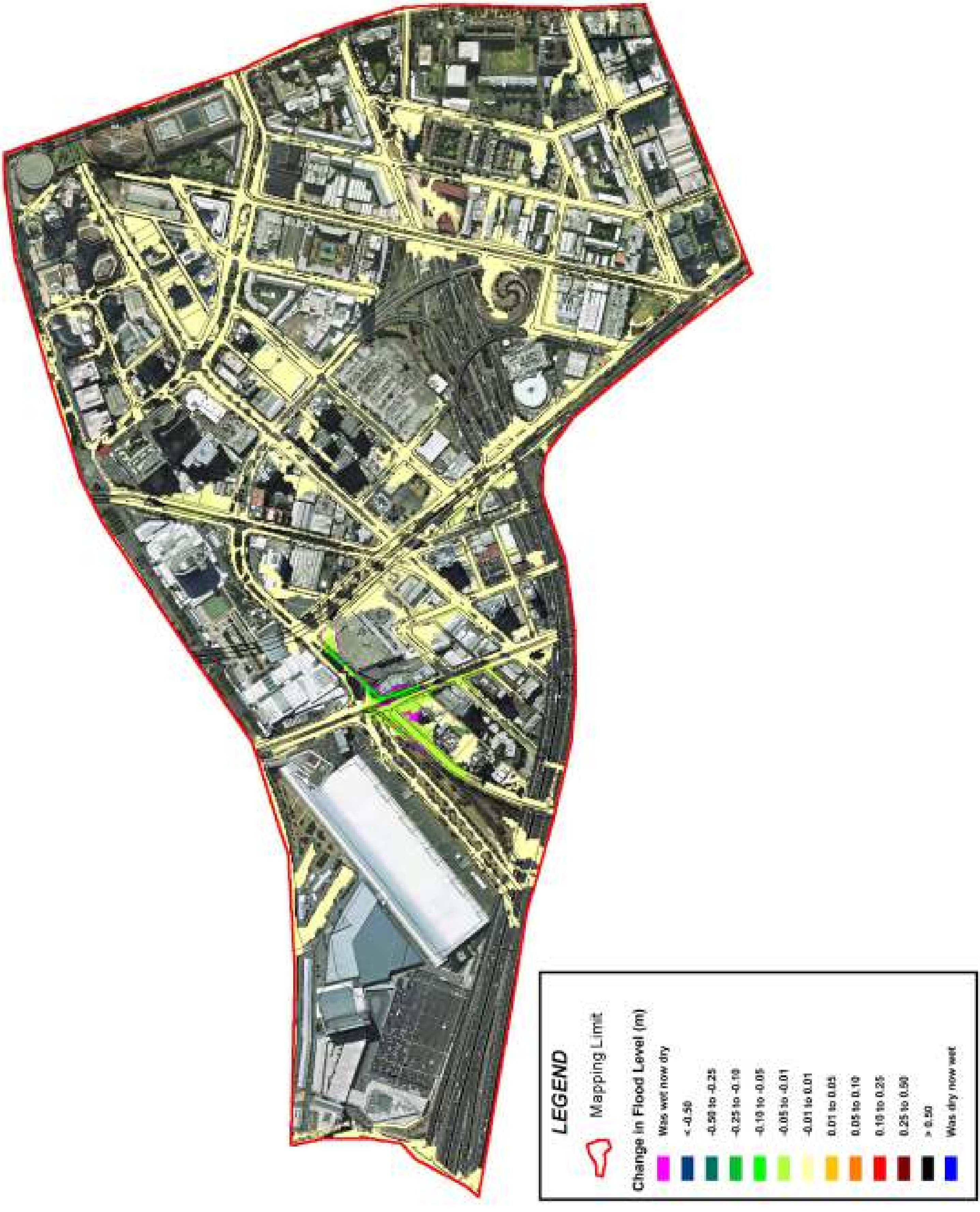
Rev:
A

N

0 125 250m
Approx. Scale

BMT WBM
www.bmtwbm.com.au

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**

N

0 125 250m
Approx. Scale

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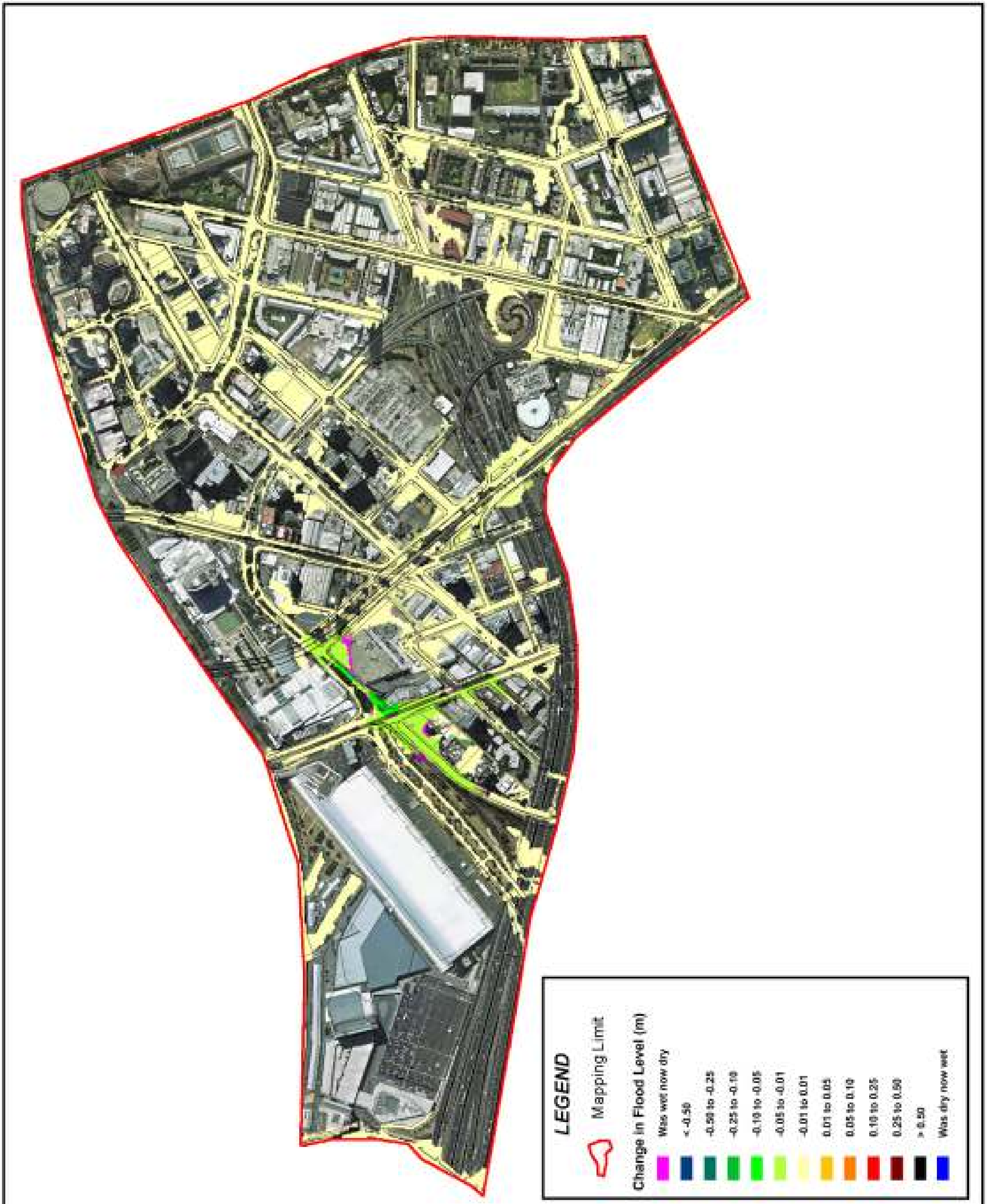
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-24_FldDif_D02_E01_50y_MSL_RevA.WOR



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

Figure:
B-25

Rev:
A

N

0 125 250m
Approx. Scale

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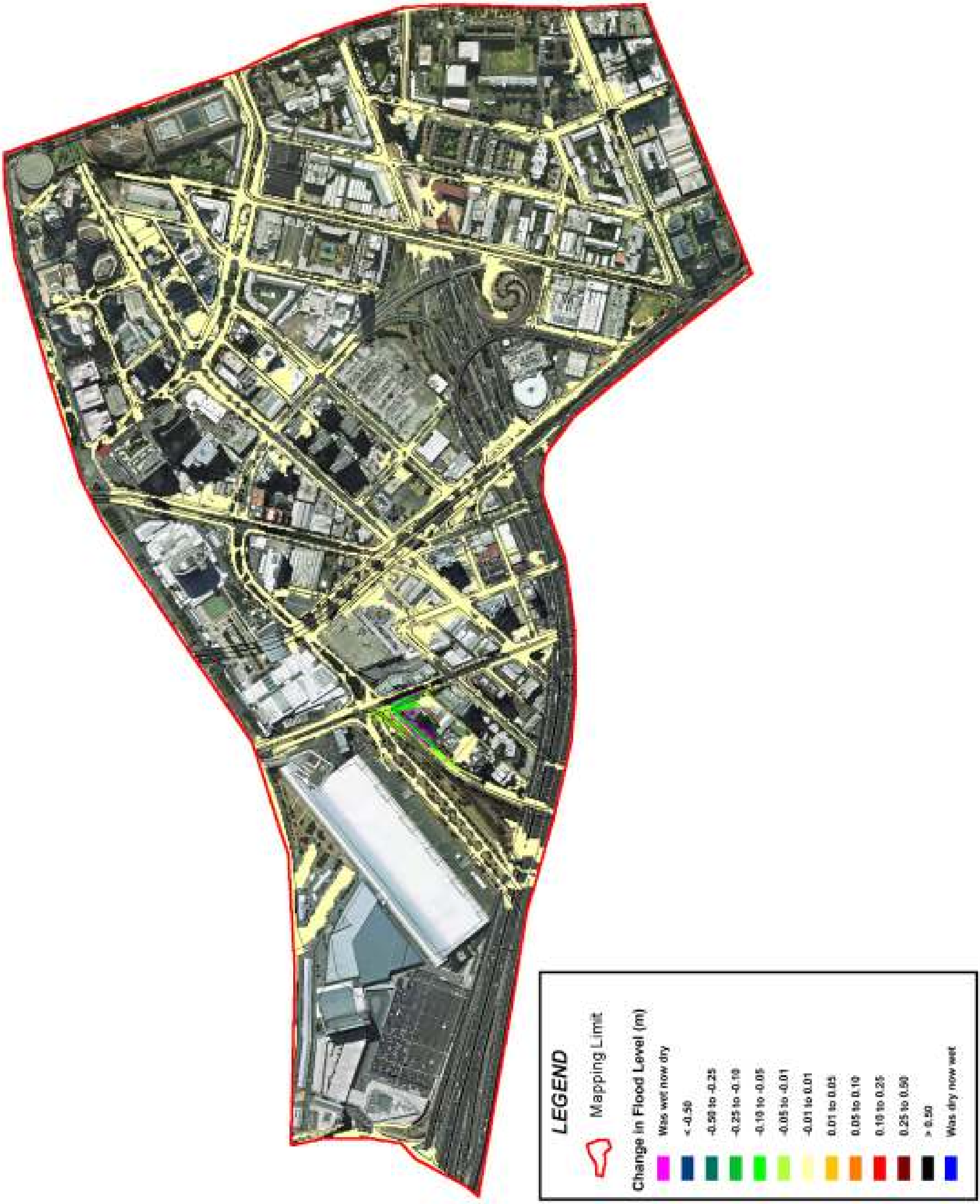
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-25_FldDif_D02_E01_100y_MSL_RevA.WOR



Title:

Southbank - Pipe

Change in 5 Year ARI Peak Flood Heights - HAT

Figure: **B-26**

Rev: **A**

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N

0 125 250m

Approx. Scale

BMT WBM

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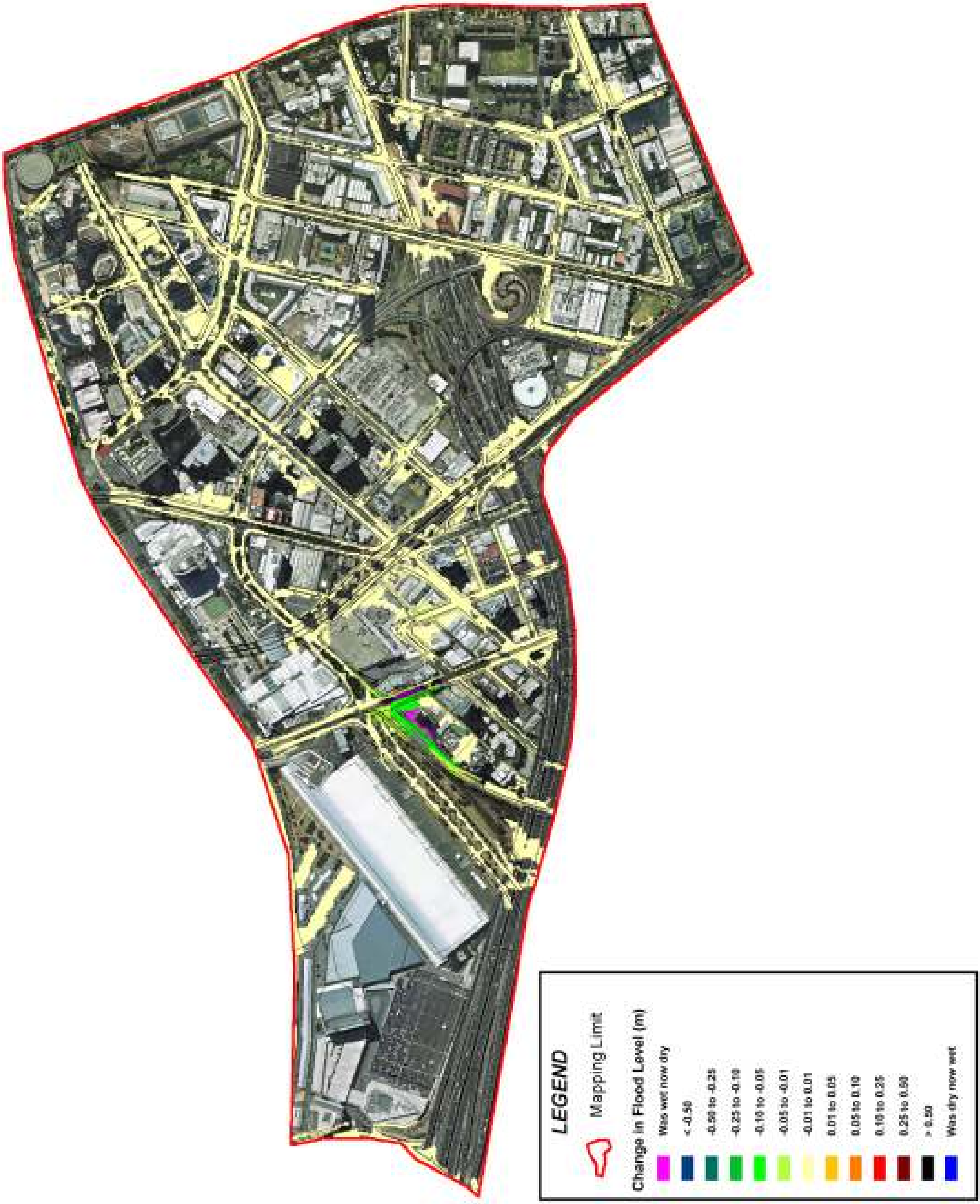

Title:

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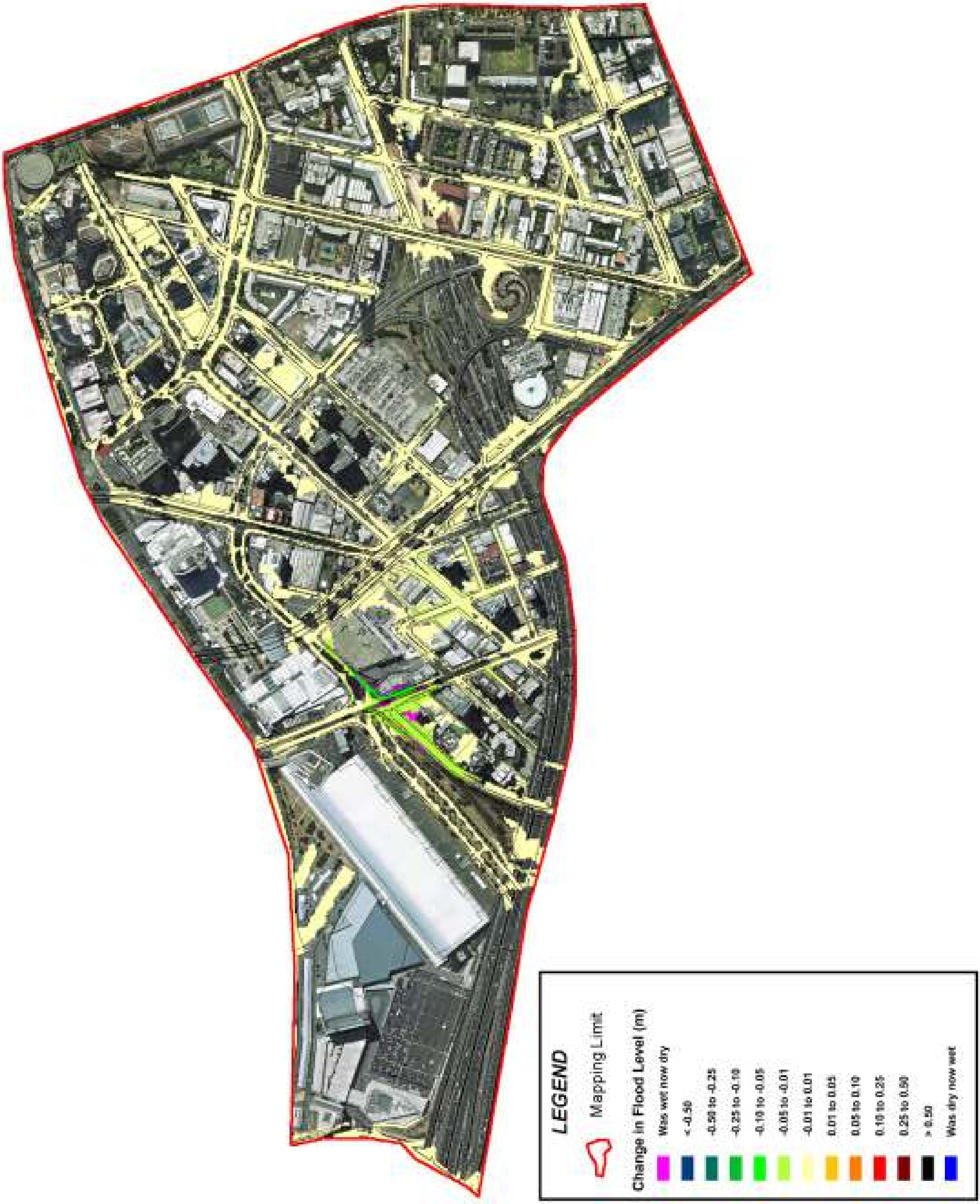
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-27_FldDif_D02_E01_10y_Storm_RevA.WOR



Title:

Southbank - Pipe

Change in 20 Year ARI Peak Flood Heights - HAT

Figure: **B-28**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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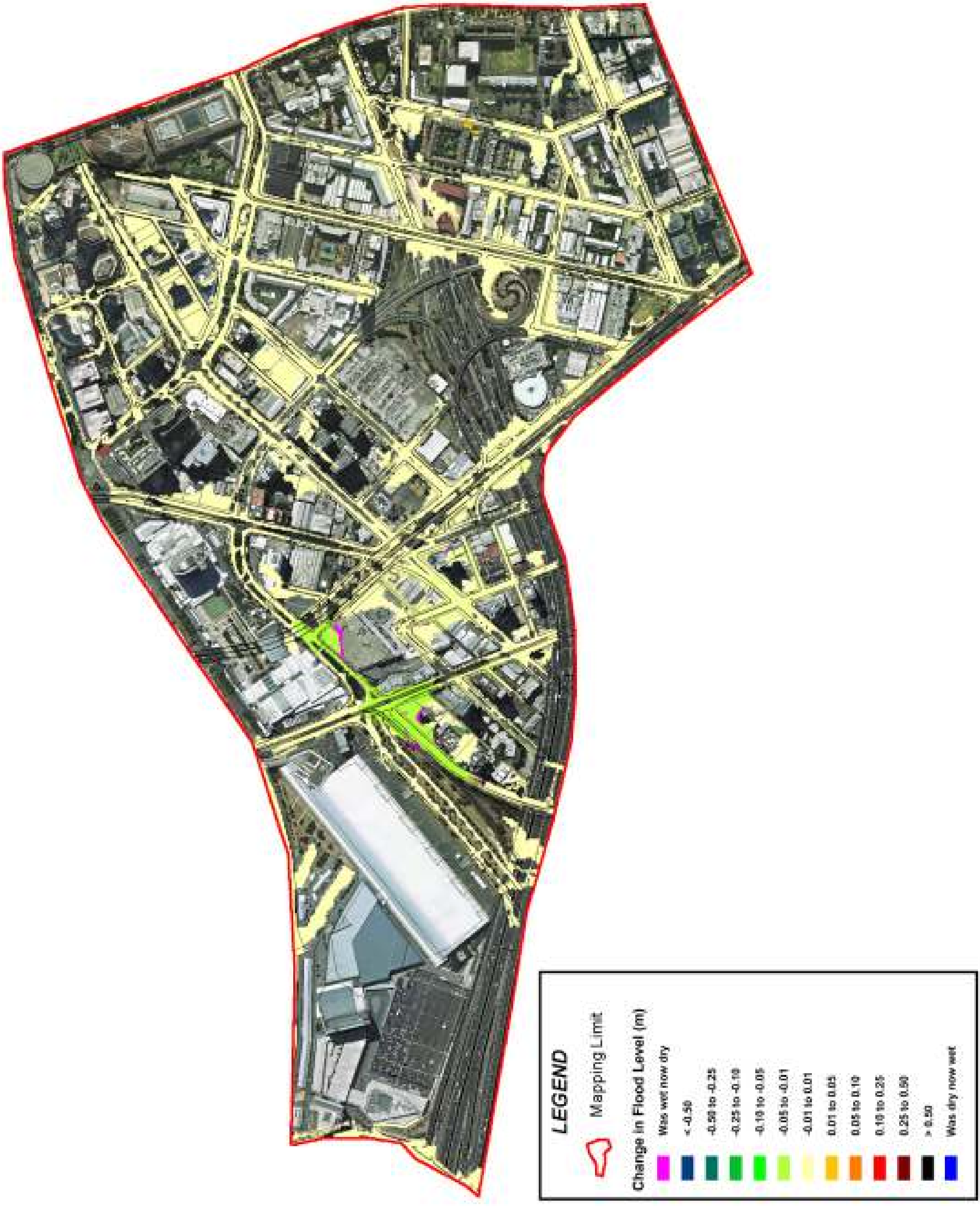
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-28_FldDif_D02_E01_20y_Storm_RevA.WOR



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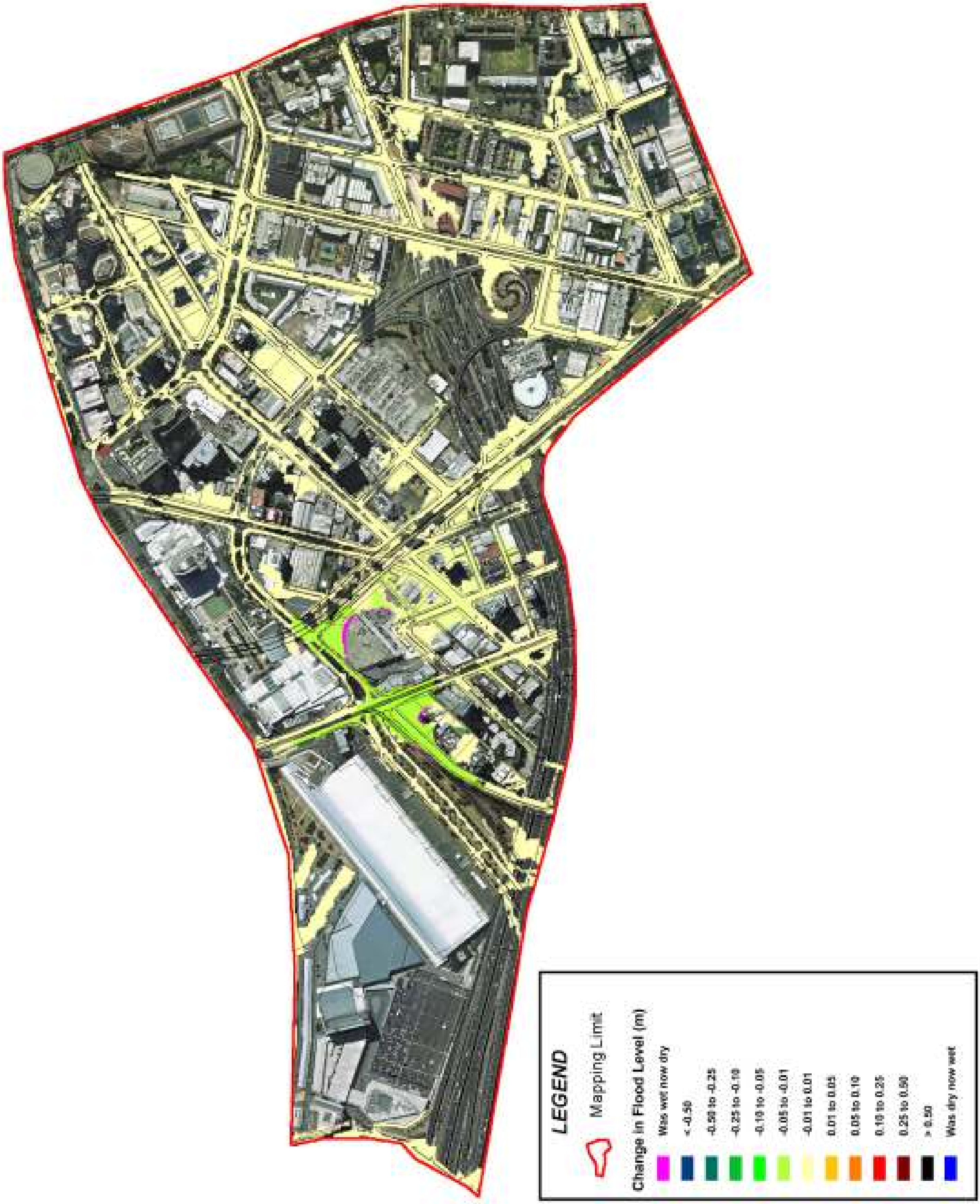
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-29_FldDif_D02_E01_50y_Storm_RevA.WOR



Title:

Southbank - Pipe

Change in 100 Year ARI Peak Flood Heights - HAT

Figure:

B-30

Rev:

A

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N

0 125 250m

Approx. Scale

BMT WBM

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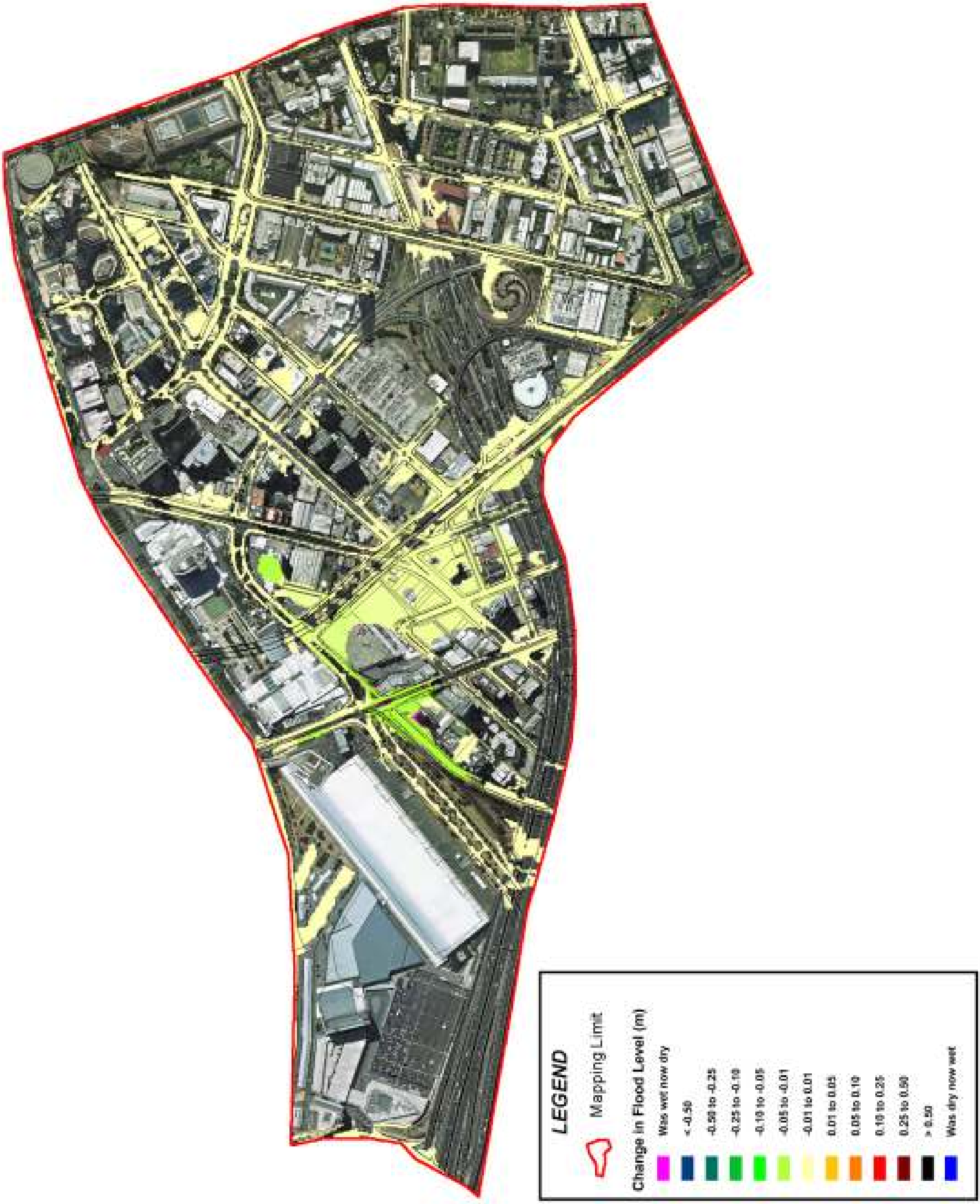
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-30_FldDif_D02_E01_100y_Storm_RevA.WOR



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

Figure: **B-31**

Rev: **A**

N

0 125 250m
Approx. Scale

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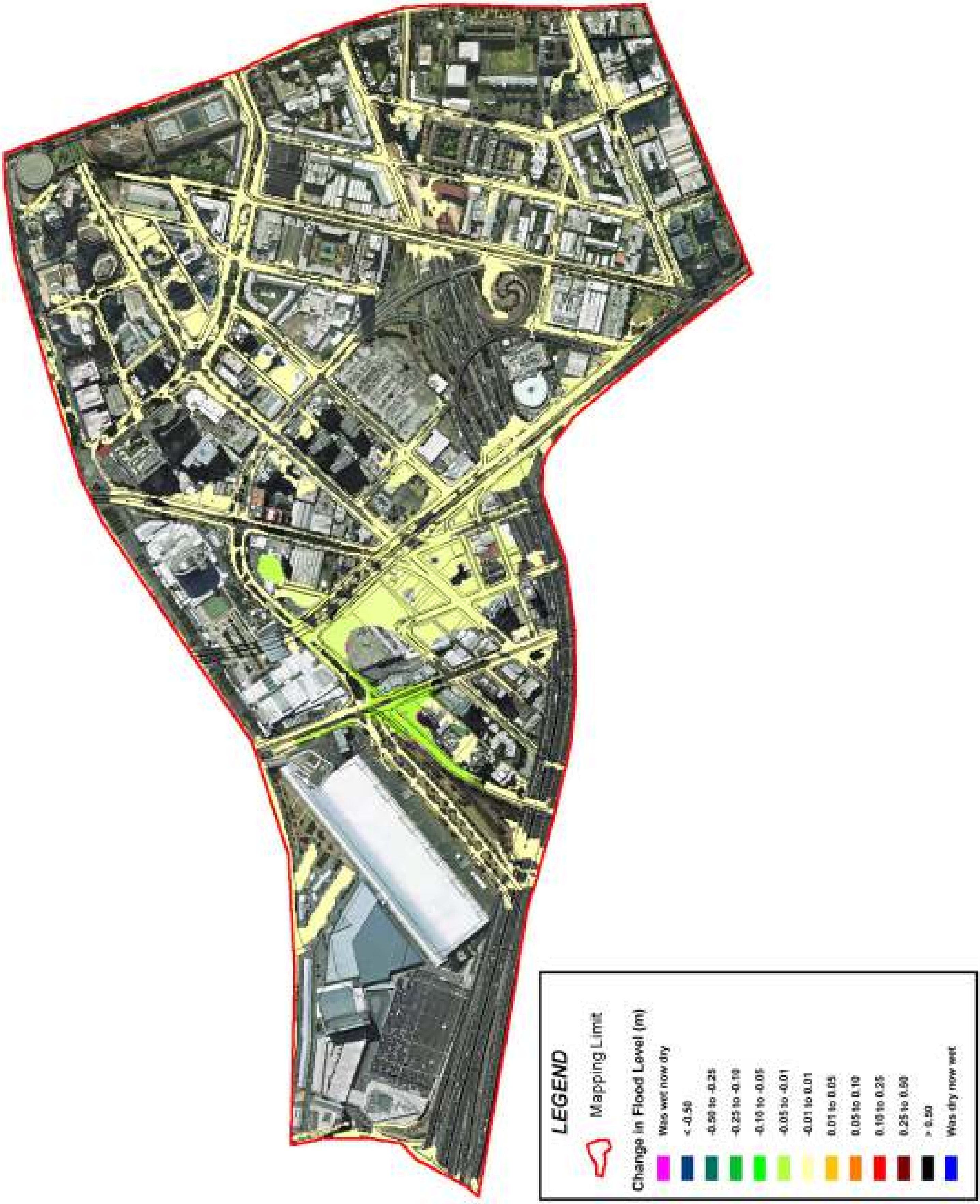
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-31_FldDif_D02_E01_5y_Storm_RevA.WOR



Title:

Southbank - Pipe

Change in 10 Year ARI Peak Flood Heights - Storm

Figure: **B-32**

Rev: **A**

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N

0 125 250m

Approx. Scale

BMT WBM

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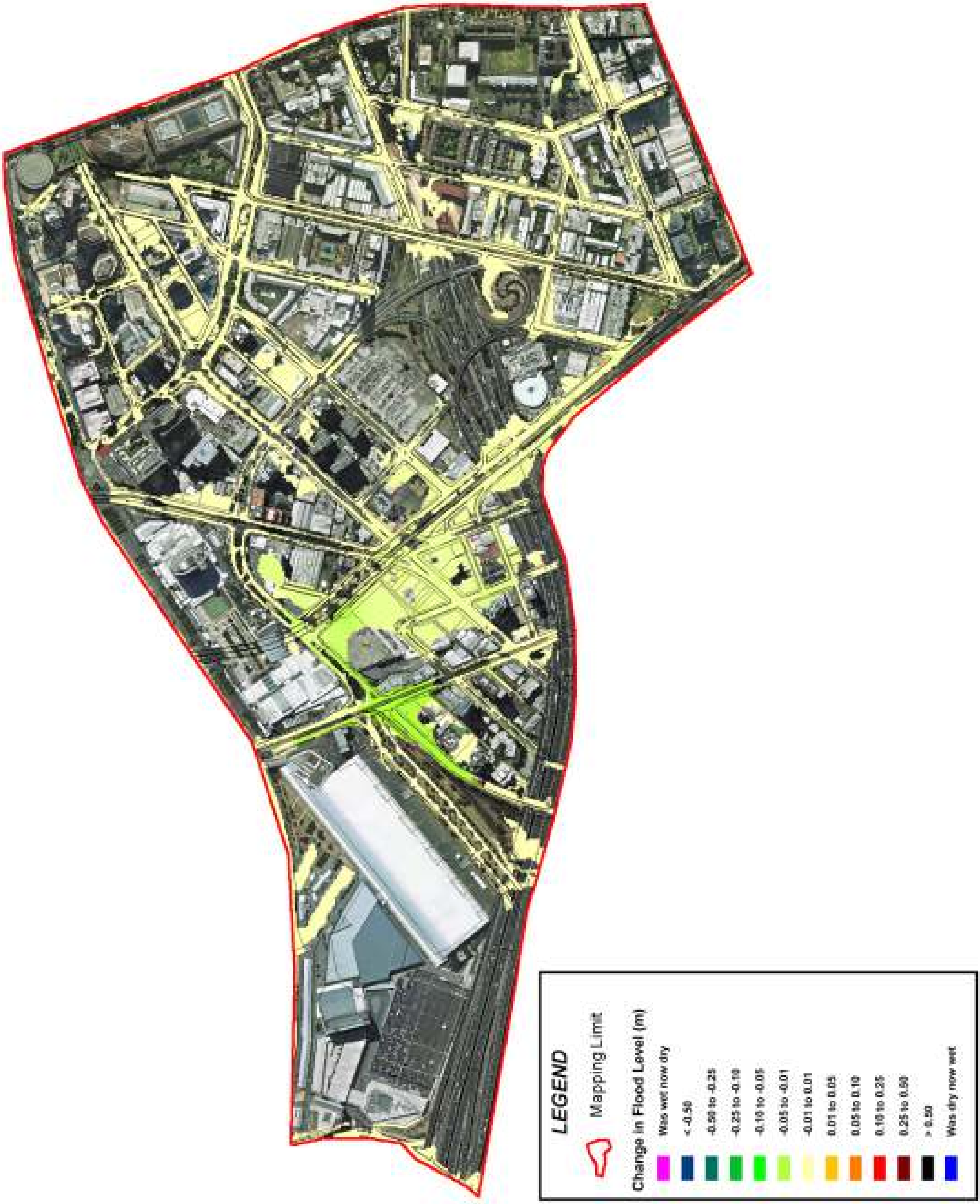
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-32_FldDif_D02_E01_10y_Storm_RevA.WOR



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

Figure:
B-33

Rev:
A

N

0 125 250m
Approx. Scale

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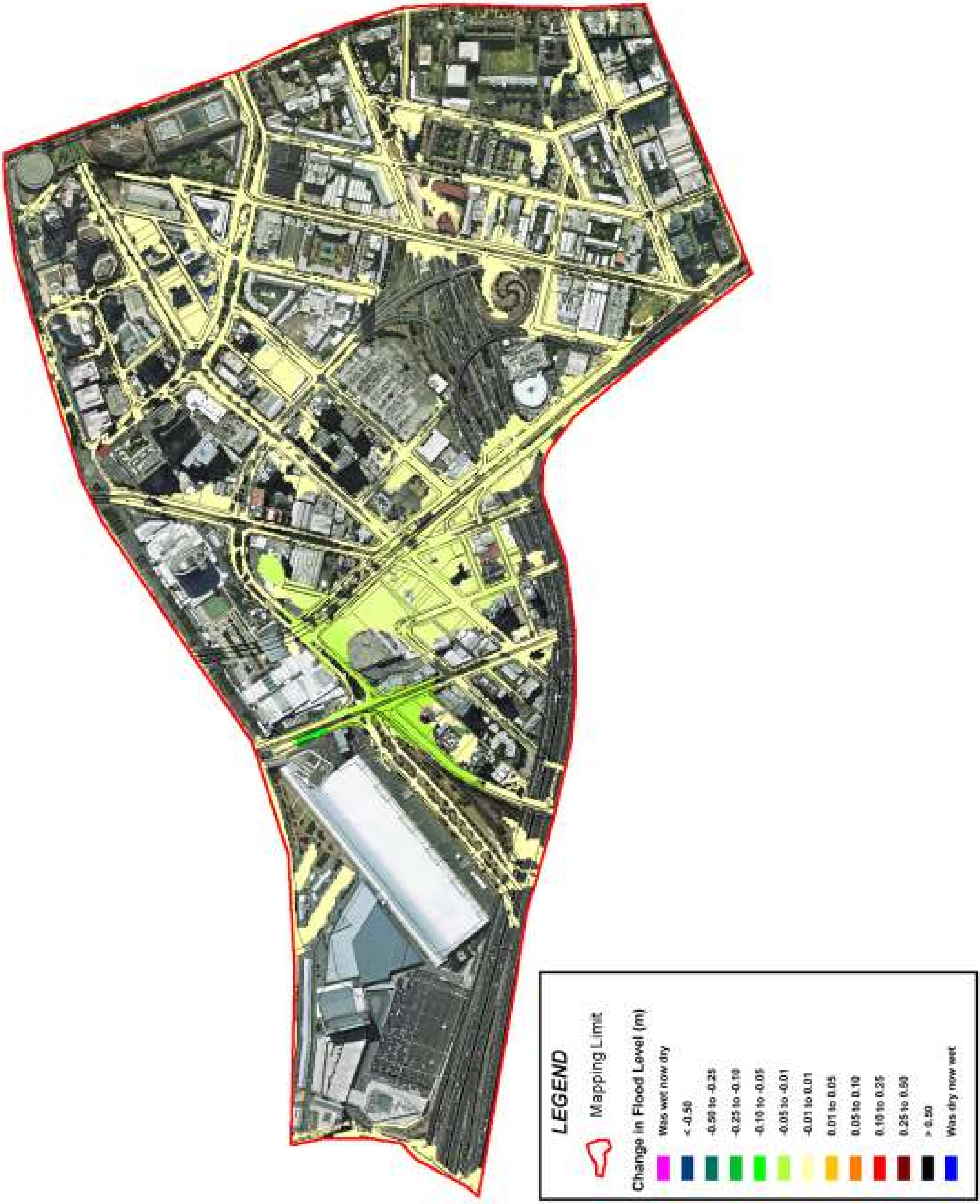
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-33_FldDif_D02_E01_20y_Storm_RevA.WOR



Title:

Southbank - Pipe

Change in 50 Year ARI Peak Flood Heights - Storm

Figure: **B-34**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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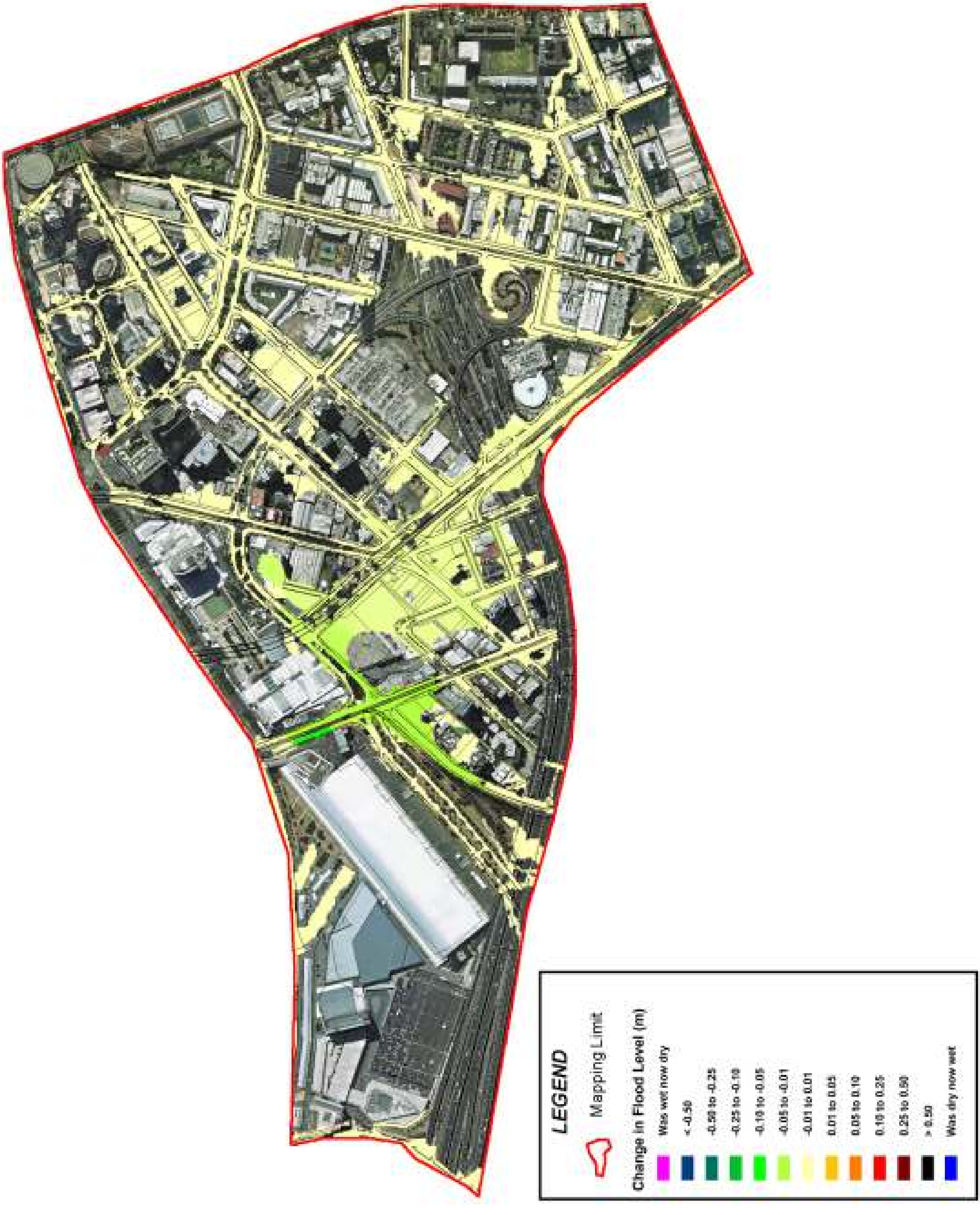
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-34_FldDif_D02_E01_50y_Storm_RevA.WOR



Title:

Southbank - Pipe

Change in 100 Year ARI Peak Flood Heights - Storm

Figure: **B-35**

Rev: **A**

N

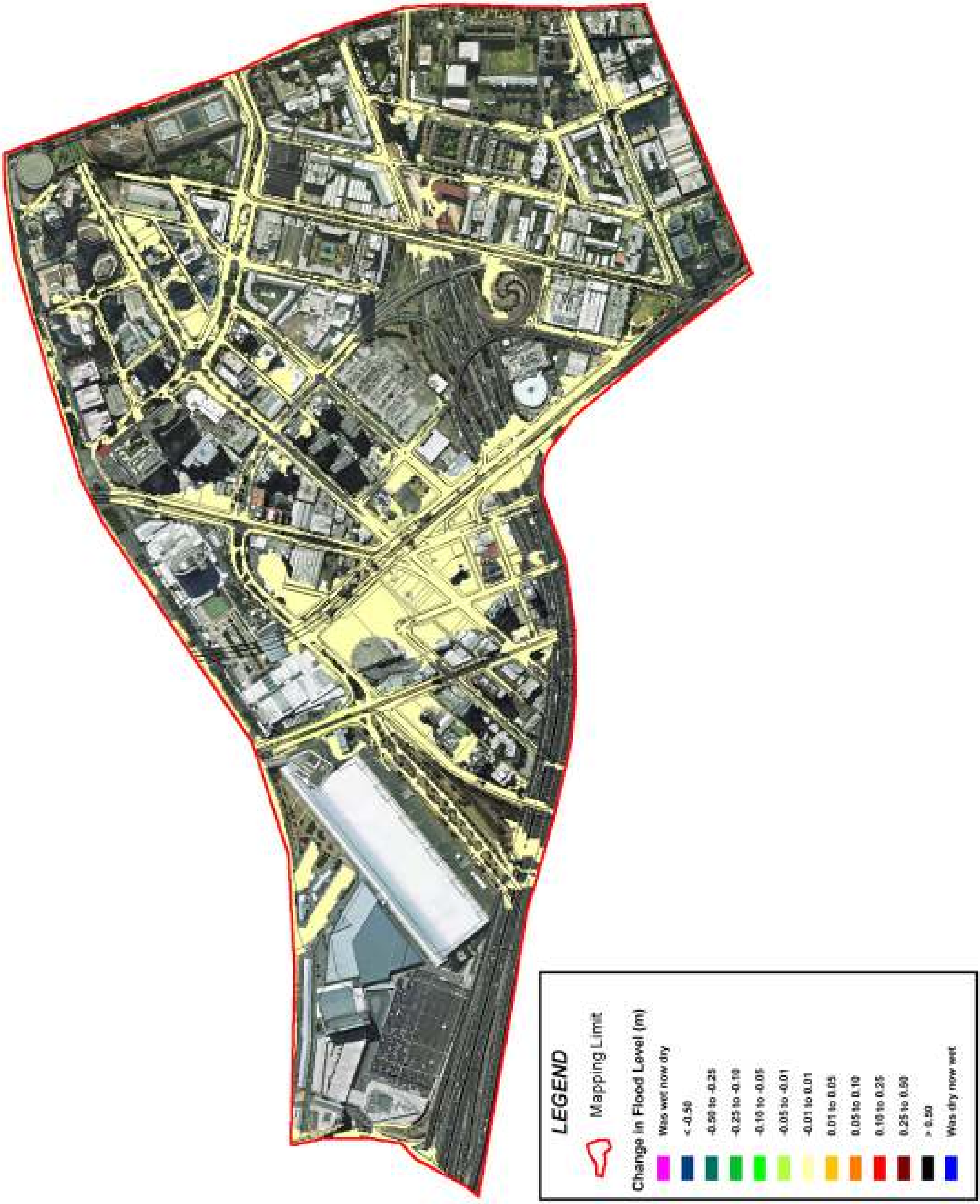
0 125 250m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

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**

N

0 125 250m
Approx. Scale

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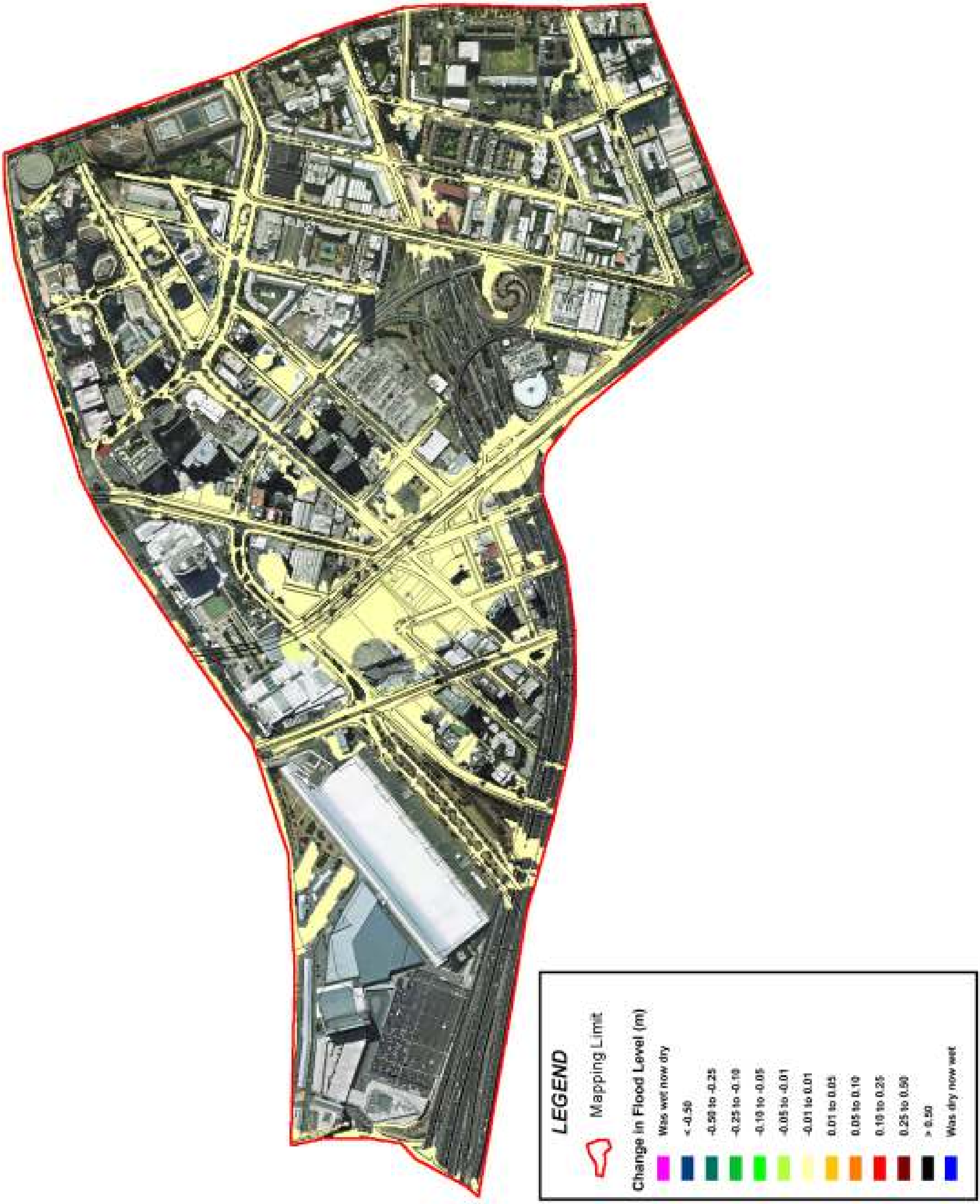
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-36_FldDif_D02_E01_5y_Yarra100y_RevA.WOR



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

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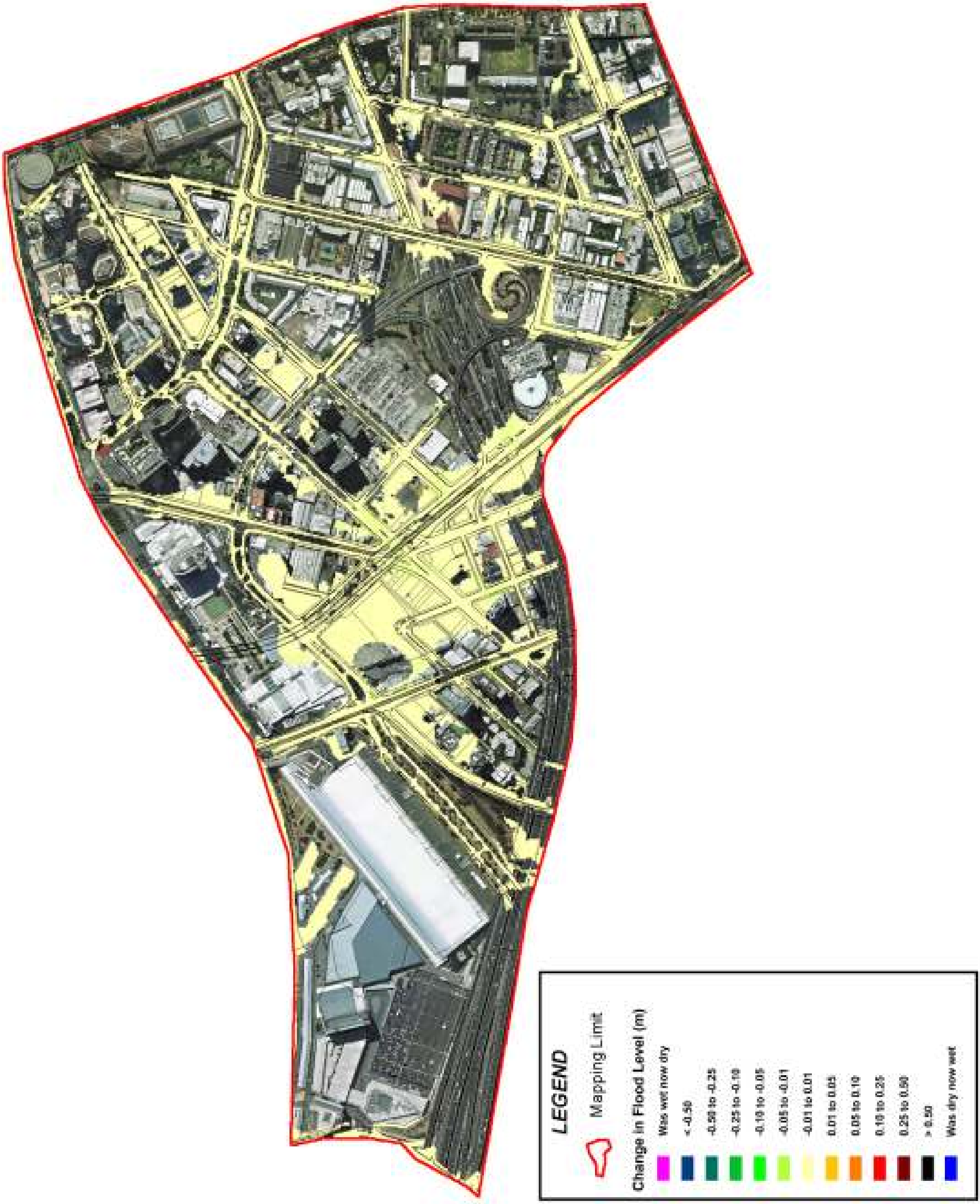
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-37_FldDif_D02_E01_10y_Yarra100y_RevA.WOR



Title:

Southbank - Pipe

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

Figure: **B-38**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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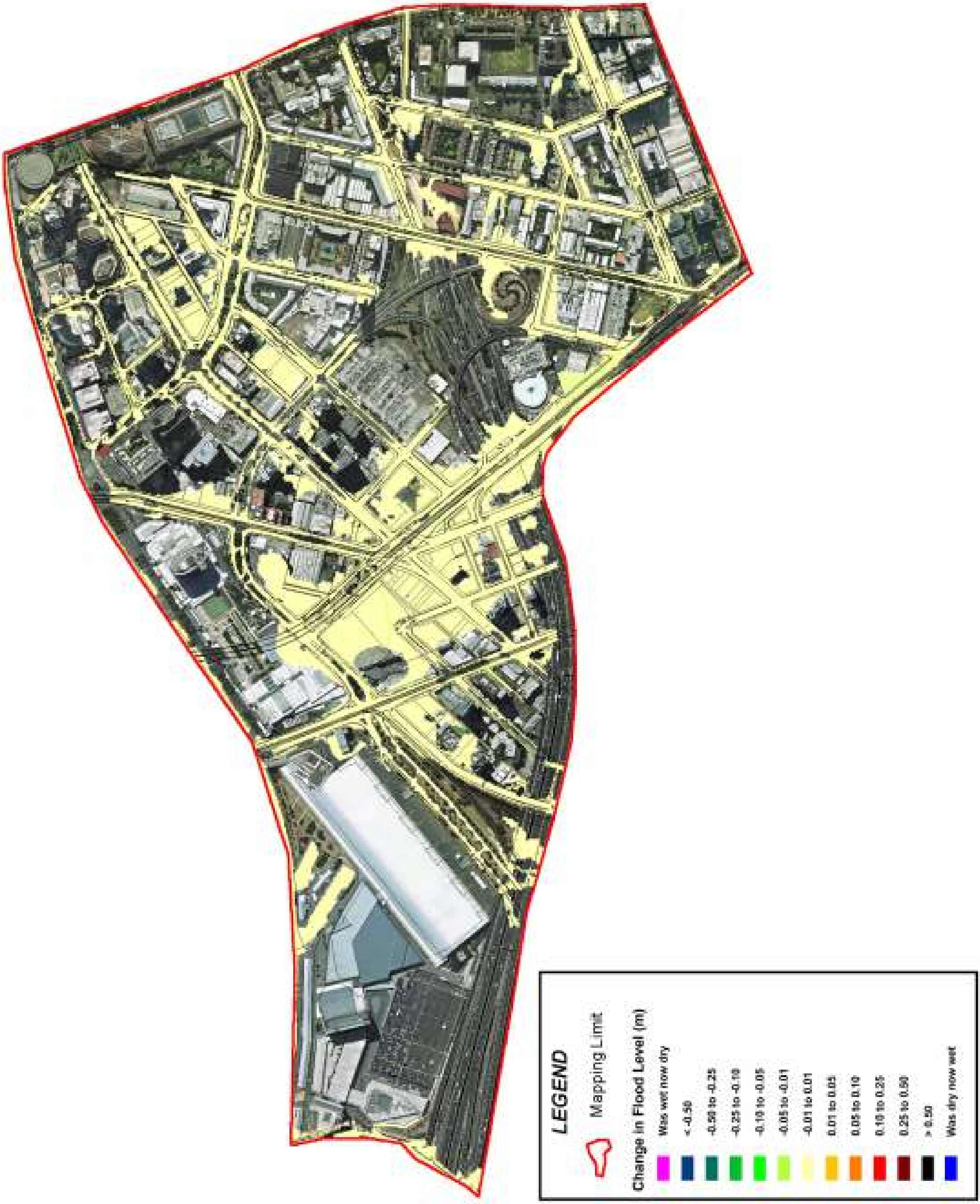
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-38_FldDif_D02_E01_20y_Yarra100y_RevA.WOR



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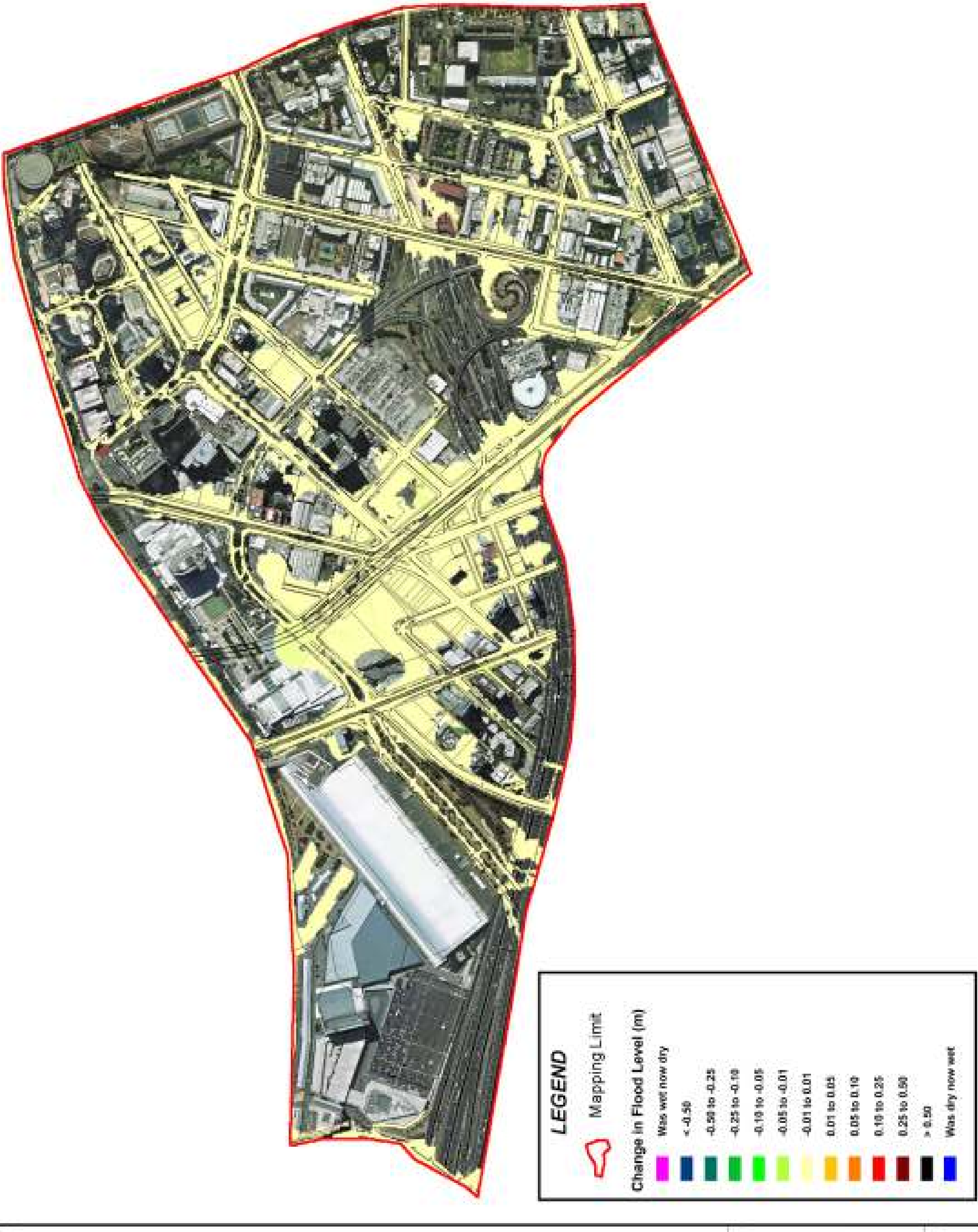
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixB\SBK_Final_FigB-39_FldDif_D02_E01_50y_Yarra100y_RevA.WOR



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

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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**

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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**

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-3_20y_MSL_C01+15%_dmax_RevA.WOR

Title:

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

Figure: C-4

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_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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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-5_100y_MSL_C01+15%_dmax_RevA.WOR

Title:

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

Figure: C-6

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\AppendixA\SBK_Final_FigC-6_5y_HAT_C01+15%_dmax_RevA.WOR

Title:

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

Figure: **C-7**

Rev: **A**

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Title:

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

Figure: **C-8**

Rev: **A**

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Title:

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

Figure: C-9

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-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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0 125 250m

Approx. Scale

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Title:

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

Figure: **C-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\AppendixC\SBK_Final_FigC-11_5y_Storm_C01+15%_dmax_RevA.WOR

Title:

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

Figure: **C-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\AppendixC\SBK_Final_FigC-12_10y_Storm_C01+15%_dmax_RevA.WOR

Title:

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

Figure: **C-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\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

N

0 125 250m
Approx. Scale

BMT WBM
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Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-14_50y_Storm_C01+15%_dmax_RevA.WOR

Title:

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

Figure: **C-15**

Rev: **A**

N

0 125 250m
Approx. Scale

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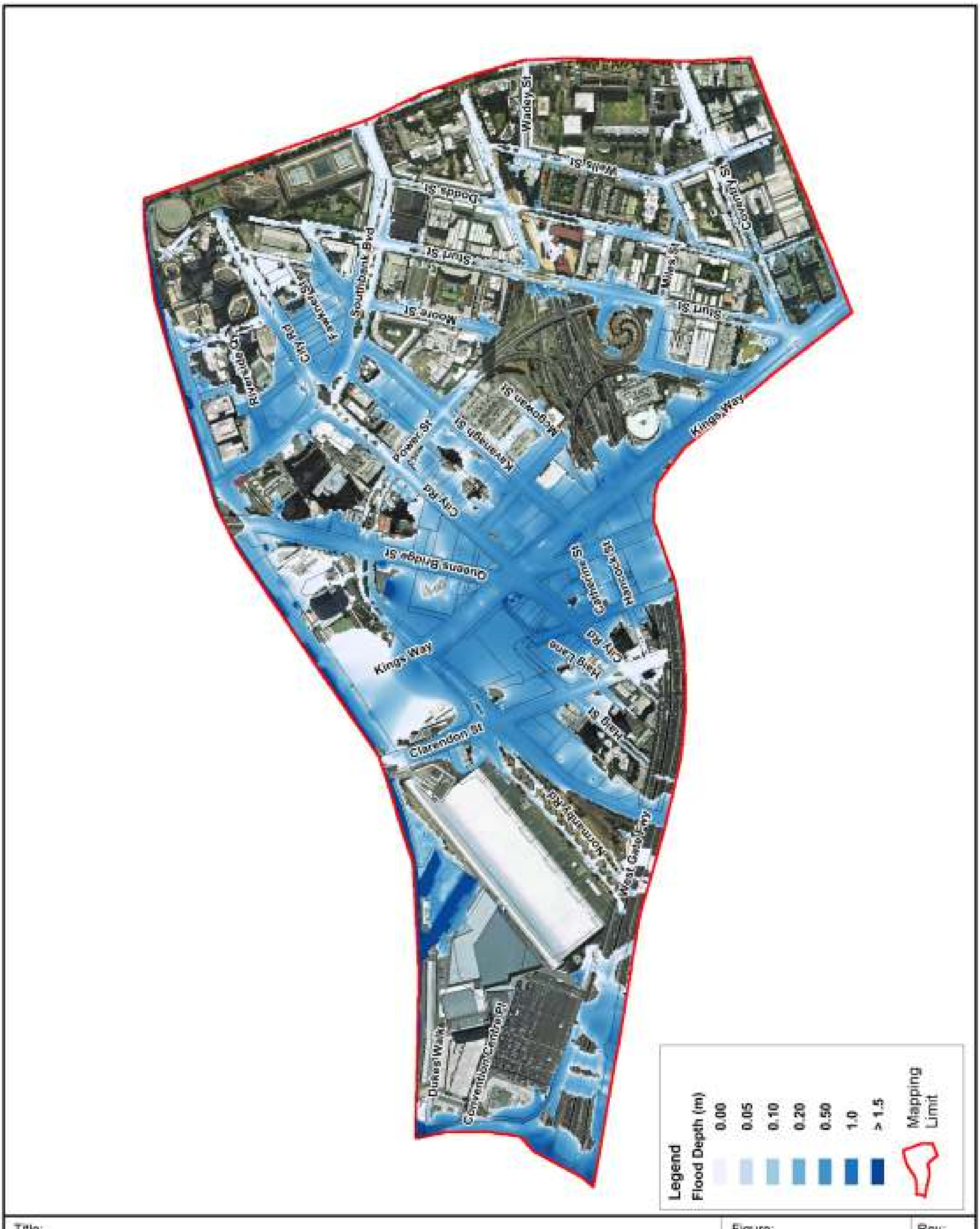
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-15_100y_Storm_C01+15%_dmax_RevA.WOR



Title:

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

Figure: C-16

Rev: A

N

0 125 250m
Approx. Scale

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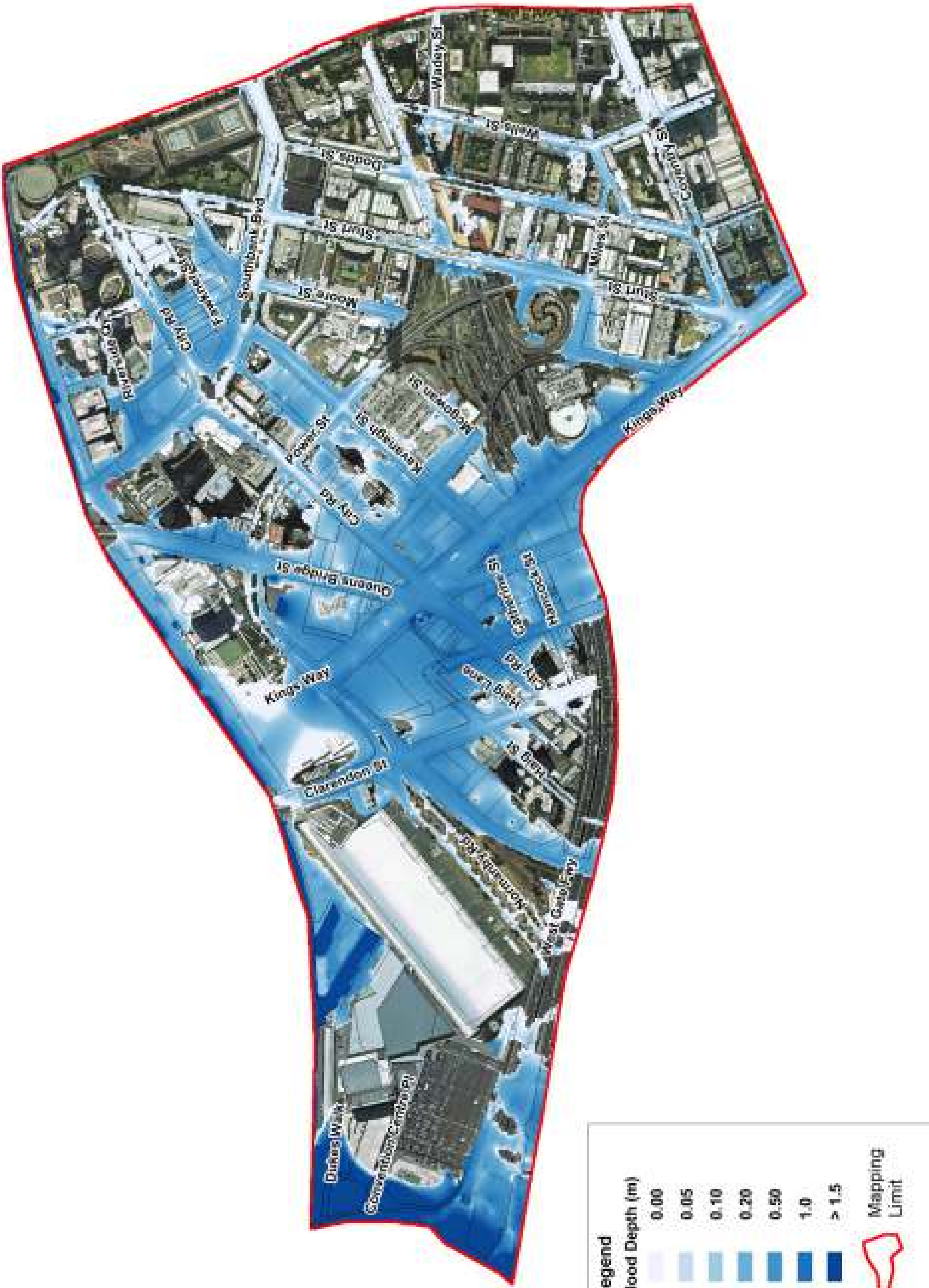
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-16_5y_Yarra100y_C01+15%_dmax_RevA.WOR



Title:

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

Figure: **C-17**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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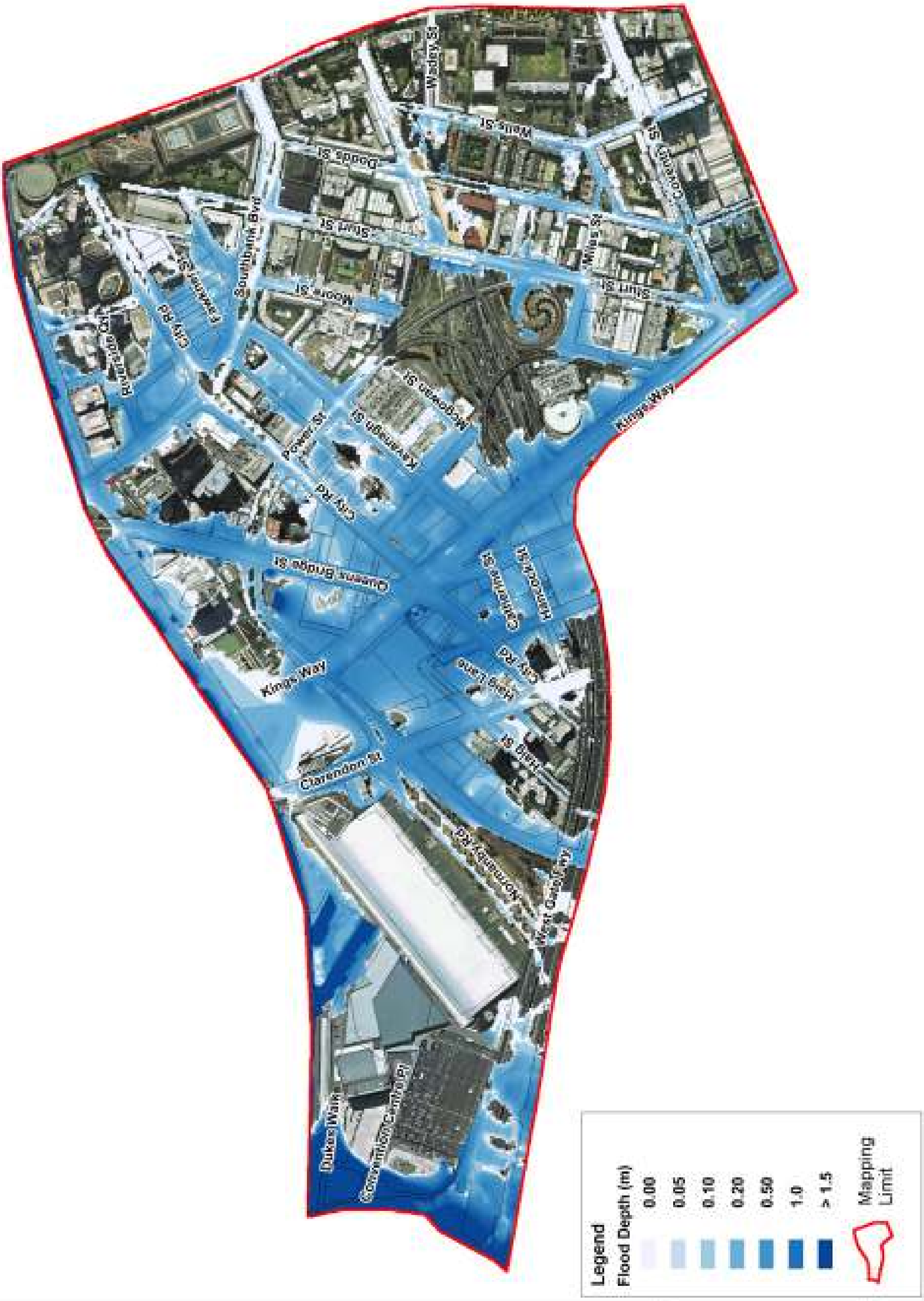
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-17_10y_Yarra100y_C01+15%_dmax_RevA.WOR



Title:

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

Figure:
C-18

Rev:
A

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Approx. Scale

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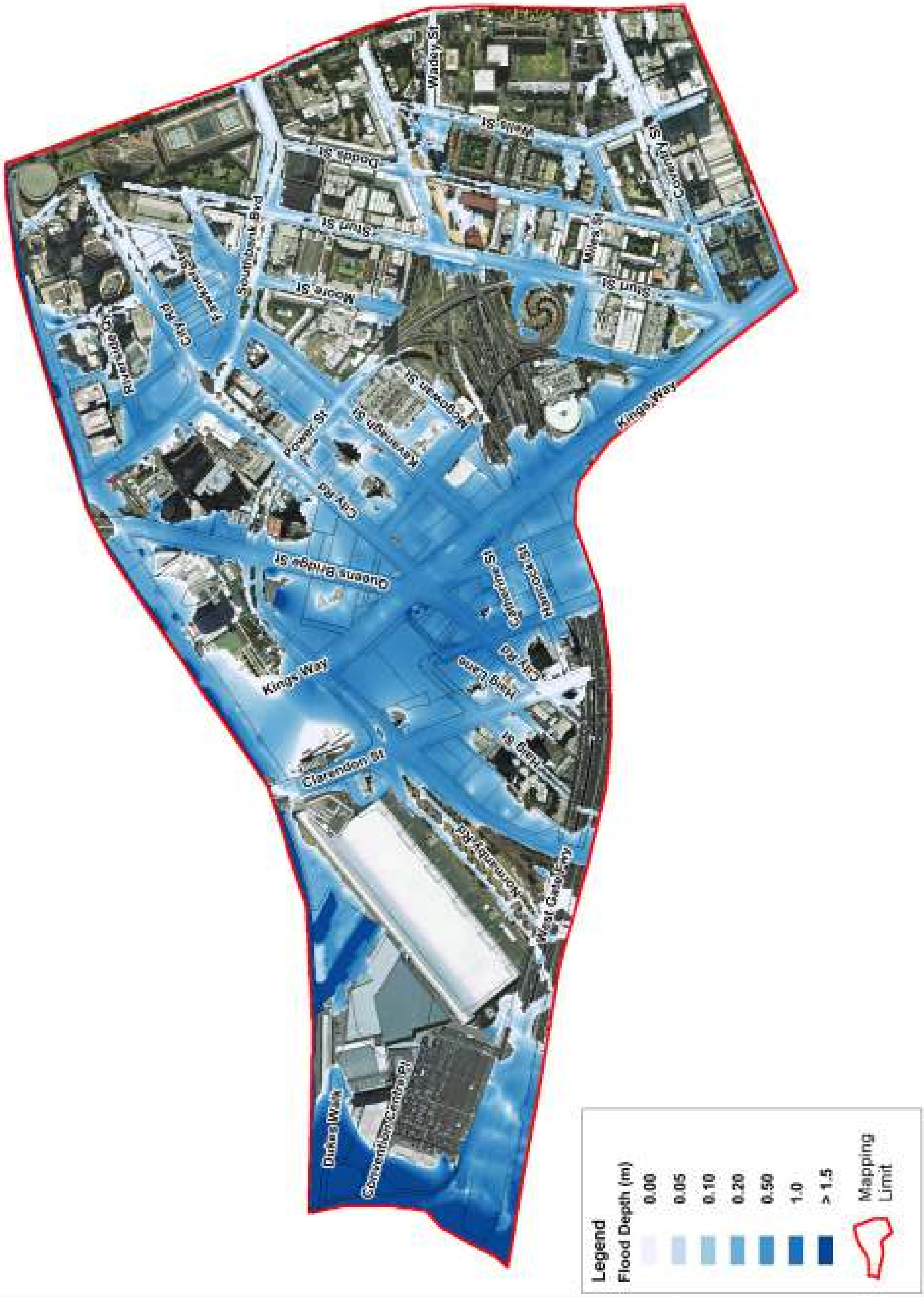

Title:

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

Figure:
C-19

Rev:
A

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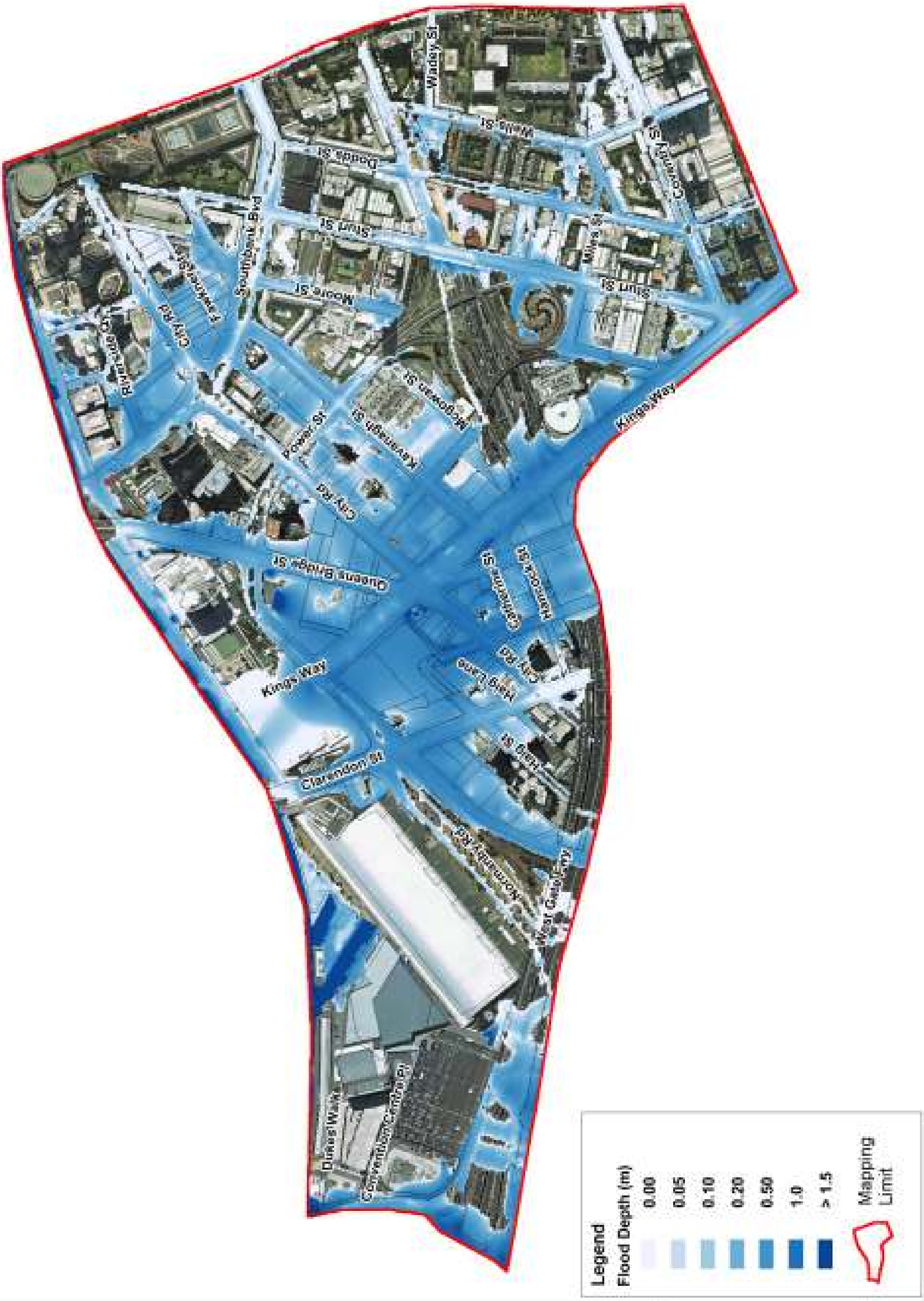
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-19_50y_Yarra100y_C01+15%_dmax_RevA.WOR



Title:

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

Figure: **C-20**

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-20_100y_Yarra100y_C01+15%_dmax_RevA.WOR

Title:

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

Figure: **C-21**

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_FigC-21_5y_MSL_C02+32%_dmax_RevA.WOR

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

Figure:
C-22

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_FigC-22_10y_MSL_C02+32%_dmax_RevA.WOR

Title:

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

Figure:

C-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\AppendixA\SBK_Final_FigC-23_20y_MSL_C02+32%_dmax_RevA.WOR

Title:

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

Figure: **C-24**

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-24_50y_MSL_C02+32%_dmax_RevA.WOR

Title:

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

Figure: C-25

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\AppendixA\SBK_Final_FigC-25_100y_MSL_C02+32%_dmax_RevA.WOR

Title:

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

Figure: **C-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\AppendixA\SBK_Final_FigC-26_5y_HAT_C02+32%_dmax_RevA.WOR

Title:

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

Figure:

C-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\AppendixA\SBK_Final_FigC-27_10y_HAT_C02+32%_dmax_RevA.WOR

Title:

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

Figure: **C-28**

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-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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N

0 125 250m
Approx. Scale

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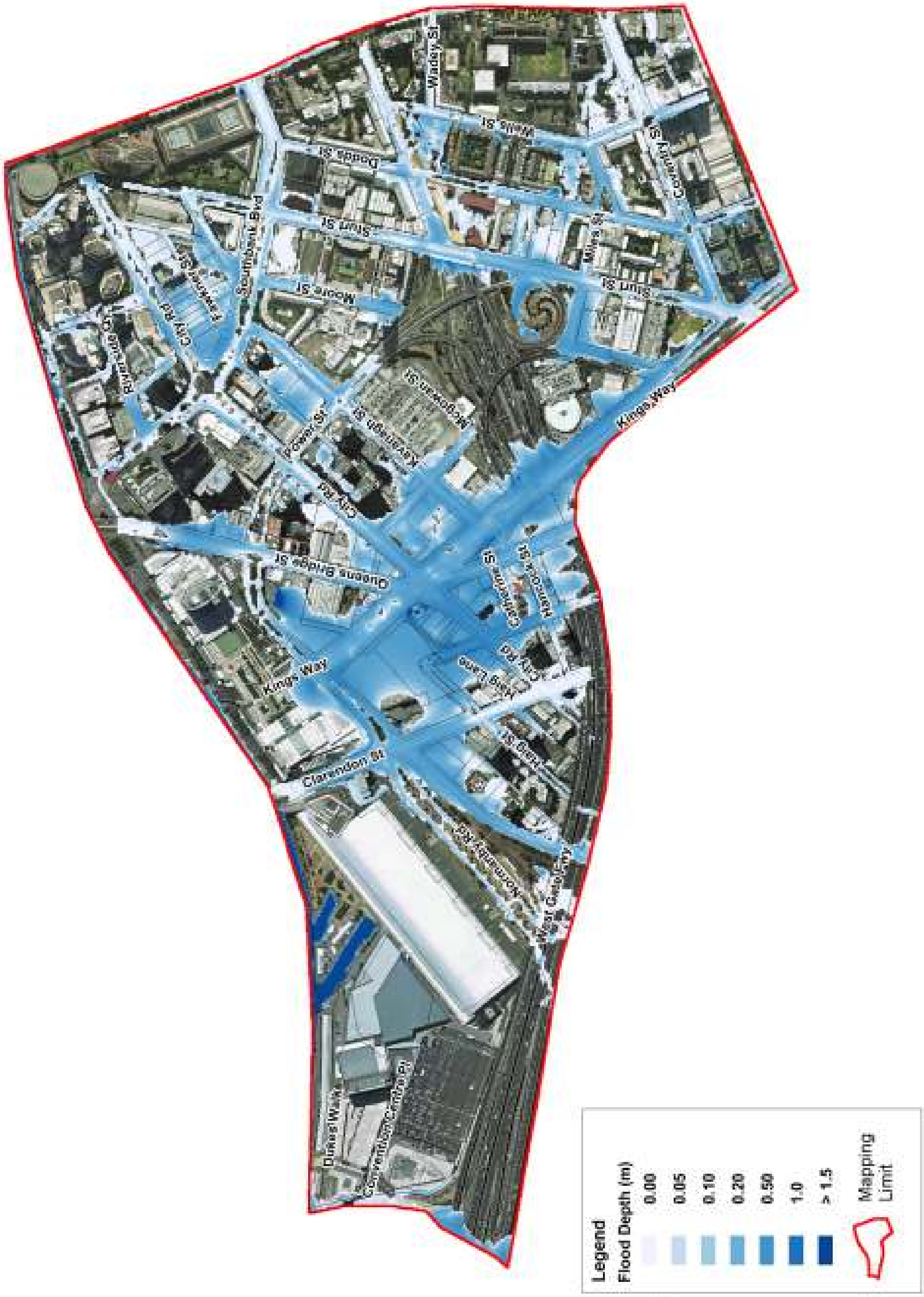
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixA\SBK_Final_FigC-29_50y_HAT_C02+32%_dmax_RevA.WOR



Title:

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

Figure:
C-30

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-30_100y_HAT_C02+32%_dmax_RevA.WOR

Title:

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

Figure: **C-31**

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\AppendixC\SBK_Final_FigC-31_5y_Storm_C02+32%_dmax_RevA.WOR

Title:

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

Figure: **C-32**

Rev: **A**

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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-32_10y_Storm_C02+32%_dmax_RevA.WOR

Title:

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

Figure: **C-33**

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\AppendixC\SBK_Final_FigC-33_20y_Storm_C02+32%_dmax_RevA.WOR

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

Figure:
C-34

Rev:
A

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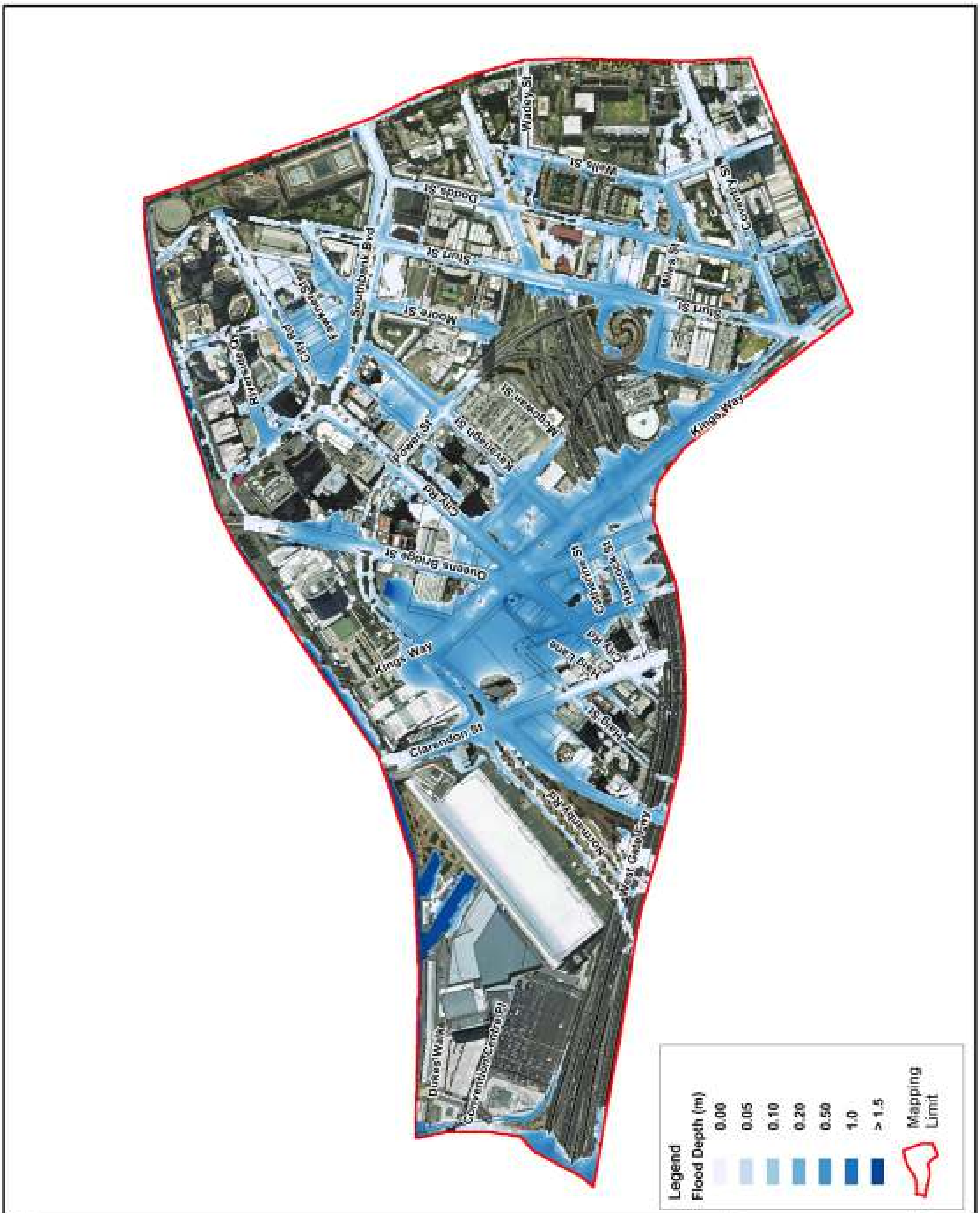
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-34_50y_Storm_C02+32%_dmax_RevA.WOR



Title:

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

Figure: **C-35**

Rev: **A**

N

0 125 250m
Approx. Scale

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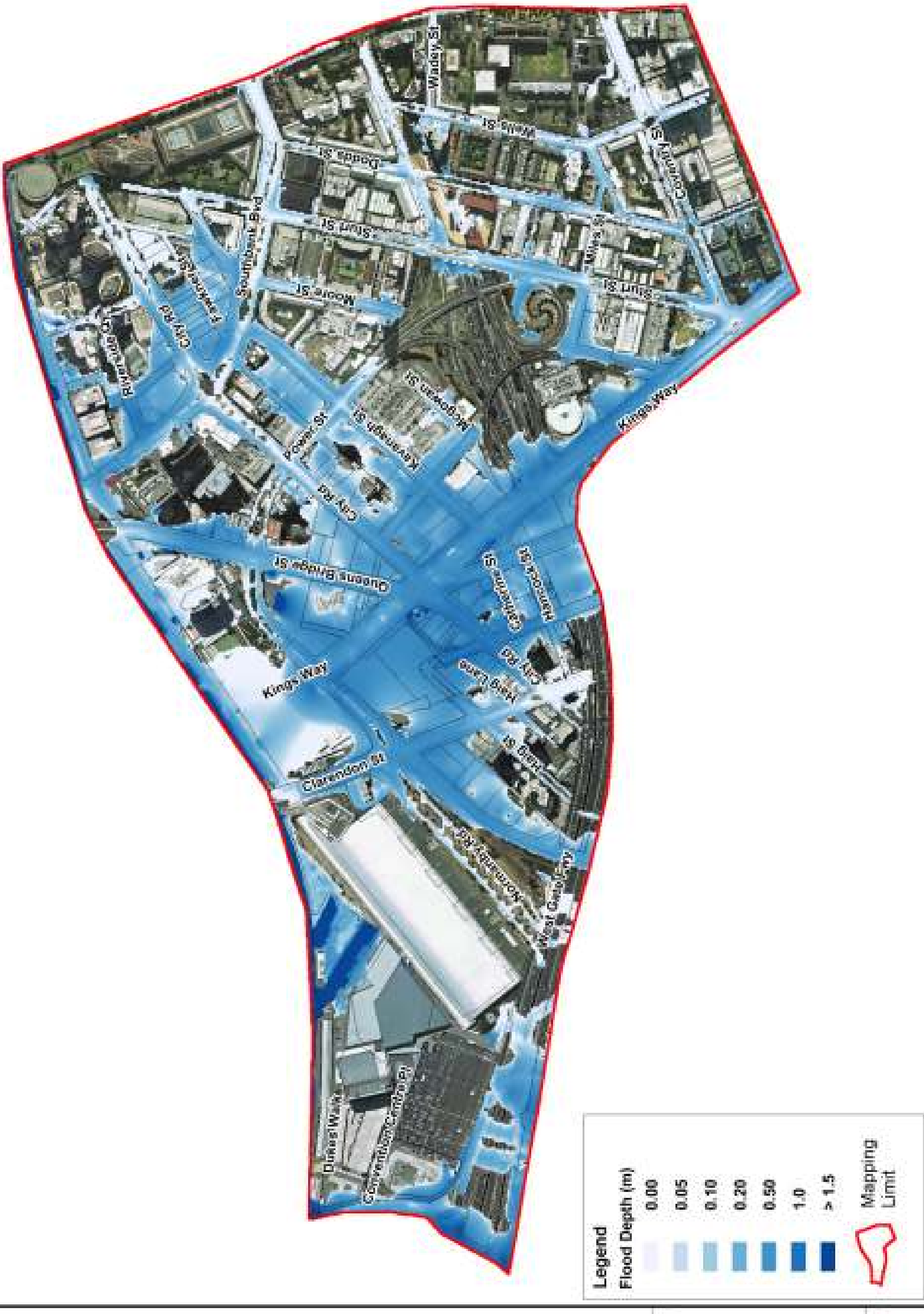
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-35_100y_Storm_C02+32%_dmax_RevA.WOR



Title:

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

Figure: **C-36**

Rev: **A**

N

0 125 250m

Approx. Scale

BMT WBM

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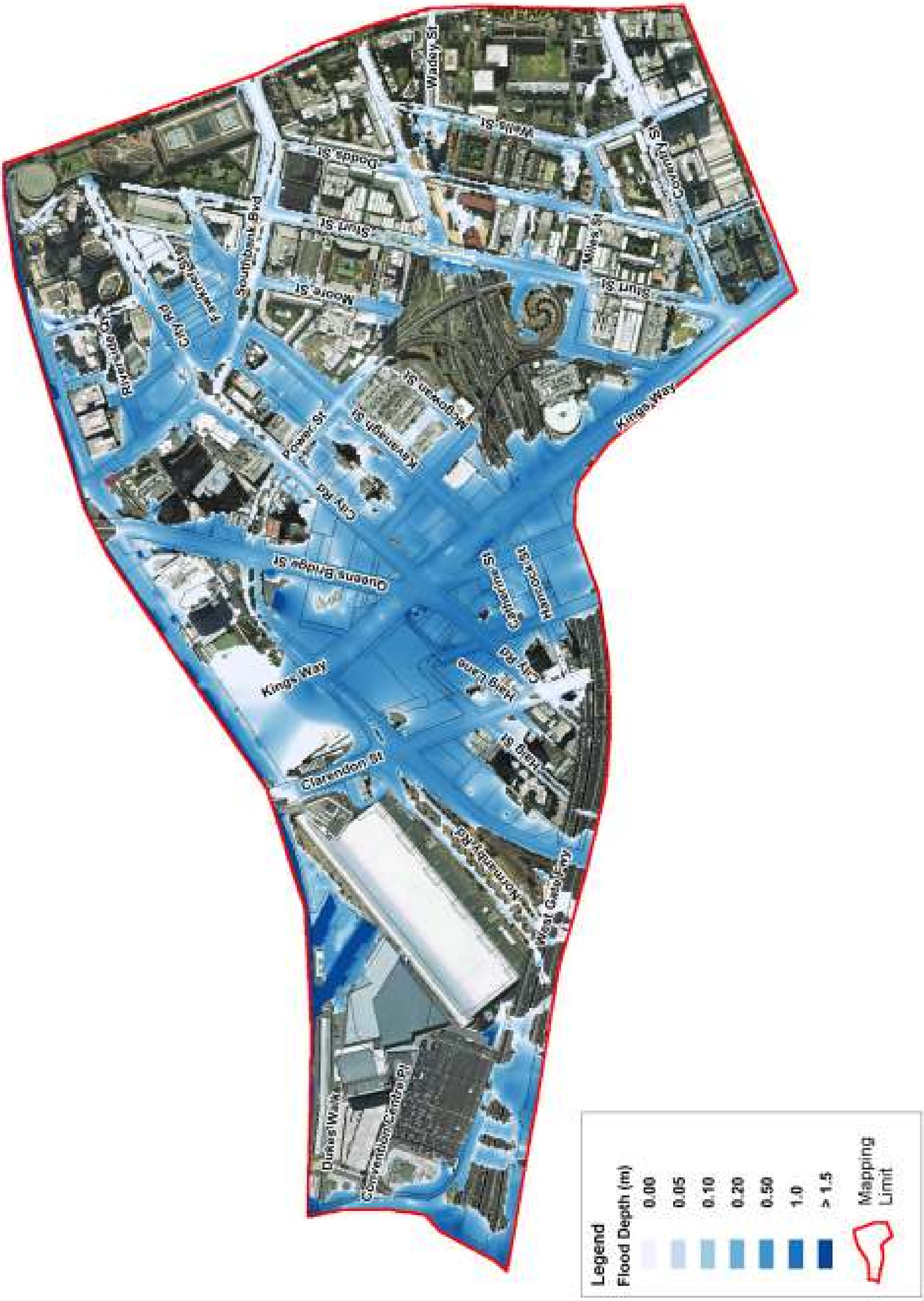
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-36_5y_Yarra100y_C02+32%_dmax_RevA.WOR



Title:

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

Figure:
C-37

Rev:
A

N

0 125 250m
Approx. Scale

BMT WBM
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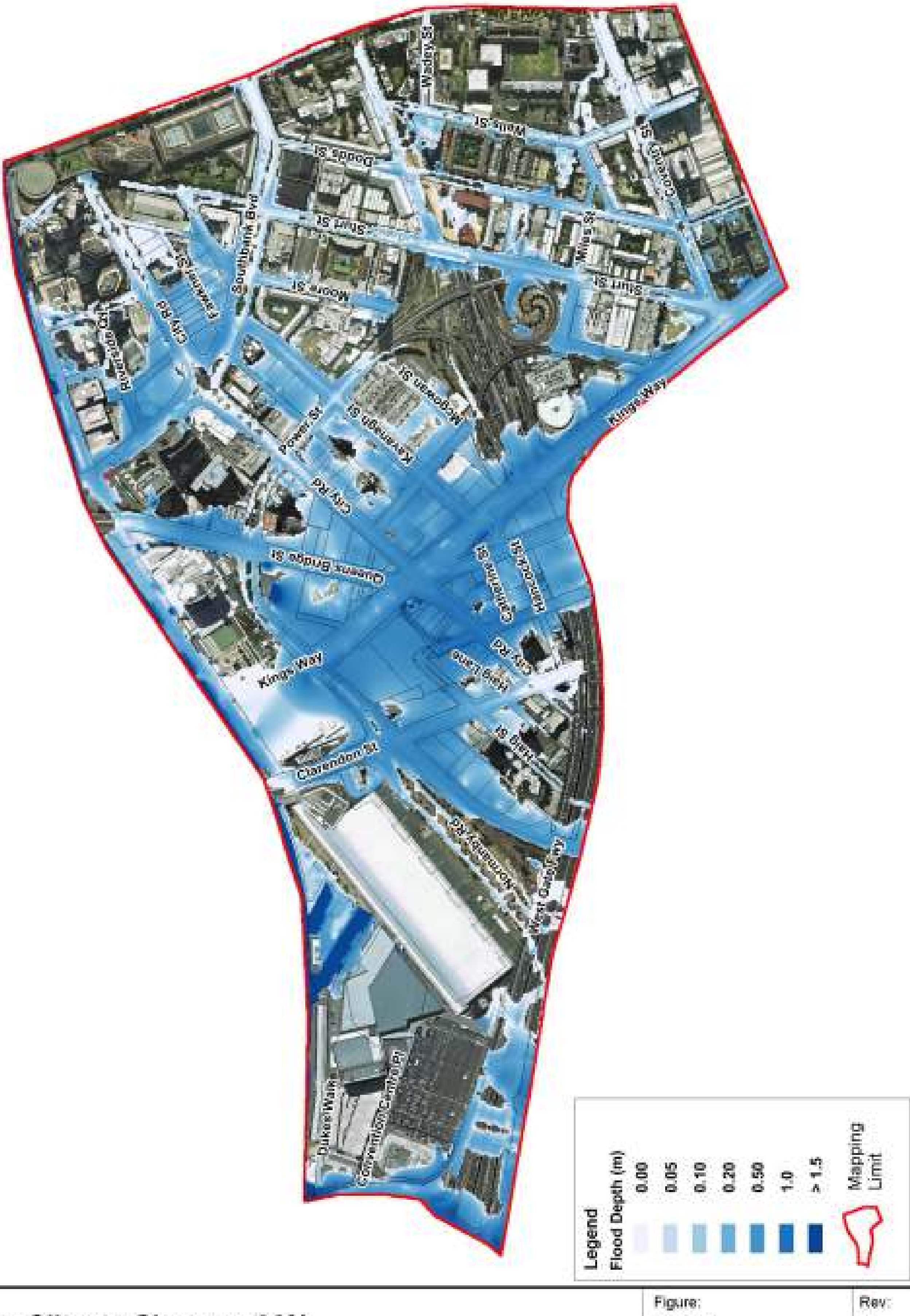
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-37_10y_Yarra100y_C02+32%_dmax_RevA.WOR



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

Figure:
C-38

Rev:
A

N

0 125 250m
Approx. Scale

BMT WBM
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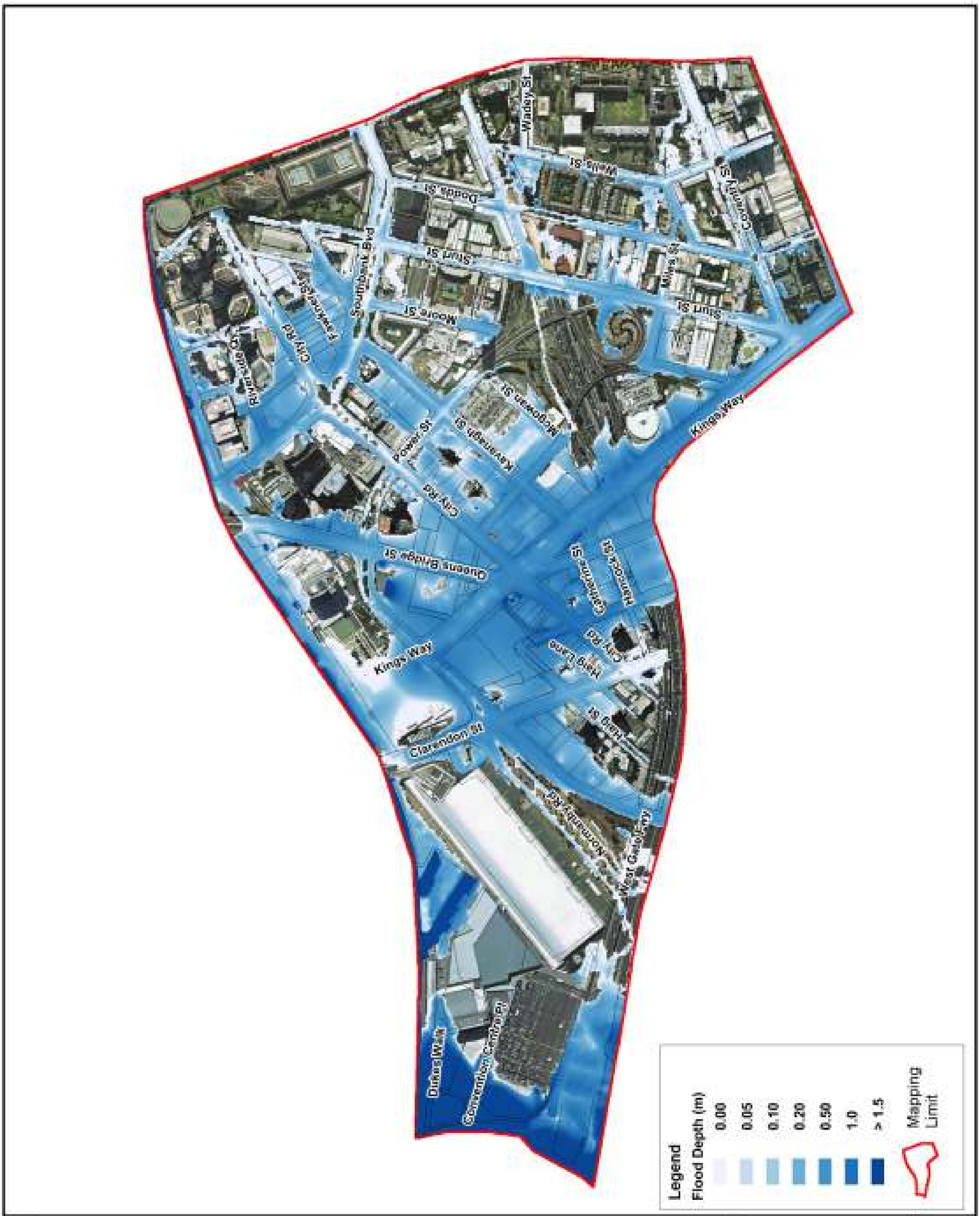
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-38_20y_Yarra100y_C02+32%_dmax_RevA.WOR



Title:

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

Figure:
C-39

Rev:
A

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Approx. Scale

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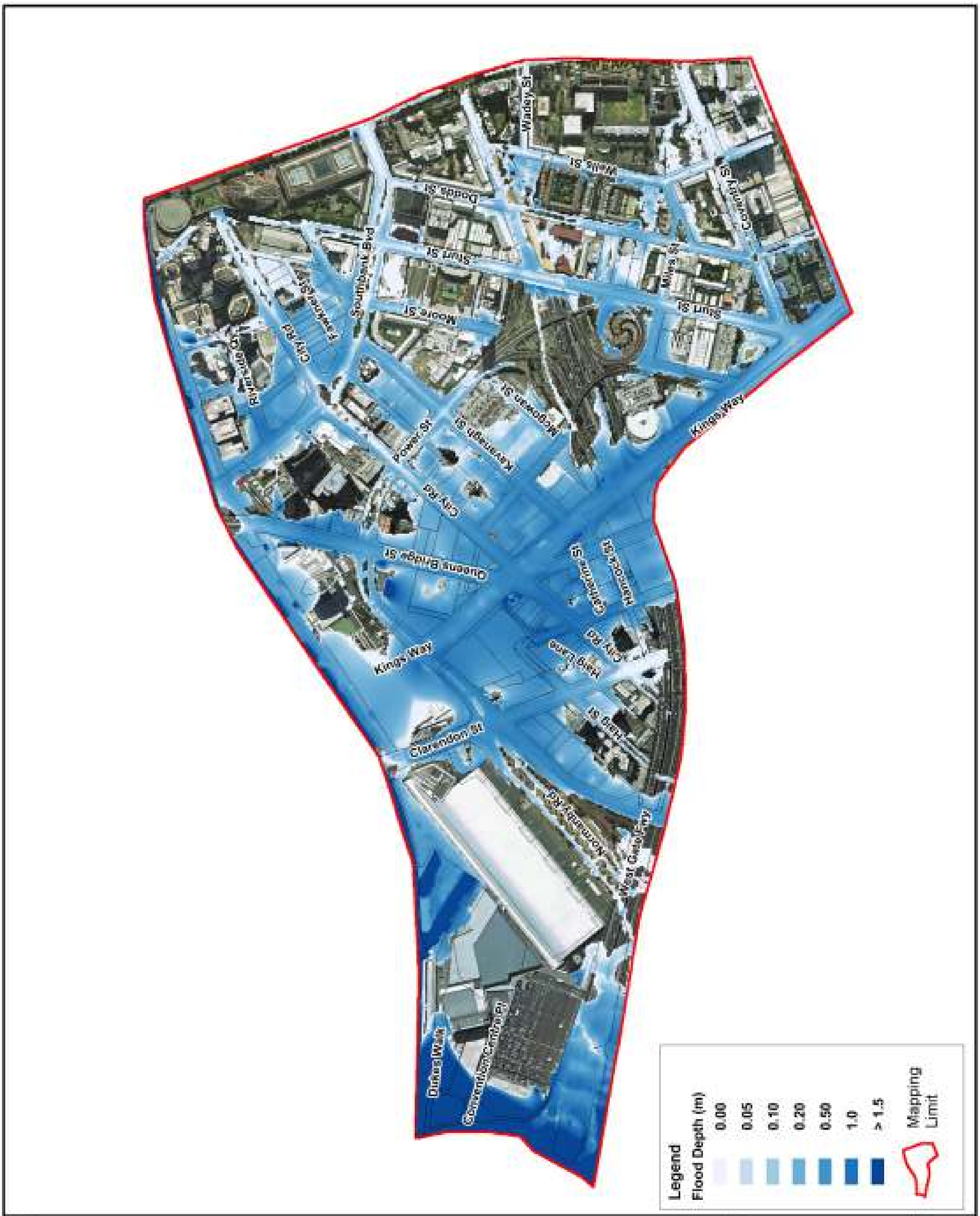
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixC\SBK_Final_FigC-39_50y_Yarra100y_C02+32%_dmax_RevA.WOR



Title:

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

Figure: **C-40**

Rev: **A**

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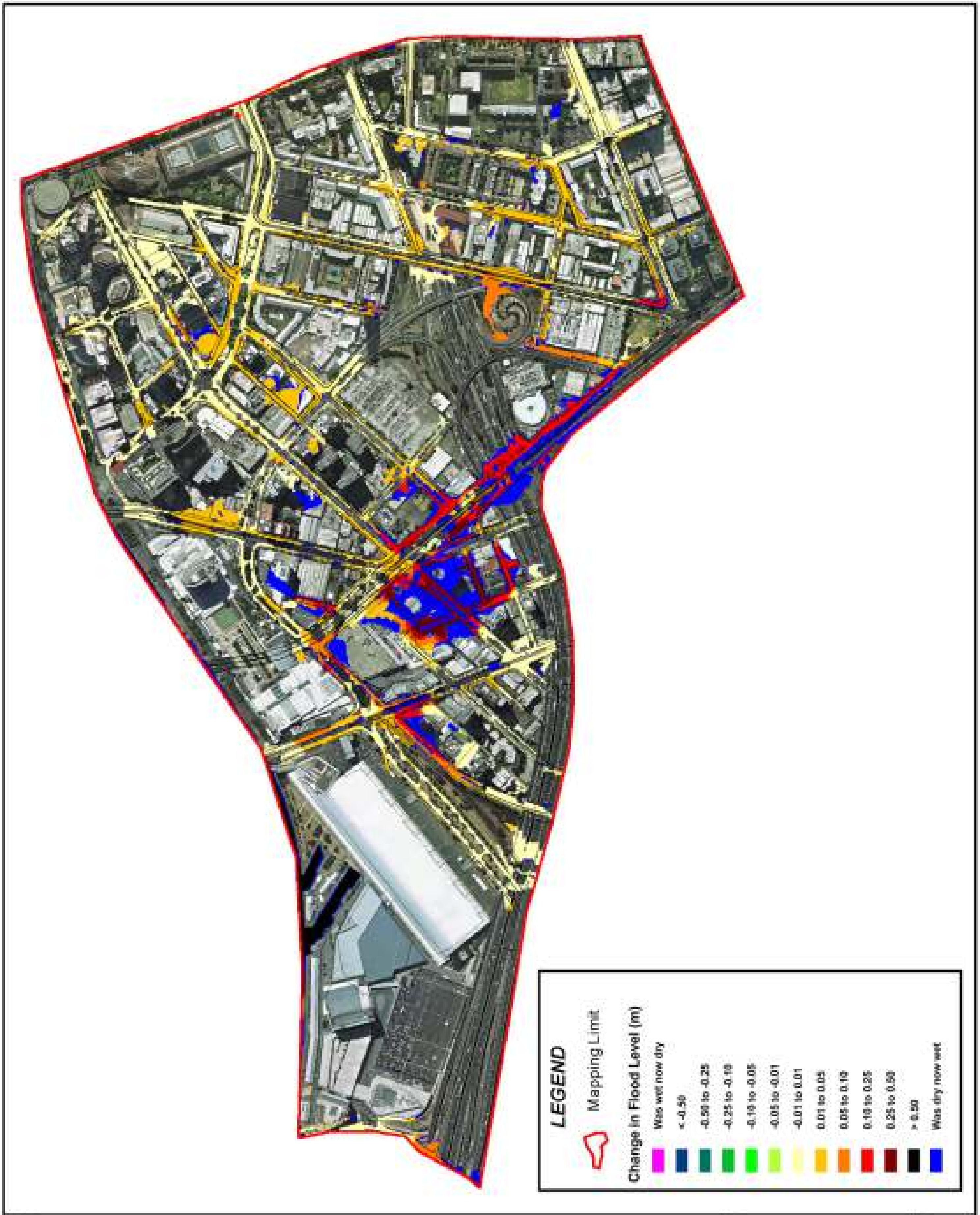
Appendix D Future Climate Mapping (Impact)



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

Figure: **D-1**

Rev: **A**

N

0 125 250m
Approx. Scale

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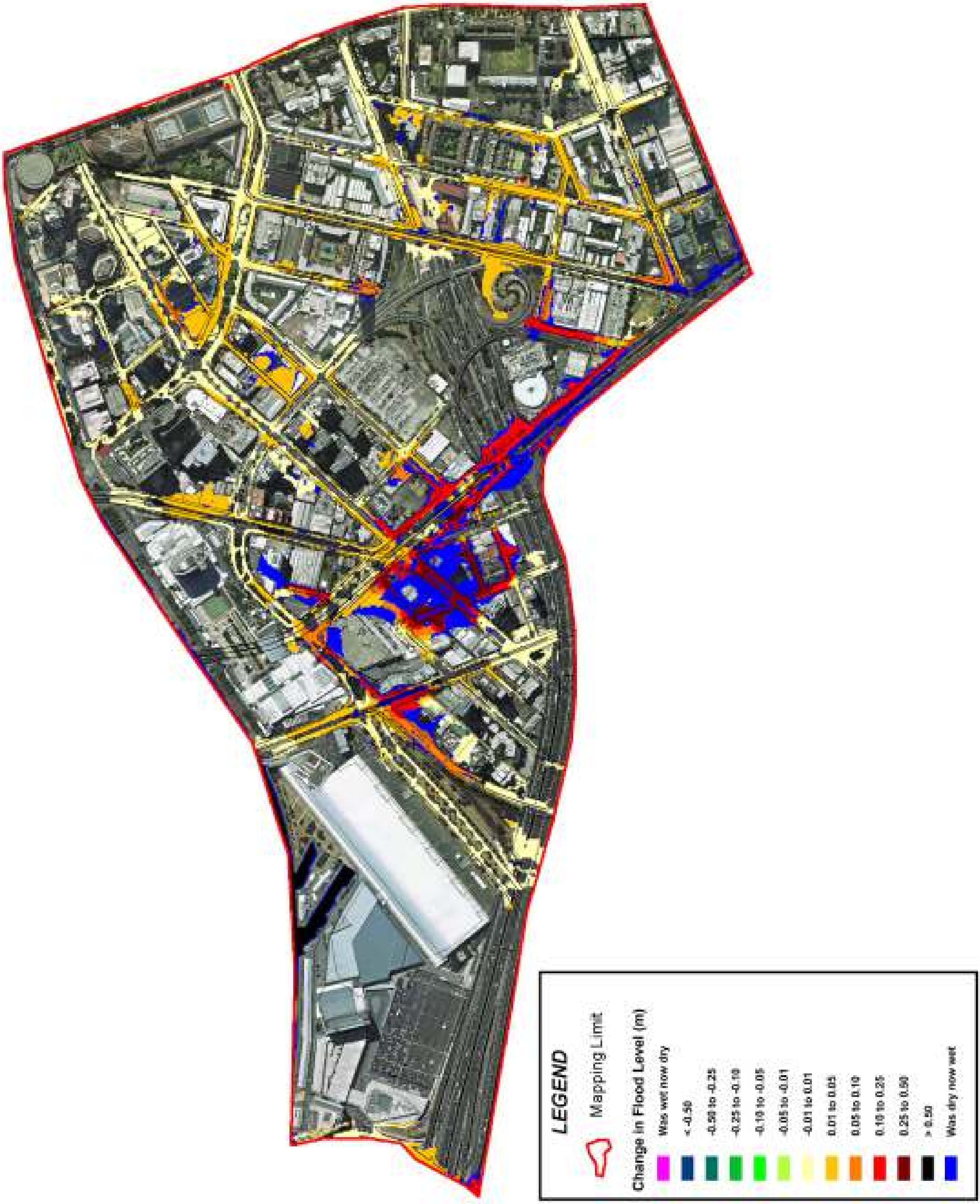
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-1_FldDif_C02_E01+15%_5y_MSL_RevA.WOR



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

Figure: **D-2**

Rev: **A**

N

0 125 250m
Approx. Scale

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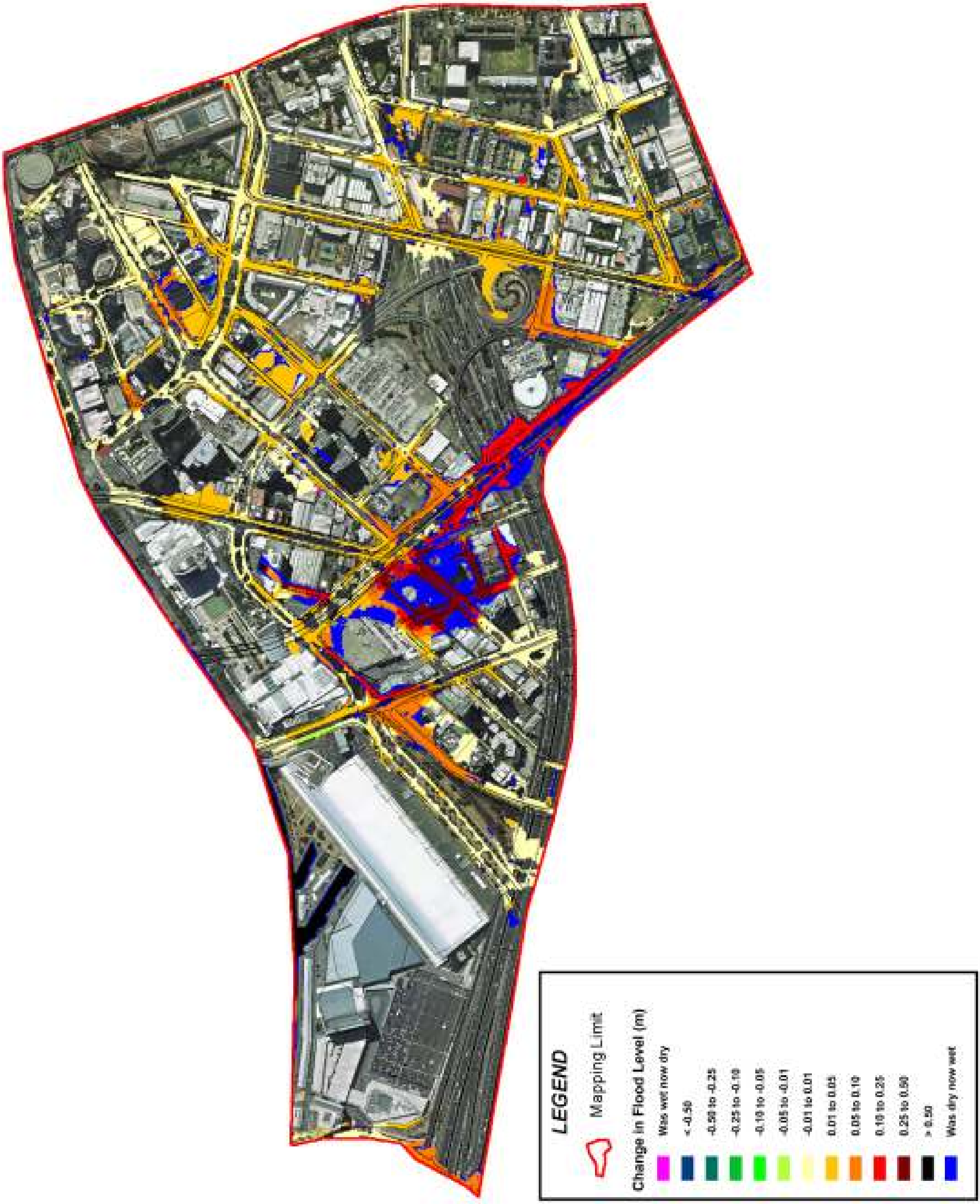
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-2_FldDif_C02_E01+15%_10y_MSL_RevA.WOR



Title:

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

Figure: **D-3**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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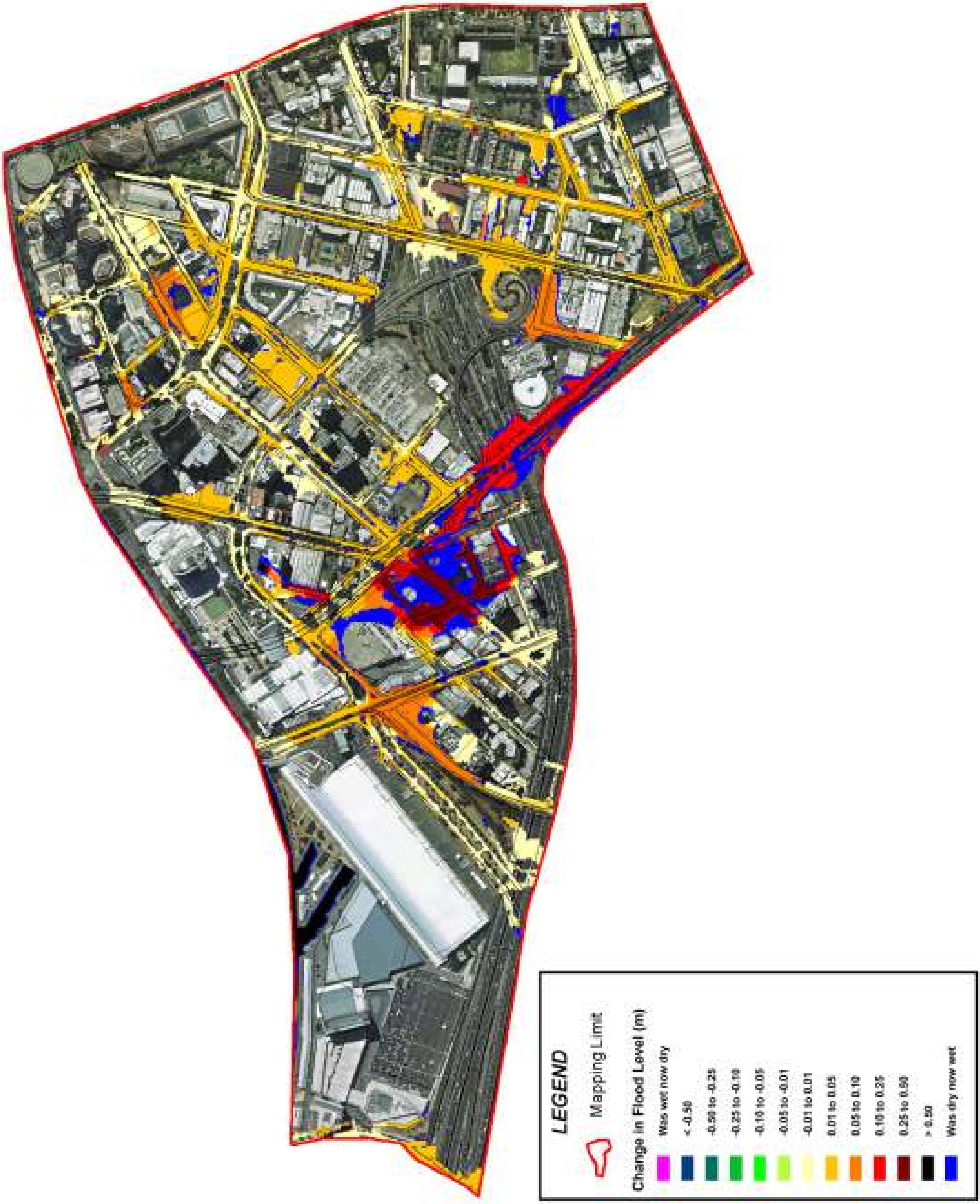
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-3_FldDif_C02_E01+15%_20y_MSL_RevA.WOR



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

Figure: **D-4**

Rev: **A**

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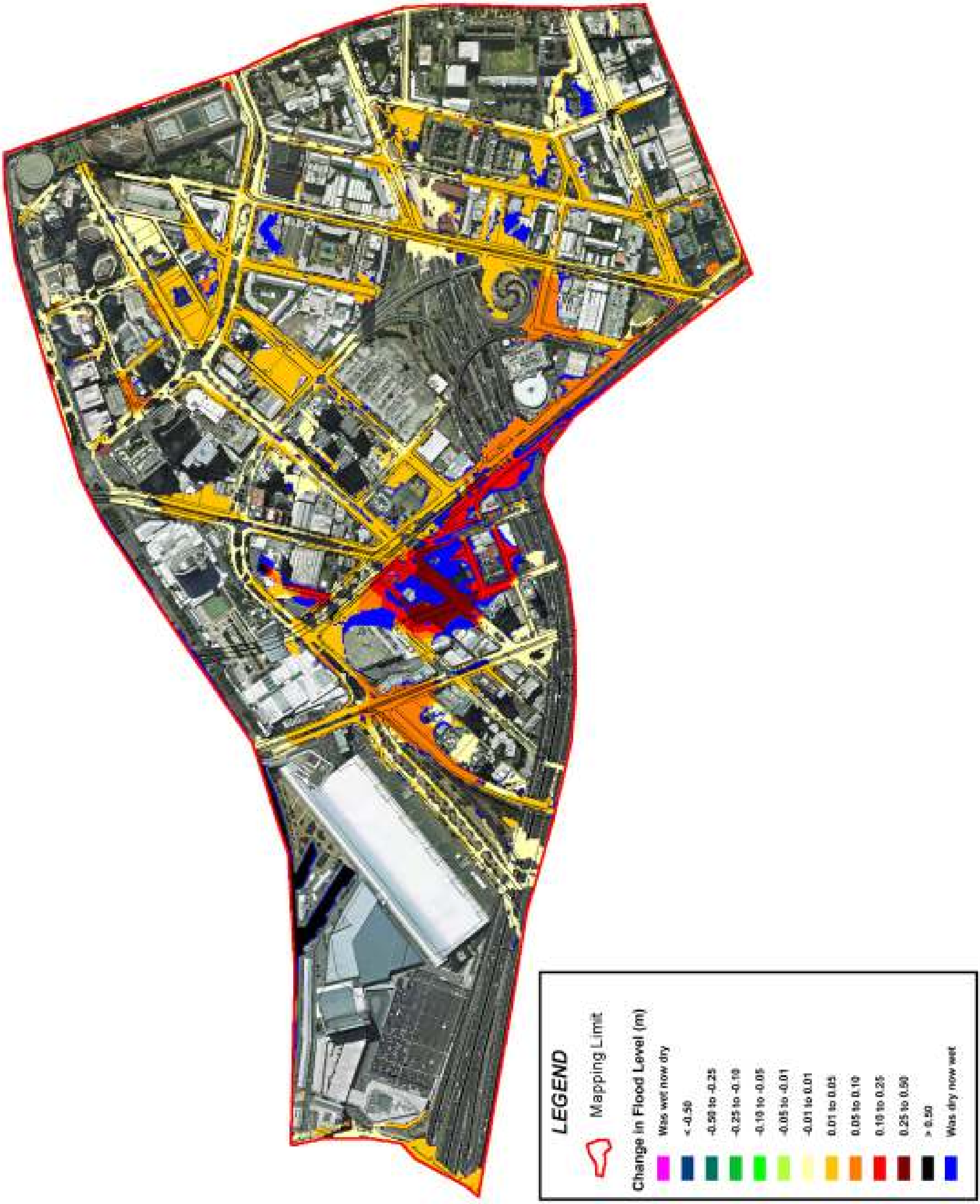
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-4_FldDif_C02_E01+15%_50y_MSL_RevA.WOR



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

Figure: **D-5**

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

0 125 250m
Approx. Scale

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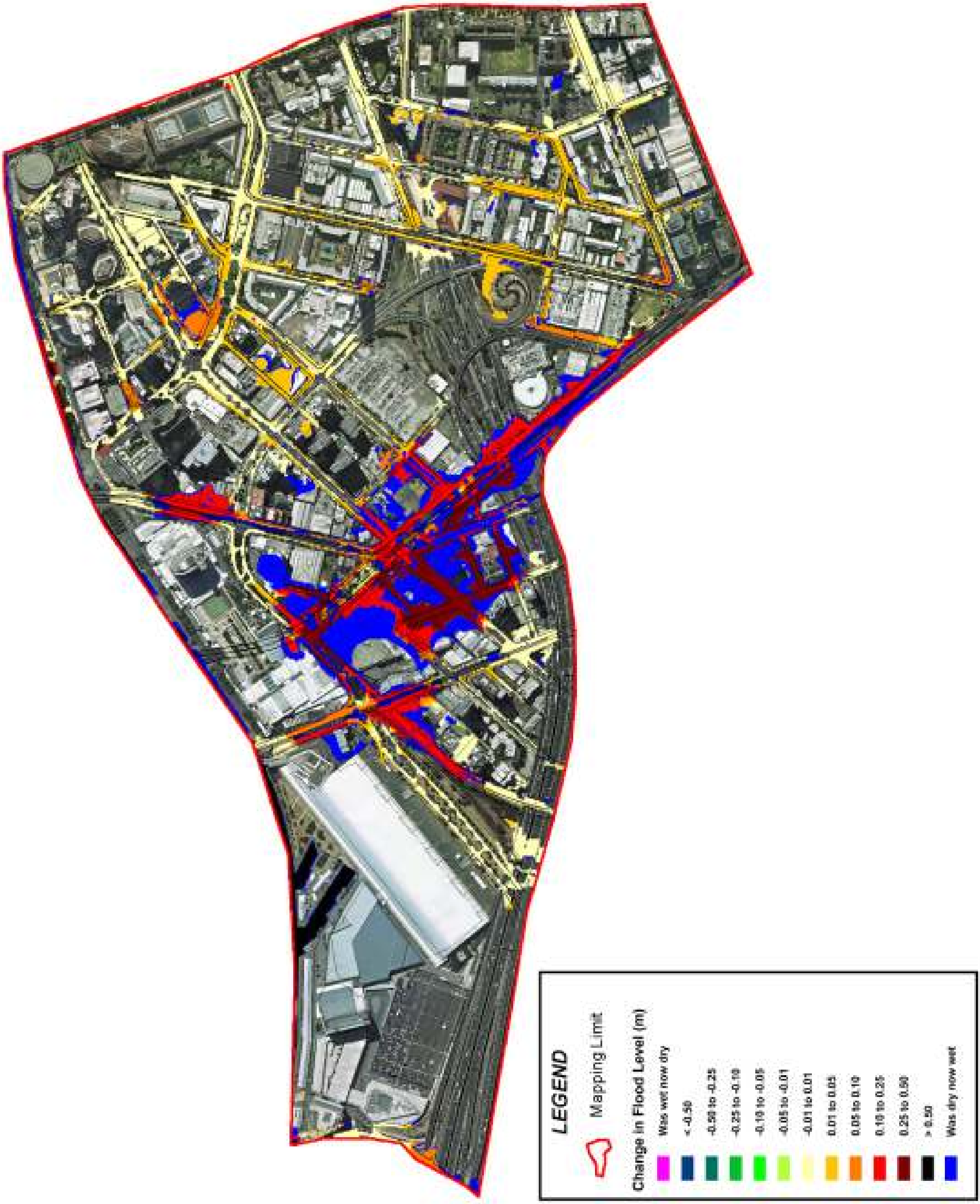
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-5_FldDif_C02_E01+15%_100y_MSL_RevA.WOR



Title:

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

Figure: **D-6**

Rev: **A**

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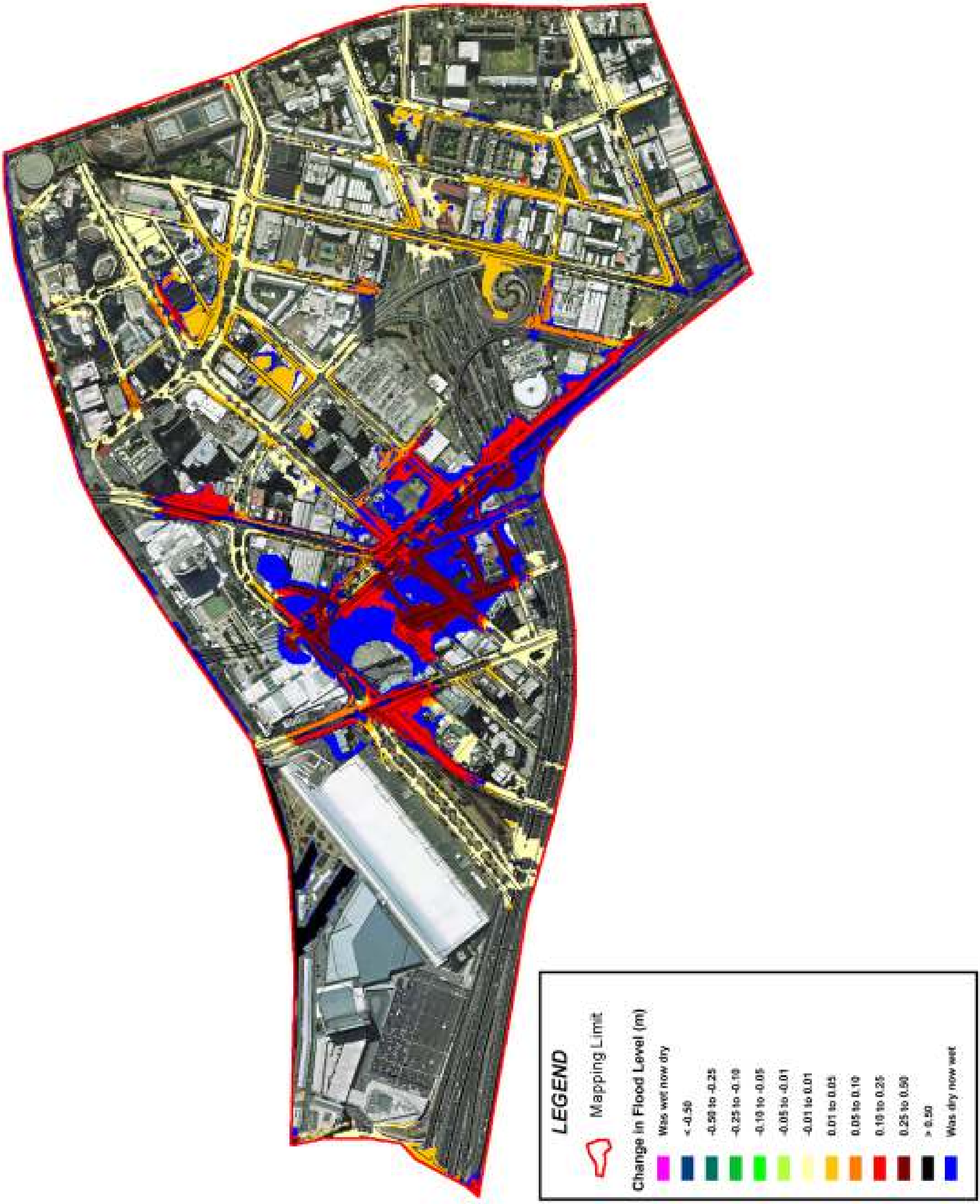
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-6_FldDif_C02_E01+15%_5y_Storm_RevA.WOR



Title:

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

Figure: **D-7**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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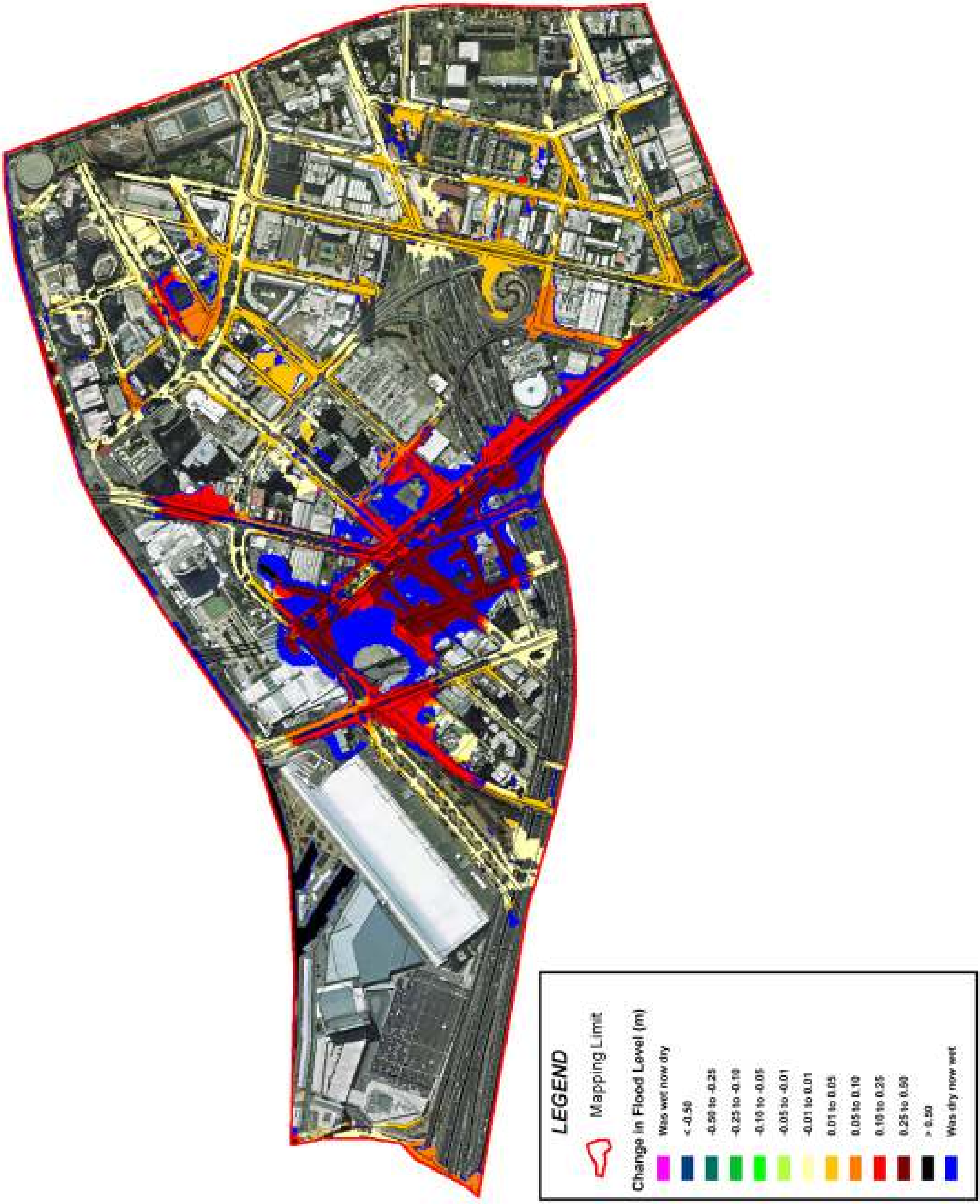
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-7_FldDif_C02_E01+15%_10y_Storm_RevA.WOR



Title:

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

Figure: **D-8**

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

0 125 250m
Approx. Scale

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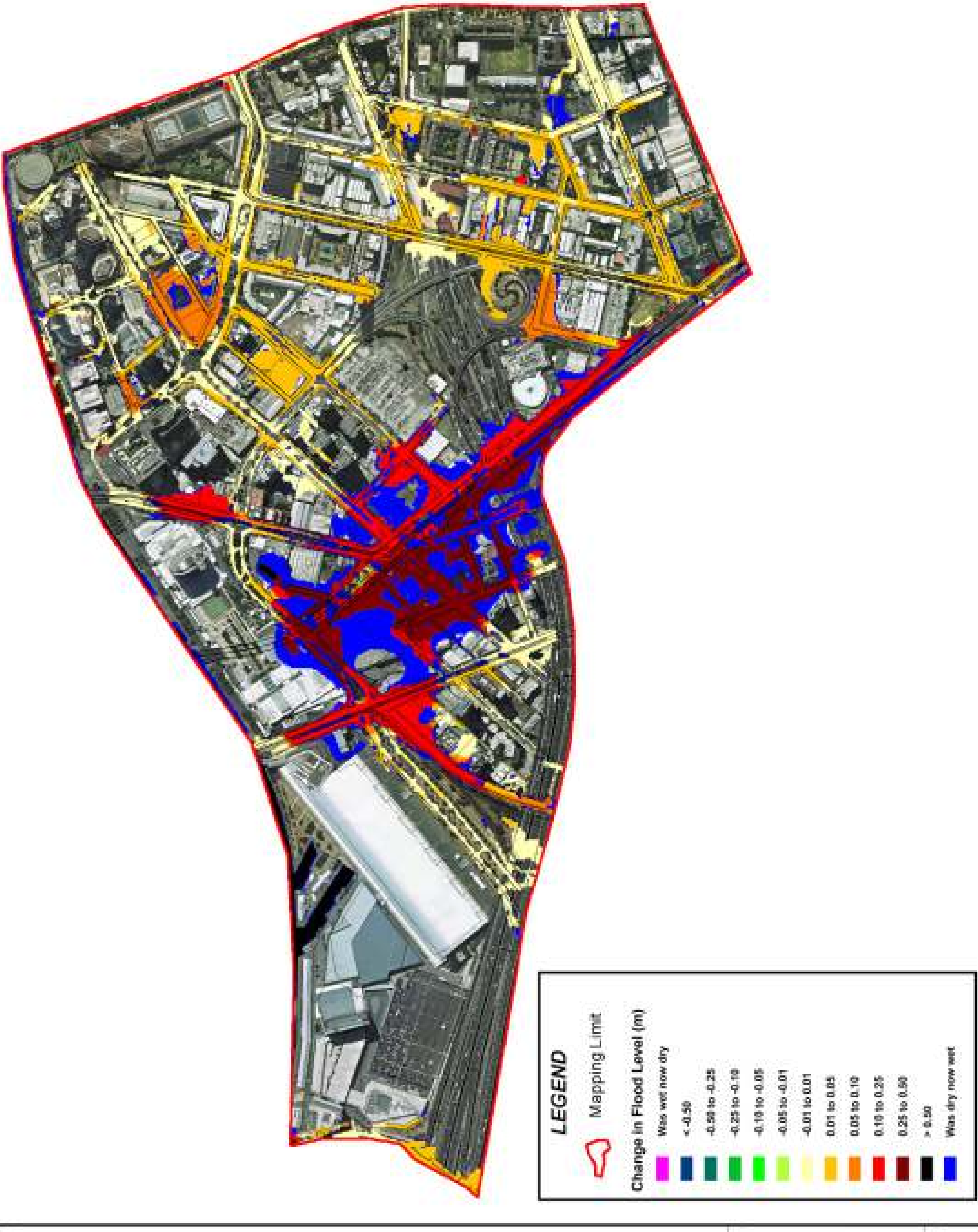
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-8_FldDif_C02_E01+15%_20y_Storm_RevA.WOR



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

Figure: **D-9**

Rev: **A**

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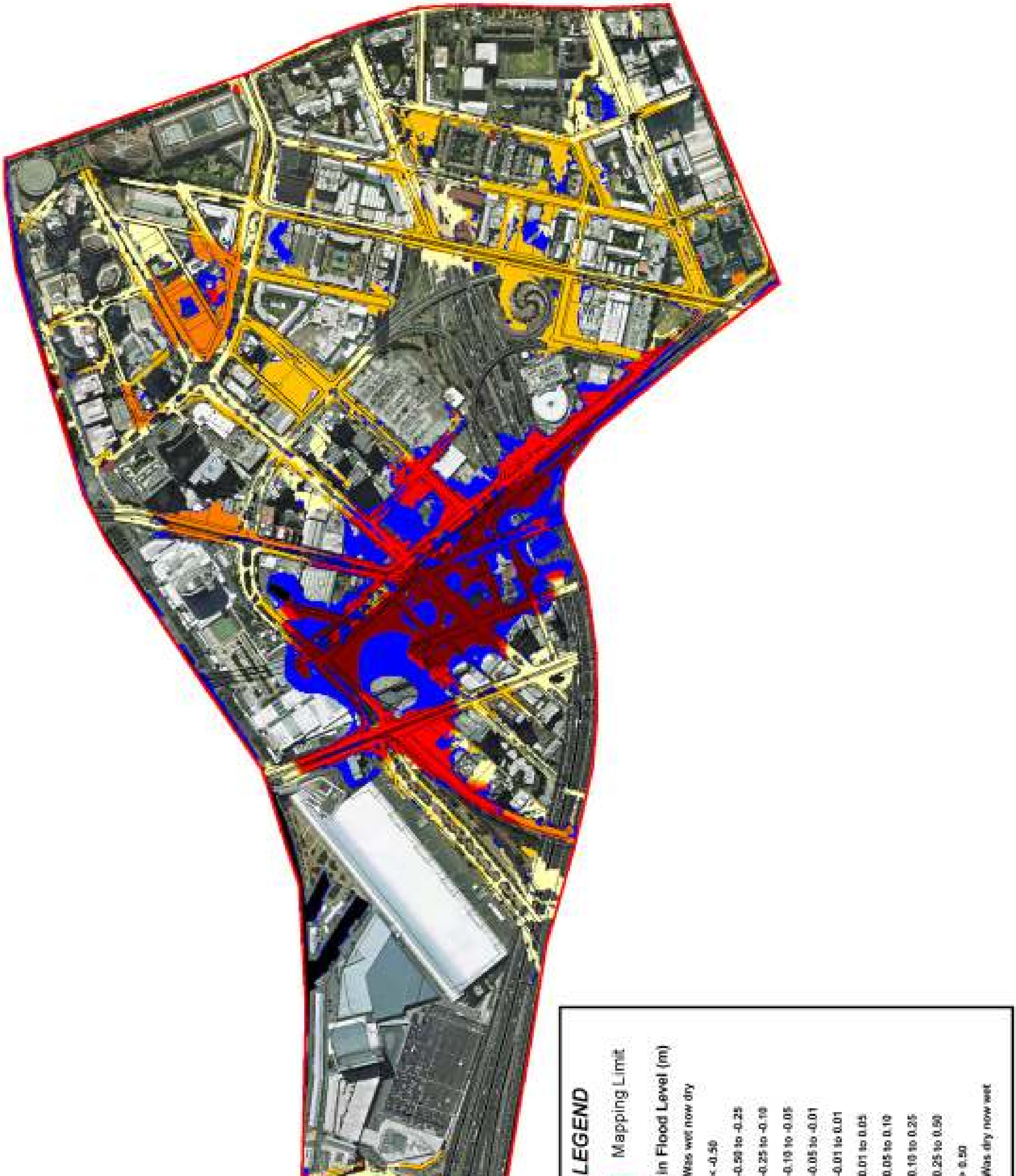
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-9_FldDif_C02_E01+15%_50y_Storm_RevA.WOR



Title:

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

Figure: **D-10**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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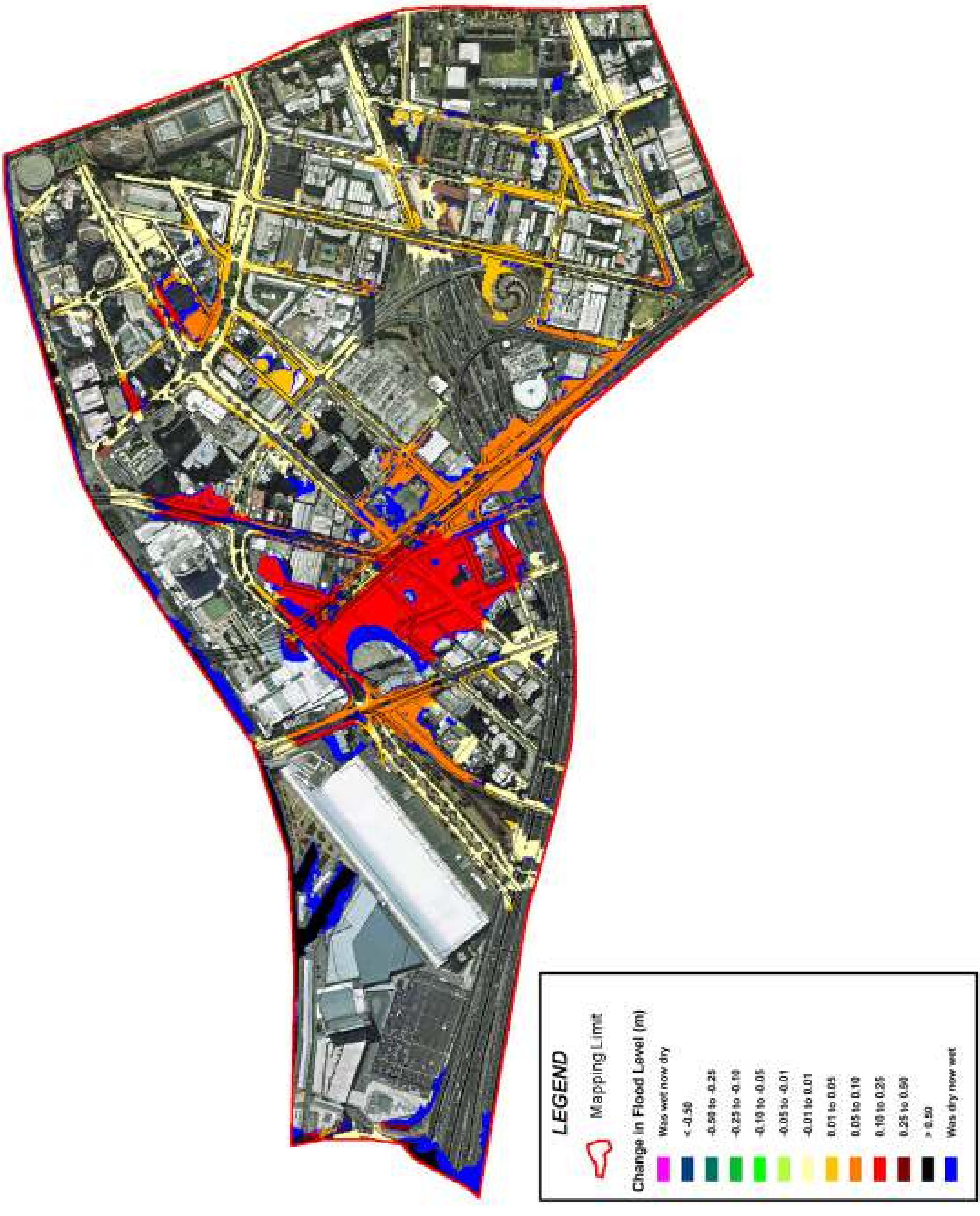
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-10_FldDif_C02_E01+15%_100y_Storm_RevA.WOR



Title:

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

Figure: **D-11**

Rev: **A**

N

0 125 250m
Approx. Scale

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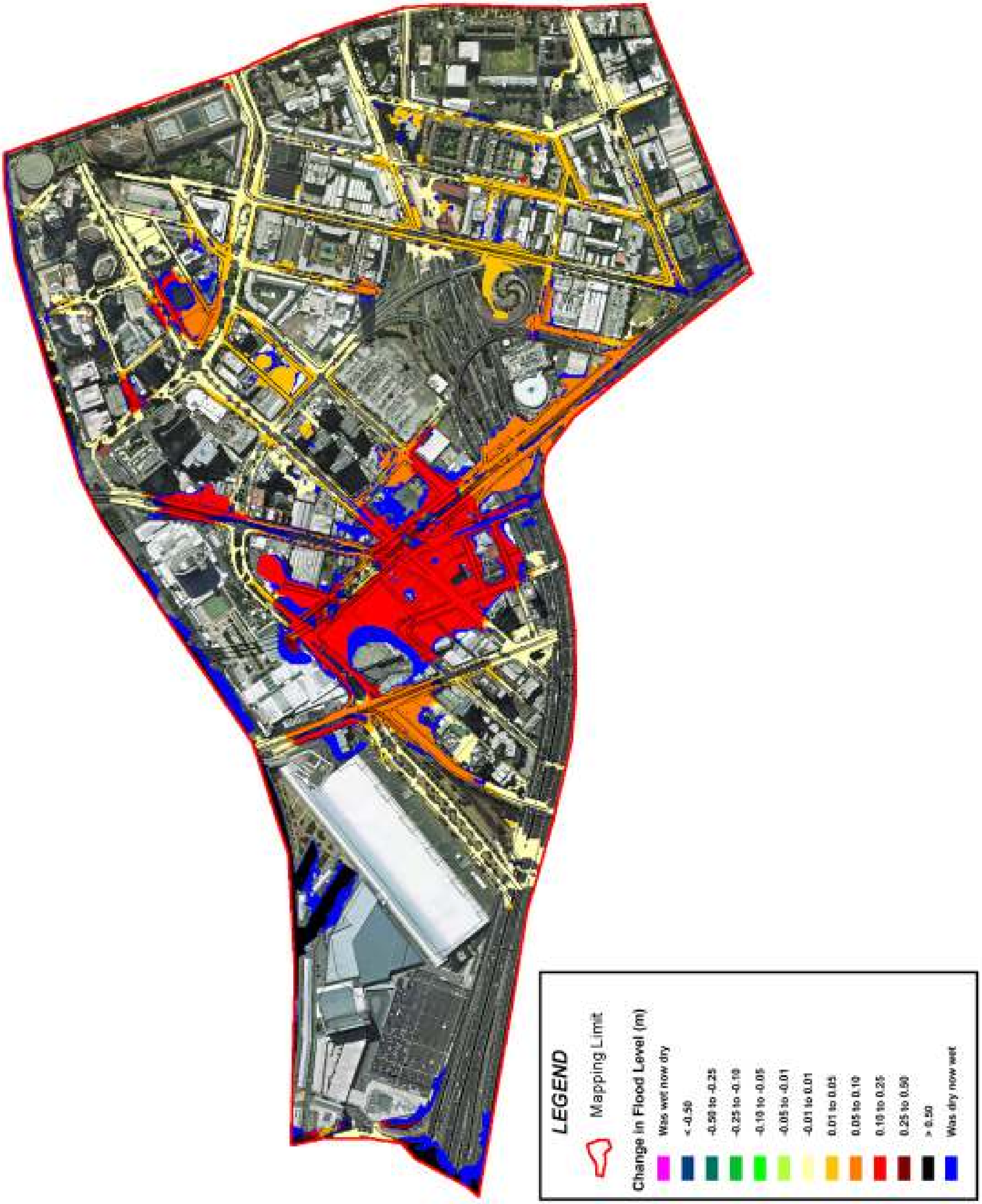
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-11_FldDif_C02_E01+15%_5y_Storm_RevA.WOR



Title:

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

Figure: **D-12**

Rev: **A**

N

0 125 250m
Approx. Scale

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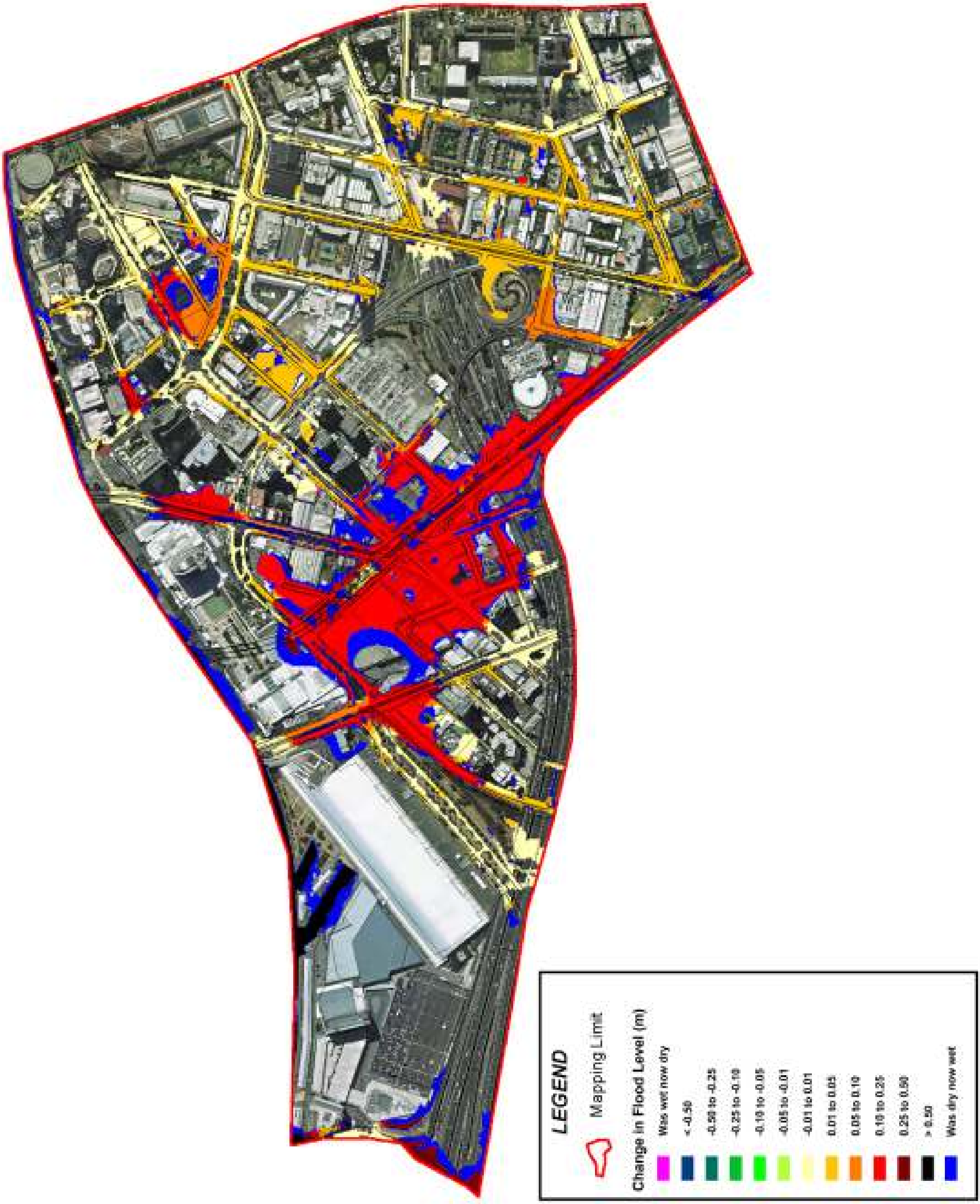
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-12_FldDif_C02_E01+15%_10y_Storm_RevA.WOR



Title:

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

Figure: **D-13**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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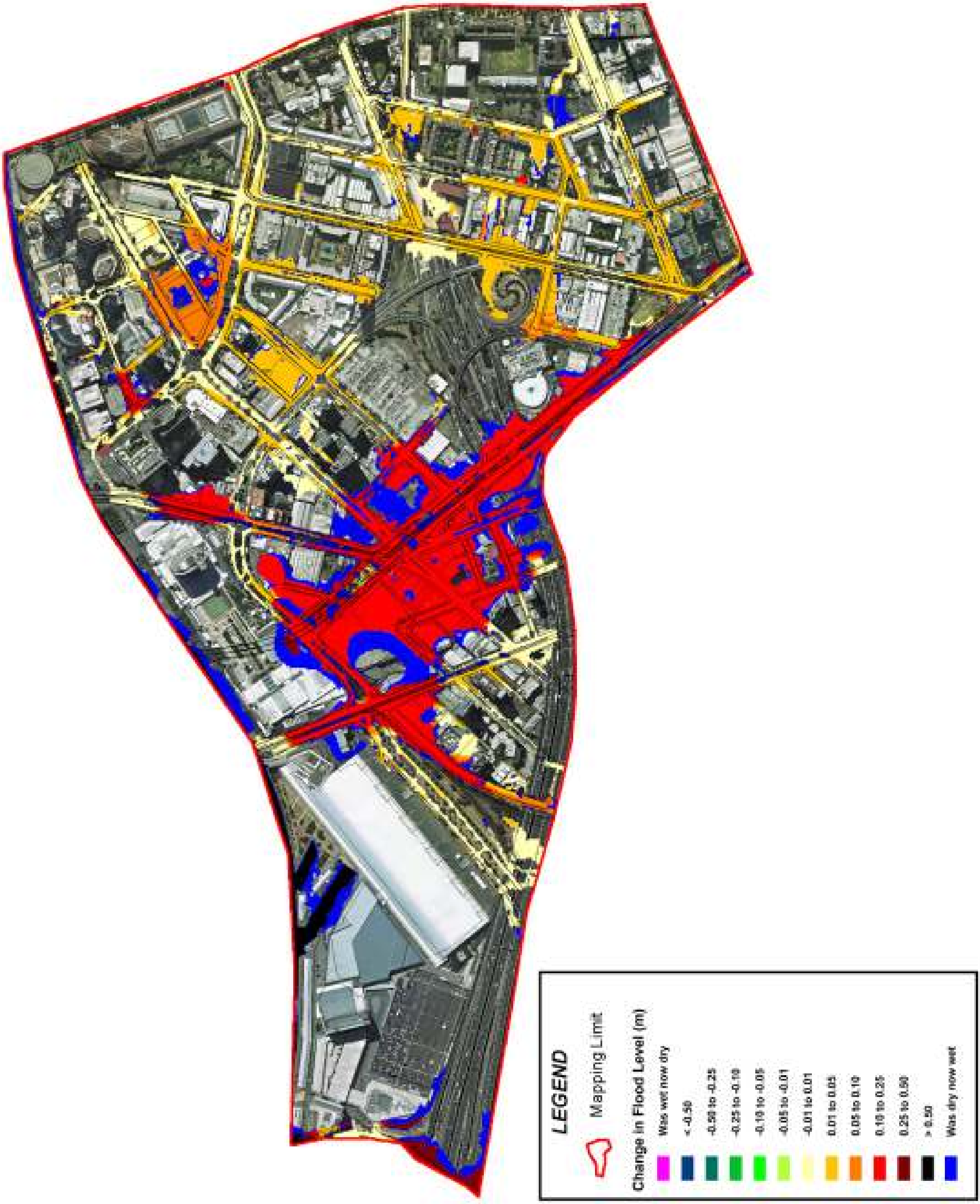
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-13_FldDif_C02_E01+15%_20y_Storm_RevA.WOR



Title:

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

Figure: **D-14**

Rev: **A**

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Approx. Scale

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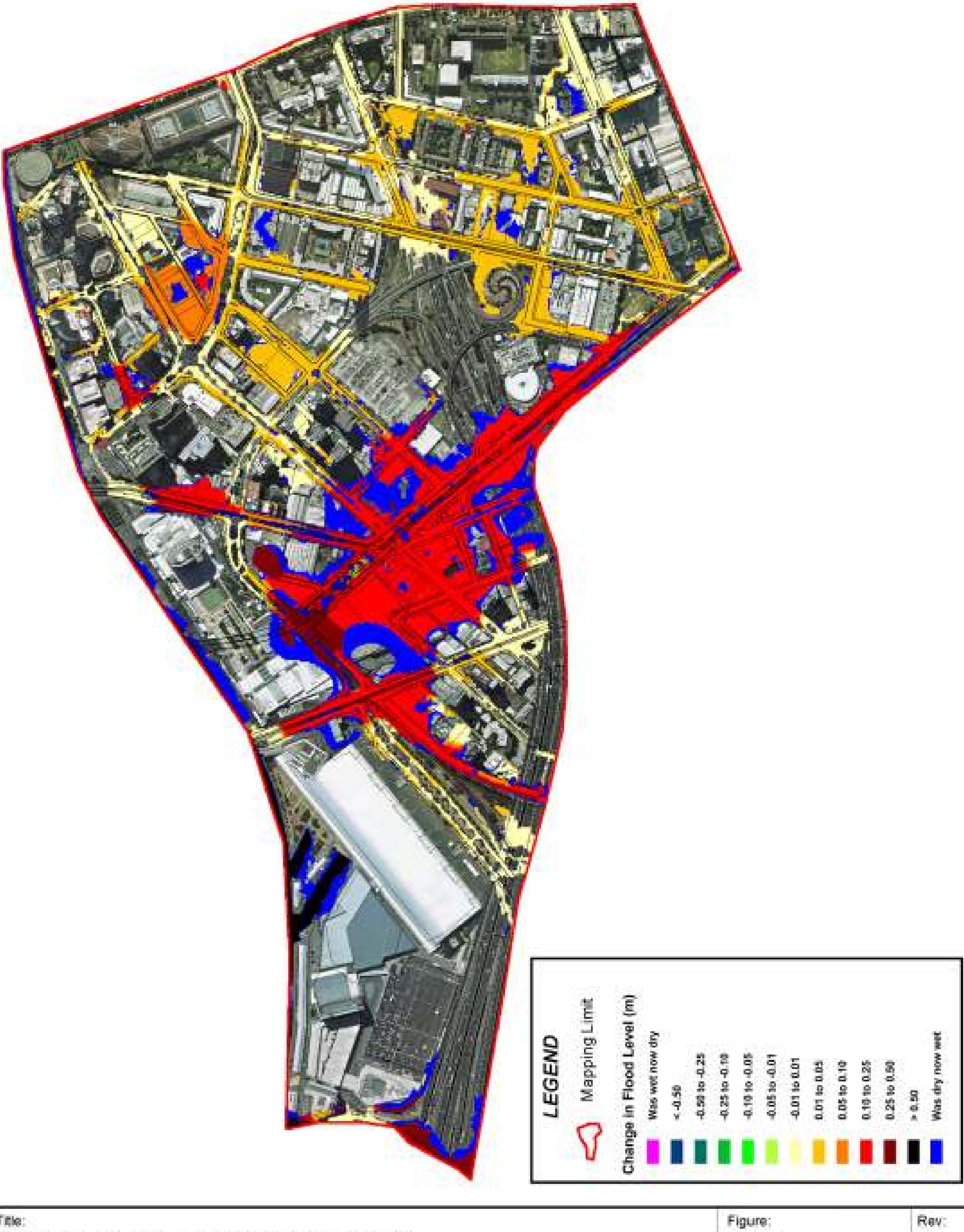
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-14_FldDif_C02_E01+15%_50y_Storm_RevA.WOR



Title:

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

Figure: **D-15**

Rev: **A**

N

0 125 250m
Approx. Scale

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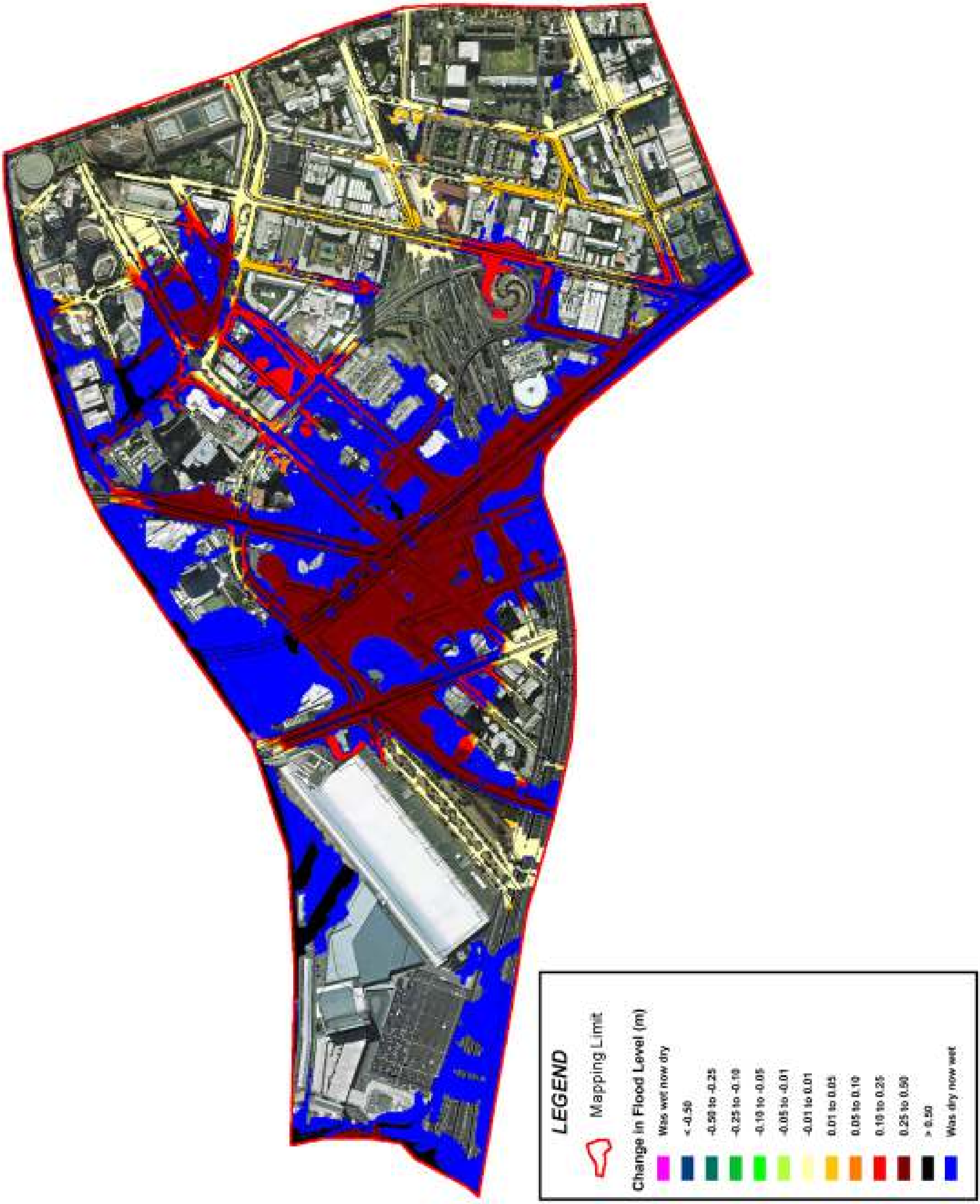
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-15_FldDif_C02_E01+15%_100y_Storm_RevA.WOR



Title:
Southbank - Climate Change +15%
Change in 5 Year ARI Peak Flood Heights - Yarra 100y

Figure: **D-16**

Rev: **A**

N

0 125 250m
Approx. Scale

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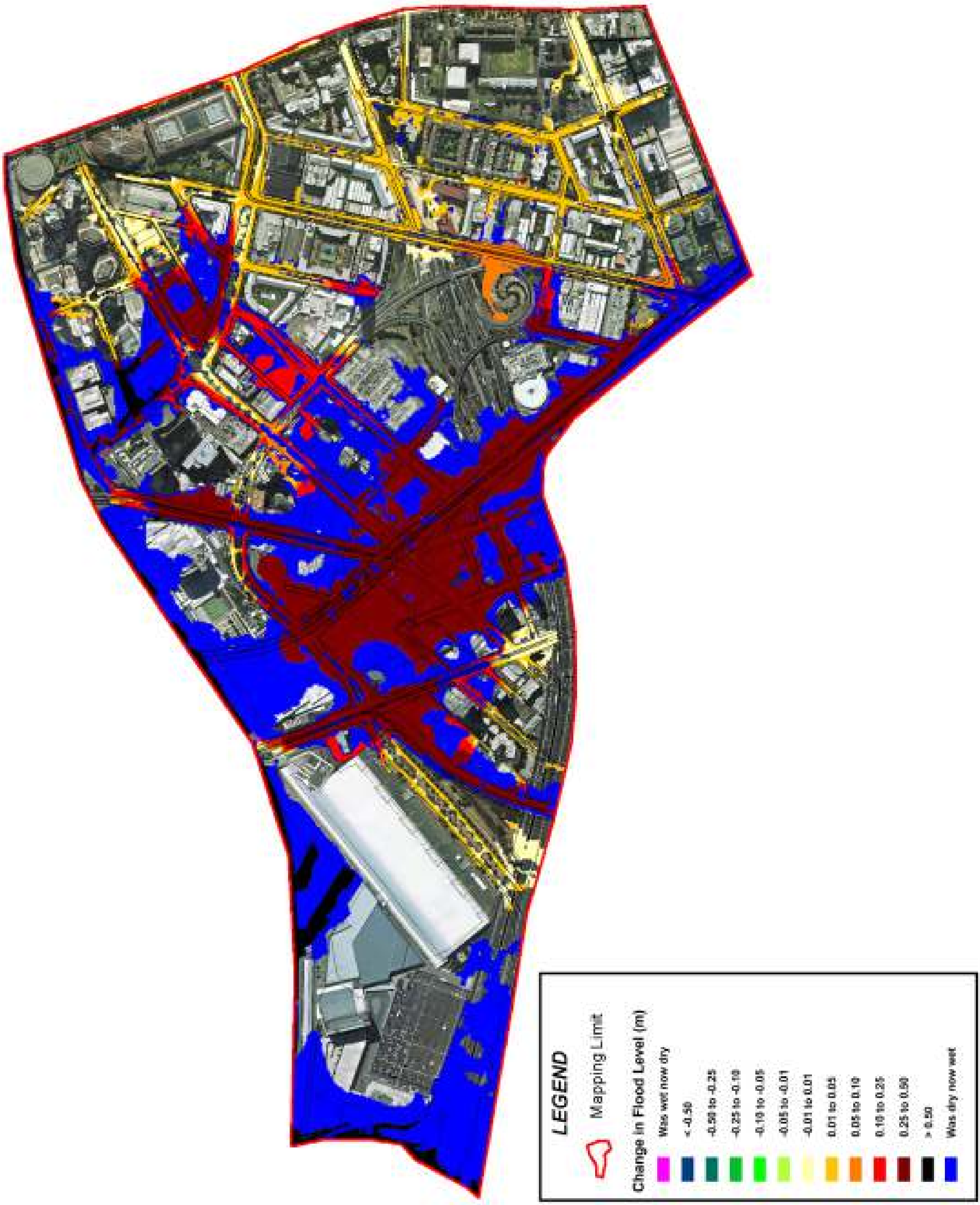
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-16_FldDif_C02_E01+15%_5y_Yarra100y_RevA.WOR



Title:
Southbank - Climate Change +15%
Change in 10 Year ARI Peak Flood Heights - Yarra 100y

Figure: **D-17**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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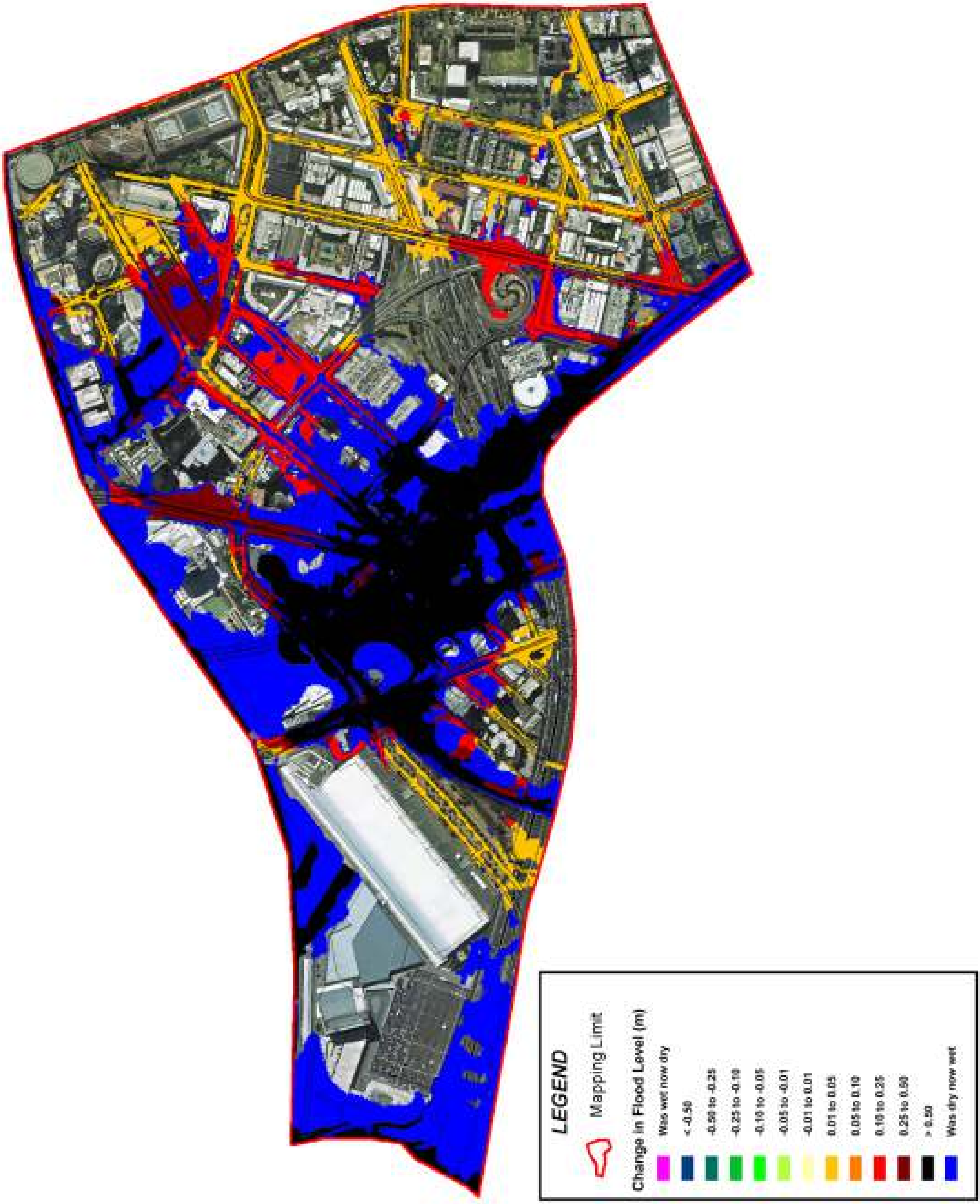
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-17_FldDif_C02_E01+15%_10y_Yarra100y_RevA.WOR



Title:

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

Figure: **D-18**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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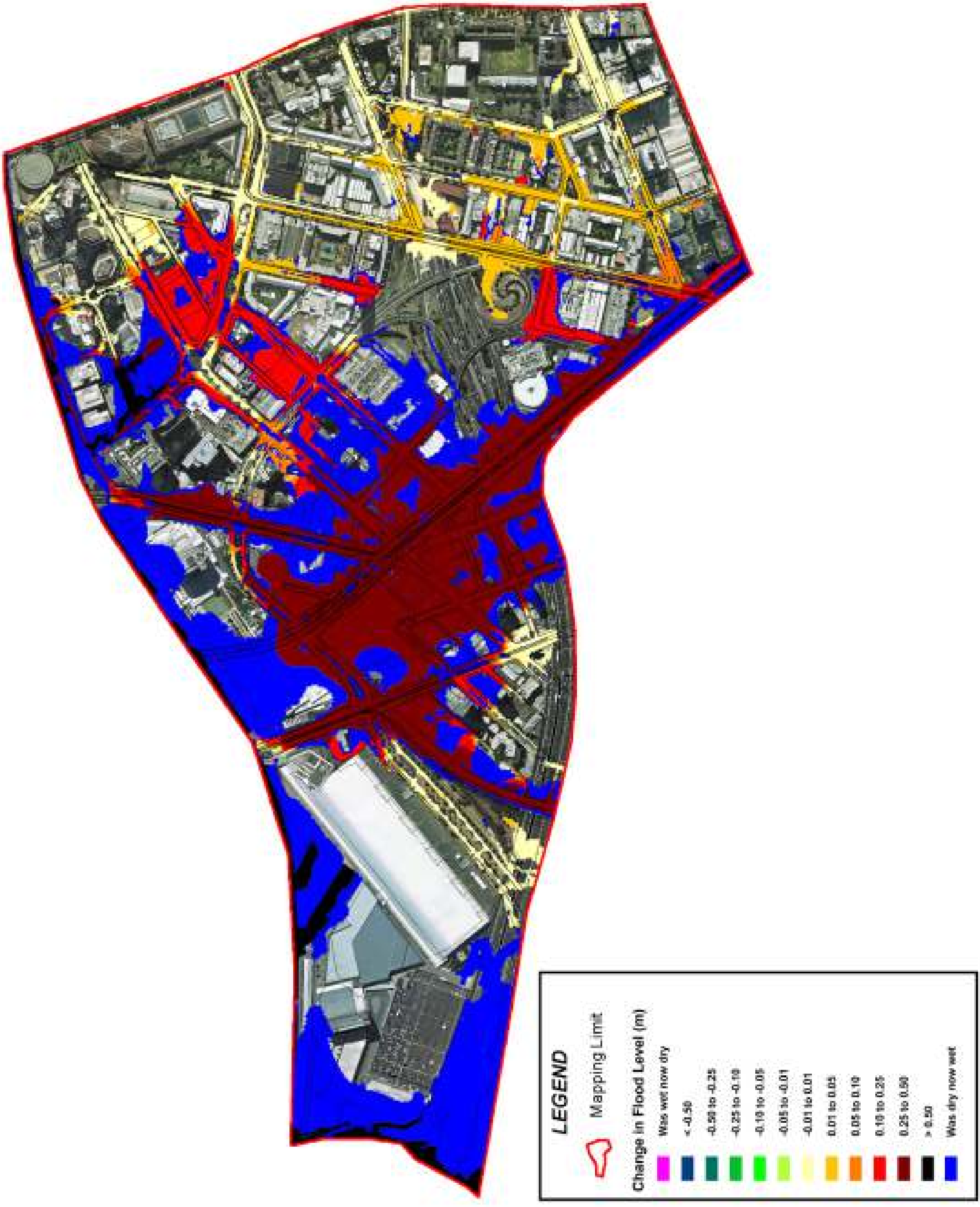
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-18_FldDif_C02_E01+15%_20y_Yarra100y_RevA.WOR



Title:

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

Figure: **D-19**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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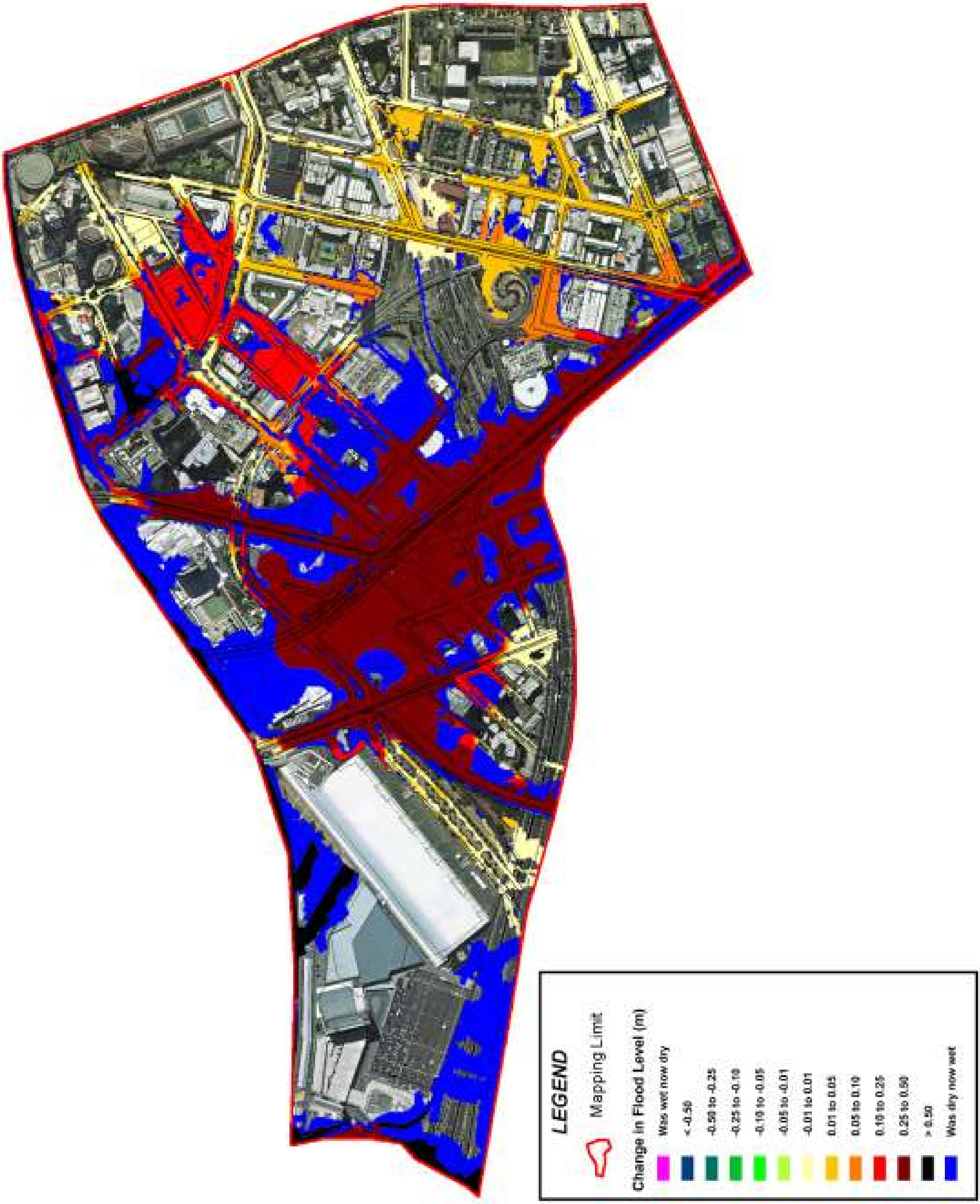
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-19_FldDif_C02_E01+15%_50y_Yarra100y_RevA.WOR



Title:

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

Figure: **D-20**

Rev: **A**

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N

0 125 250m
Approx. Scale

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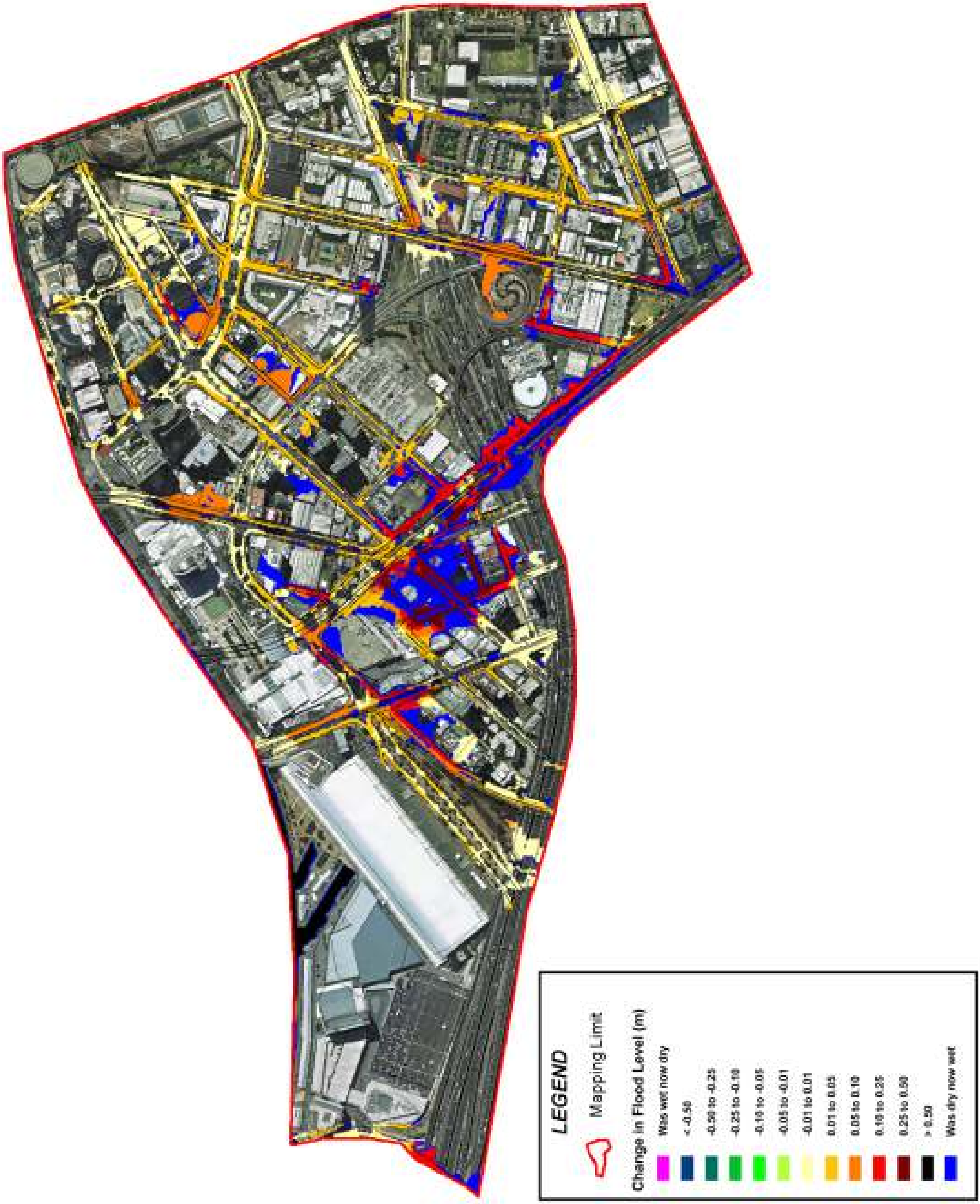
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-20_FldDif_C02_E01+15%_100y_Yarra100y_RevA.WOR



Title:

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

Figure: **D-1**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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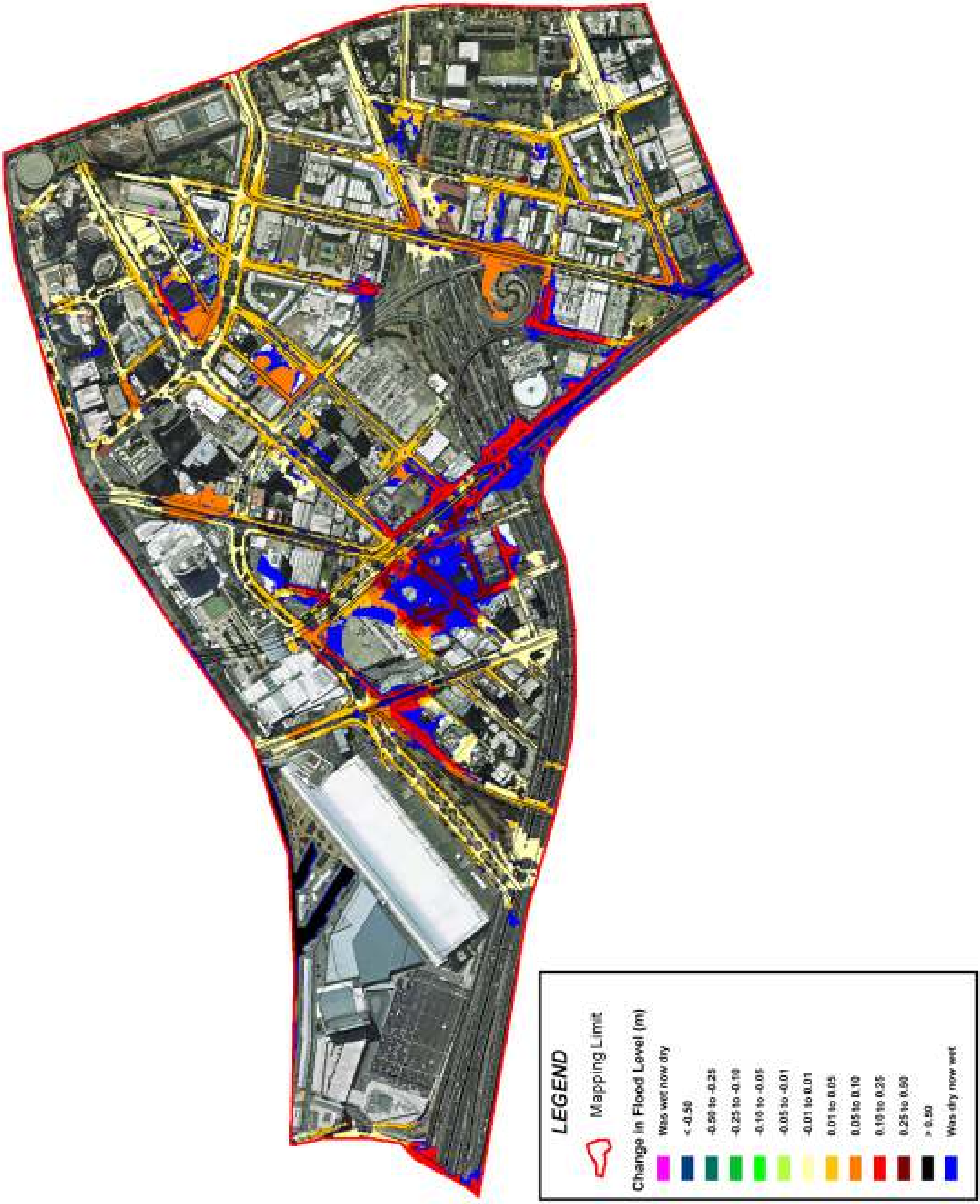
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-1_FldDif_C02_E01+32%_5y_MSL_RevA.WOR



Title:

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

Figure: **D-22**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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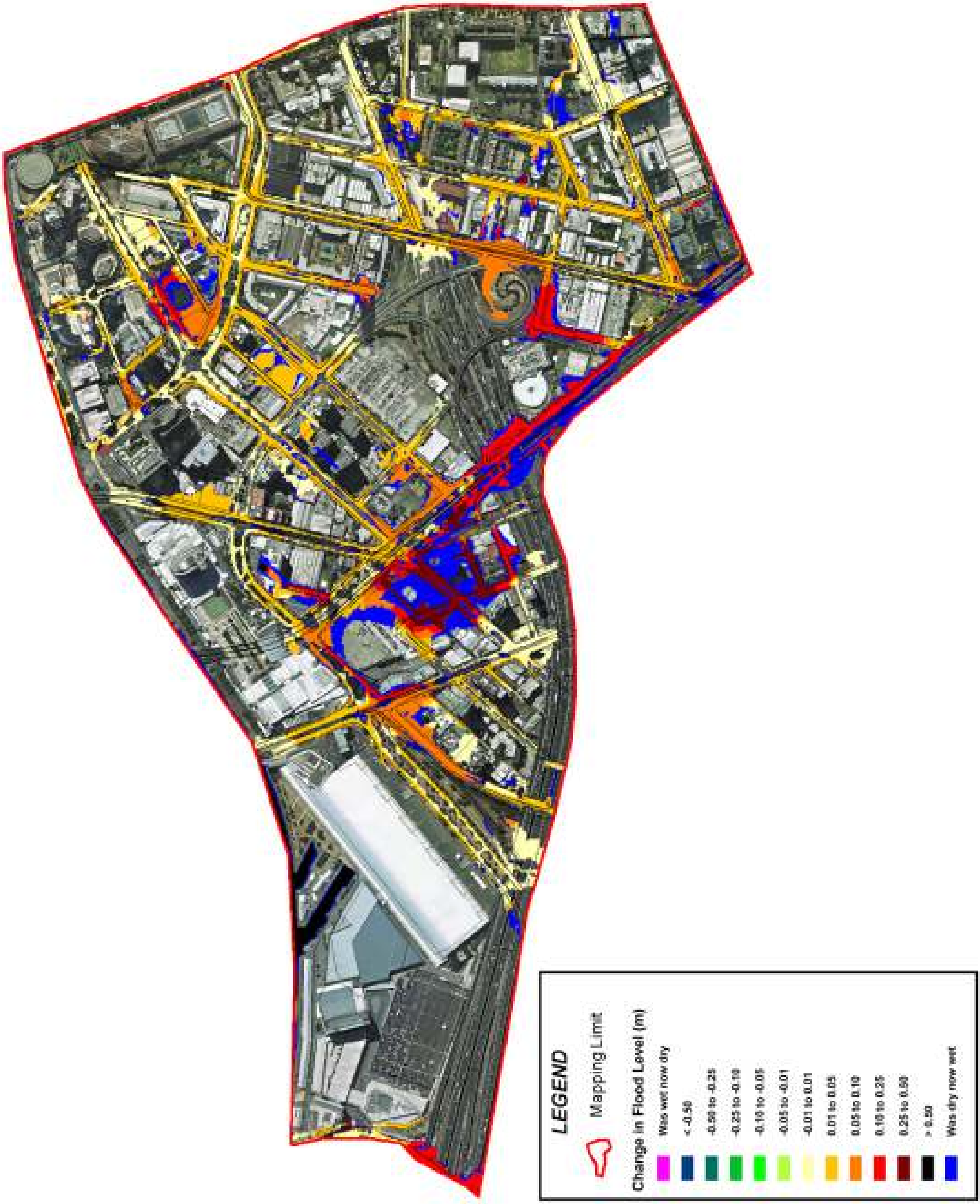
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-22_FldDif_C02_E01+32%_10y_MSL_RevA.WOR



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

Figure:
D-23

Rev:
A

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N

0 125 250m
Approx. Scale

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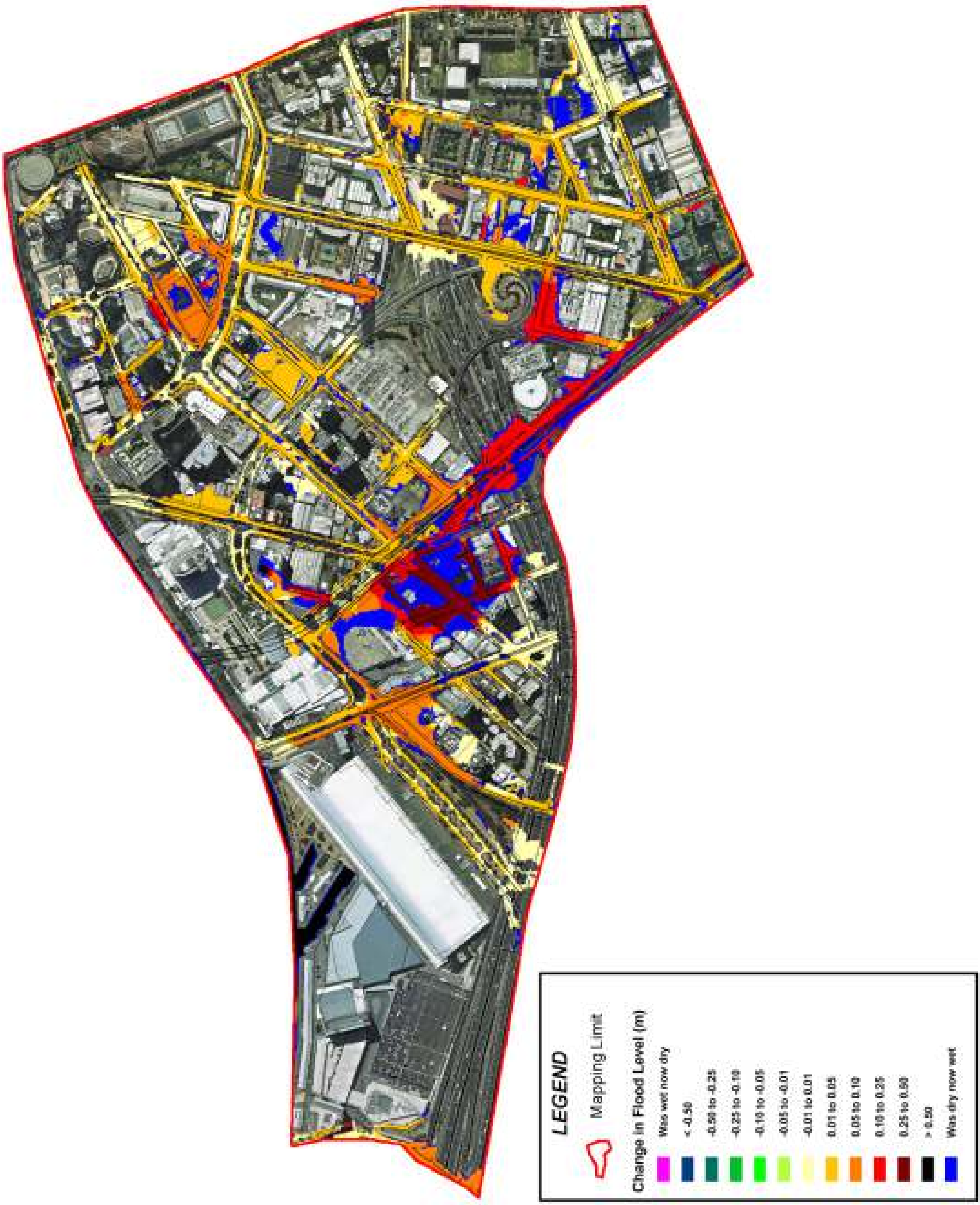
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-23_FldDif_C02_E01+32%_20y_MSL_RevA.WOR



Title:

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

Figure: **D-24**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM

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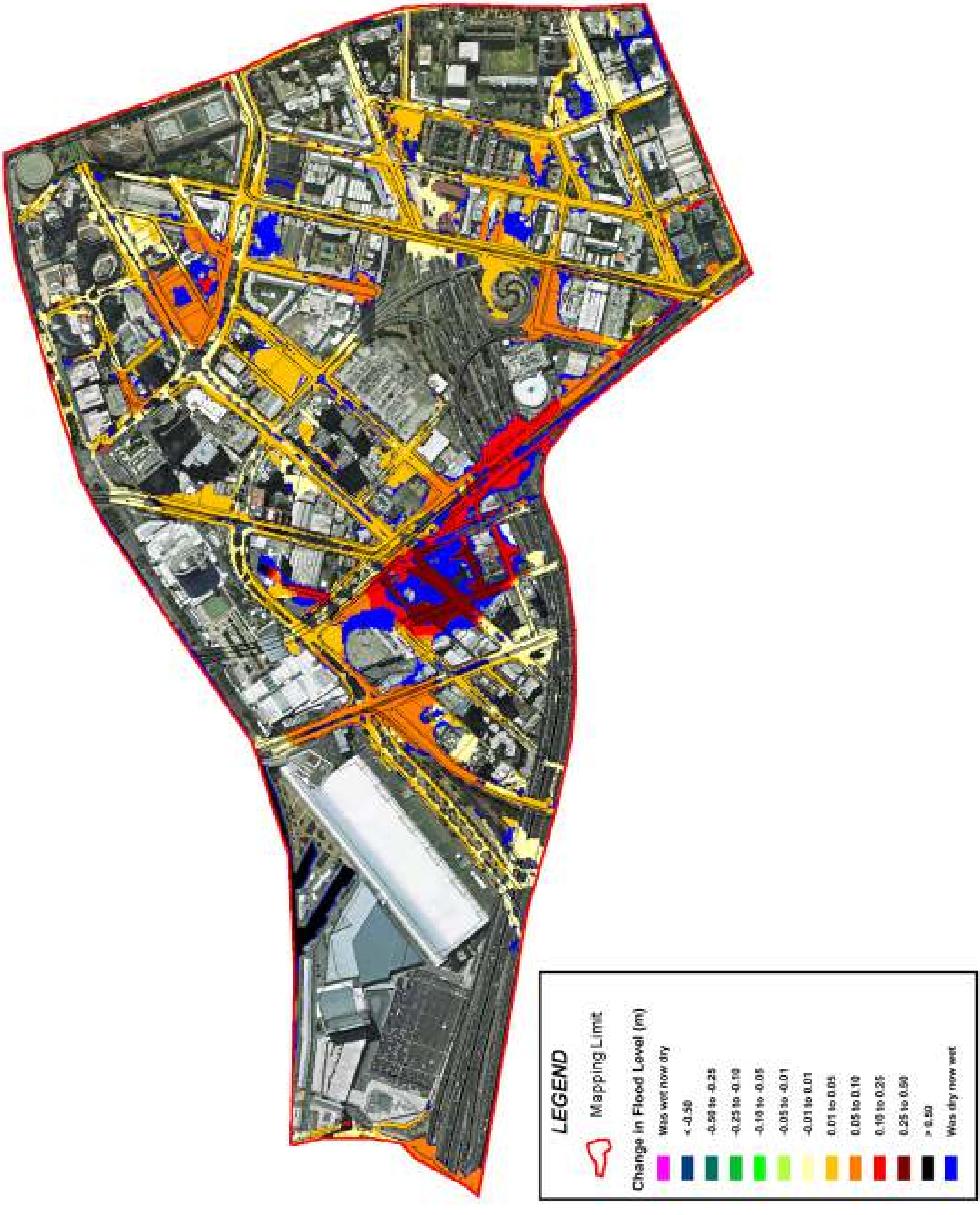
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-24_FldDif_C02_E01+32%_50y_MSL_RevA.WOR



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

Figure: **D-25**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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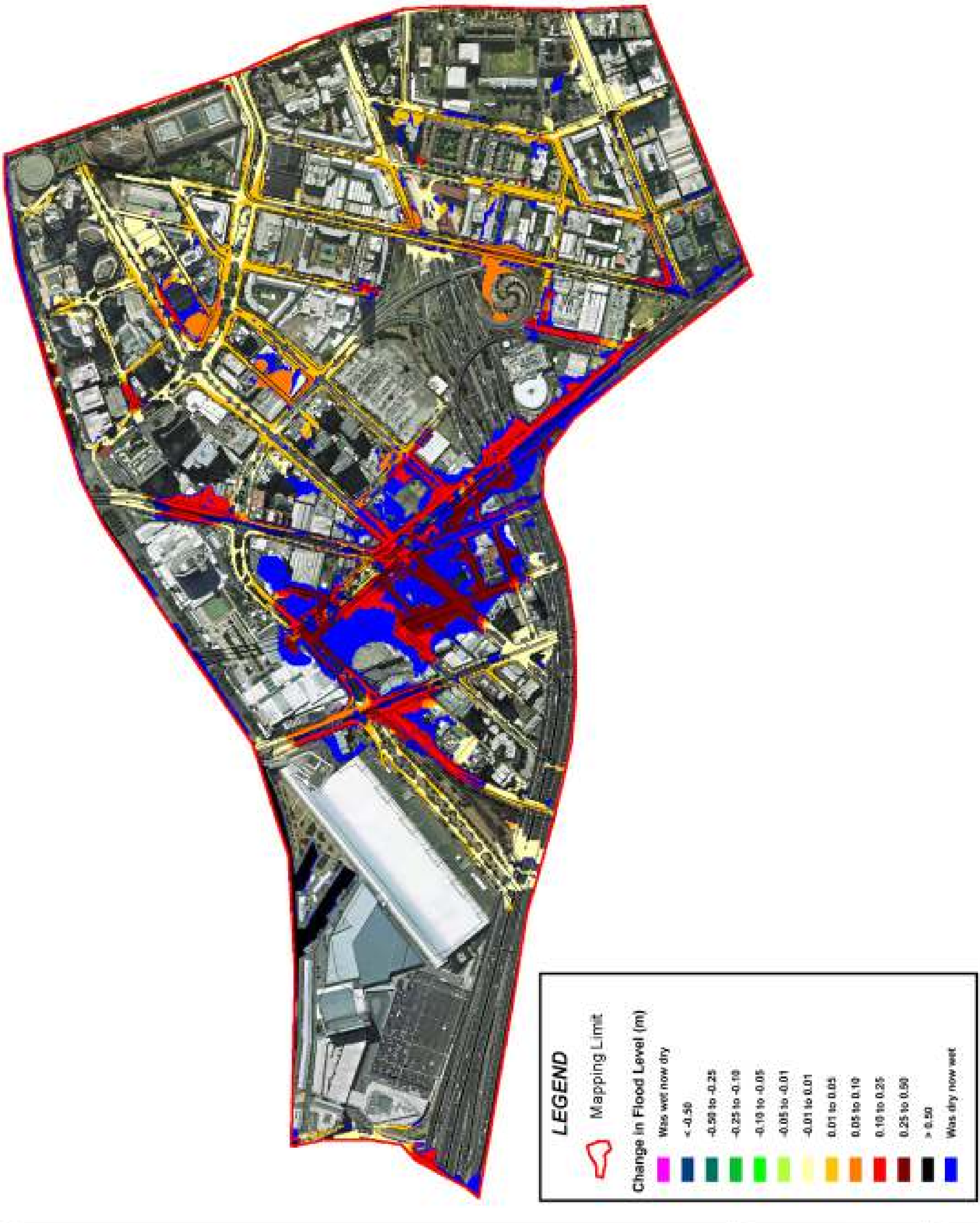
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-25_FldDif_C02_E01+32%_100y_MSL_RevA.WOR



Title:

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

Figure: **D-26**

Rev: **A**

BMT WBM

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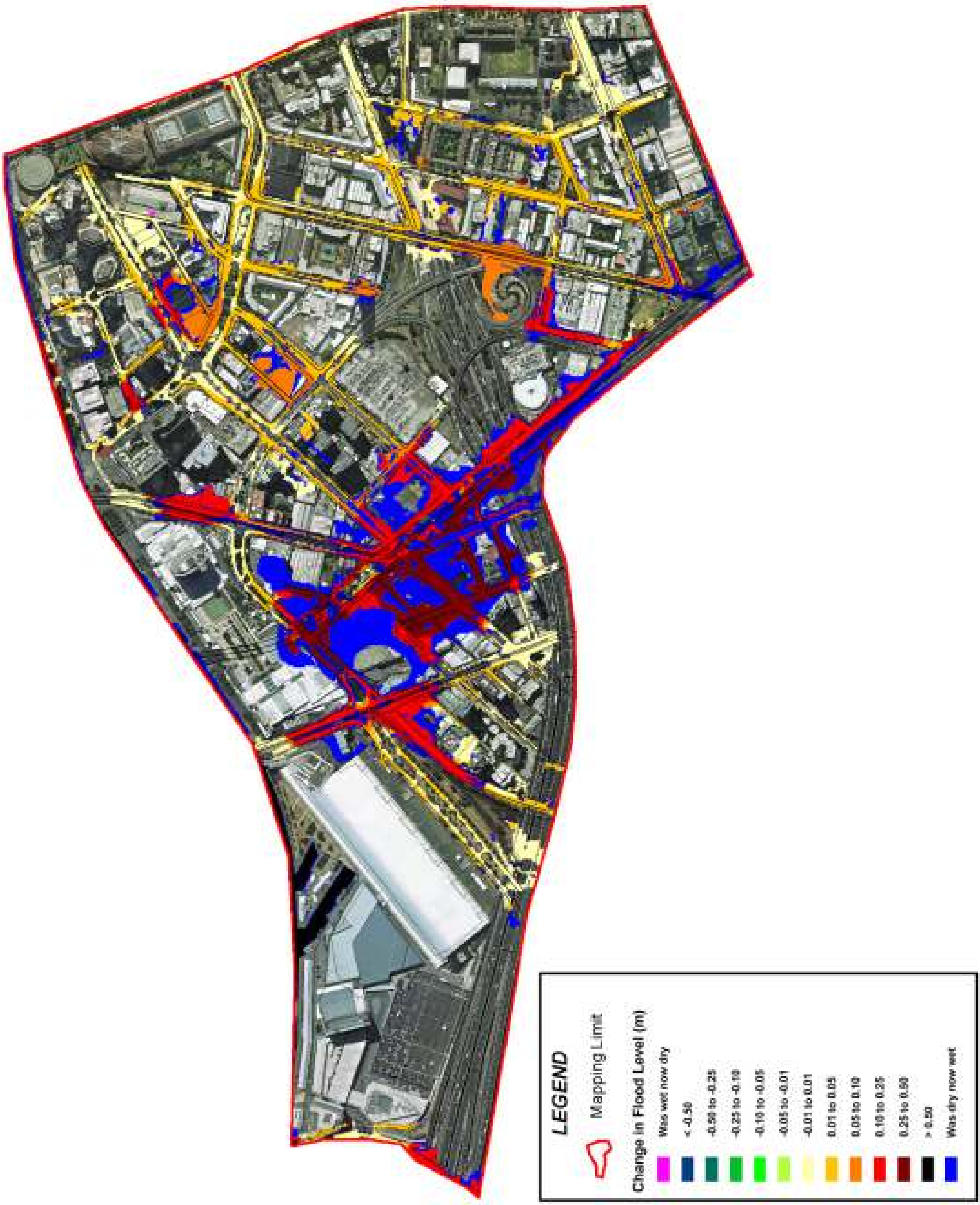
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-26_FldDif_C02_E01+32%_5y_Storm_RevA.WOR



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

Figure:
D-27

Rev:
A

BMT WBM
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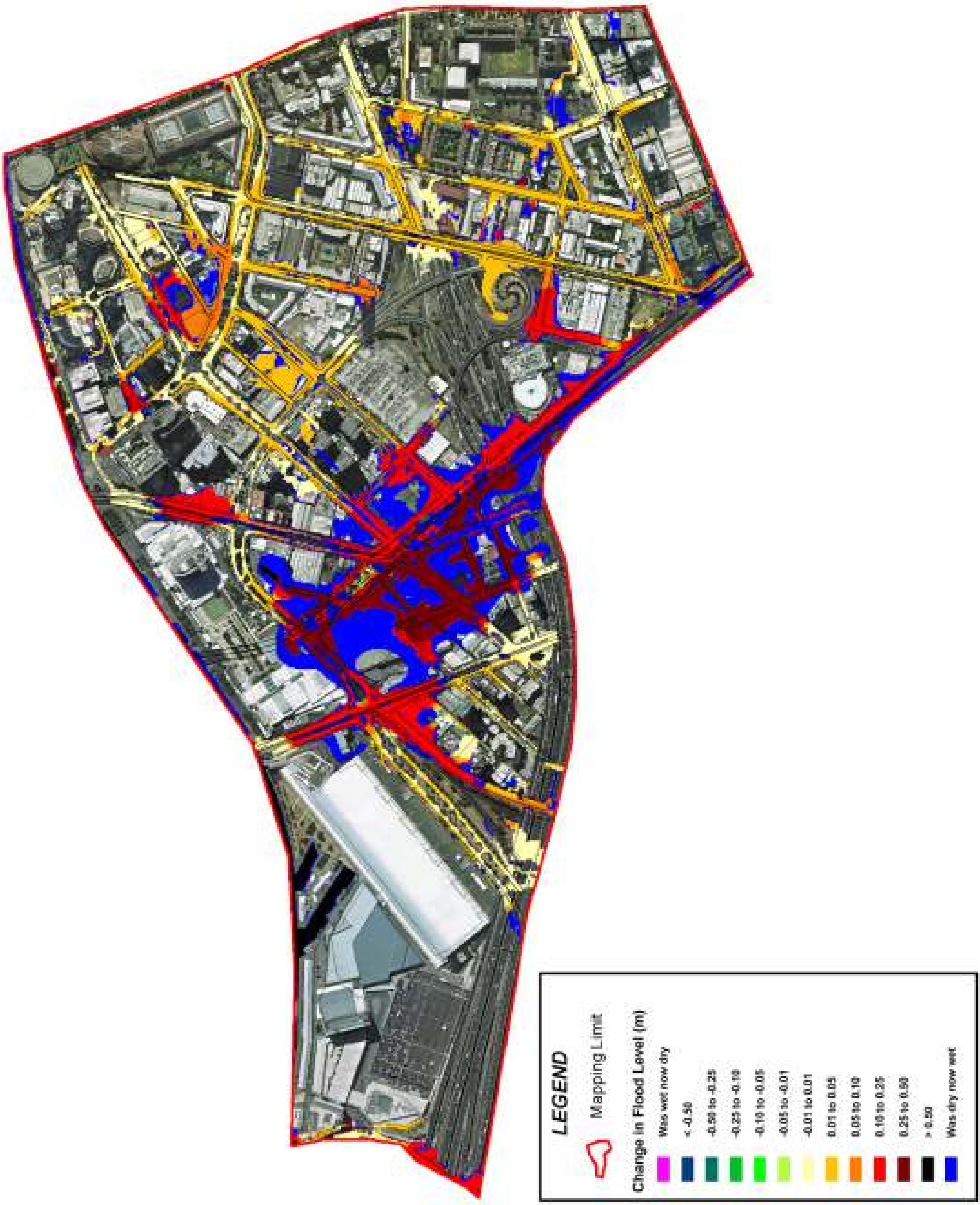
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-27_FldDif_C02_E01+32%_10y_Storm_RevA.WOR



Title:

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

Figure: **D-28**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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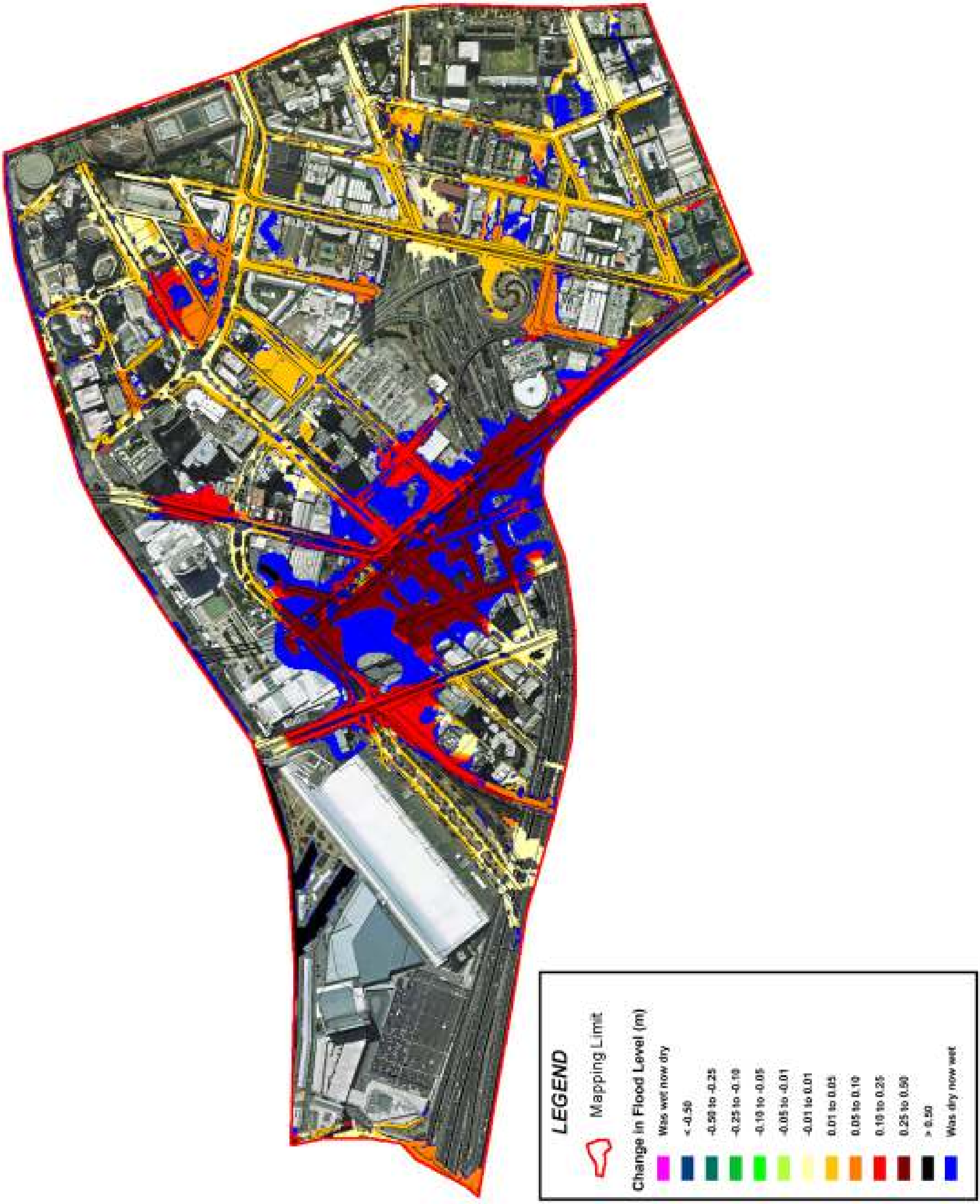
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-28_FldDif_C02_E01+32%_20y_Storm_RevA.WOR



Title:

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

Figure: **D-29**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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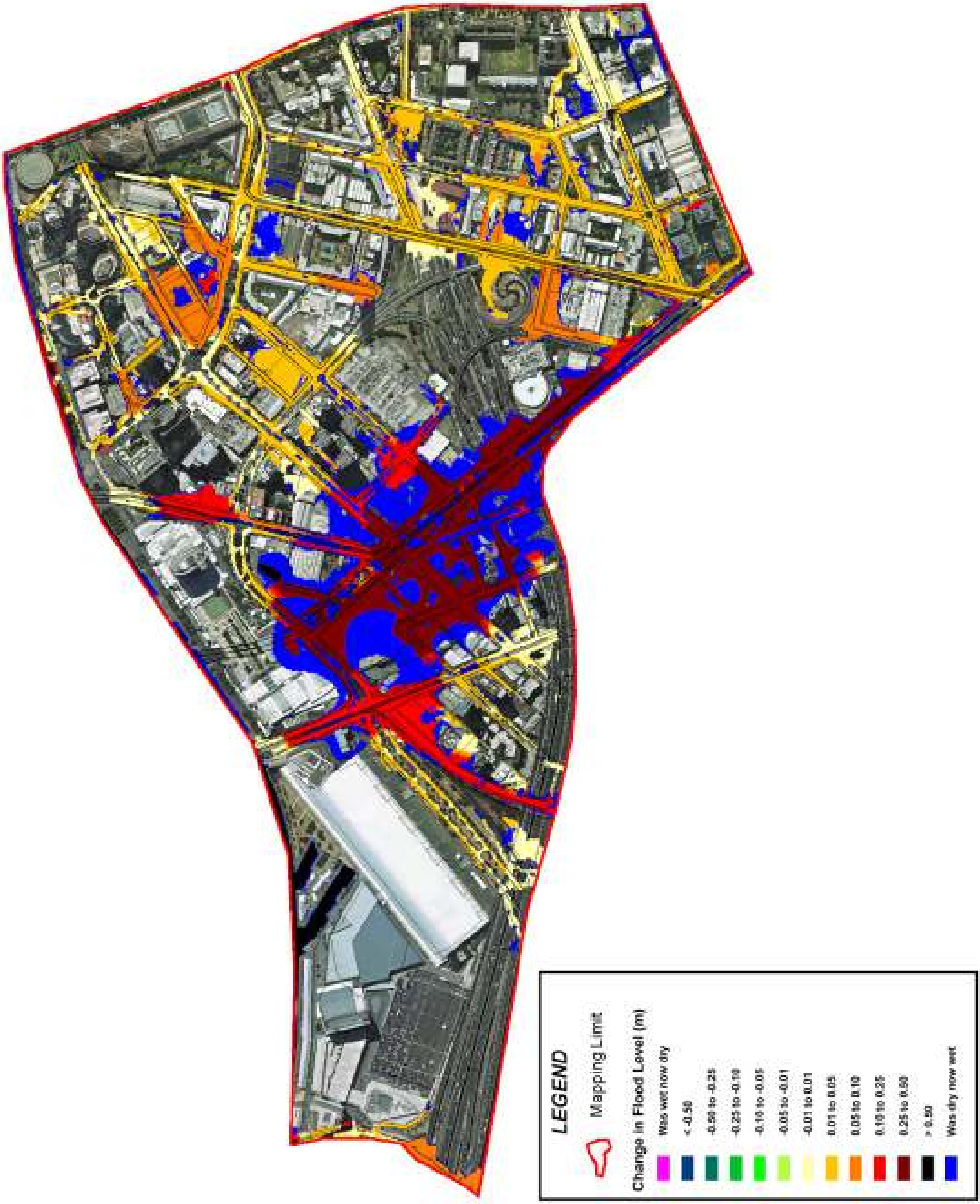
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-29_FldDif_C02_E01+32%_50y_Storm_RevA.WOR



Title:

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

Figure:
D-30

Rev:
A

BMT WBM
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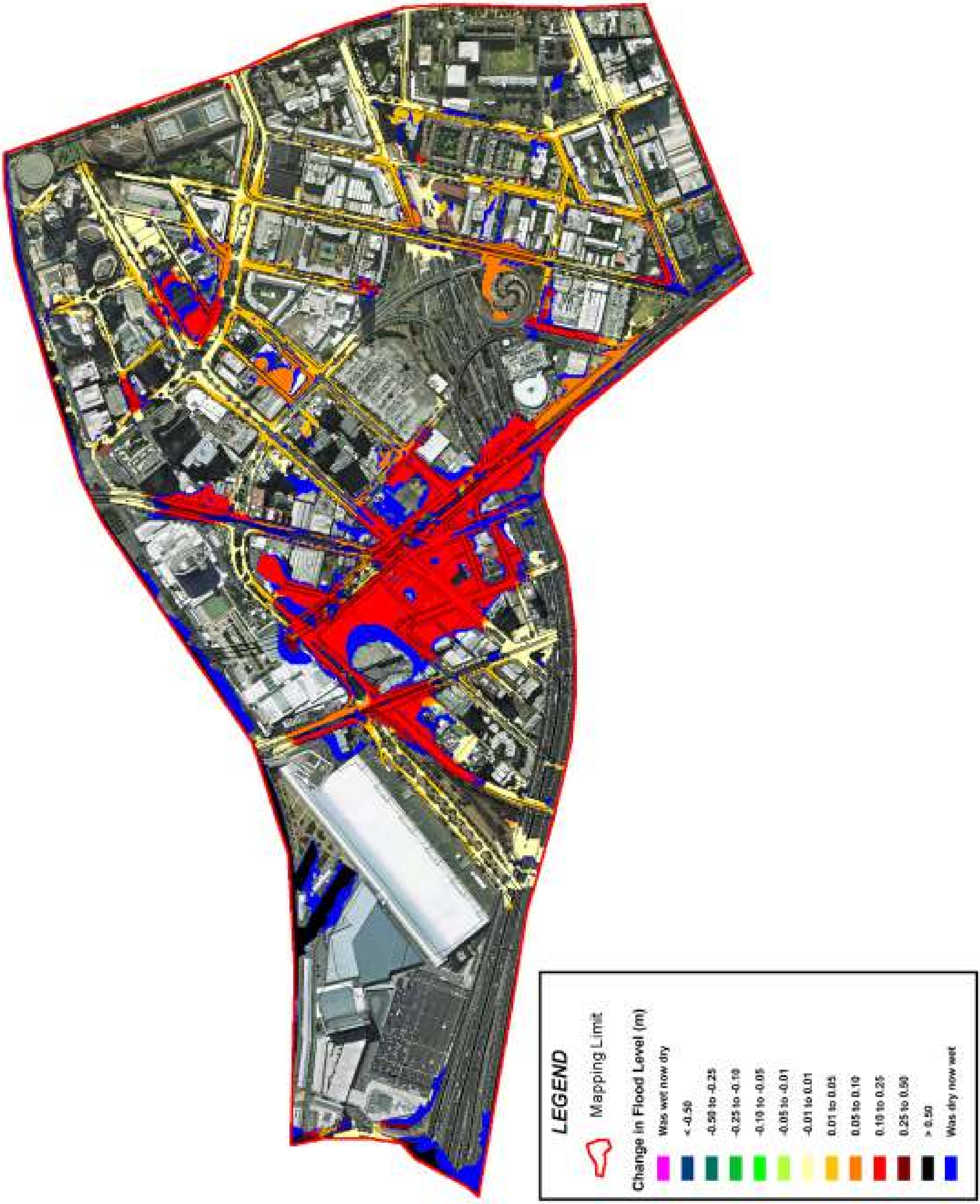
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-30_FldDif_C02_E01+32%_100y_Storm_RevA.WOR



Title:

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

Figure: **D-31**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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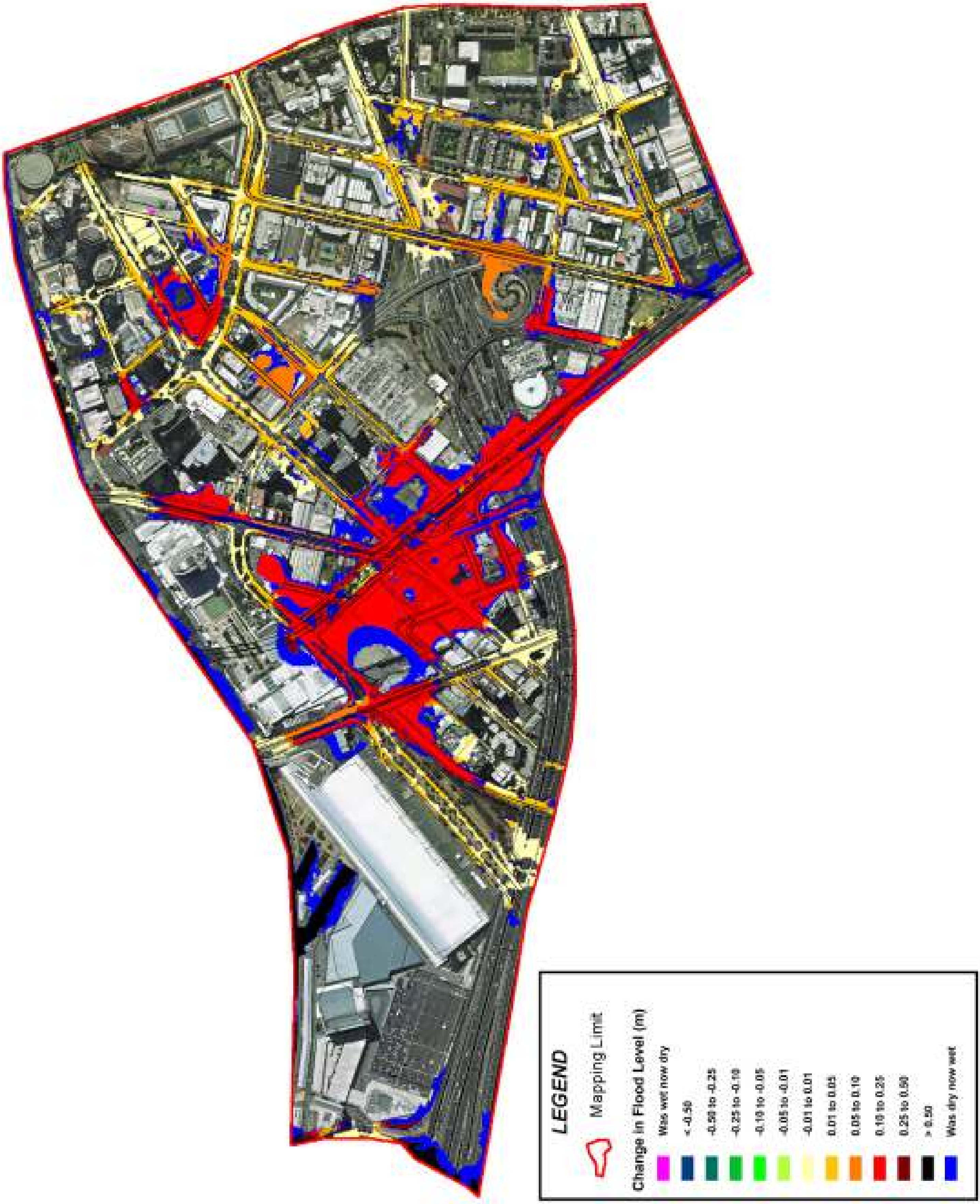
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-31_FldDif_C02_E01+32%_5y_Storm_RevA.WOR



Title:

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

Figure: **D-32**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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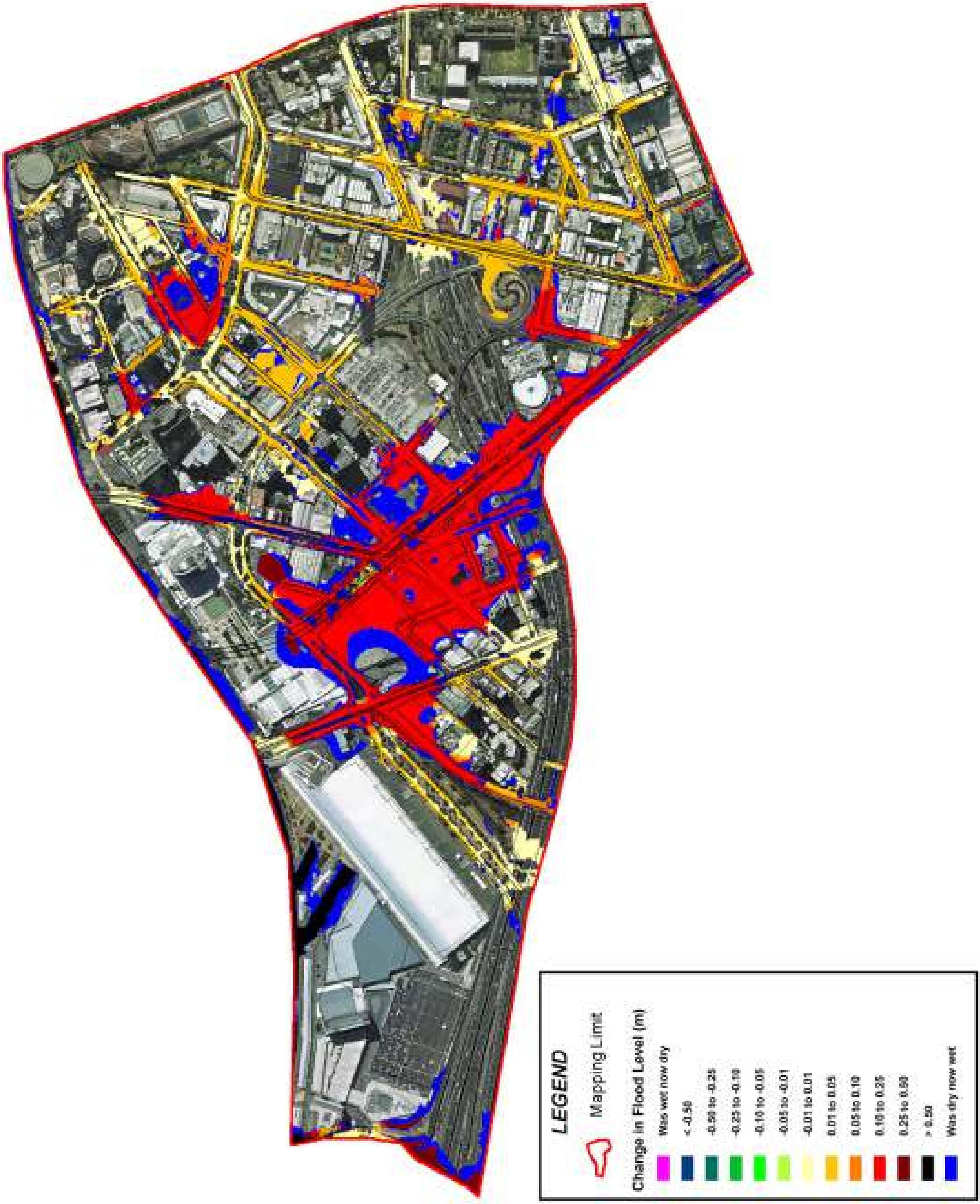
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-32_FldDif_C02_E01+32%_10y_Storm_RevA.WOR



Title:

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

Figure: **D-33**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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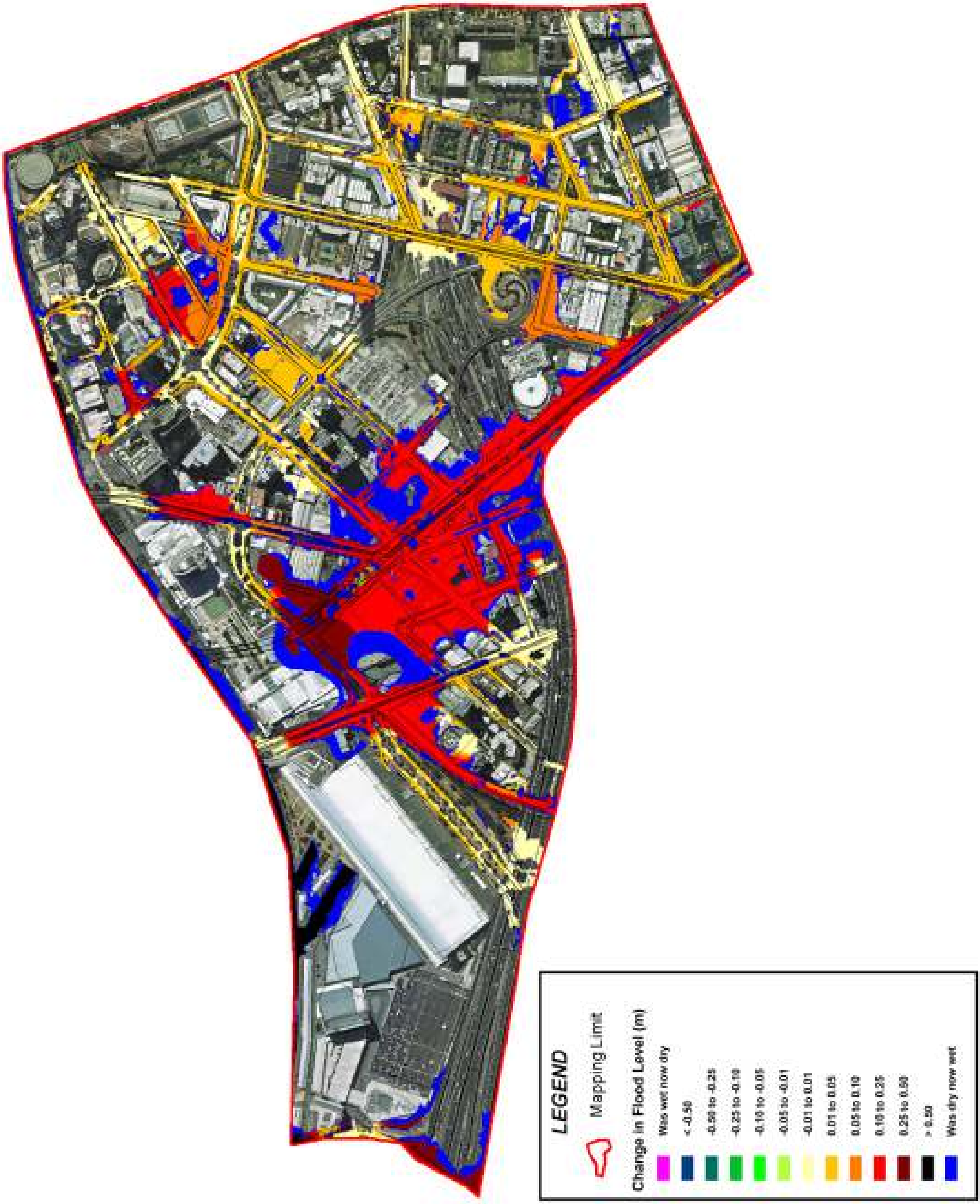
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-33_FldDif_C02_E01+32%_20y_Storm_RevA.WOR



Title:

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

Figure: **D-34**

Rev: **A**

BMT WBM
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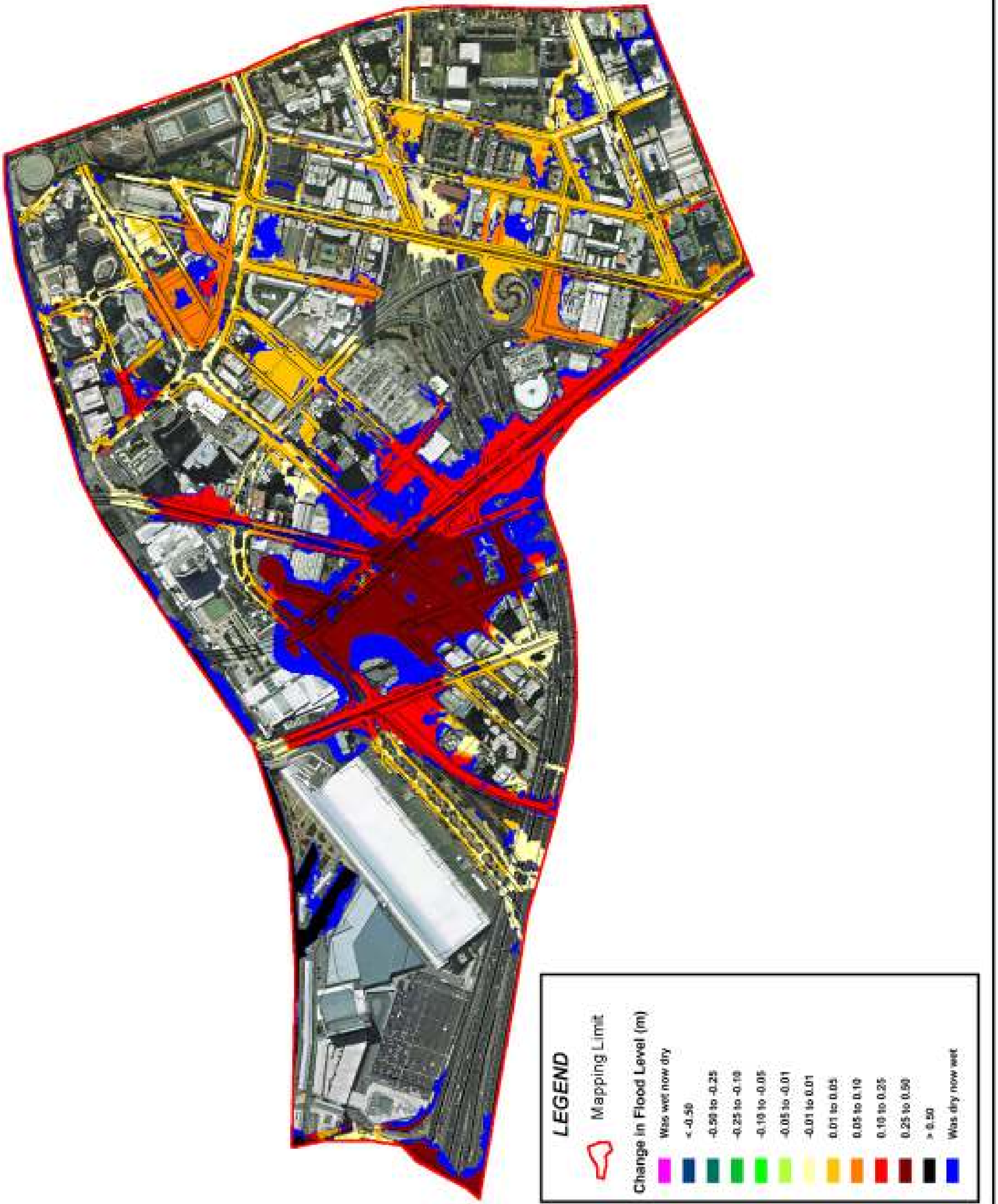
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-34_FldDif_C02_E01+32%_50y_Storm_RevA.WOR



Title:

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

Figure: **D-35**

Rev: **A**

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N

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Approx. Scale

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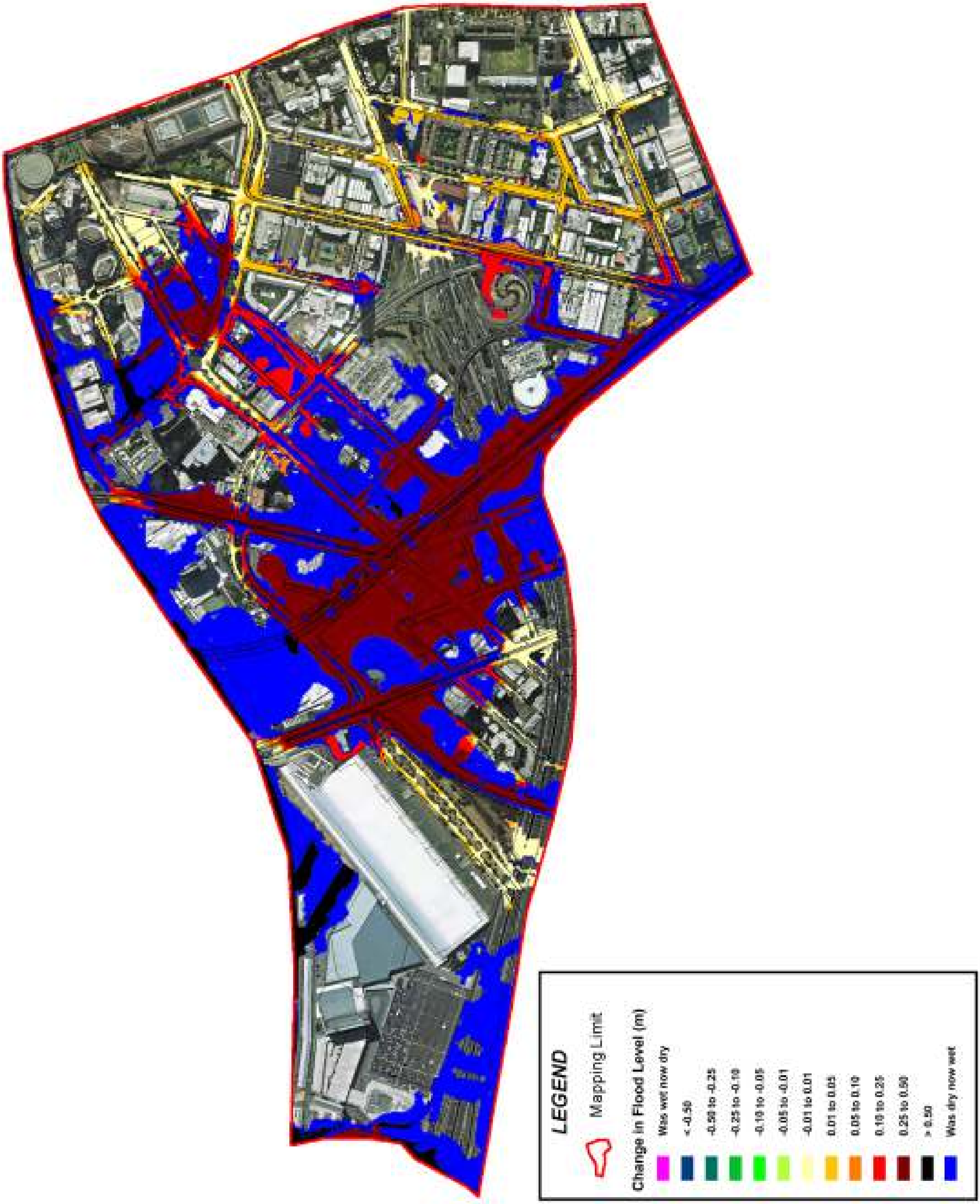
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-35_FldDif_C02_E01+32%_100y_Storm_RevA.WOR



Title:

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

Figure: **D-36**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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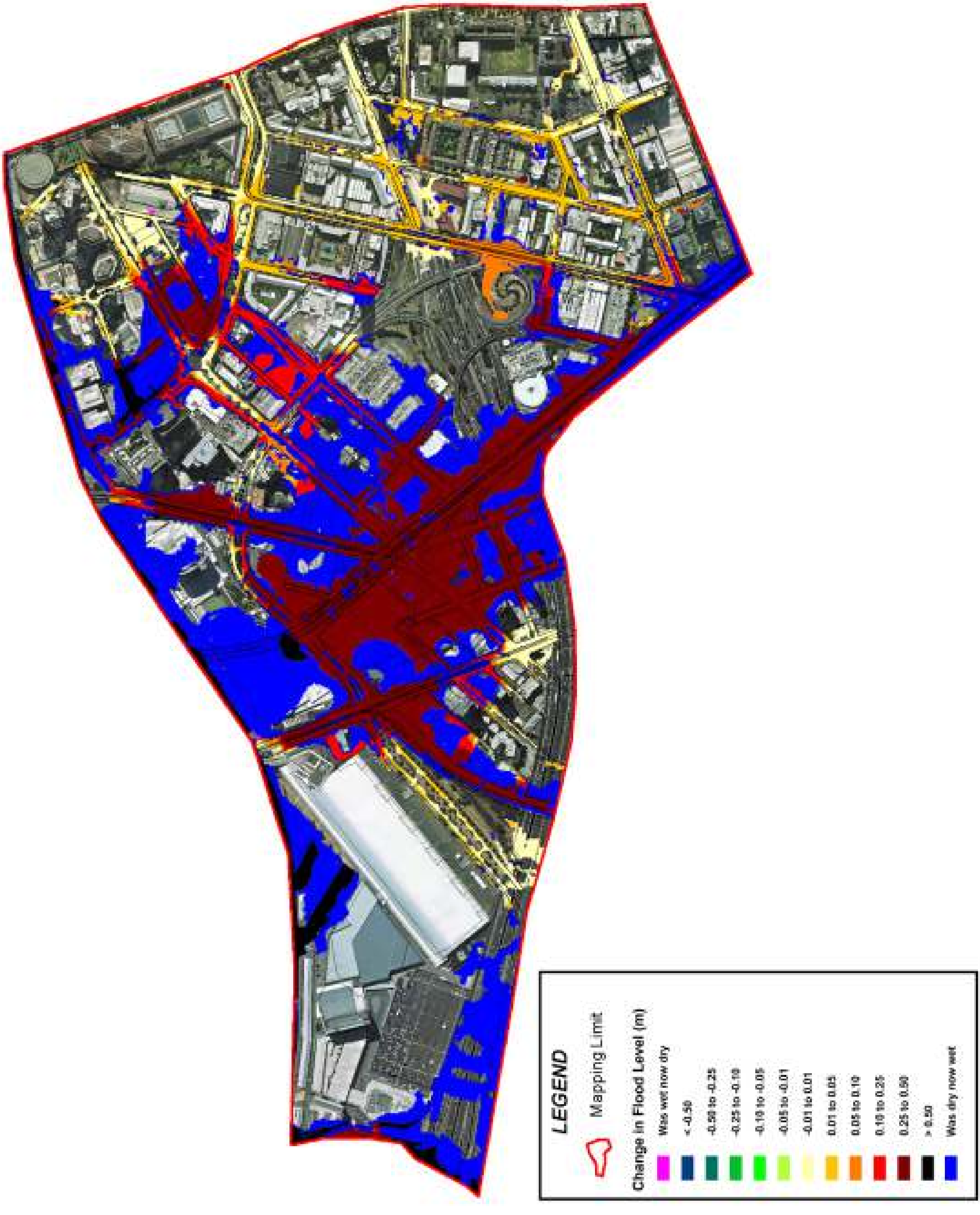
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-36_FldDif_C02_E01+32%_5y_Yarra100y_RevA.WOR



Title:

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

Figure:
D-37

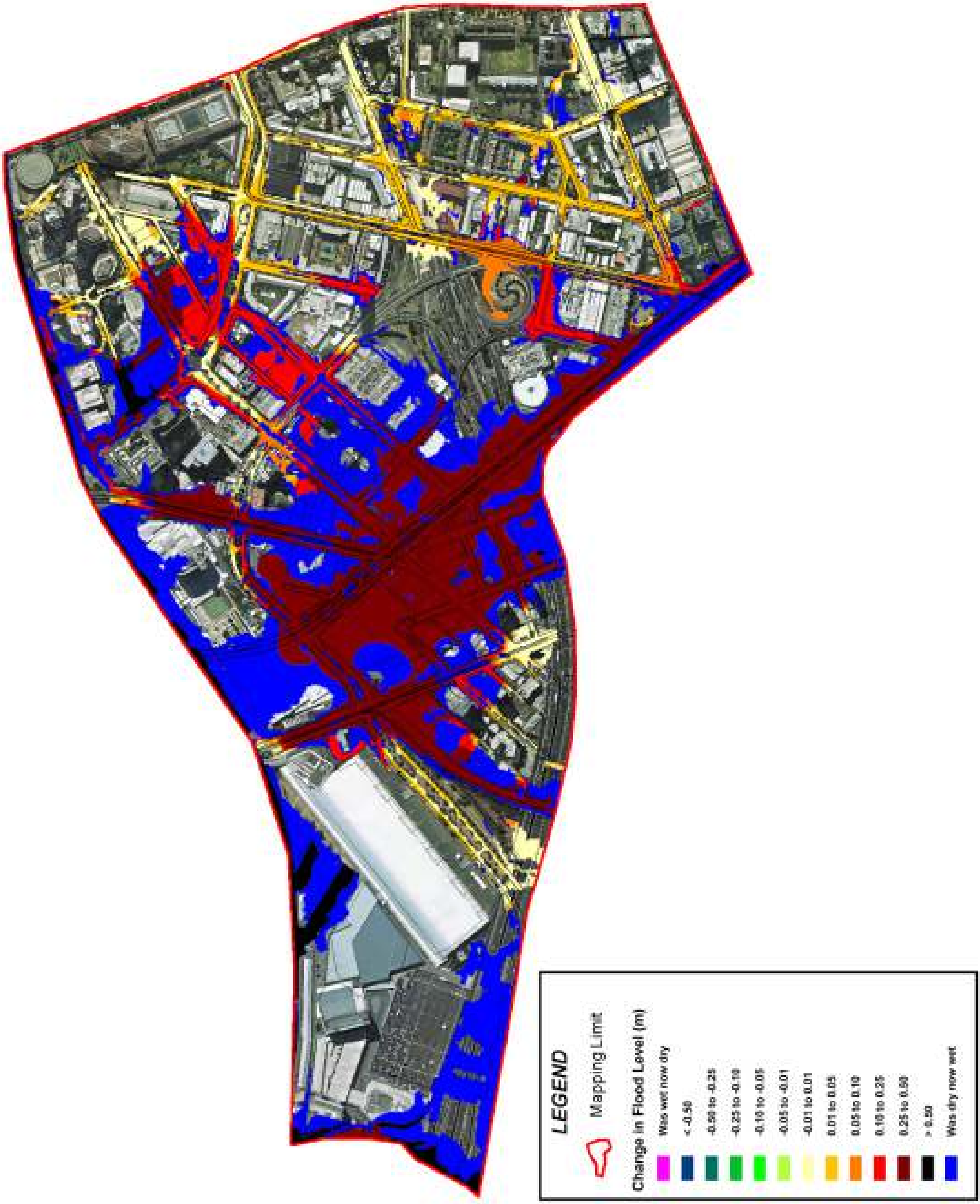
Rev:
A

N

0 125 250m
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-37_FldDif_C02_E01+32%_10y_Yarra100y_RevA.WOR



Title:

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

Figure: **D-38**

Rev: **A**

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N

0 125 250m
Approx. Scale

BMT WBM
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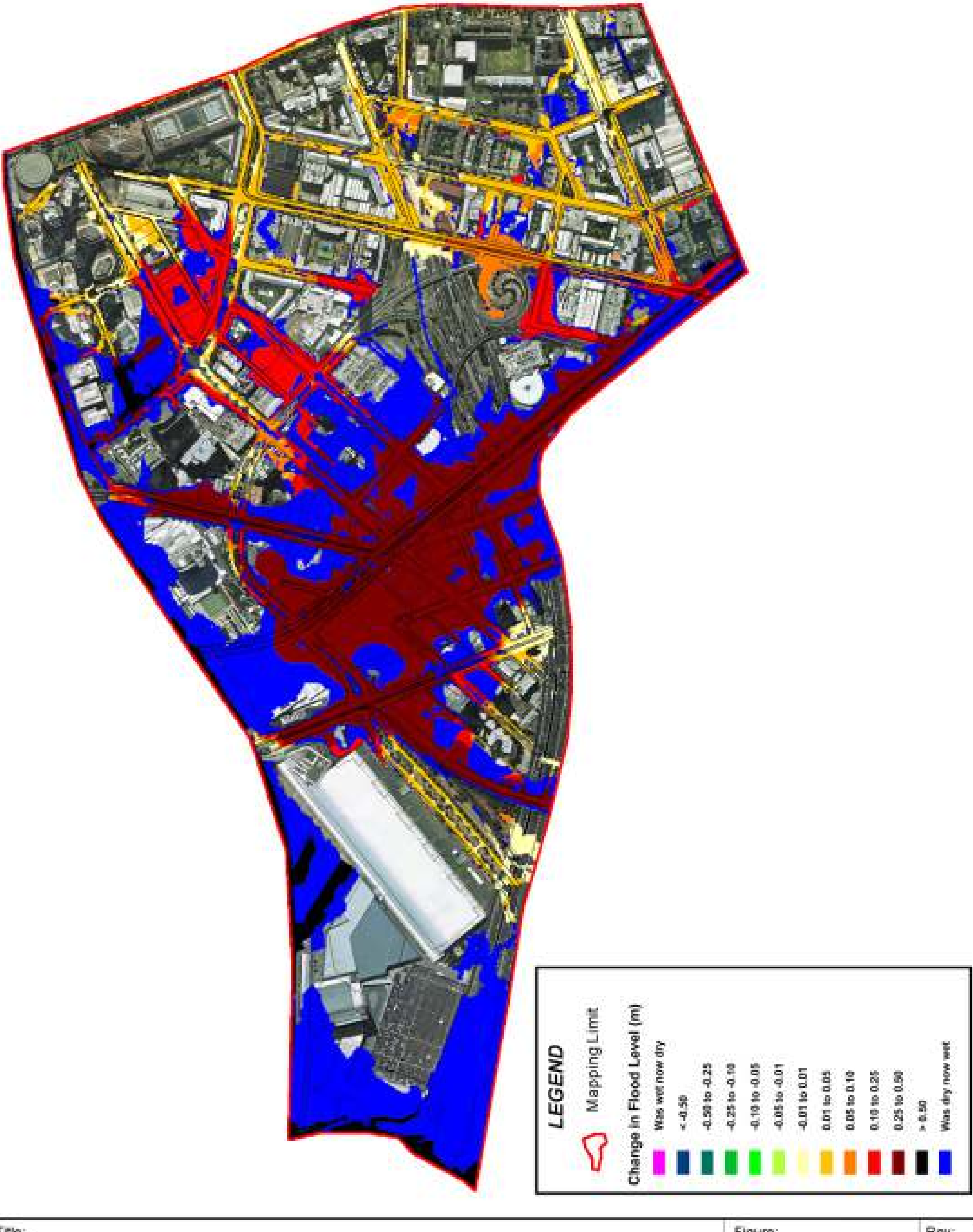
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-38_FldDif_C02_E01+32%_20y_Yarra100y_RevA.WOR



Title:

Southbank - Climate Change +32%

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

Figure: **D-39**

Rev: **A**

N

0 125 250m
Approx. Scale

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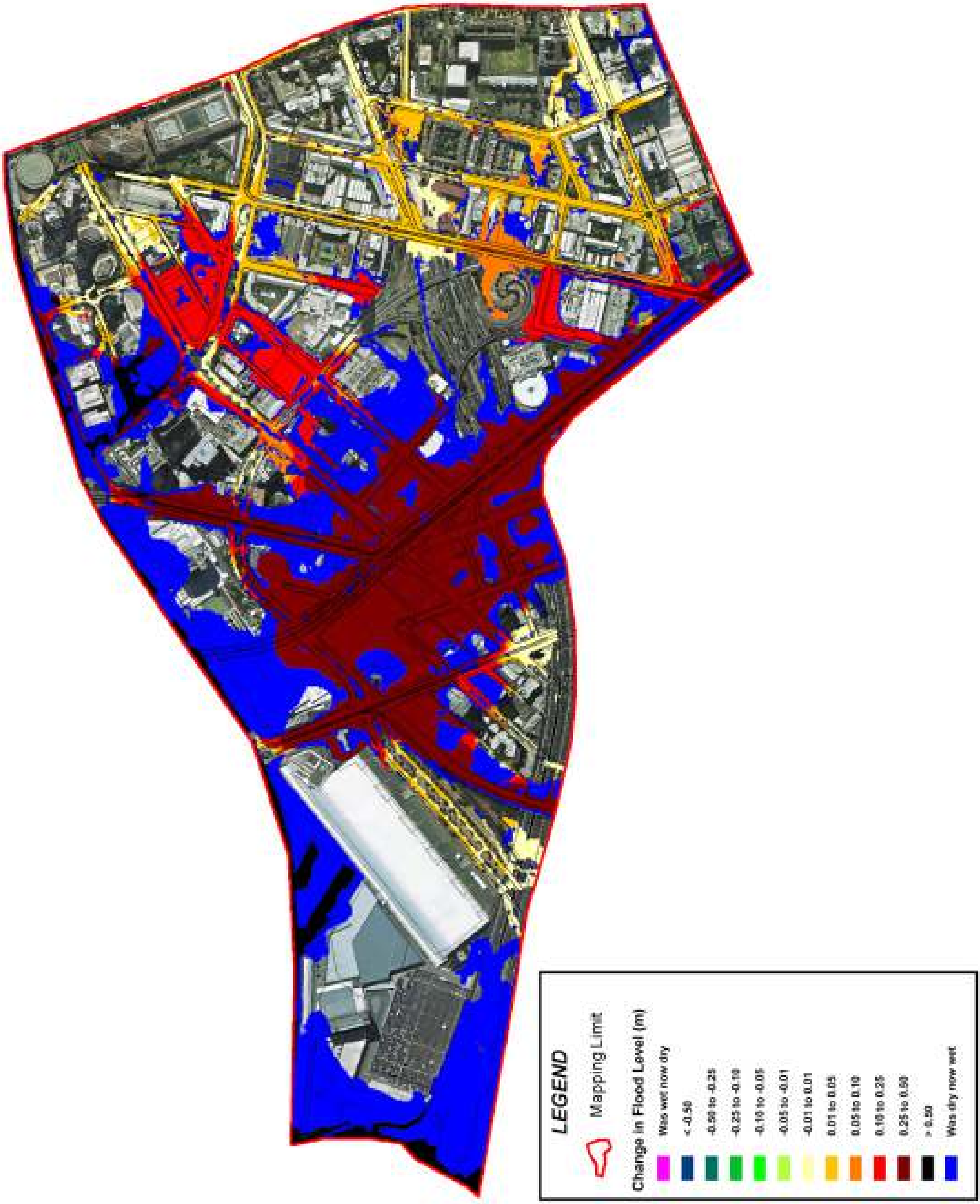
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-39_FldDif_C02_E01+32%_50y_Yarra100y_RevA.WOR



Title:

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

Figure: **D-40**

Rev: **A**

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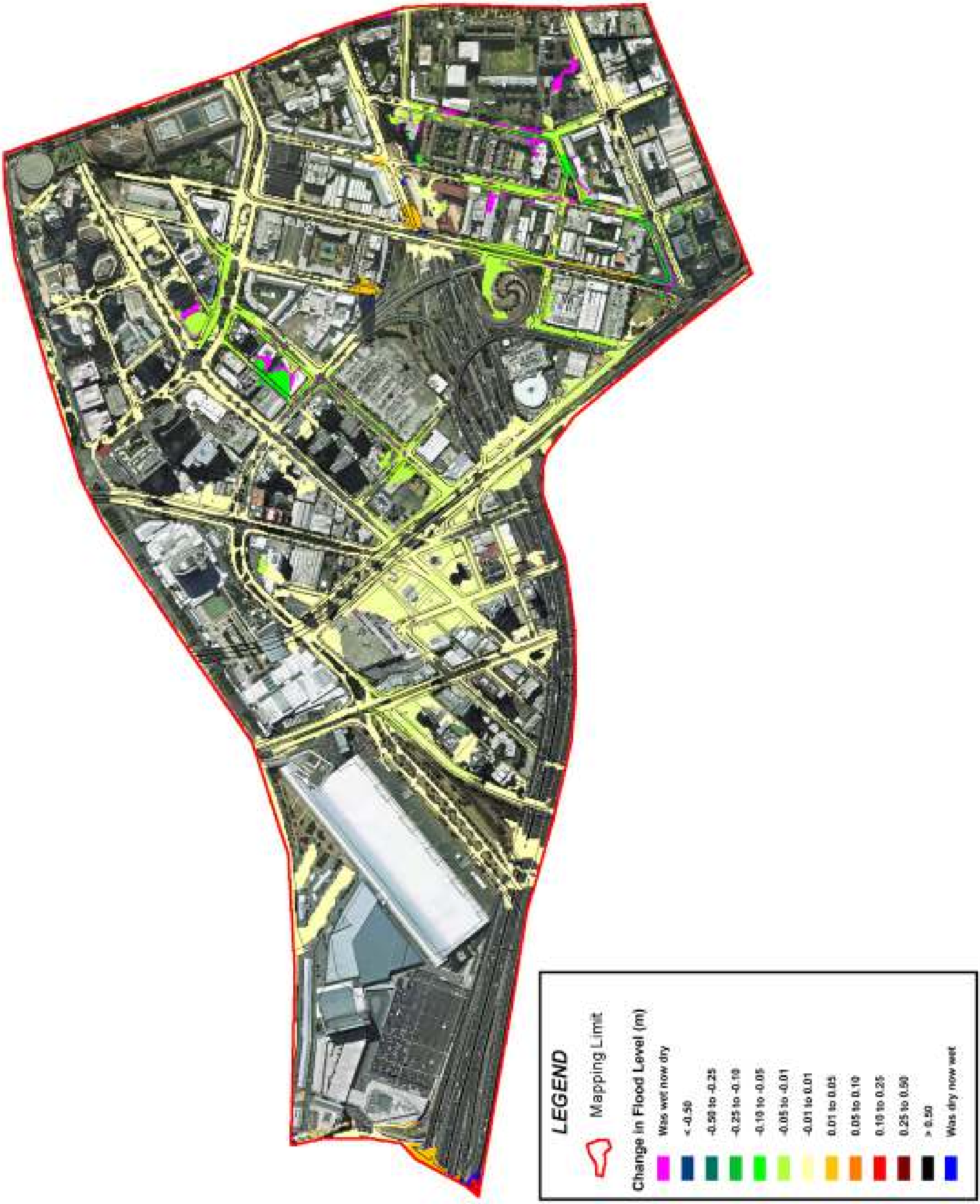
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixD\SBK_Final_FigD-40_FldDif_C02_E01+32%_100y_Yarra100y_RevA.WOR

Appendix E Opportunities Mapping (Future Climate)



Title:

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

Figure: **E-1**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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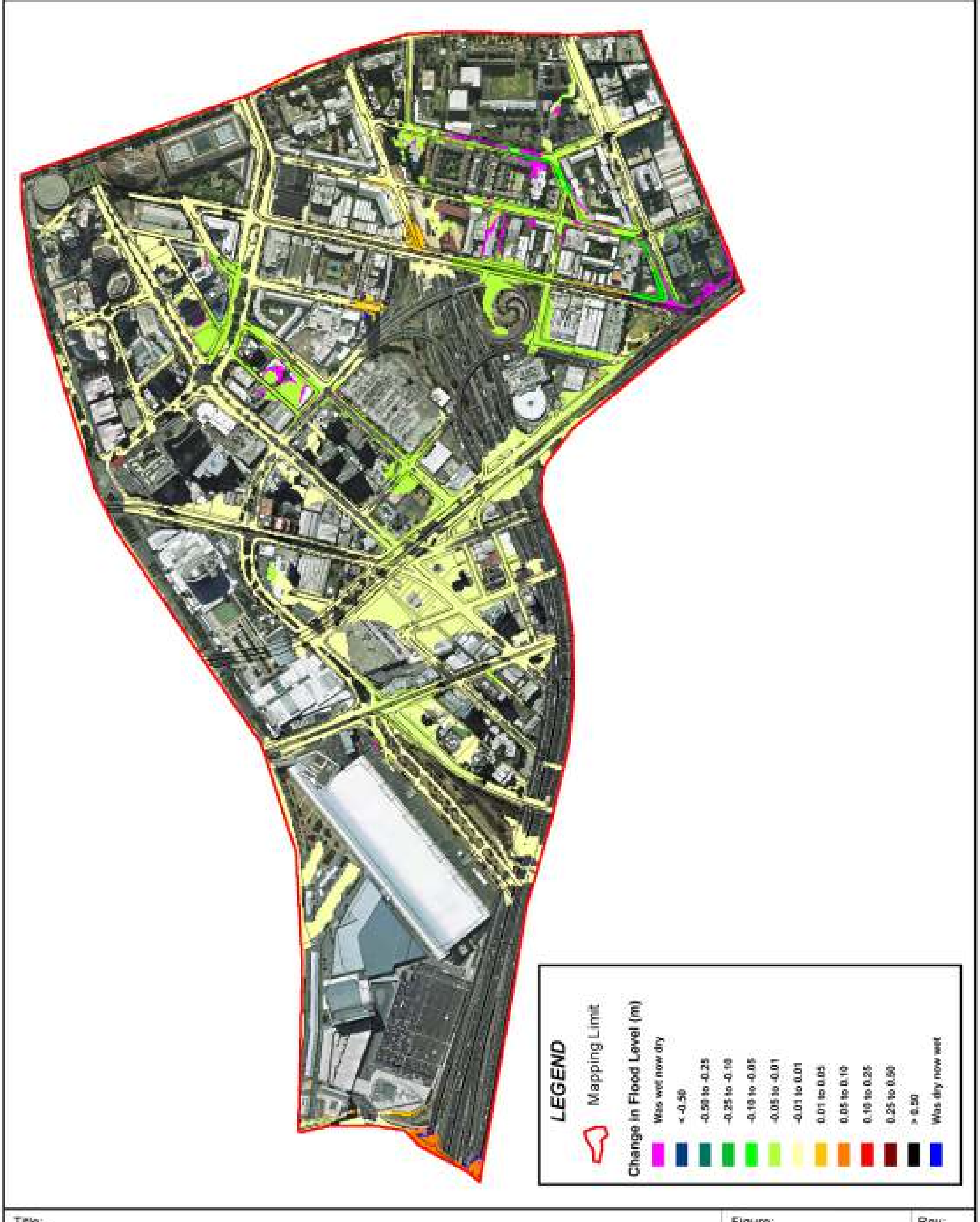
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-1_FldDif_D11_C01+15%_5y_MSL_RevA.WOR



Title:

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

Figure: **E-2**

Rev: **A**

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N

0 125 250m
Approx. Scale

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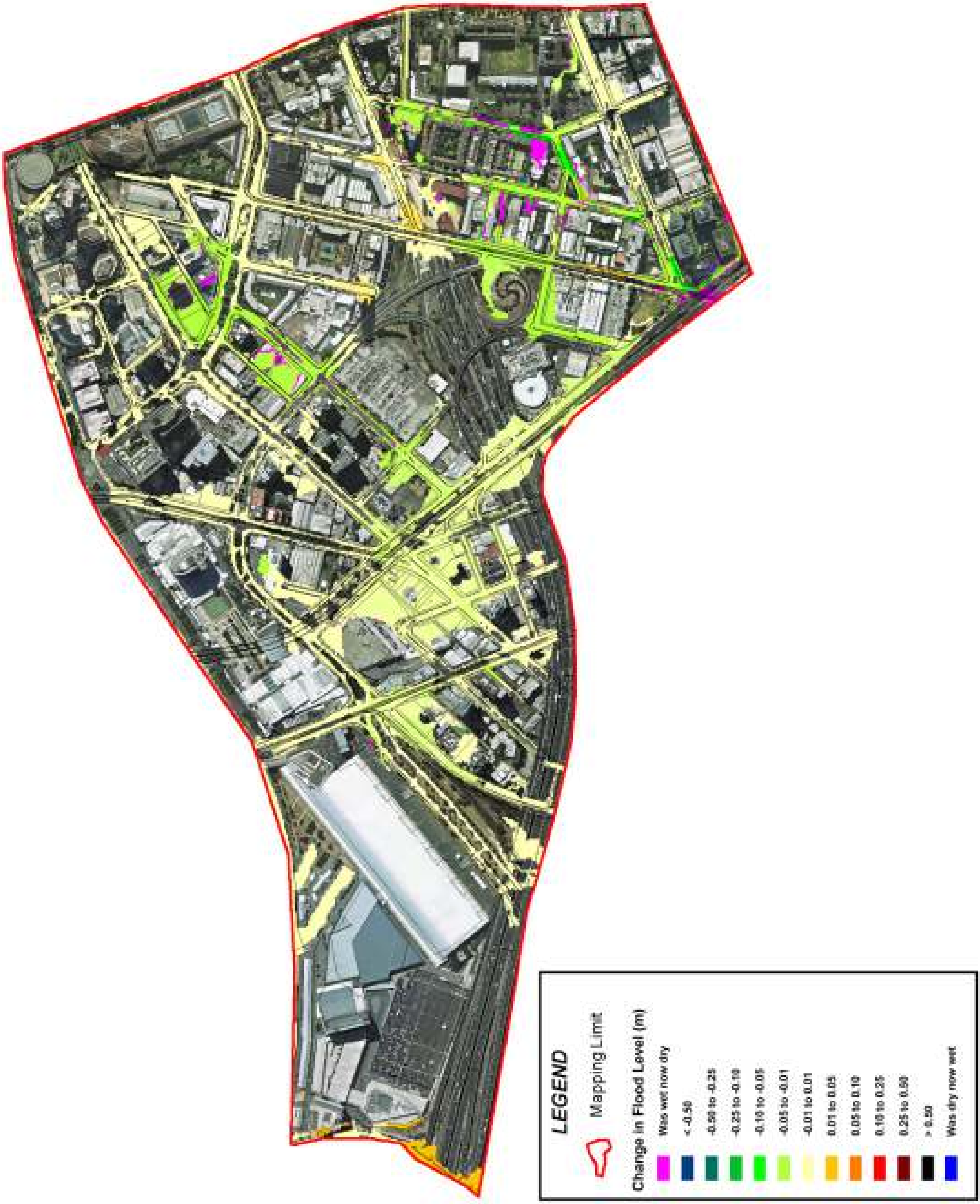

Title:

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

Figure: **E-3**

Rev: **A**

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N

0 125 250m
Approx. Scale

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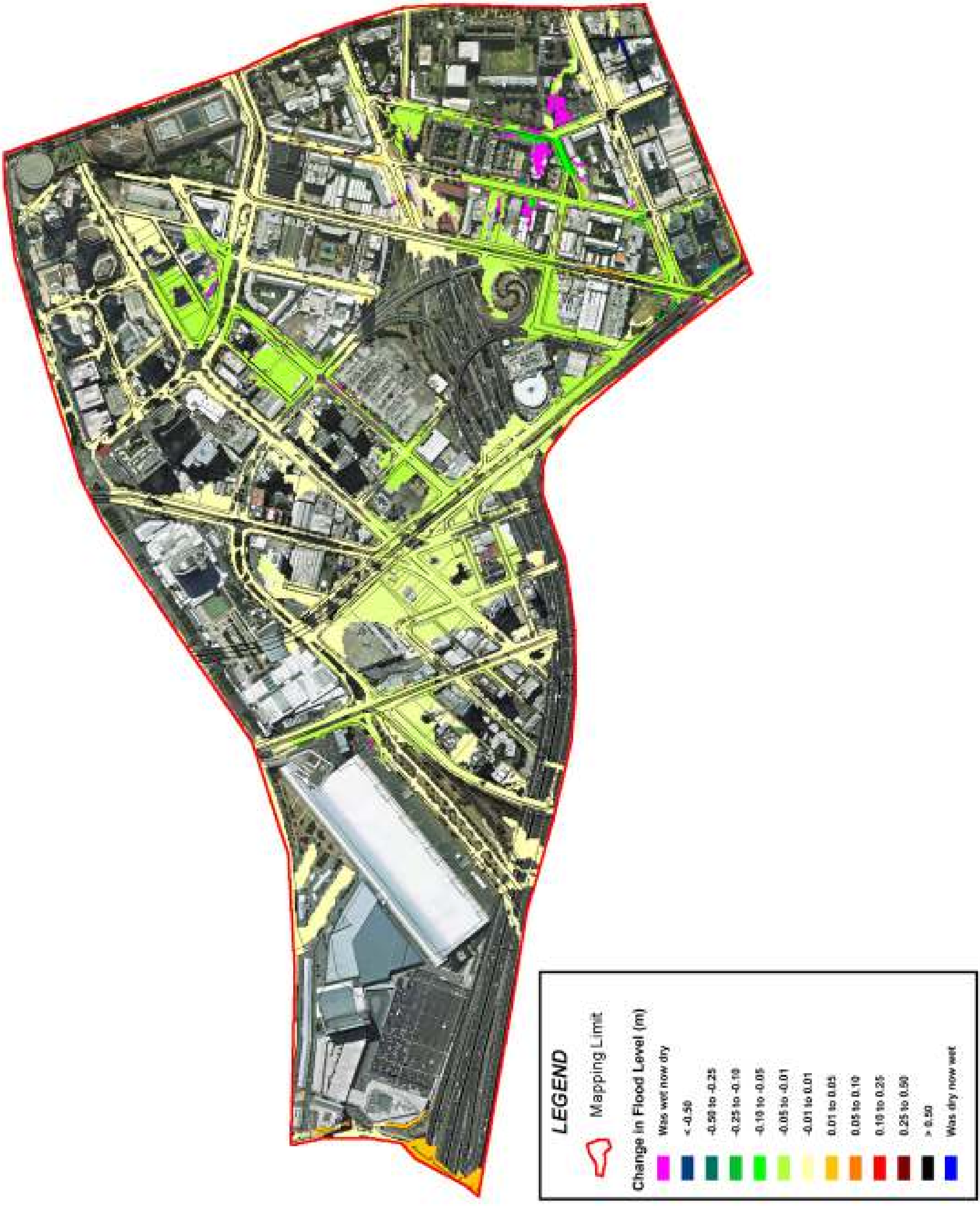

Title:
Southbank - Climate Change +32% - WSUD
Change in 50 Year ARI Peak Flood Heights - MSL

Figure: **E-4**

Rev: **A**

N

0 125 250m
Approx. Scale

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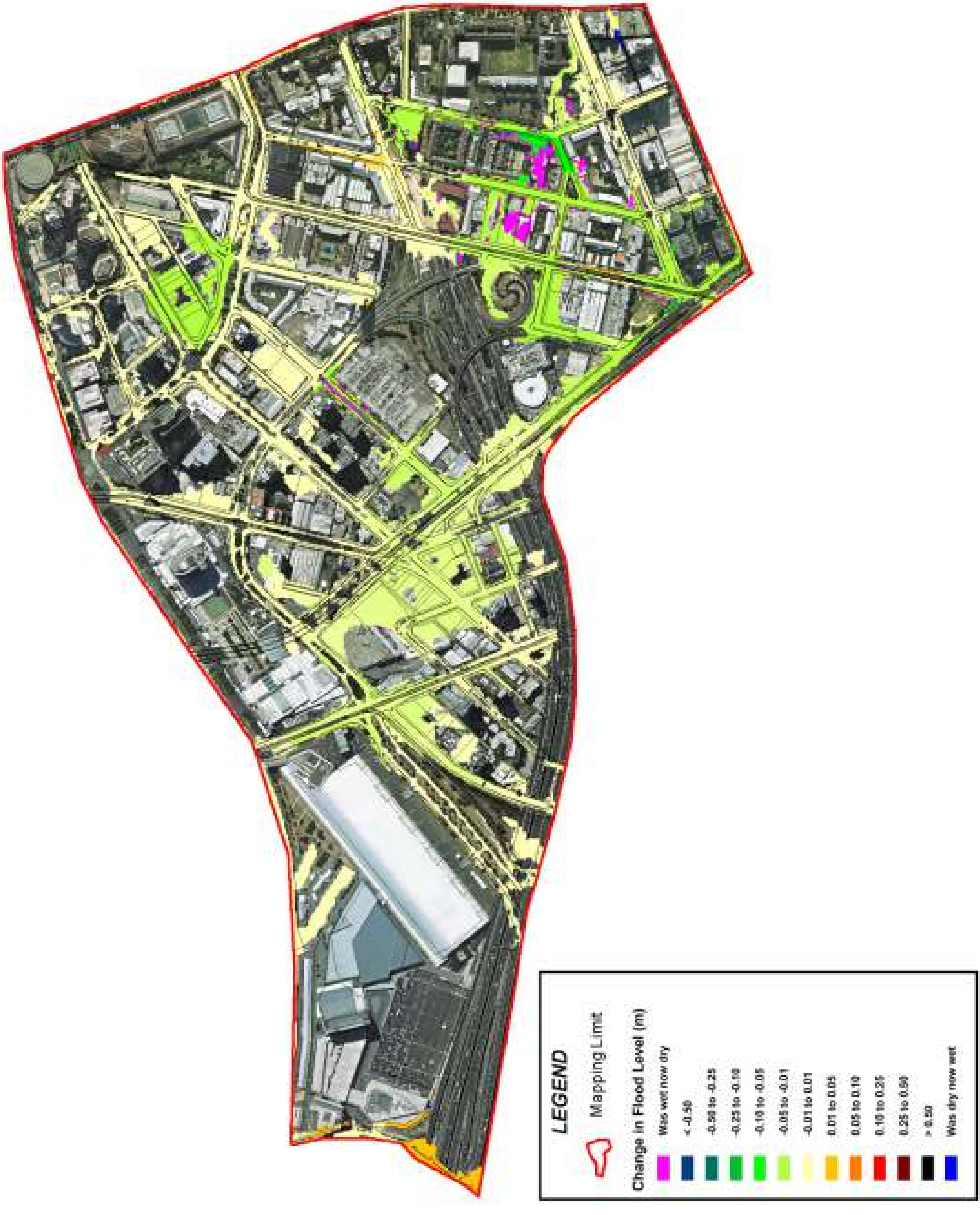
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-4_FldDif_D11_C01+15%_50y_MSL_RevA.WOR



Title:

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

Figure: **E-5**

Rev: **A**

N

0 125 250m
Approx. Scale

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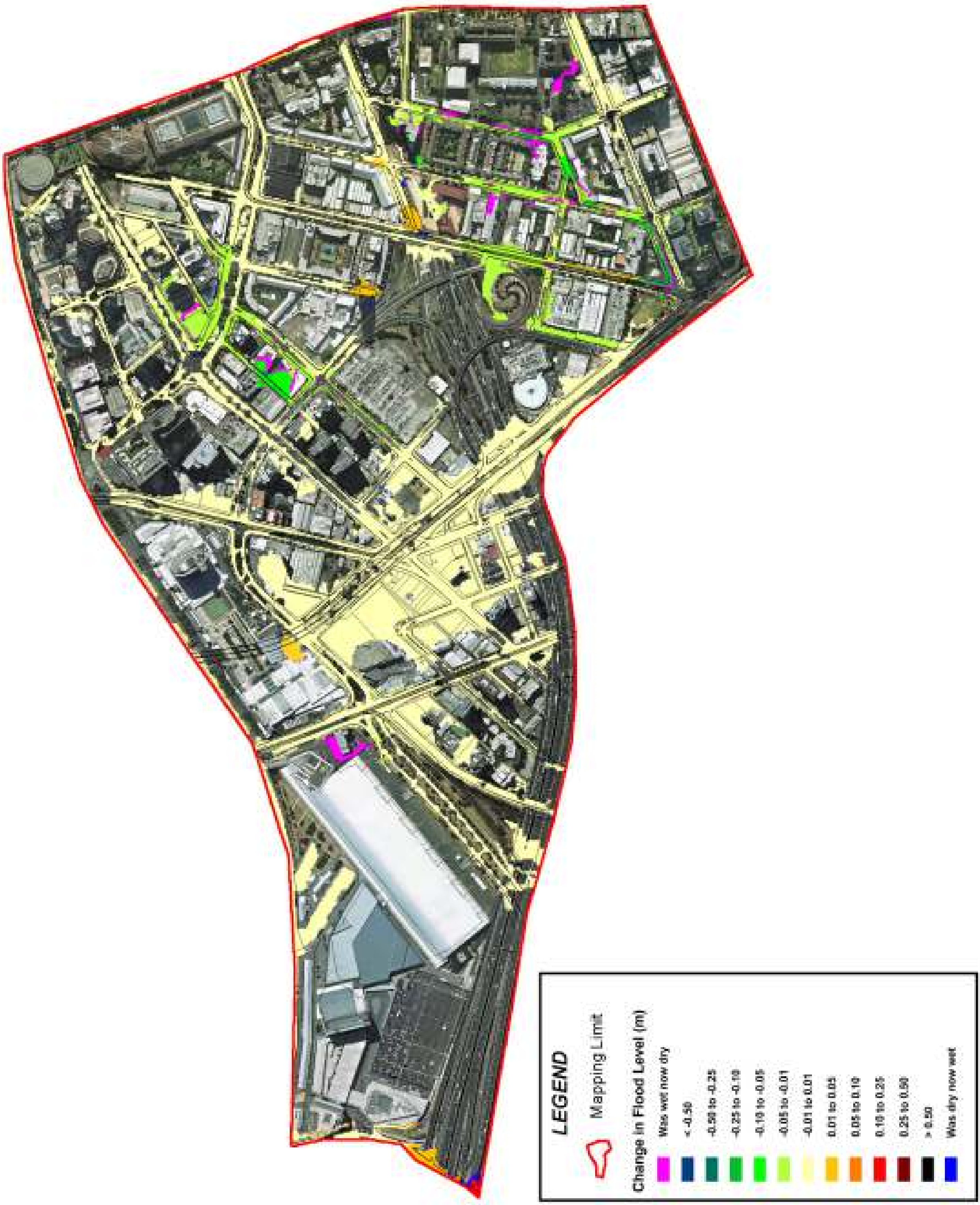
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-5_FldDif_D11_C01+15%_100y_MSL_RevA.WOR



Title:

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

Figure: **E-6**

Rev: **A**

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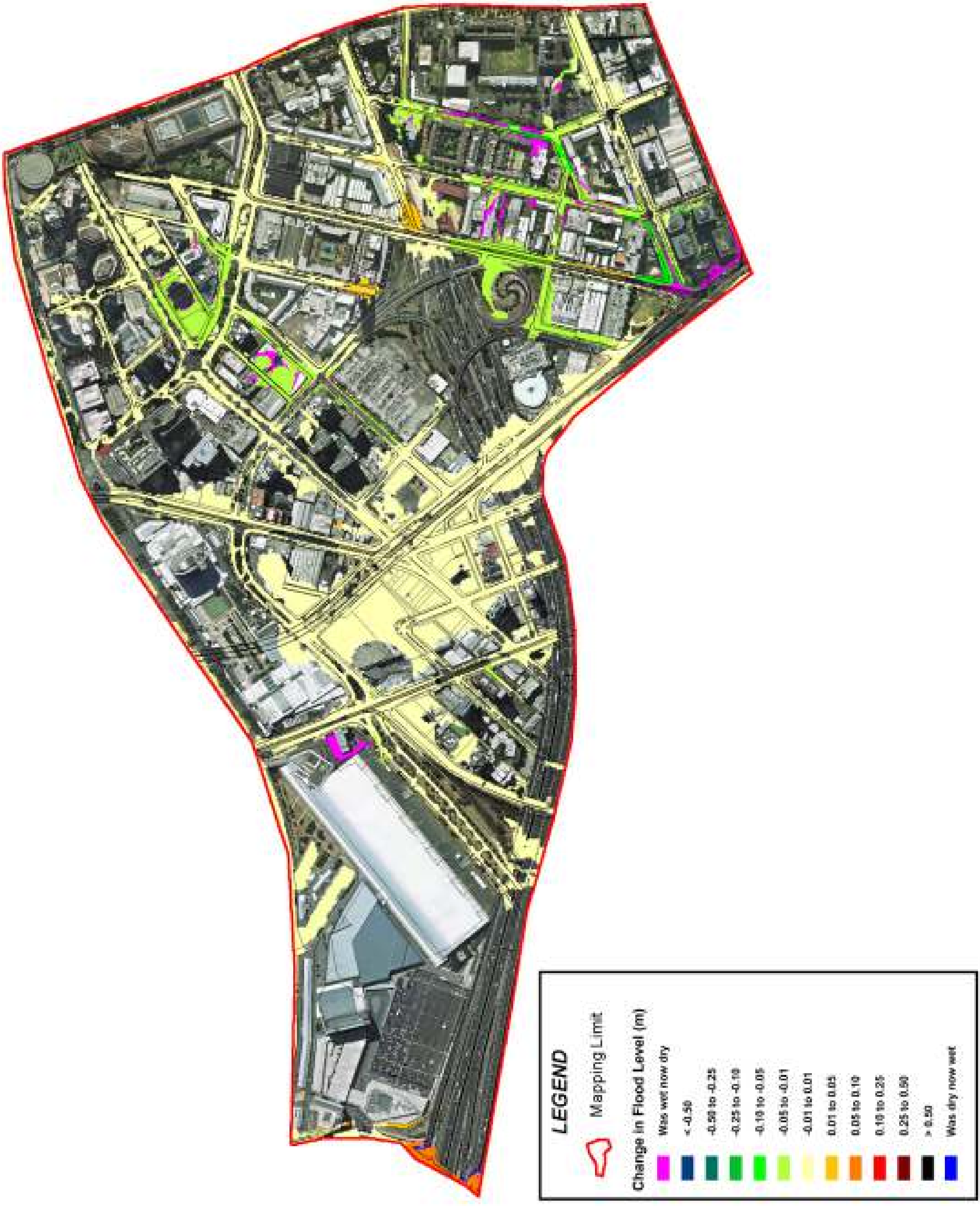
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-6_FldDif_D11_C01+15%_5y_Storm_RevA.WOR



Title:

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

Figure: **E-7**

Rev: **A**

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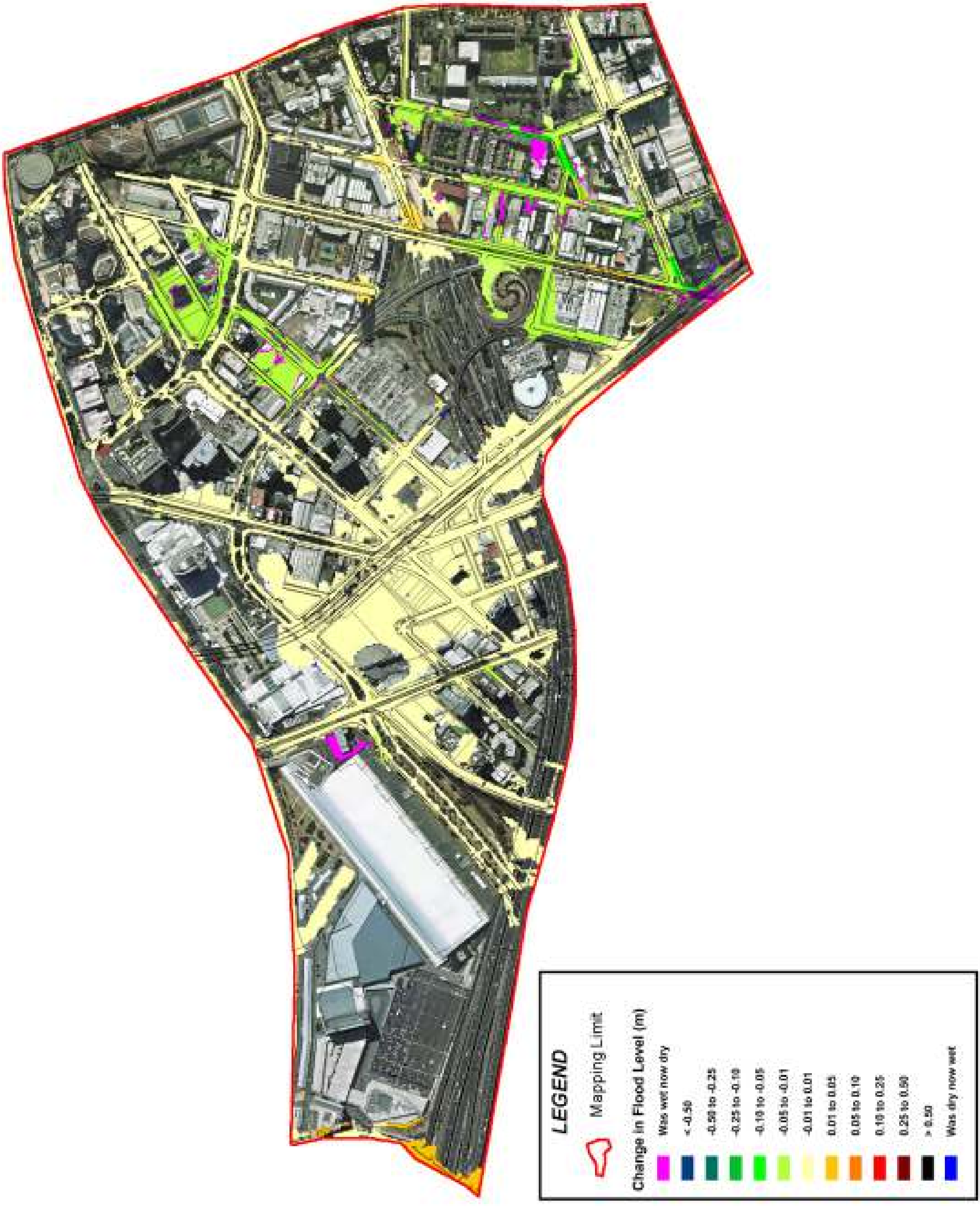
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-7_FldDif_D11_C01+15%_10y_Storm_RevA.WOR



Title:

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

Figure: **E-8**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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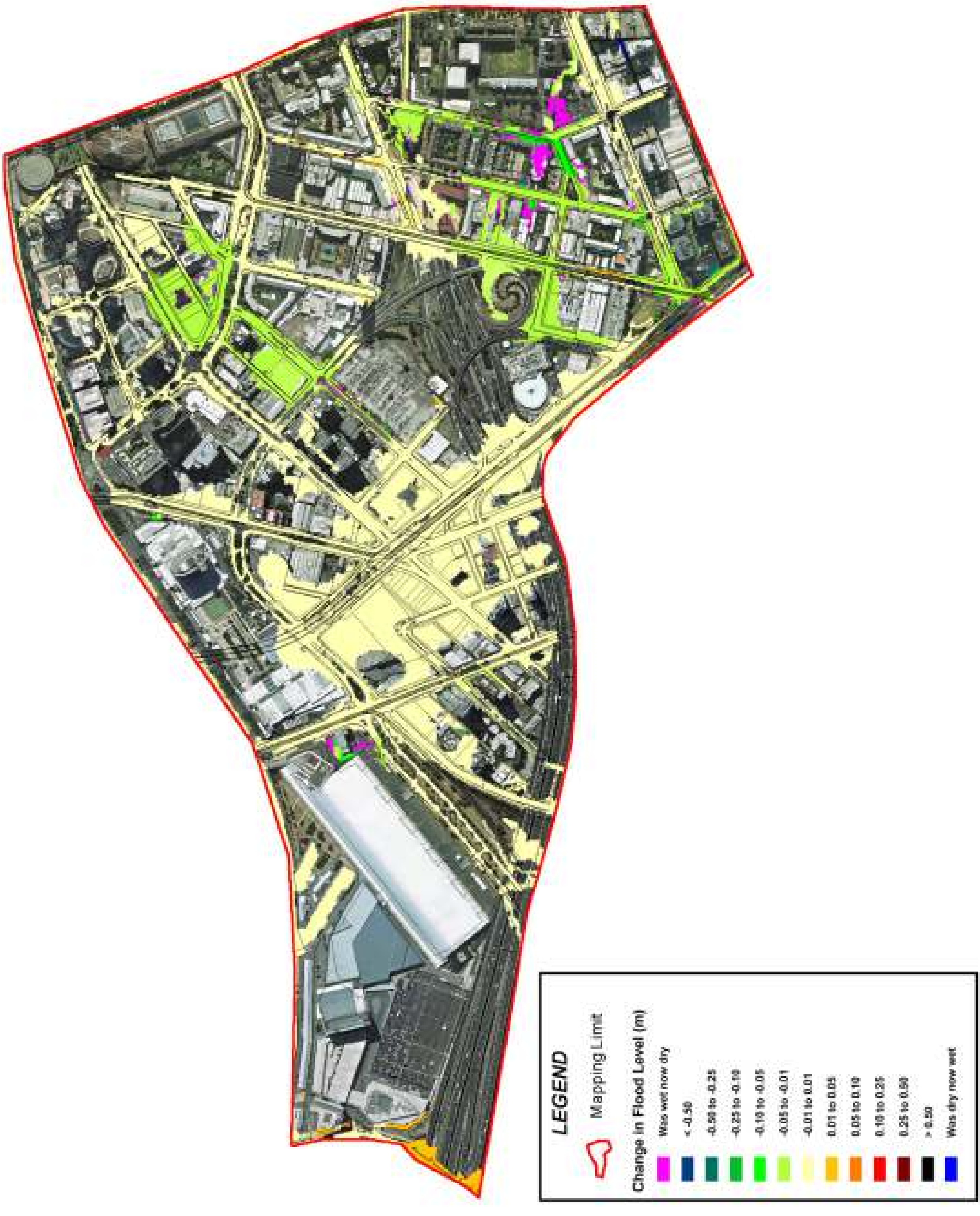
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-8_FldDif_D11_C01+15%_20y_Storm_RevA.WOR



Title:

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

Figure: E-9

Rev: A

BMT WBM

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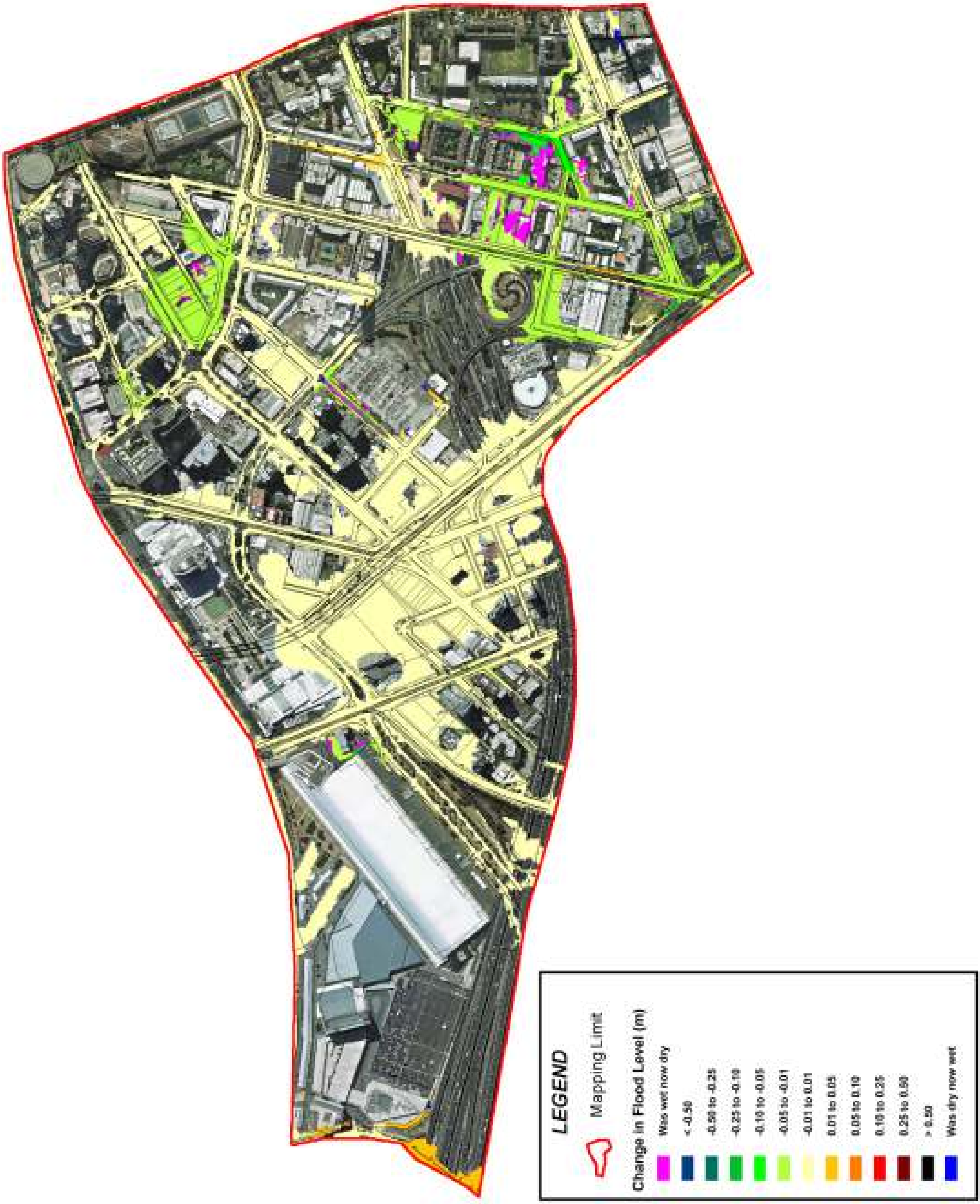
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-9_FldDif_D11_C01+15%_50y_Storm_RevA.WOR



Title:

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

Figure: **E-10**

Rev: **A**

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N

0 125 250m
Approx. Scale

BMT WBM
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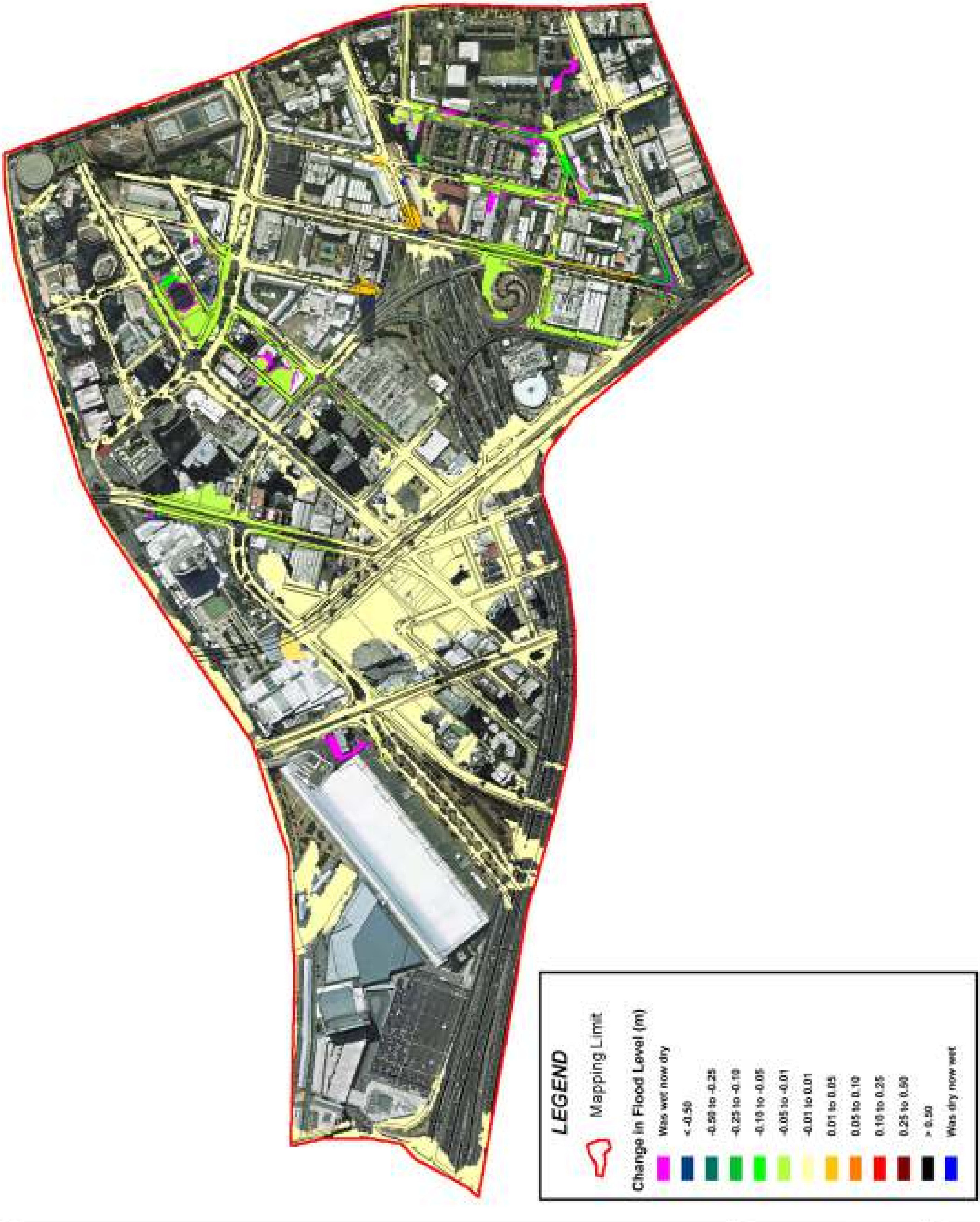
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-10_FldDif_D11_C01+15%_100y_Storm_RevA.WOR



Title:

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

Figure: **E-11**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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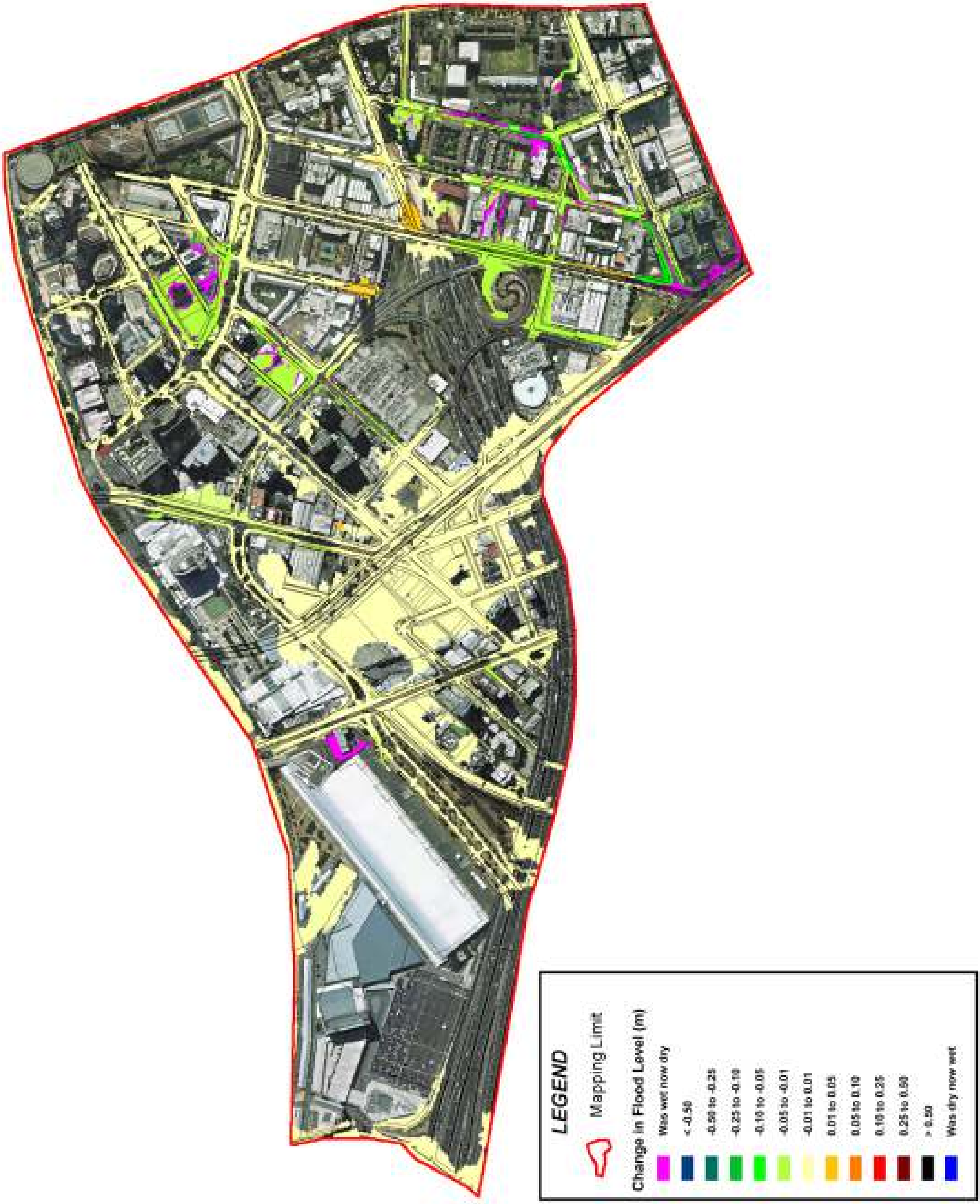
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-11_FldDif_D11_C01+15%_5y_Storm_RevA.WOR



Title:

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

Figure:
E-12

Rev:
A

N

0 125 250m
Approx. Scale

BMT WBM
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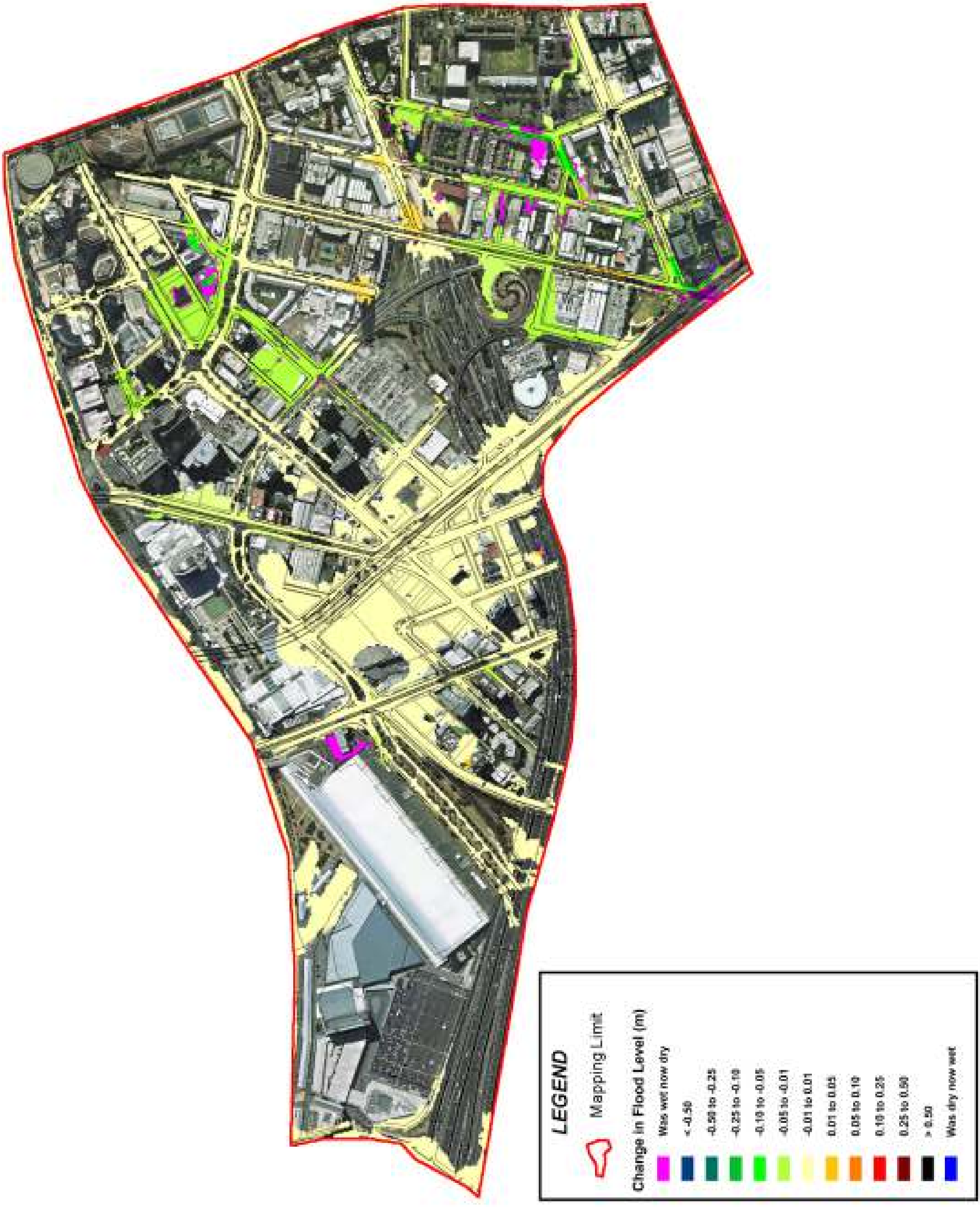
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-12_FldDif_D11_C01+15%_10y_Storm_RevA.WOR



Title:

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

Figure: **E-13**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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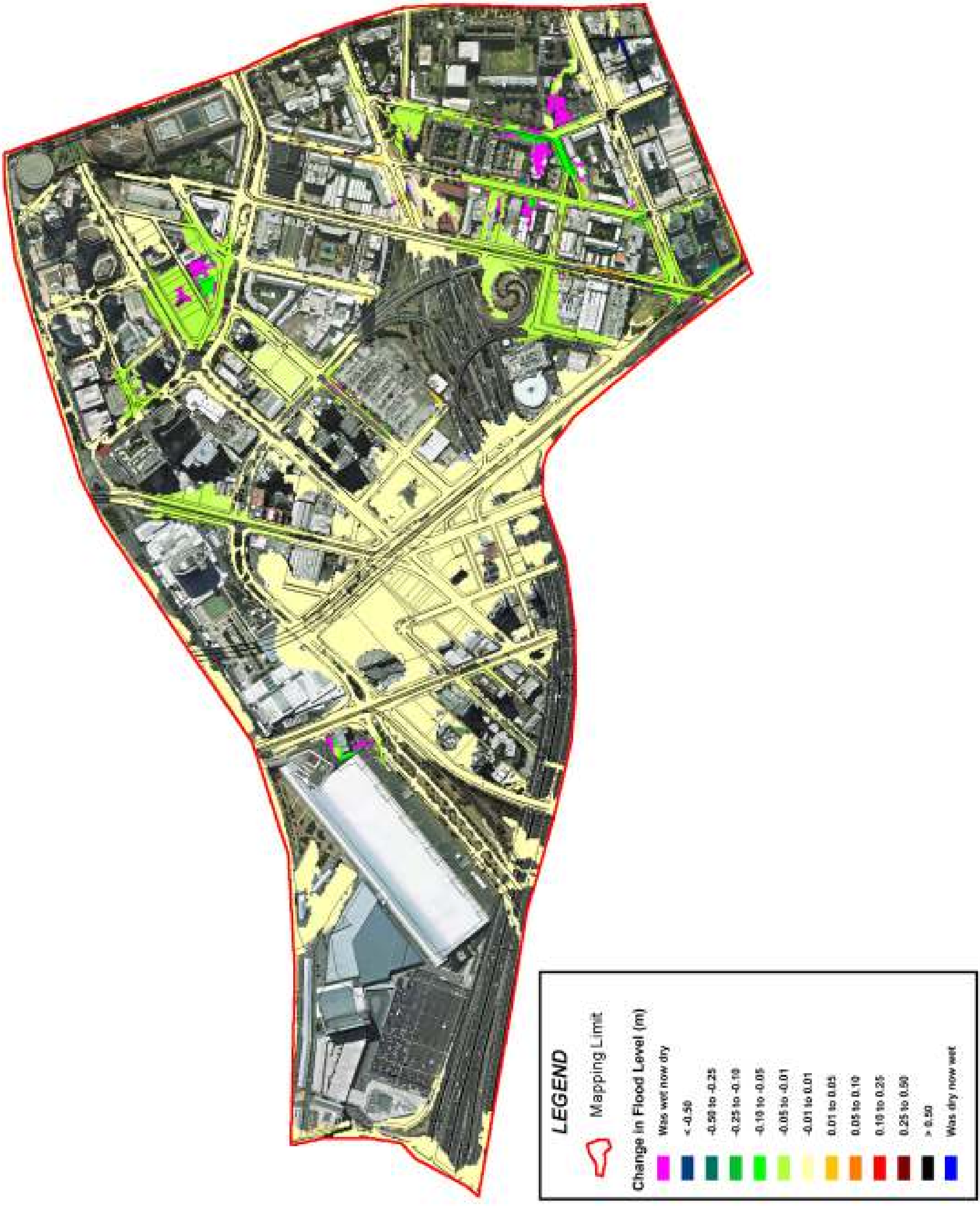
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-13_FldDif_D11_C01+15%_20y_Storm_RevA.WOR



Title:

Southbank - Climate Change +32% - WSUD
Change in 50 Year ARI Peak Flood Heights - Storm Surge

Figure: **E-14**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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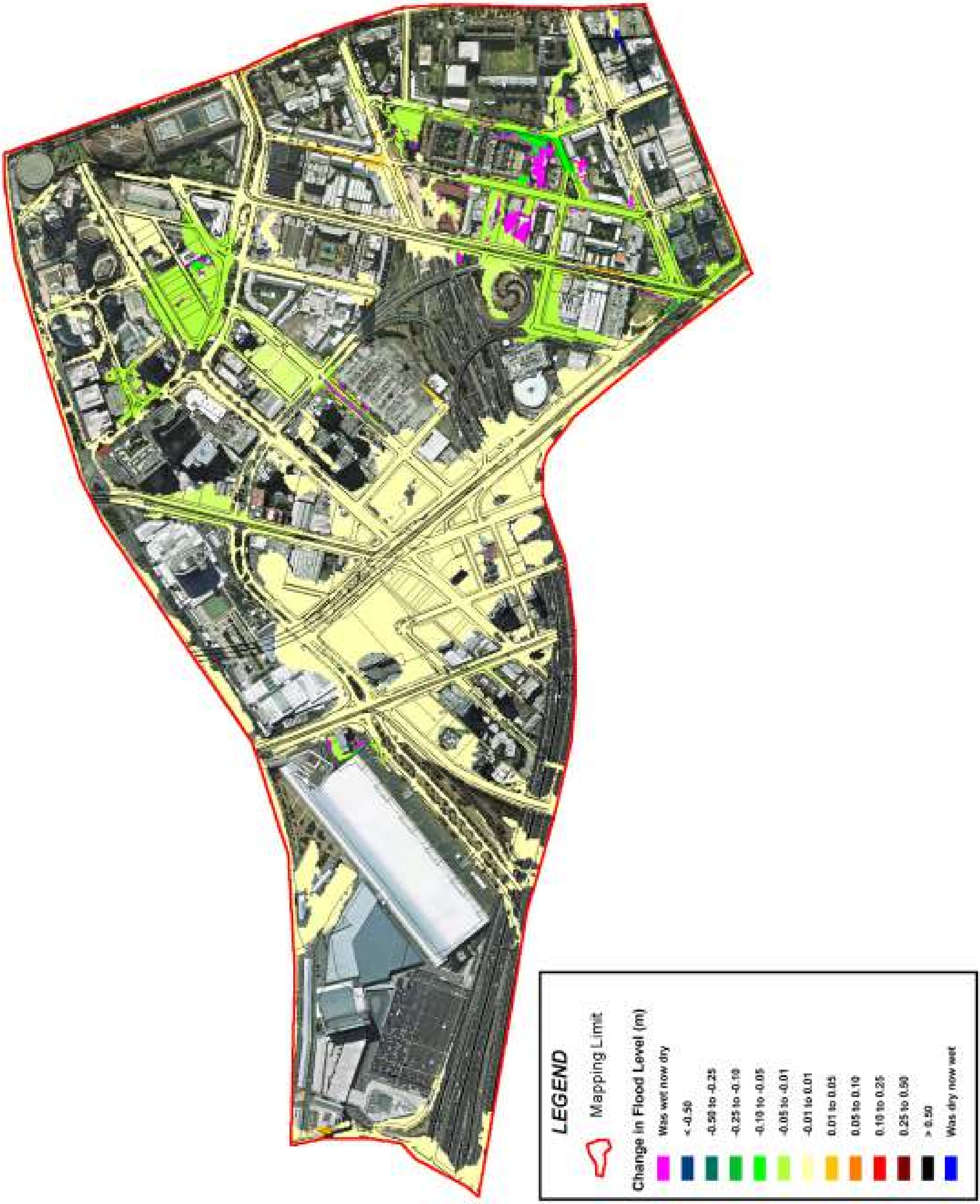
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-14_FldDif_D11_C01+15%_50y_Storm_RevA.WOR



Title:

Southbank - Climate Change +32% - WSUD
Change in 100 Year ARI Peak Flood Heights - Storm Surge

Figure: **E-15**

Rev: **A**

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N

0 125 250m
Approx. Scale

BMT WBM
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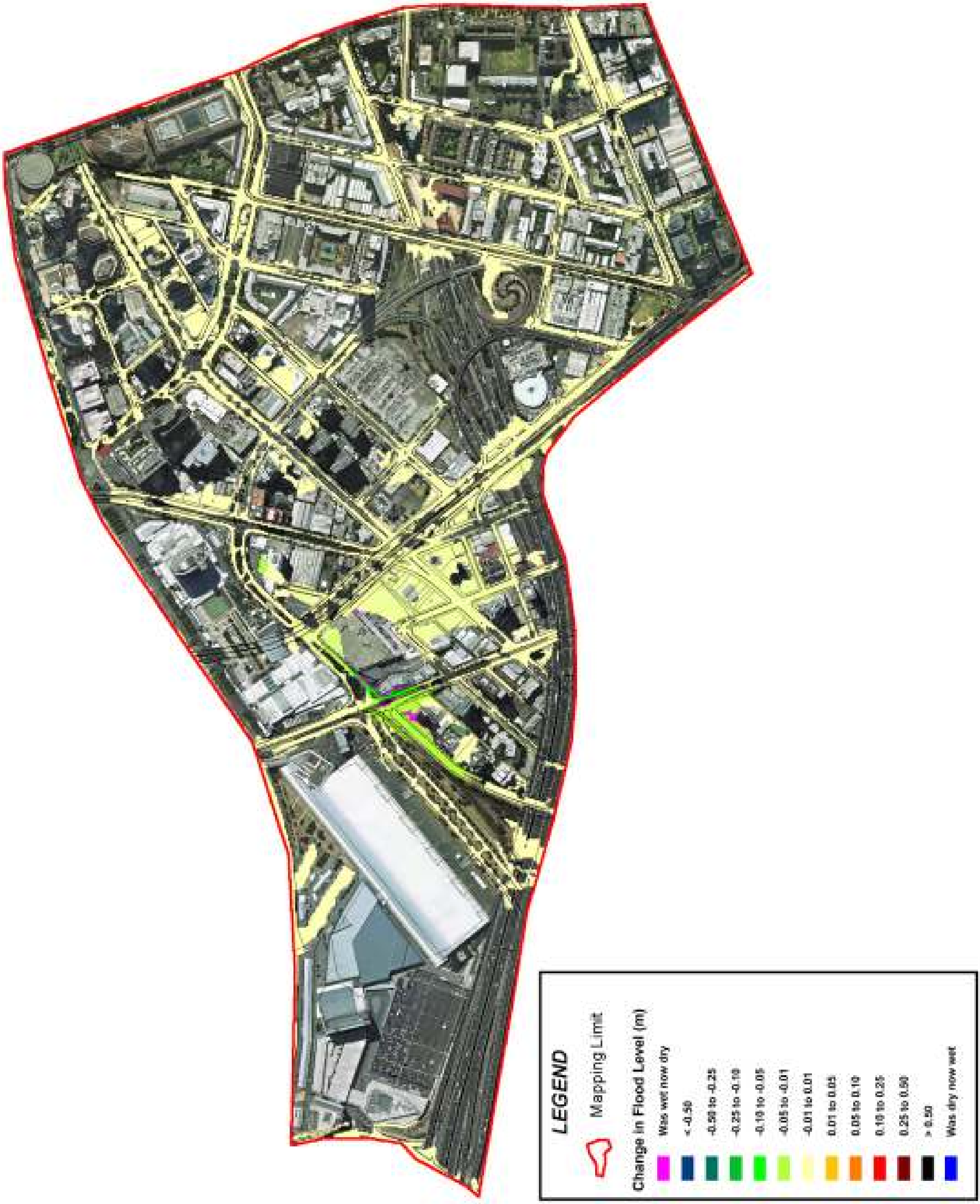
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-15_FldDif_D11_C01+15%_100y_Storm_RevA.WOR



Title:

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

Figure: E-1

Rev: A

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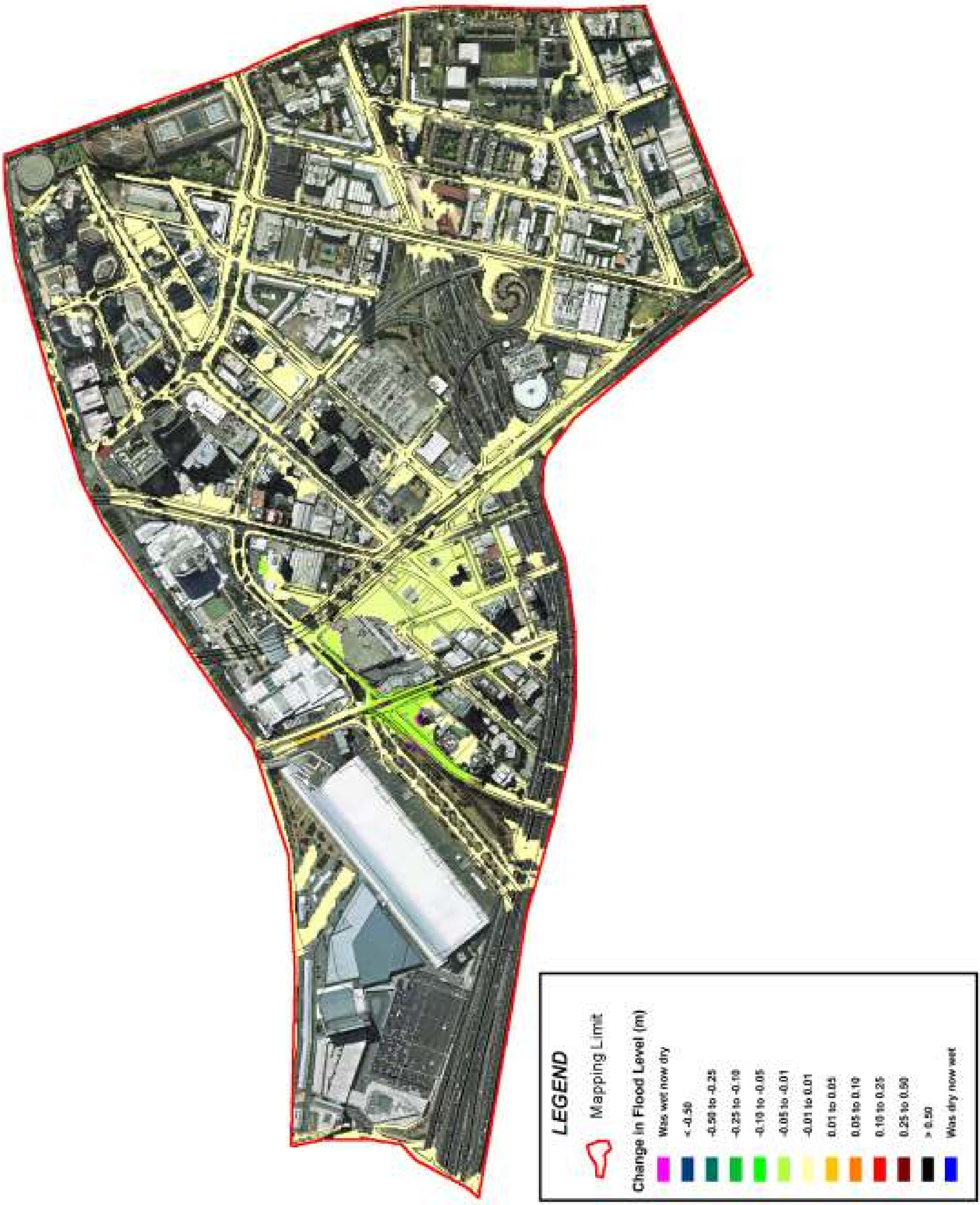
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-1_FldDif_D12_C01+15%_5y_MSL_RevA.WOR



Title:

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

Figure: **E-22**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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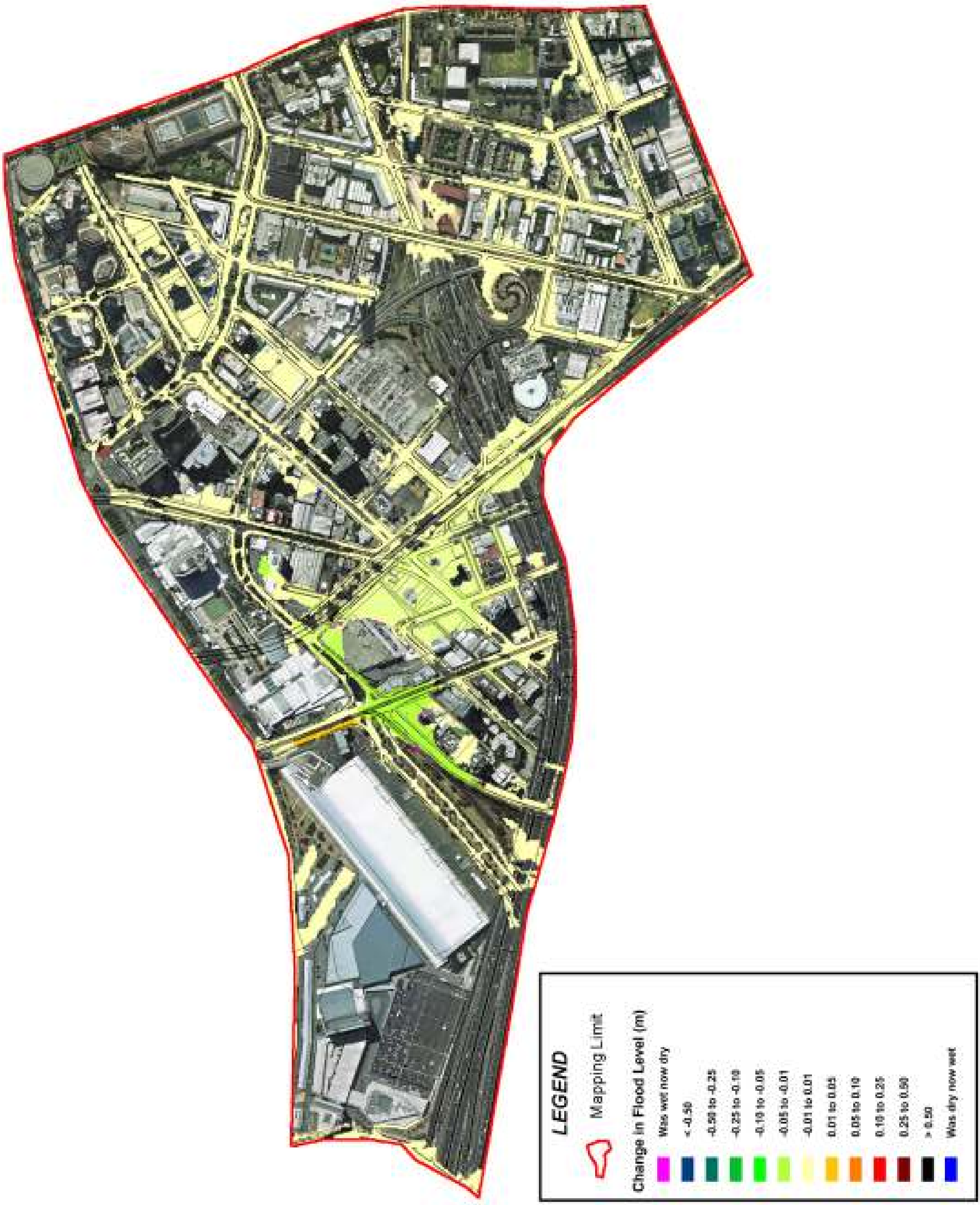
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-22_FldDif_D12_C01+15%_10y_MSL_RevA.WOR



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

Figure:
E-23

Rev:
A

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N

0 125 250m
Approx. Scale

BMT WBM
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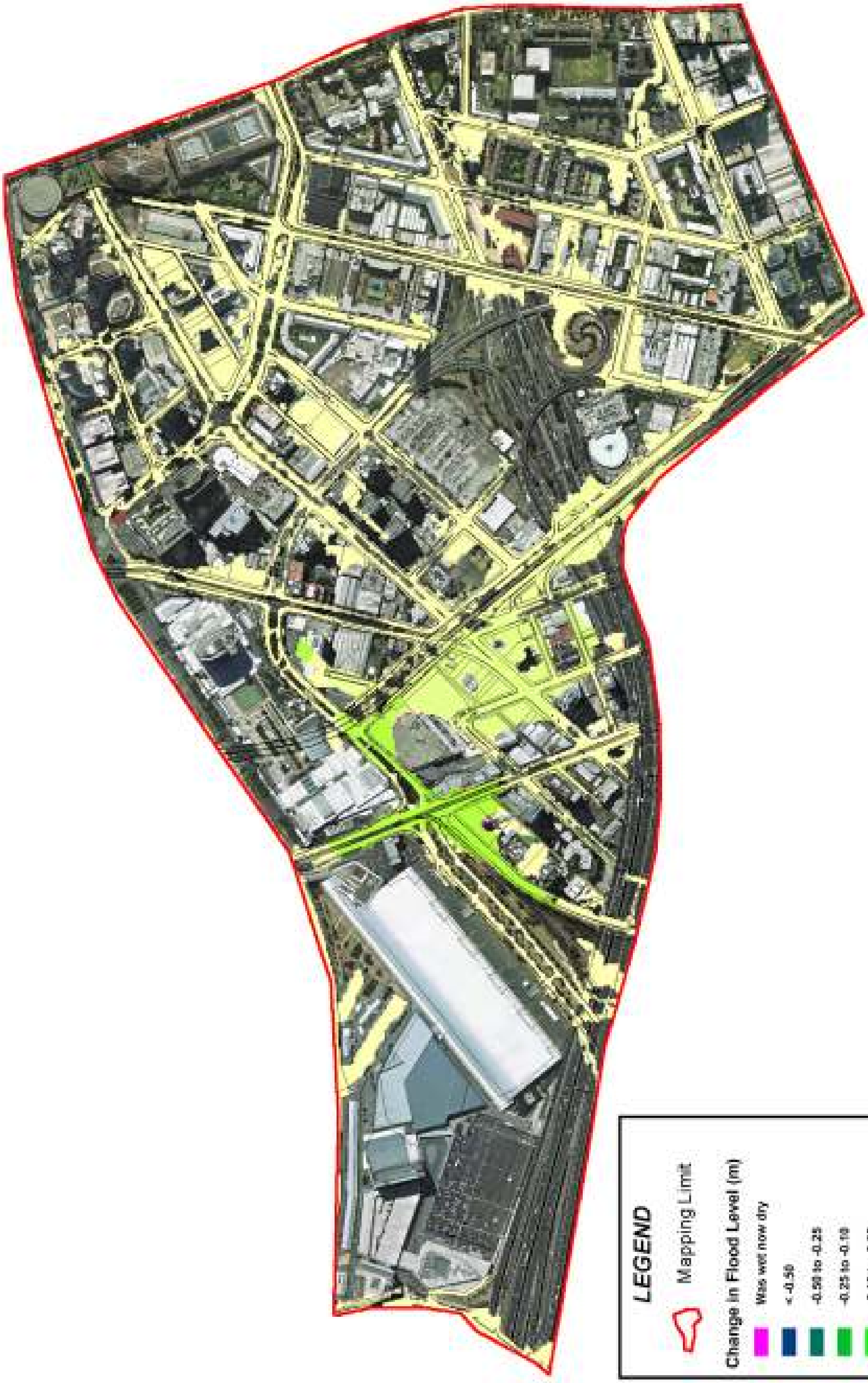
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-23_FldDif_D12_C01+15%_20y_MSL_RevA.WOR



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

Figure: **E-24**

Rev: **A**

N

0 125 250m
Approx. Scale

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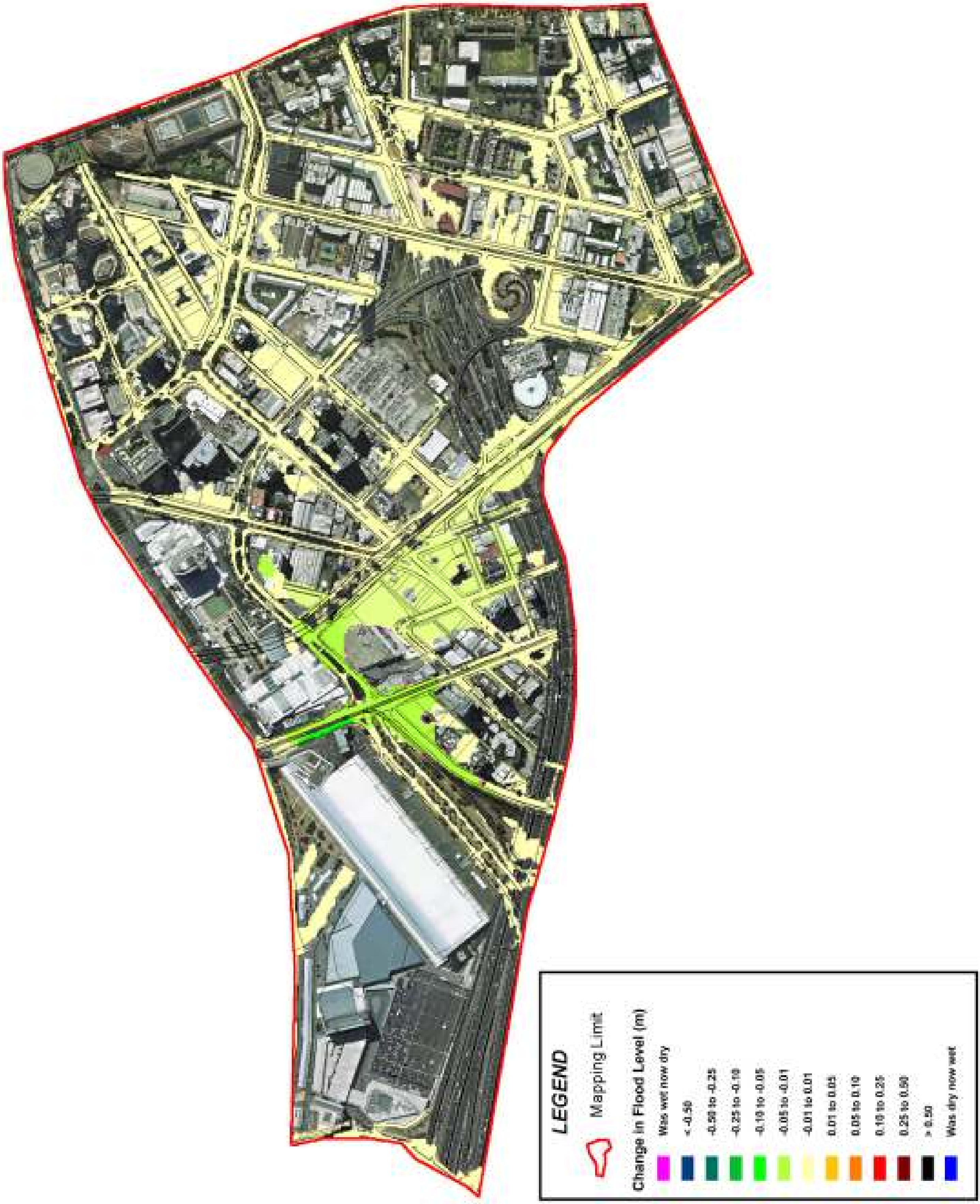
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-24_FldDif_D12_C01+15%_50y_MSL_RevA.WOR



Title:

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

Figure: **E-25**

Rev: **A**

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N

0 125 250m

Approx. Scale

BMT WBM

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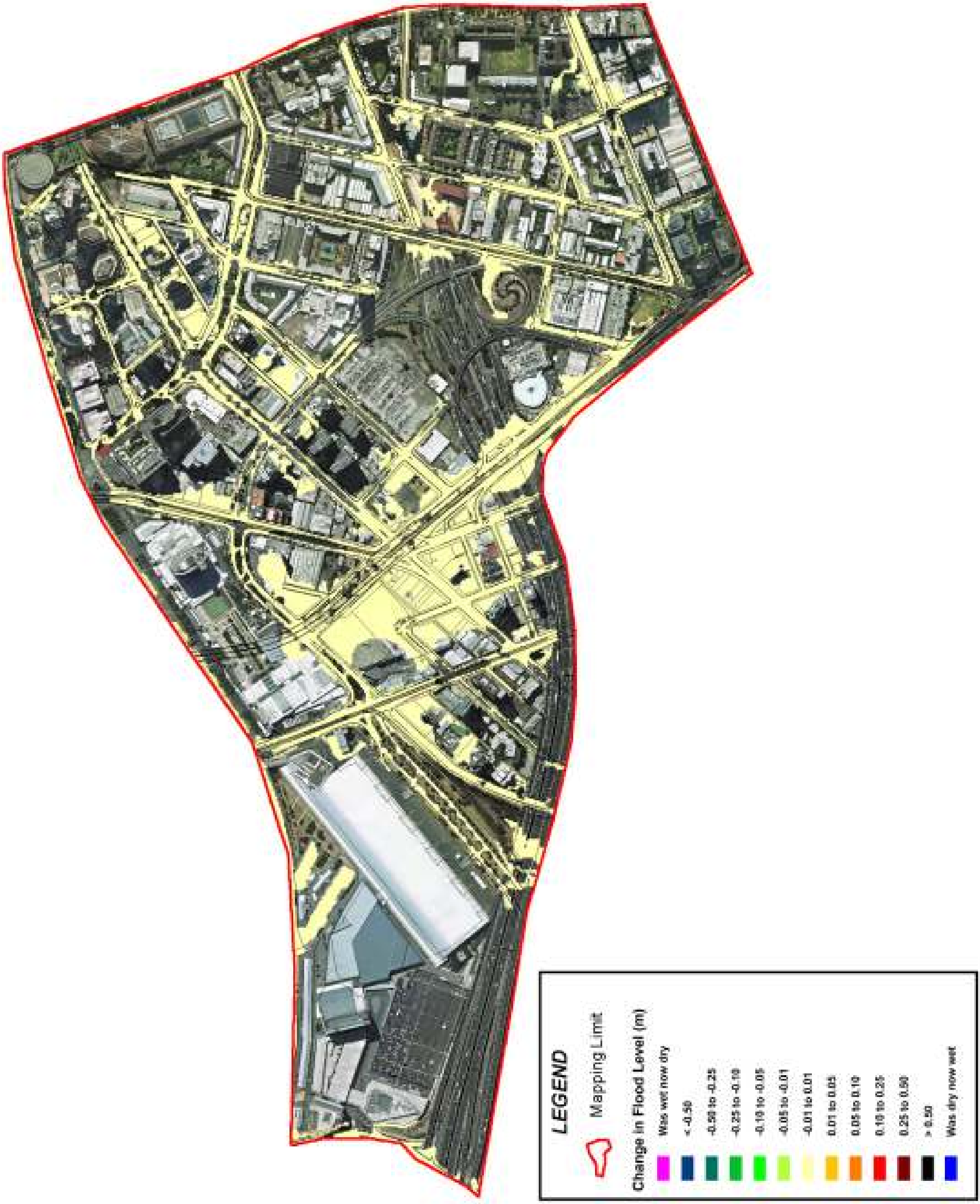
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-25_FldDif_D12_C01+15%_100y_MSL_RevA.WOR



Title:

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

Figure: **E-26**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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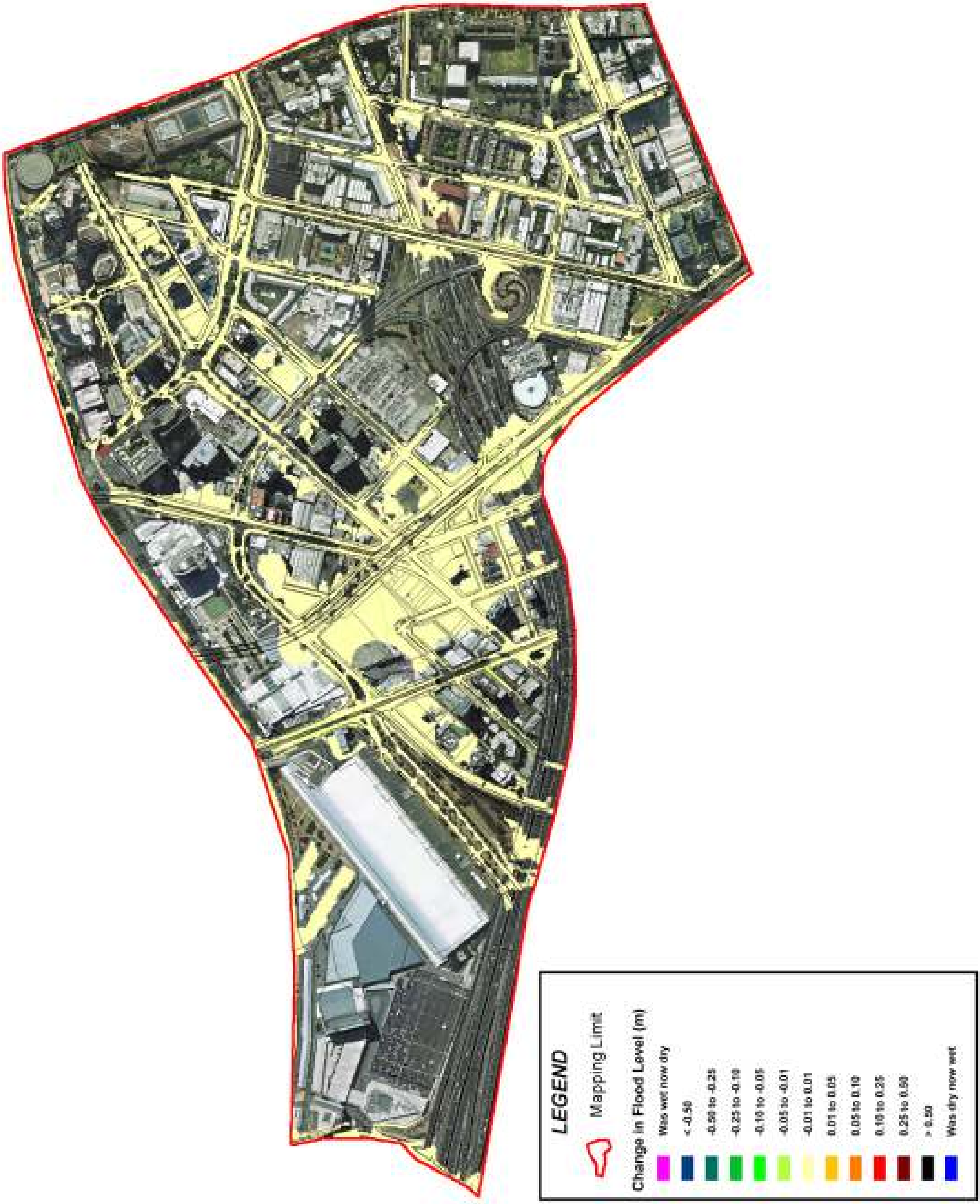
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-26_FldDif_D12_C01+15%_5y_Storm_RevA.WOR



Title:

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

Figure: **E-27**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
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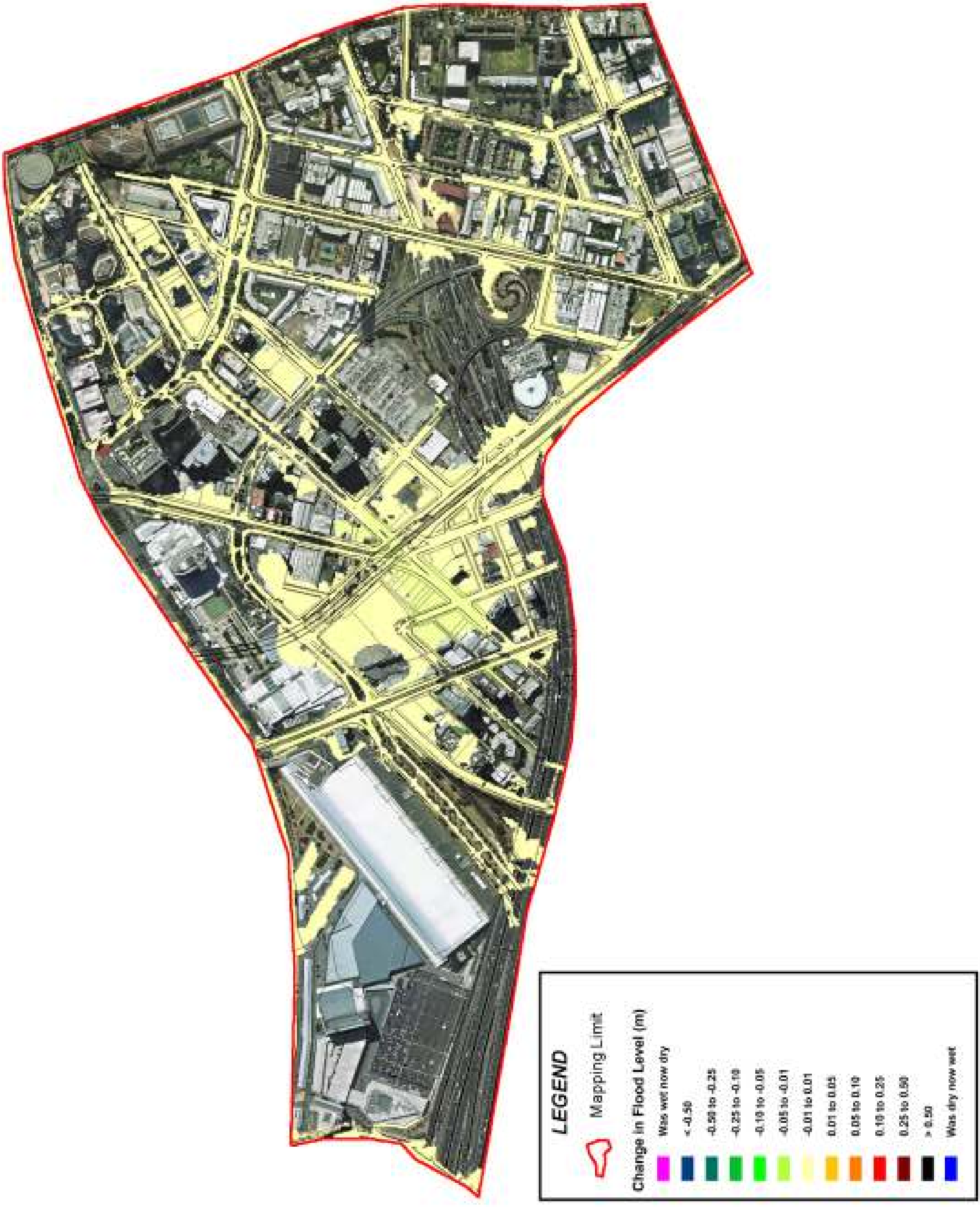
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-27_FldDif_D12_C01+15%_10y_Storm_RevA.WOR



Title:

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

Figure:

E-28

Rev:

A

N

0 125 250m
Approx. Scale

BMT WBM
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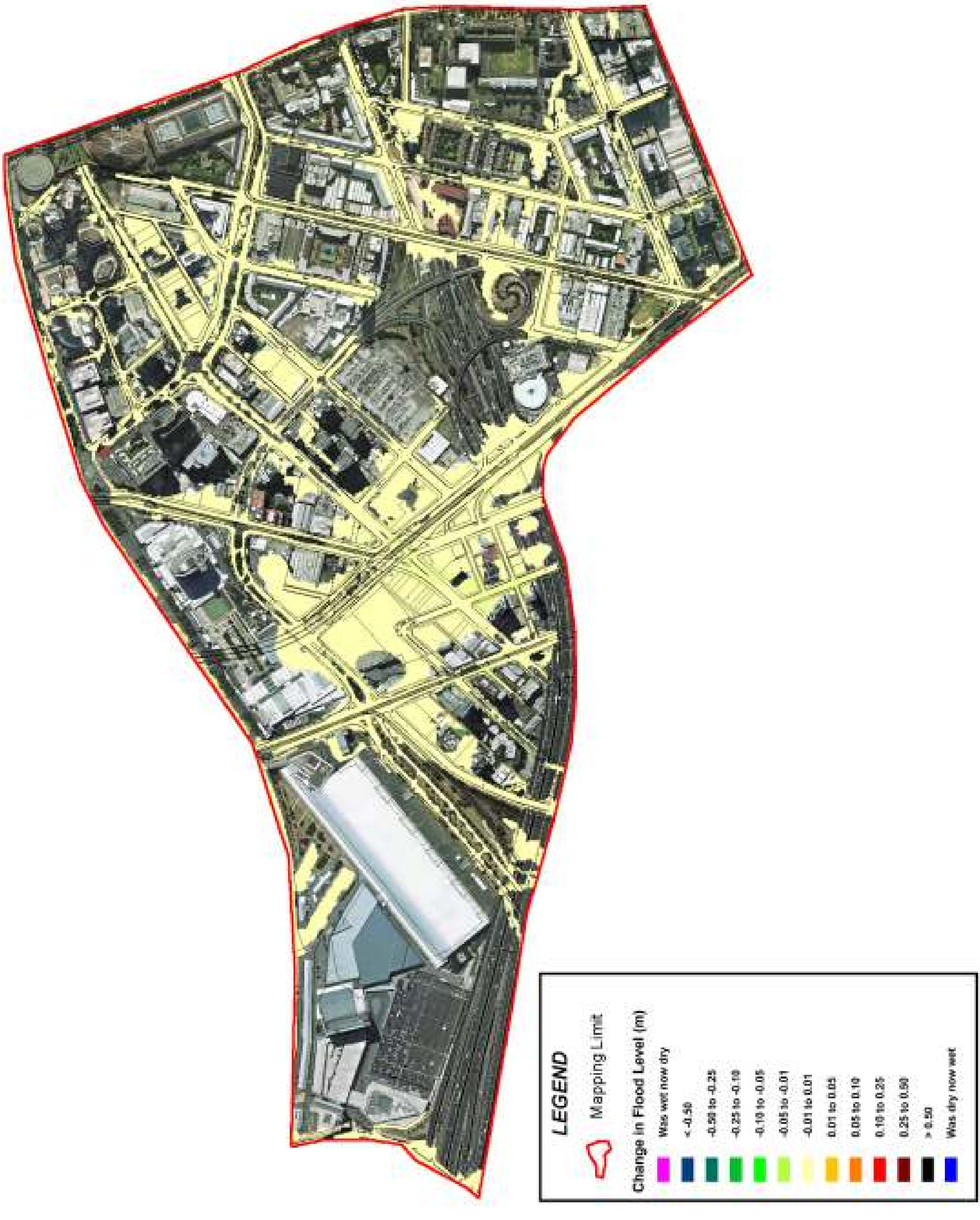
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-28_FldDif_D12_C01+15%_20y_Storm_RevA.WOR



Title:

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

Figure: **E-29**

Rev: **A**

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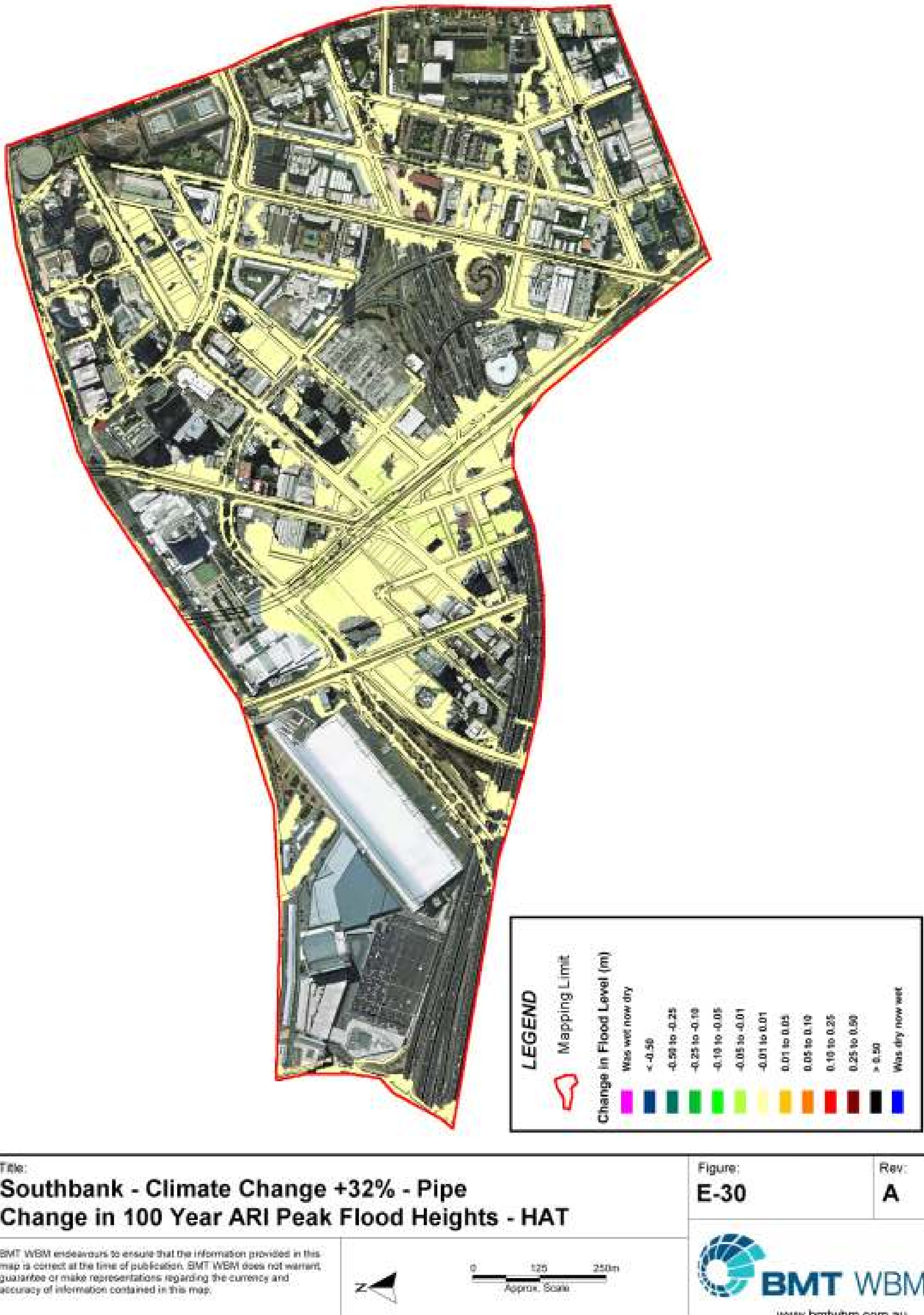
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-29_FldDif_D12_C01+15%_50y_Storm_RevA.WOR



Title:

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

Figure: **E-30**

Rev: **A**

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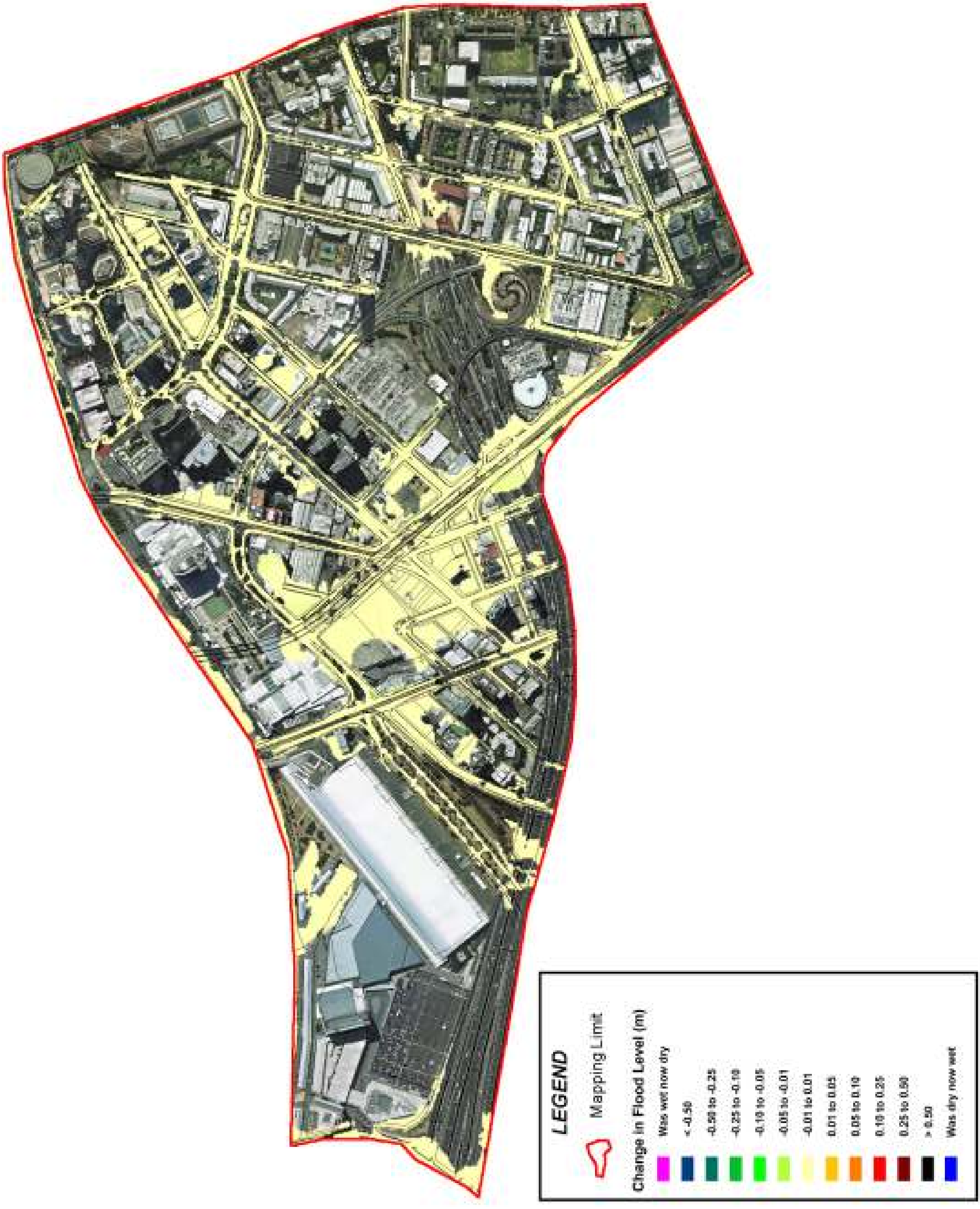

Title:

Southbank - Climate Change +32% - Pipe
Change in 5 Year ARI Peak Flood Heights - Storm Surge

Figure: **E-31**

Rev: **A**

N

0 125 250m
Approx. Scale

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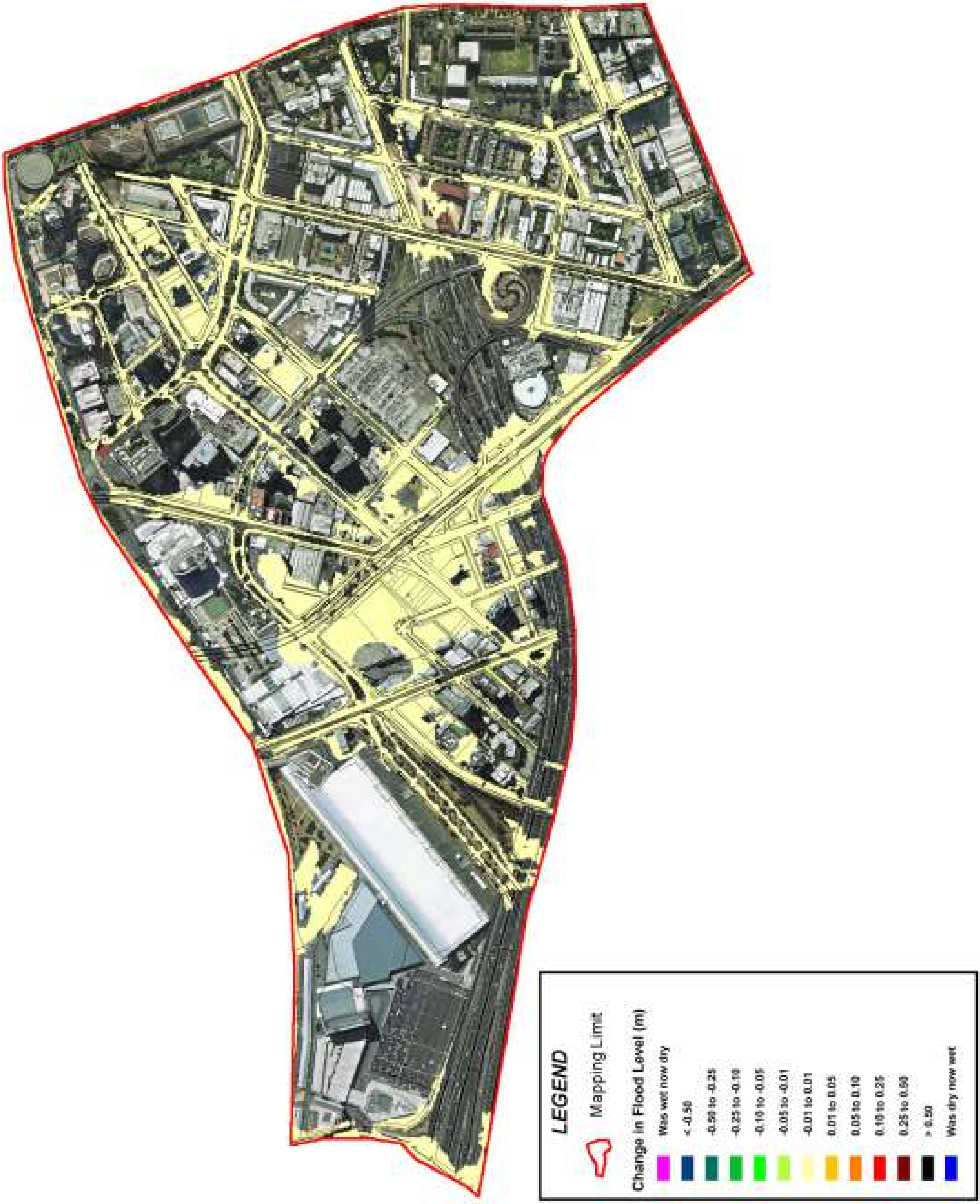
Filepath : T:\M20555.PP.SouthbankStormwater\MI\Drawings\R.M20555.004.00.Final\AppendixE\SBK_Final_FigE-31_FldDif_D12_C01+15%_5y_Storm_RevA.WOR



Title:

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

Figure: **E-32**

Rev: **A**

N

0 125 250m
Approx. Scale

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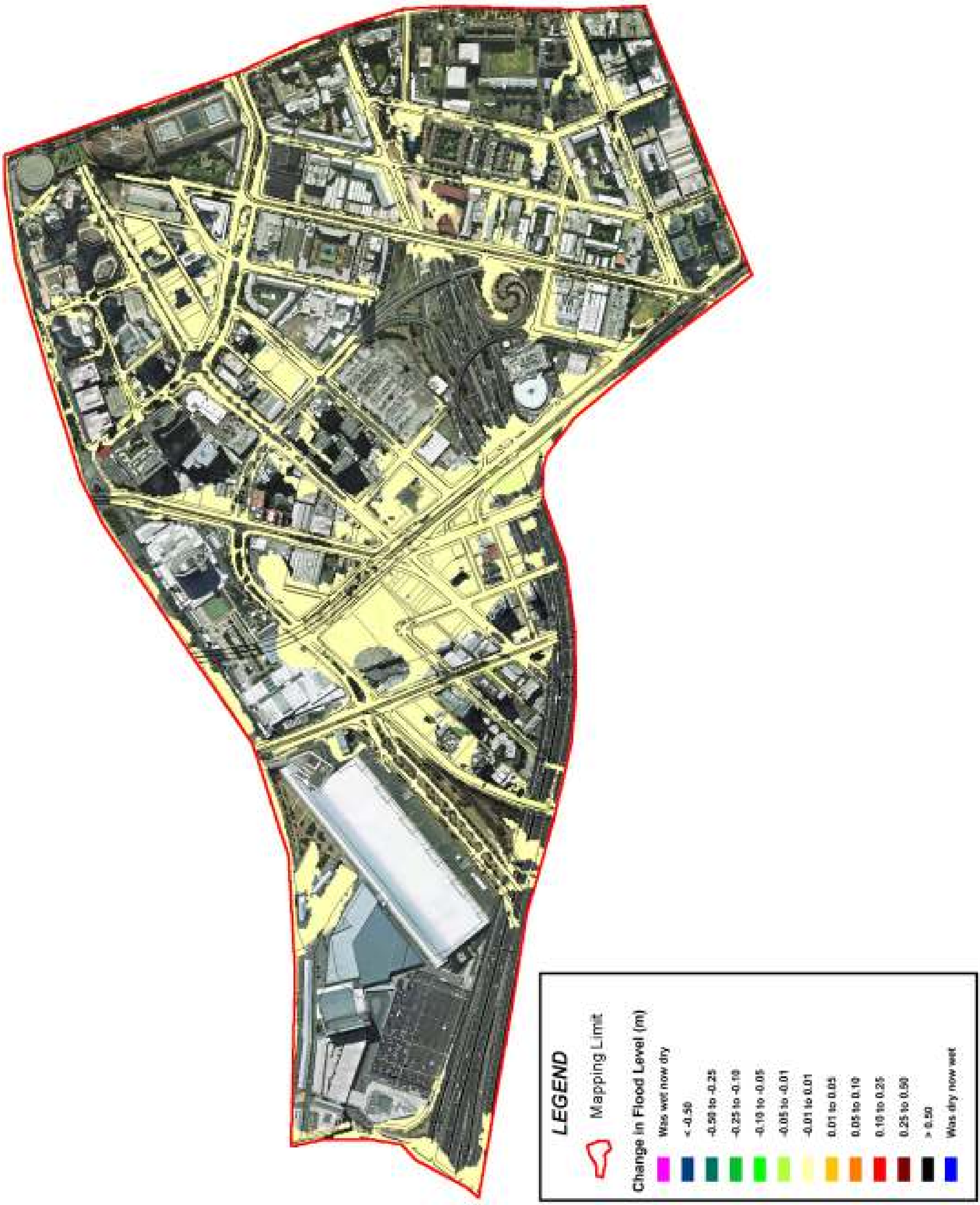

Title:

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

Figure: **E-33**

Rev: **A**

N

0 125 250m
Approx. Scale

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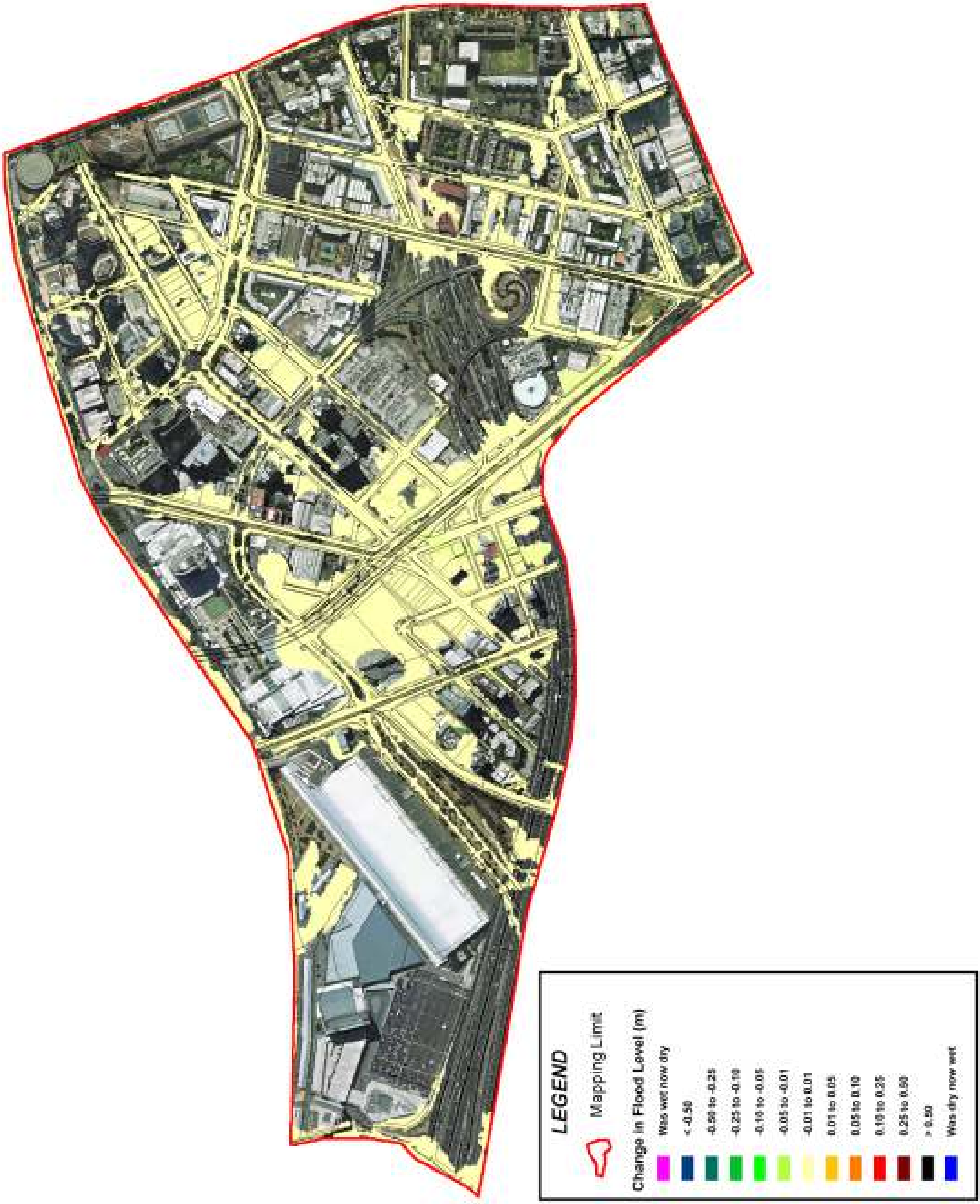

Title:

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

Figure: **E-34**

Rev: **A**

N

0 125 250m
Approx. Scale

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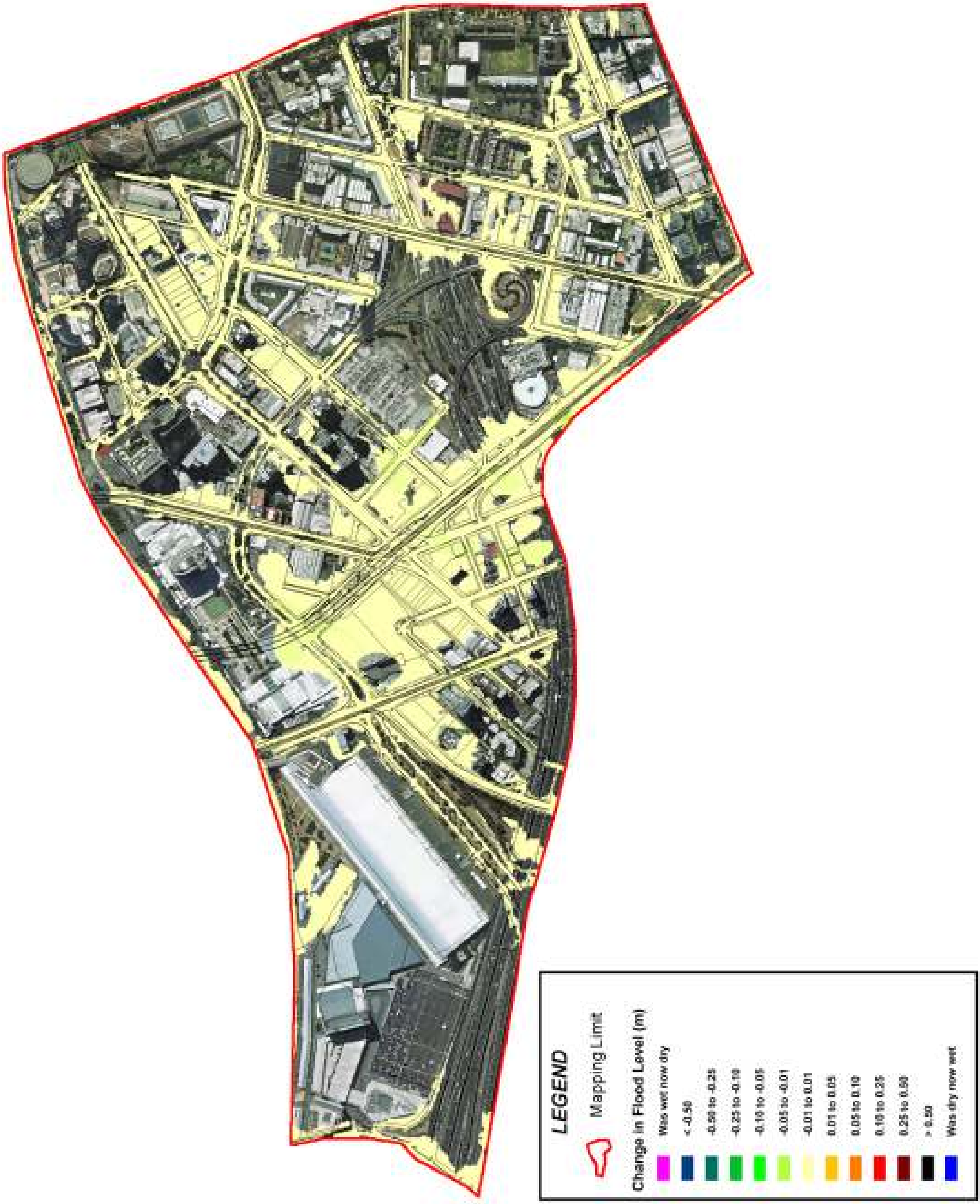

Title:

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

Figure: **E-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\AppendixE\SBK_Final_FigE-35_FldDif_D12_C01+15%_100y_Storm_RevA.WOR

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