6 FLOOD DAMAGES ASSESSMENT

Flood damage assessment is an important component of any floodplain management framework. This type of analysis enables the floodplain manager to gain an understanding of the magnitude of assets under threat from flooding. The method adopted for the study is ANUFLOOD, which is described in more detail in the following sections.

6.1 Methodology

The basic procedure for calculating the monetary flood damages is provided below.

- Prepare the appropriate relationships between depth of flooding and the assigned monetary value of damages (stage-damage curves).
- Gather the required input information detailing the characteristics of the buildings, agricultural enterprises and infrastructure that will be assessed. This includes data such as floor level and, building type, size and condition.
- Determine the design flood event impacts on individual properties and buildings. For this assessment the 20%, 10%, 5%, and 1% design flood events have been used.
- Produce the total estimated potential damages for each design flood event across the study area and present the results in a probability-damage graph.
- Assume indirect damages based on the magnitude of direct damages.
- Determine the average annual damages (AAD).

6.1.1 Key Assumptions

In order to undertake a damage assessment a number of assumptions are required. The key assumptions for the flood damages assessment for the study were as follows:

- The damage rates used were based on those contained in the RAM and ANUFLOOD methods. They were indexed to a monetary value relative to that at the end of the December quarter of 2012.
- Property boundaries were defined by the cadastral layer provided by CoGG. The properties within this were then given a land use type based on the planning scheme zones provided by CoGG.
- Building floor levels were provided for properties identified by the CoGG as being “at risk” of flooding.
- External residential damages were determined for all properties within the study area, while building damages were determined for those with floor levels supplied by CoGG.
- On a given property, a mean flood depth of below 50 mm results in no external damages and maximum external damages are incurred at a mean flood depth of 500 mm.

- There are no damages as a result of flooding in a 50% AEP (2 year ARI) design event.
- Velocities experienced within the floodplain were not of a magnitude to destroy a building beyond repair.
- Indirect damages were 30% of direct damages as recommended in the RAM guidelines (NRE 2000).
- The community is inexperienced with flooding. This assumption was based on the potentially long time periods between major flood events in the catchment.
- The community have less than 2 hours warning time before a flood event occurs.
- The condition of all buildings is good. This assumption was made as there is no data available describing the condition of individual buildings.

6.1.2 Stage-Damage Curves

ANUFLOOD residential stage-damage curves were used for this flood damage assessment. These curves were sourced from the *RAM Guidelines* (DNRE, 2000). The non-residential stage-damage curves, also ANUFLOOD curves, were sourced from a journal paper by Smith (1994), *Flood Damage Estimation – A review of urban stage-damage curves and loss functions*.

The RAM Guidelines suggest that the ANUFLOOD curves underestimate flood damages and should be increased by 60%. In order to convert the potential damages to actual damages the curves were also factored by 0.8 to account for an inexperienced community with less than 2 hours warning.

For the external damages to residential properties stage-damage curves were sourced from *Floodplain Management in Australia* (DPIE 1992). It is assumed that a mean flood depth of below 50 mm results in no external damages and maximum external damages are incurred at a mean flood depth of 500 mm.

The non-residential (commercial/industrial) stage-damage curves used for this assessment were also sourced from Smith (1994). These curves represent damages for buildings in fair condition. There are three building size classes:

- small – smaller than 186m^2,
- medium – between 186 and 650m^2, and
- large – larger than 650m^2.

As with the residential damages, the non-residential damages have been increased by 60% and factored by 0.8 to convert from potential to actual damages.

6.1.3 Damage Calculations

The mean depth of flooding was determined at each property within the study area and the depth of flooding above floor level was determined for those properties identified as being "at risk" for the 20%, 10%, 5% and 1% AEP events. The associated damages were then extracted from the stage-damage relationships. Total damages for each flood event were determined by summing the predicted damages for each individual dwelling. The AAD was then calculated.

The AAD is the average damage in dollars per year that would occur in a designated area from flooding over a long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events). Estimation of the AAD provides a basis for comparing the effectiveness of different management measures (i.e. the reduction in the AAD). The AAD is the area under the probability-damage graph. Ideally the probable maximum flood damages are included in the AAD analysis, and it is also necessary to assume a flood AEP in which no damages occur. As no flood larger than the 1% AEP event was modelled, the probability-damages graph was extrapolated, and it was assumed that no damages would occur in the 50% AEP event.

6.2 Existing Conditions Flood Damages

The total existing conditions damages for each design flood event are presented in Table 6-1. They are also illustrated in Figure 6-1. The existing conditions AAD for the Highton study area, as presented in Table 6-1, is $389,000.

Table 6-1 Existing Conditions Damages Summary

Event		Existing Case				
(Years ARI)	AEP	Residential Damages	Commercial / Industrial Damages	Total Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF*	0.0%				$3,430,000*	
100	1%	$2,284,000	$77,000	$708,000	$3,069,000	$32,000
20	5%	$1,206,000	$45,000	$375,000	$1,626,000	$94,000
10	10%	$816,000	$28,000	$253,000	$1,097,000	$68,000
5	20%	$519,000	$17,000	$161,000	$697,000	$90,000
2	50%					$105,000
Average Annual Damage						**$389,000**

*PMF damages are an extrapolation of the 1% AEP data, i.e. they were not calculated using PMF flood levels.

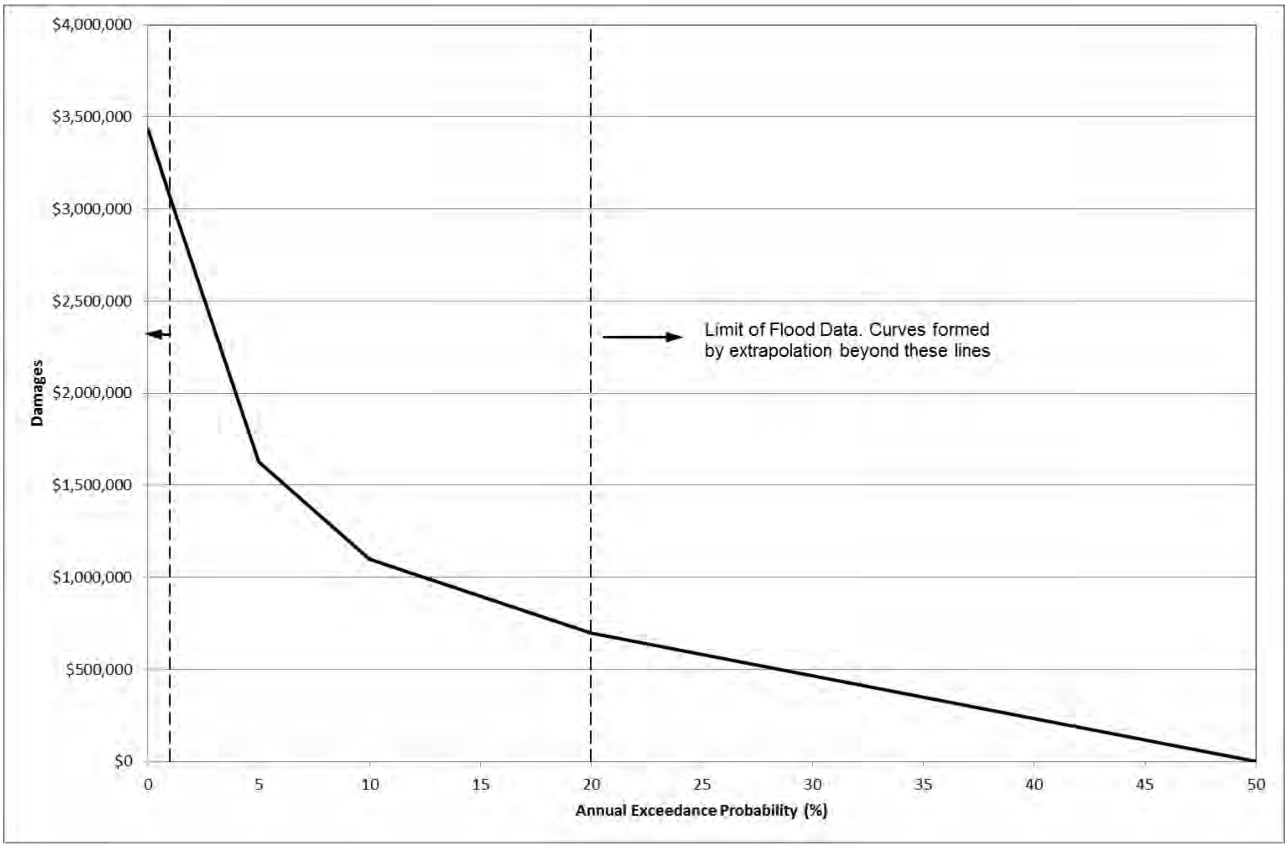


Figure 6-1 Existing Conditions Damages Probability Curve

7 MITIGATION SCHEMES ASSESSMENT

This section outlines and investigates mitigation schemes designed to reduce existing flood damages: a scheme is a combination of several mitigation options. This section provides details on the formulation and evaluation of each of the schemes and considers the benefit/cost of the proposed works (tangible benefits) along with various other economic and non-economic factors to assist in recommending a preferred strategy.

The assessment followed four key stages:

1. identification of focus areas;
2. mitigation option screening;
3. preliminary assessment of options; and
4. detailed assessment of Schemes.

7.1 Focus Areas

Through the modelling of the existing conditions in the study area, widespread shallow flooding was observed throughout the study area. Despite the number of properties exposed to flooding, relatively few houses had above floor flooding. However, the majority of houses that would be subject to above floor flooding are concentrated within several different locations;

- the intersect of Mount Pleasant Road and Murray Street,
- along the major flow path downstream of the Barrabool Road Lower and Wandana Drive Retarding Basins between Scenic Rd and the intersection Barrabool Road and Glenmire Street, and
- on the western side of Belle Vue Avenue between Roslyn Road and Patern Street.

Consequently, reducing the flood levels at these three locations, in particular downstream of the Barrabool Road Lower and Wandana Drive Retarding Basins, formed the focus of the mitigation schemes.

7.2 Mitigation Option Screening

A wide range of mitigation options were considered as part of the “first pass” assessment. Options such as localised pipe system upgrades were considered to alleviate a number of the flooding issues in the areas of concern. Table 7-1 sets out the broad categories of options considered and whether any detailed investigation was undertaken. The decision on which options were to be considered was undertaken in consultation with the CoGG.

The options that were selected for consideration are described in more detail in the following sections.

Table 7-1 Mitigation Option Element Screening

Element Type		Strategy Elements	Comment	Assessed
Urban	Structural Measures	Pipe system upgrade	Considered	✓
		Pumps	Not appropriate	✗
		Soakage Pits	Not appropriate	✗
		Retarding Basin	Considered	✓
		Diversions	Considered	✓
		Floodways	Not appropriate	✗
		Open Drain	Not appropriate	✗
		Channel Improvement	Considered on small scale to compliment retarding basin works	✓
		Bund Walls	Not feasible	✗
		Lot scale infiltration	Not appropriate	✗
		Lot scale detention	Not appropriate	✗
		Individual Property Floodproofing	Possible, however very expensive	✗
	Non-Structural Measures	Planning Scheme Amendments	Considered	✗
		Voluntary House Purchase	Considered	✗
		Voluntary House Raising	Considered	✗
Rural	Structural Measures	Levees	Not applicable	✗
		Floodwalls	Not applicable	✗
		Floodways	Not applicable	✗
		Floodplain Modification	Not applicable	✗
		Channel Improvement	Not applicable	✗
		Individual Property Floodproofing	Not applicable	✗
		Flood Storage	Not applicable	✗
		Diversions	Not applicable	✗
	Non-Structural Measures	Flood Warning Systems	Not applicable	✗
		Land Use Planning	Not applicable	✗
		Floodplain Education Programs	Not applicable	✗
		Purchase and Relocation	Not applicable	✗
		Information and Data Collection	Not applicable	✗
		Planning Scheme Amendments	Not applicable	✗
		Regulation and Enforcement	Not applicable	✗

7.3 Detailed Assessment

7.3.1 Non-Structural Options

The non-structural options considered for the economic assessment were voluntary house raising, voluntary house purchase and amendments to the planning scheme. Voluntary house raising was not considered further because it has limited application in this catchment, where many of the flood affected buildings cannot be economically raised. This is due in part to many vulnerable houses being of slab-on-ground construction. Voluntary house purchase was not considered viable because of the cost of the buy back and re-construction.

7.3.2 Structural Options

The CoGG required that three mitigation schemes be assessed, with one of the schemes being "No Structural Works". The four schemes that were assessed for the study area are summarised in Table 7-2 and Schemes One, Two and Three are shown in Figure 7-1, Figure 7-2 and Figure 7-3 respectively. Hydraulic and economic assessments were undertaken for each scheme.

Table 7-2 Mitigation Scheme Details

Scheme Number	Details
One	The augmentation of the existing Barrabool Road Upper, Barrabool Road Lower and Wandana Drive Retarding Basins to increase potential storage volume, including works to better divert piped/overland flows into the retarding basins. New pipe, with connecting side entry pits, laid along the southern side of Mount Pleasant Road between Murray Street and Arkana Avenue, where it connects into the existing pipe network. The pipe provides additional flow conveyance along Mount Pleasant Road.
Two	The excavation of the Highton Recreation Reserve to provide storage of high flows diverted from the piped system running along Barrabool Road. The scheme is designed to reduce surcharging out of the pipe system downstream of the reserve and to increase the flow capacity to aid in the alleviation of ponded water along Belle Vue Avenue. A bypass pipe running from the easement on the east side of Belle Vue Avenue, south of Roslyn Road to alleviate flooding along Belle Vue Avenue.
Three	A combination of the retarding basin works from Scheme One and the works from Scheme Two.
Four	No Structural Works

7.3.2.1 Retarding Basin Works

The proposed retarding basin works have been summarised below for the respective schemes.

Scheme One Retarding Basin Works

Scheme One proposed retarding basin works includes the augmentation of the existing Barrabool Road Upper, Barrabool Road Lower and Wandana Drive Retarding Basins to increase potential storage volume, including works to better divert piped/overland flows into the retarding basins.

Augmentation of the Barrabool Road Upper Retarding Basin, based on preliminary investigations undertaken by the CoGG, involved re-aligning the crest of the retarding basin and increasing its height, lowering the base level and providing a formal secondary spillway. The realignment of the retarding basin embankment closer to Barrabool Road allows the crest level to be increased from approximately 84.3 m to 85.3 m AHD to help maximise the available storage. Reshaping the base of the retarding basin, whilst maintaining the current invert level of 80.4 m AHD, allows for additional storage to be created whilst maintaining the existing outlet pipe. A formal secondary spillway over the crest of the RB would also be constructed at a level of 84.9 m AHD. The existing inlet pipe configurations remained, while the 1050 mm RCP outlet has been modelled with a 600 mm diameter orifice plate attached to the end wall to reduce the outflow.

Augmentation of the Barrabool Road Lower Retarding Basin, based on preliminary investigations undertaken by the CoGG, involved the excavation of the basin base to a level of 65.5 m AHD. To ensure that potential storage within the basin was optimised, two of the three 375 mm RCP outlets have been blocked, leaving one remaining 375 mm RCP outlet.

Augmentation of the Wandana Drive Retarding Basin, based on preliminary investigations undertaken by the CoGG, involved raising the crest level to 63.0 m AHD and excavating the base to 61.15 m AHD. The inlet and outlet structure configurations remain unchanged.

Scheme Two Retarding Basin Works

Scheme Two proposed retarding basin works involve the excavation of the Highton Recreation Reserve to provided storage of high flows diverted from the piped system running along Barrabool Road. The reserve has been excavated to achieve a base level of 18.6 m AHD, with the embankment crest level along the eastern edge of the reserve raised to 21.5 m AHD.

Flows into the retarding basin are diverted from the existing Barrabool Road pipe network via a 1350 mm RCP. The flow into the pipe is controlled by a side-spill weir which sits 800 mm above the invert of the Barrabool Road pipe network. This side-spill weir is designed to allow smaller, more frequent flows, to remain in the underground pipe network and only allow higher flows to spill into the recreation reserve. The outlet configuration comprises a single 300 mm RCP pipe at a level of 18.6 m AHD, connecting into the existing pipe network at the entrance to the car park located on the north-eastern boundary of the reserve.

Scheme Three Retarding Basin Works

Scheme Three proposed retarding basin works comprises the retarding basin works detailed for Schemes One and Two.

7.3.2.2 Pipe Works

Scheme One Pipe Works

Scheme One’s proposed pipe works includes a new 450 mm RCP running east along Mount Pleasant Road for approximately 400 m from the existing side entry pit located on the southern side of Mount Pleasant Road opposite Lambhill Crescent to join with the existing pipe system at Arkana Avenue. Further pipes are required to convey flow from inlet pits on Murray Street and Marcus Street to the proposed new pipe along Mount Pleasant Road. The limited capacity of the receiving pipe system along Arkana Avenue restricted the size of the proposed new pipe to a 450 mm RCP.

Scheme Two Pipe Works

Scheme Two’s proposed pipe works includes a diversion pipe running for approximately 850 m from the easement on the east side of Belle Vue Avenue, south of Roslyn Road to an outfall into the Barwon River adjacent to the existing outlet. The proposed diversion pipe will duplicate the diameter and alignment of the existing pipe running north along Belle Vue Avenue before running north east along Barrabool Road to the outfall. The proposed diversion pipe has a diameter of 1950 mm with the exception of the final section of pipe (located under the Barwon River reserve) where the diameter is 2100 mm. The proposed diversion pipe does not have intermediate connections into the surface or the existing pipe system.

Scheme Three Pipe Works

Scheme Three comprises the same proposed pipe works detailed for Scheme Two.

7.3.2.3 Pit Works

Scheme One Pit Works

To achieve a water level of 63.0 m AHD in the Wandana Drive Retarding Basin the existing side entry pit on the north-west corner of the Roslyn Road and Scenic Road intersection would need to be converted to a closed junction pit.

The existing pits along the alignment of the new pipe alignment on southern side of Mount Pleasant Road would be converted to triple side entry pits, whilst new triple side entry pits would be required on Murray Street and Marcus Street.

Scheme Two Pit Works

Scheme Two proposed pit works include the reconstruction of the existing junction pit on Barrabool Road to incorporate a flow diversion structure for the inlet into the Highton Recreation Reserve. The junction pit in the entrance to the car park located on the north-eastern boundary of the reserve will also need to be reconstructed to incorporate the outlet pipe.

Scheme Three Pit Works

Scheme Three proposed pit works comprises the reconstruction of the side entry pit at the Roslyn Road and Scenic Road intersection as part of the Wandana Drive Retarding Basin works from Scheme One and the pit works detailed for Scheme Two.

7.3.2.4 Further Works

Scheme One Further Works

To ensure that the maximum possible volume of pipe/overland flow is diverted into the Barrabool Road Upper and Lower Retarding Basins, further works are required upstream of the retarding basins.

To provide a more unrestricted flowpath for water to enter the Barrabool Road Upper Retarding Basin a section of existing pipe on the west side of Barrabool Road upstream of Thoroughbred Drive has been replaced with an open channel (approximate 5 m base width). Four 600 mm RCPs are then used to convey flow under Thoroughbred Drive, discharging into an open channel flowing into the retarding basin with an approximate base width of 7 m.

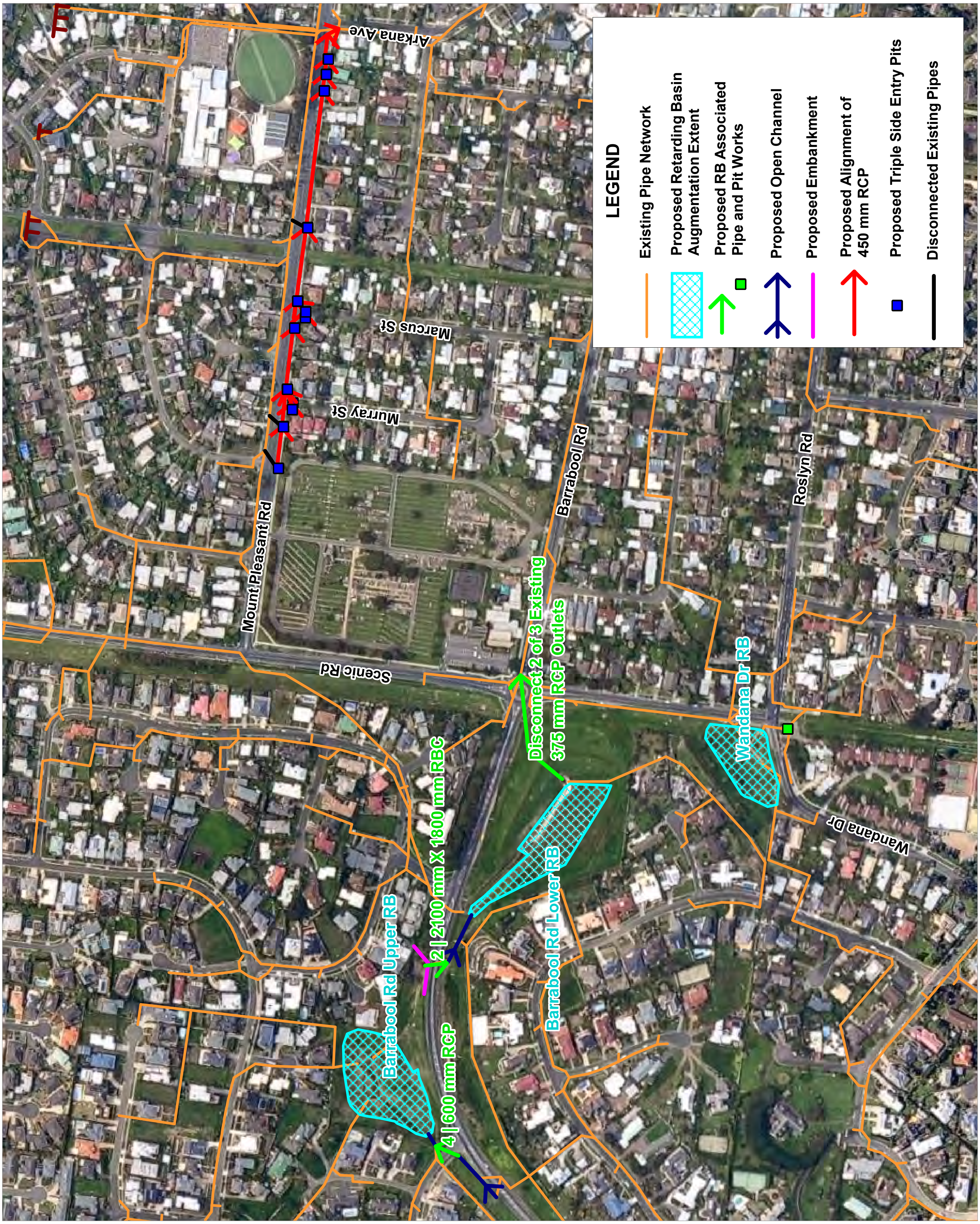
To ensure that overland flow downstream of the Barrabool Road Upper Retarding Basin is directed into the Barrabool Road Lower Retarding Basin and prevented from flowing down Barrabool Road, the existing pipes under Barrabool Road that provide the connection between the two retarding basins have been reconfigured. This involves replacing the pipes downstream of Barrabool Road with an open channel of an approximate 5 m base width and replacing the pipes under Barrabool Road with two 2100 mm x 1800 mm RBCs. To ensure that maximum amount of flow possible enters the culverts an embankment at a level of 77.5 m AHD downstream of the inlet structure is required to increase the upstream water level and prevent flow from continuing down Barrabool Road.

Scheme Two Further Works

Works are required to provide an inlet structure for the bypass pipe in the easement on Belle Vue Avenue and the outlet structure into the Barwon River requires reconstruction to incorporate the additional pipe.

Scheme Three Further Works

Scheme Three proposed further works comprises the further works detailed for Schemes One and Two.



Title:

Scheme One Proposed Mitigation Works

Figure: **7-1**

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Title:

Scheme Two Proposed Mitigation Works

Figure: 7-2

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Title:

Scheme Three Proposed Mitigation Works

Figure: **7-3**

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7.3.3 Hydraulic Assessment

The 20%, 10%, 5% and 1% AEP design floods were assessed using the same nine storm duration events as used for the existing case. A peak flood height envelope was then developed for each flood event for Schemes One, Two and Three. The change in peak flood height for each scheme was calculated by subtracting the existing case peak flood heights from the scheme peak flood heights at each TUFLOW grid. The change in peak flood height was then colour contoured and mapped. The modelling and mapping was not done for the "no structural works" scheme as there were no changes from the existing conditions.

Peak flood height surfaces were used to calculate the number of properties flooded and depth of above floor flooding, which was then used in the flood damages assessment for the schemes.

The mapping pertaining to each scheme in the hydraulic assessment illustrates no change in flood level within a ± 0.03 m tolerance as a yellow colour, reductions in flood level are shaded with greens and increases in flood level are shaded with browns/reds. A pink colour indicates a region where flooding currently occurs but would no longer occur if the scheme was implemented, and a blue colour indicates a region where flooding currently does not occur but would if the scheme was implemented.

7.3.3.1 Scheme One

The change in peak flood height and the properties with above floor flooding, for Scheme One of the study area, are mapped in Figure 7-4 to Figure 7-7 for the four flood events assessed. Table 7-3 summarises the reduction in flooded properties for Scheme One.

Modelling of the augmentation of the Barrabbol Road retarding basins did not show significant reductions in downstream flood levels. As shown in the mapping, only in the 1% AEP event do reductions exceed the 0.03 m tolerance along the major flow path downstream of the Barrabool Road Lower and Wandana Drive Retarding Basins between Scenic Road and the intersection of Barrabool Road and Glenmire Street. The addition of a pipe along the southern side of Mount Pleasant Road has not reduced flood levels at the corner of Mount Pleasant Road and Murray Street. The limited reductions in flood levels achieved under Scheme One results in no reduction to the number of properties inundated and only two floors saved in the 1% AEP event.

Table 7-3 Reduction in Flooded Properties – Scheme One

AEP	No. Flooded Grounds		Reduction	No. Flooded Floors*		Reduction
	Existing	Scheme One		Existing	Scheme One	
20%	1402	1402	***0***	14	14	***0***
10%	1719	1719	***0***	16	16	***0***
5%	1976	1976	***0***	22	21	***1***
1%	2318	2318	***0***	35	33	***2***

* Results based on properties surveyed by CoGG.

7.3.3.2 Scheme Two

The change in peak flood height and the properties with above floor flooding, for Scheme Two of the study area, are mapped in Figure 7-8 to Figure 7-11 for the four flood events assessed. Table 7-4 summarises the reduction in flooded properties for Scheme Two.

Modelling of Scheme Two shows a reduction in flood levels downstream of the Highton Recreation Reserve along Barrabool Road and along the main drainage path running from Belle Vue Avenue for all AEP events. This results in five properties with above floor flooding being saved in the 1% AEP event in the lower part of the study area.

Table 7-4 Reduction in Flooded Properties – Scheme Two

AEP	No. Flooded Grounds		Reduction	No. Flooded Floors*		Reduction
	Existing	Scheme Two		Existing	Scheme Two	
20%	1402	1402	***0***	14	13	**1**
10%	1719	1718	***1***	16	15	**1**
5%	1976	1976	***0***	22	21	**1**
1%	2318	2294	***24***	35	30	**5**

* Results based on properties surveyed by CoGG.

7.3.3.3 Scheme Three

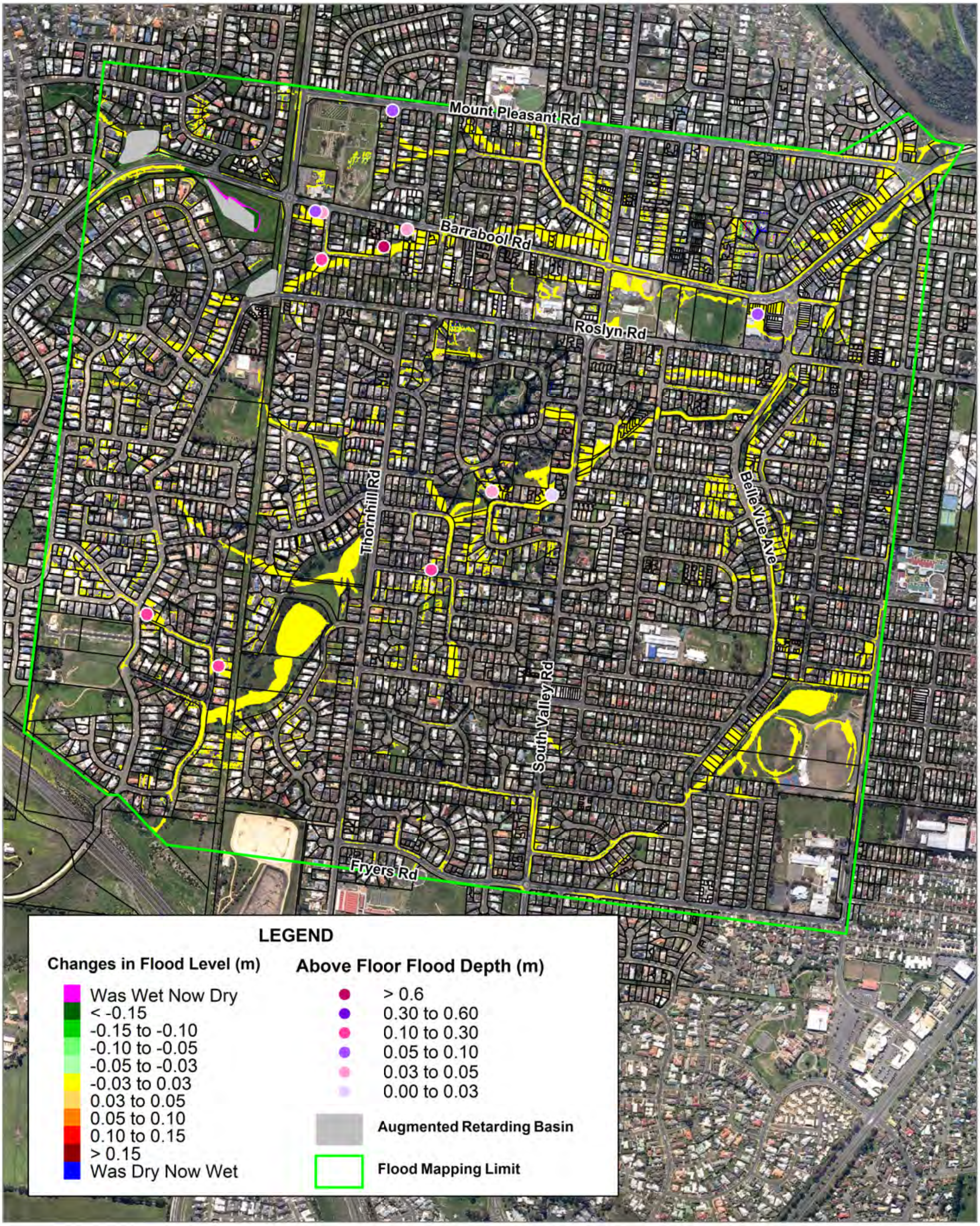
The change in peak flood height and the properties with above floor flooding, for Scheme Three of the study area, are mapped in Figure 7-12 to Figure 7-15 for the four flood events assessed. Table 7-5 summarises the reduction in flooded properties for Scheme Three.

As expected the reductions in flood levels associated with Scheme Three are similar to those observed in Schemes One and Two in the focus areas. As a result, significant reductions in the number of properties inundated or flooded floor levels has not been achieved in Scheme Three, with a reduction of six flooded floor levels compared to existing conditions in the 1% AEP event.

Table 7-5 Reduction in Flooded Properties – Scheme Three

AEP	No. Flooded Grounds		Reduction	No. Flooded Floors*		Reduction
	Existing	Scheme Two		Existing	Scheme Three	
20%	1402	1402	***0***	14	113	**1**
10%	1719	1719	***0***	16	15	**1**
5%	1976	1963	***13***	22	20	**2**
1%	2318	2288	***30***	35	29	**6**

* Results based on properties surveyed by CoGG.



Title:

Mitigation Scheme One
20% AEP Peak Flood Impacts

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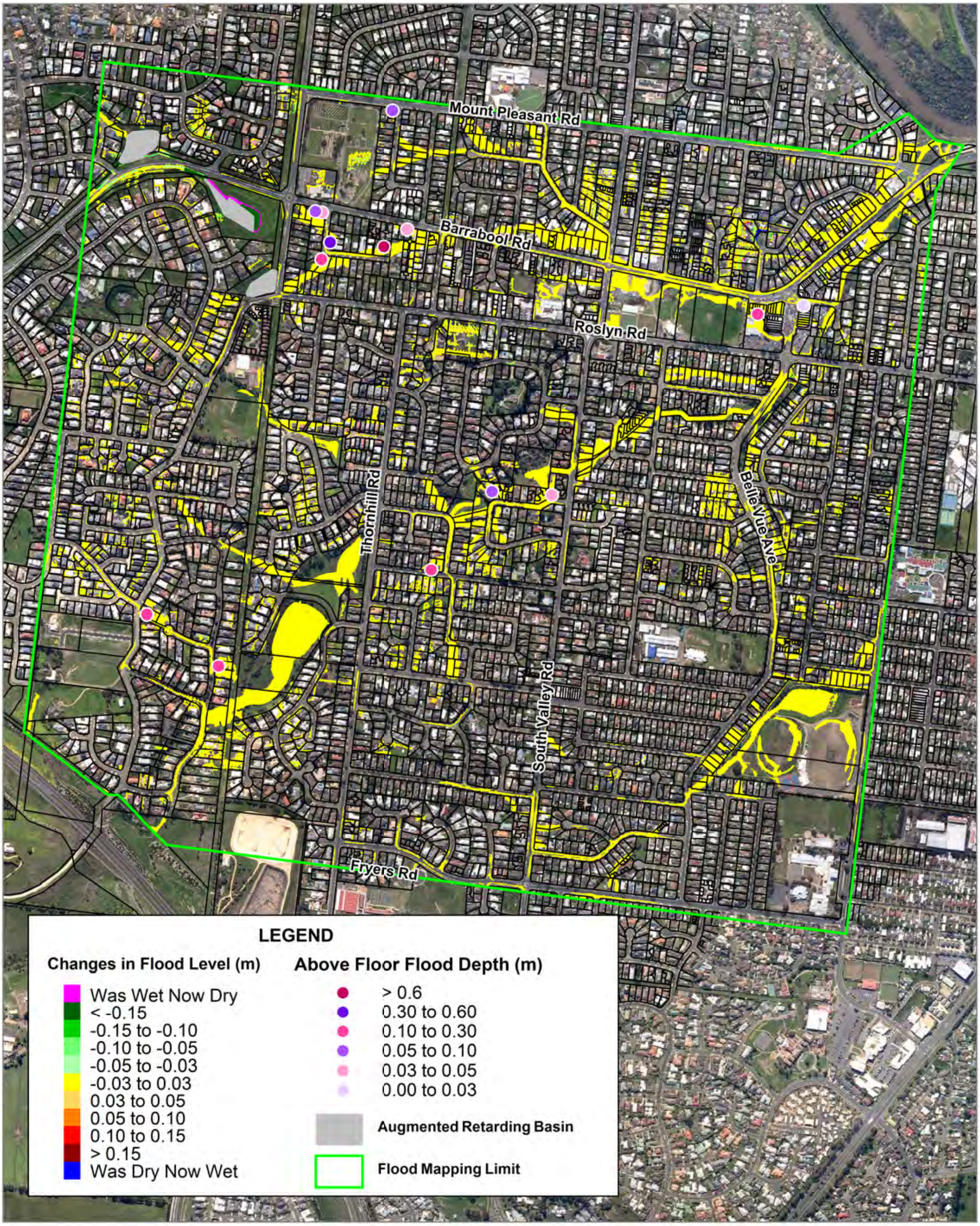

Title:

Mitigation Scheme One
10% AEP Peak Flood Impacts

Figure: 7-5

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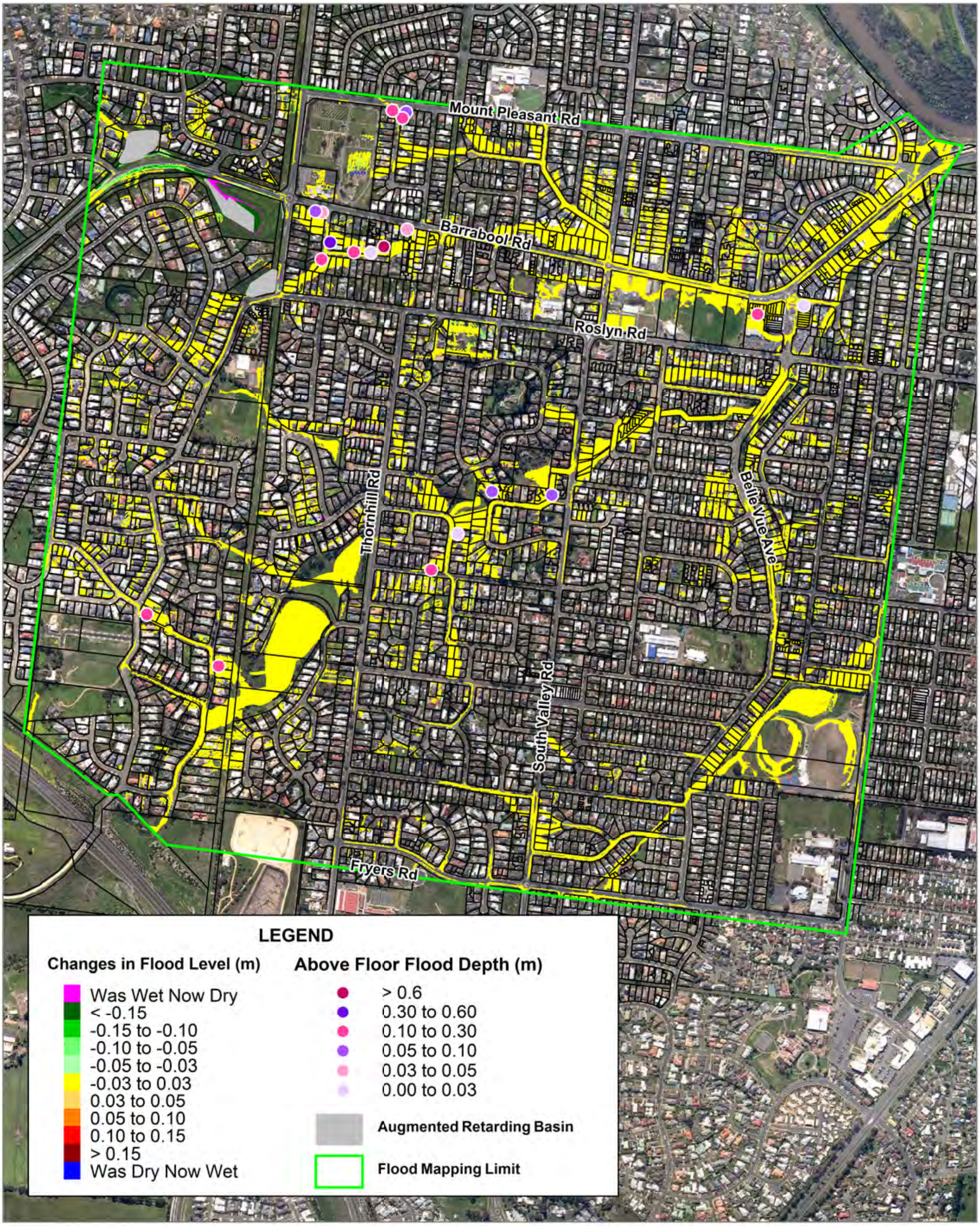

Title:
Mitigation Scheme One
5% AEP Peak Flood Impacts

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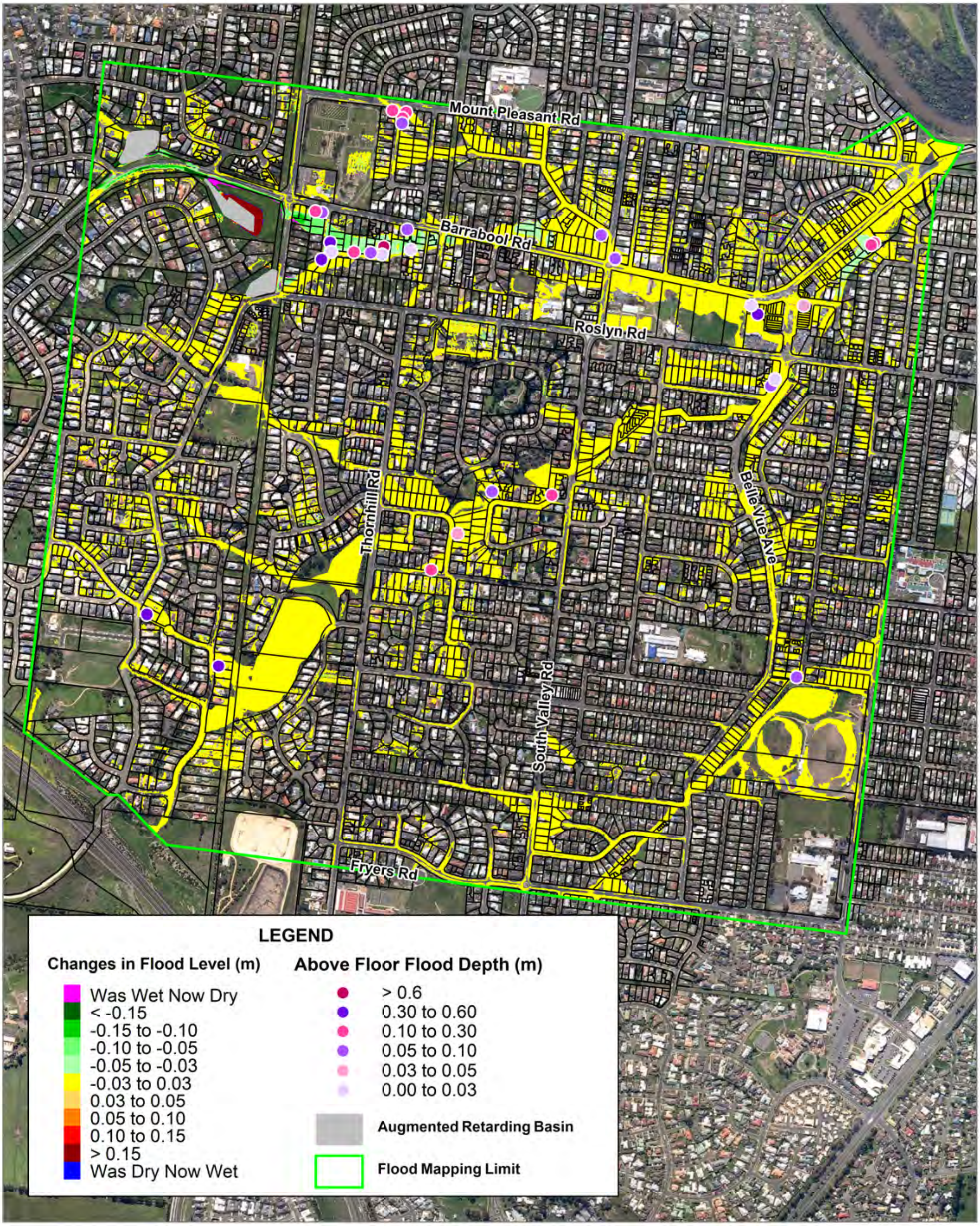

Title:

Mitigation Scheme One
1% AEP Peak Flood Impacts

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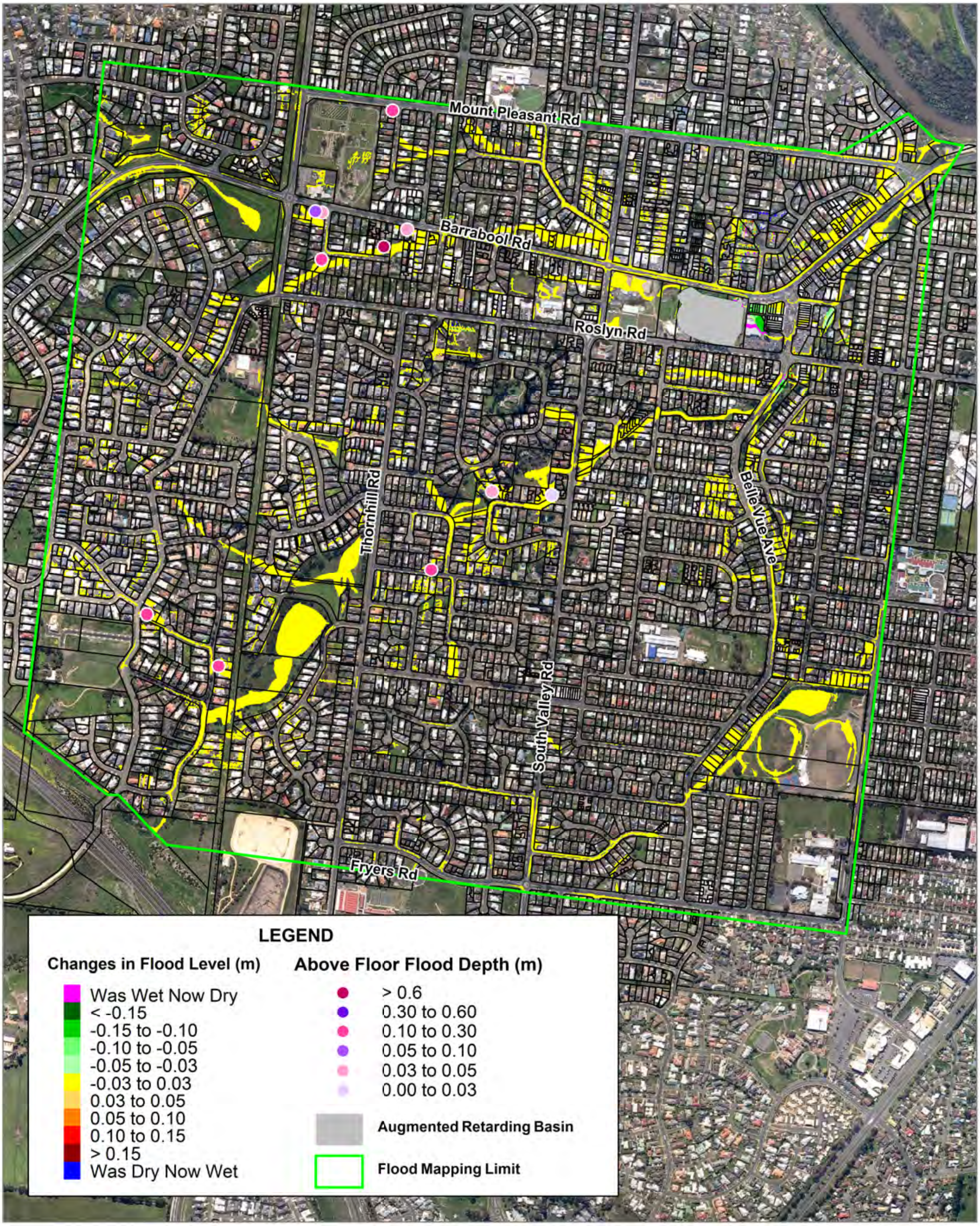

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Mitigation Scheme Two 20% AEP Peak Flood Impacts

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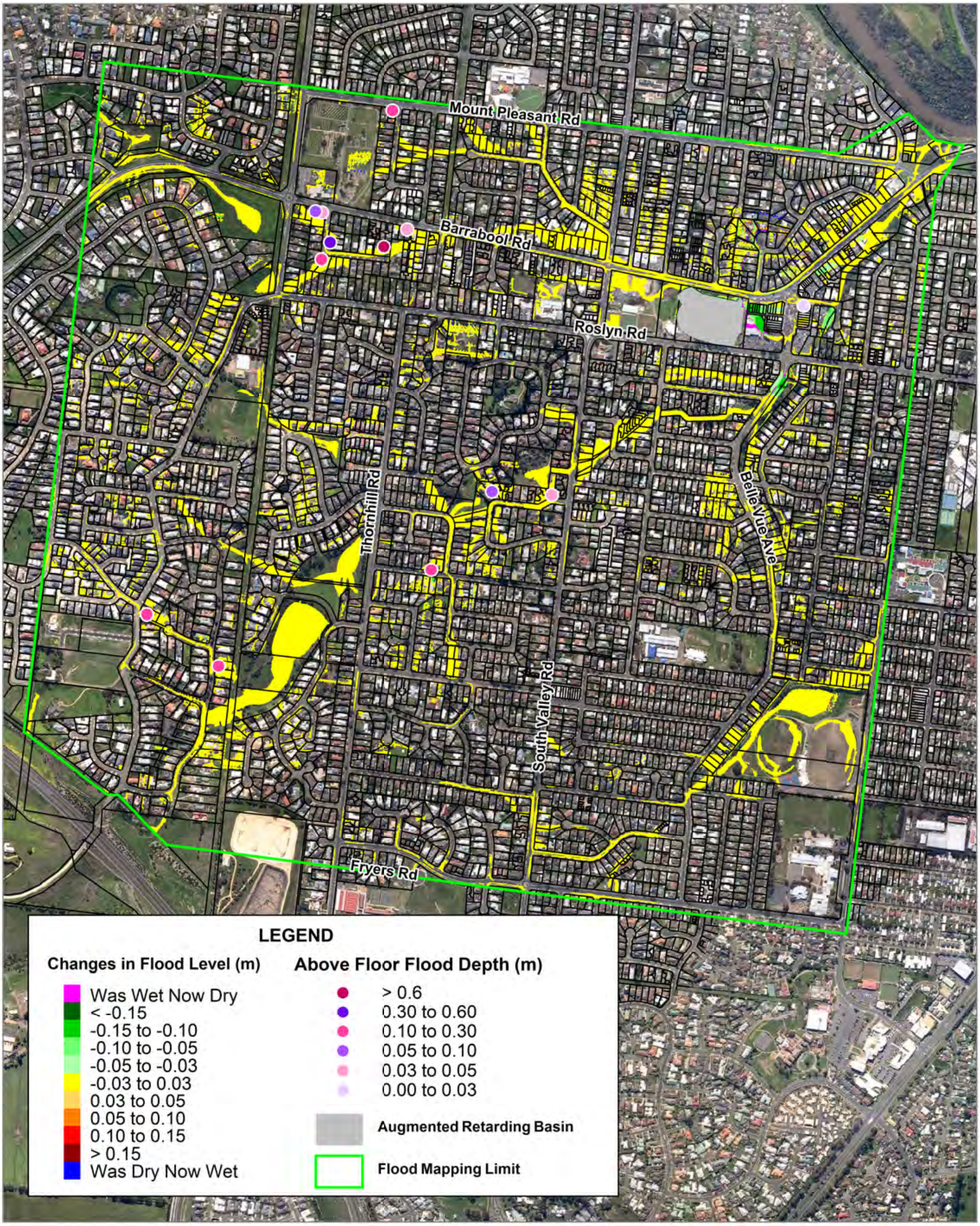

Title:

Mitigation Scheme Two
10% AEP Peak Flood Impacts

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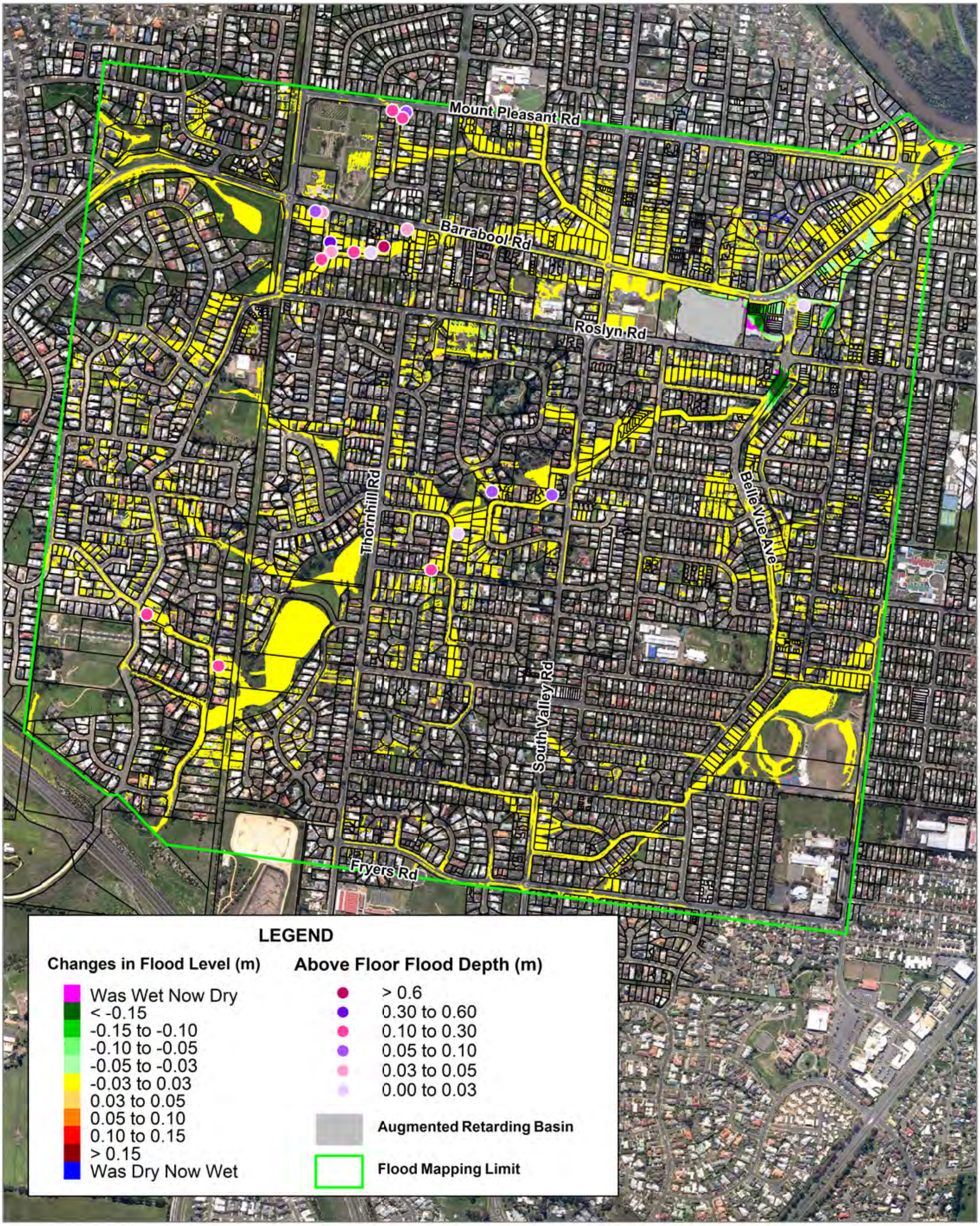

Title:

Mitigation Scheme Two
5% AEP Peak Flood Impacts

Figure: 7-10

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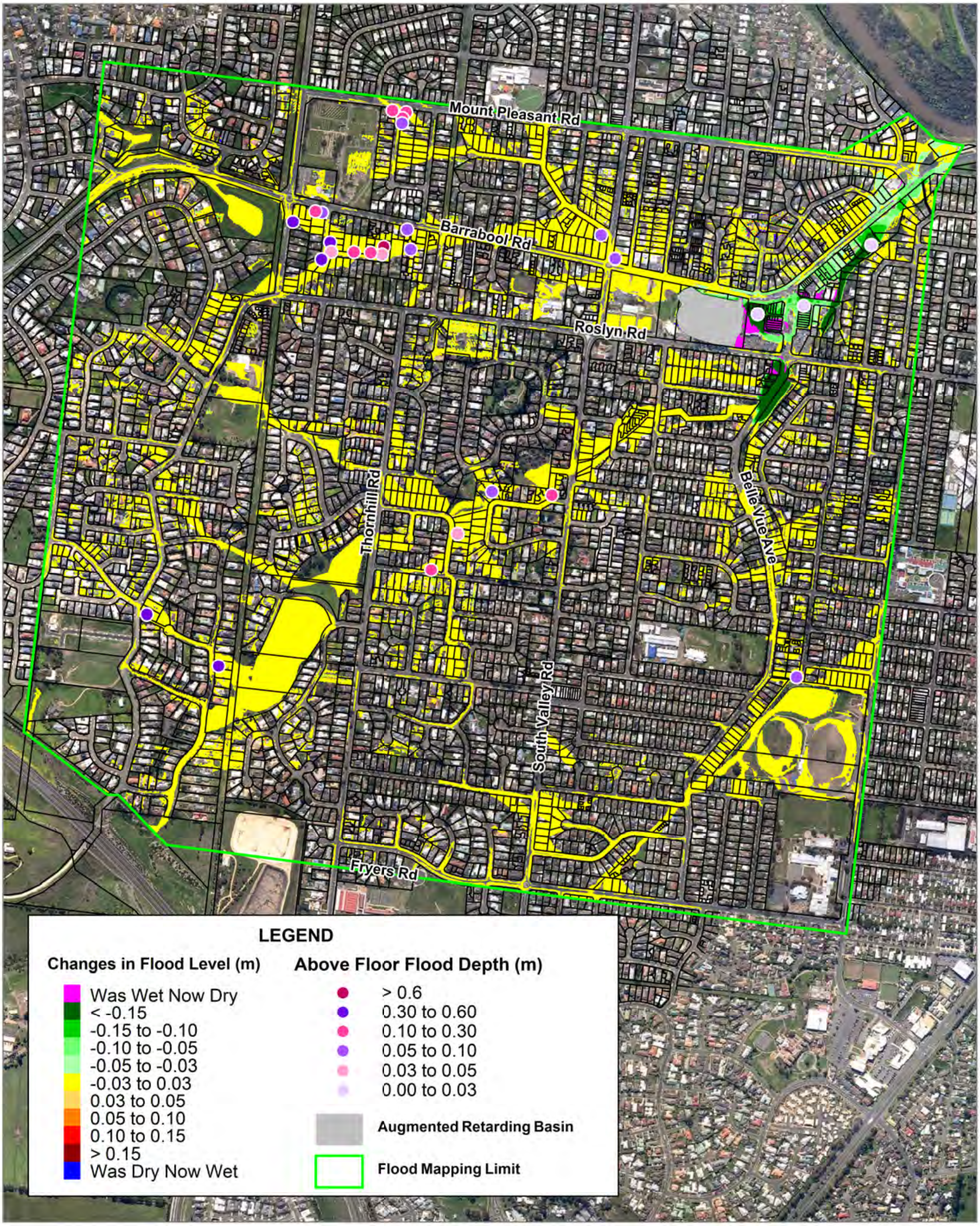

Title:

Mitigation Scheme Two
1% AEP Peak Flood Impacts

Figure: **7-11**

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N

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Approx. Scale

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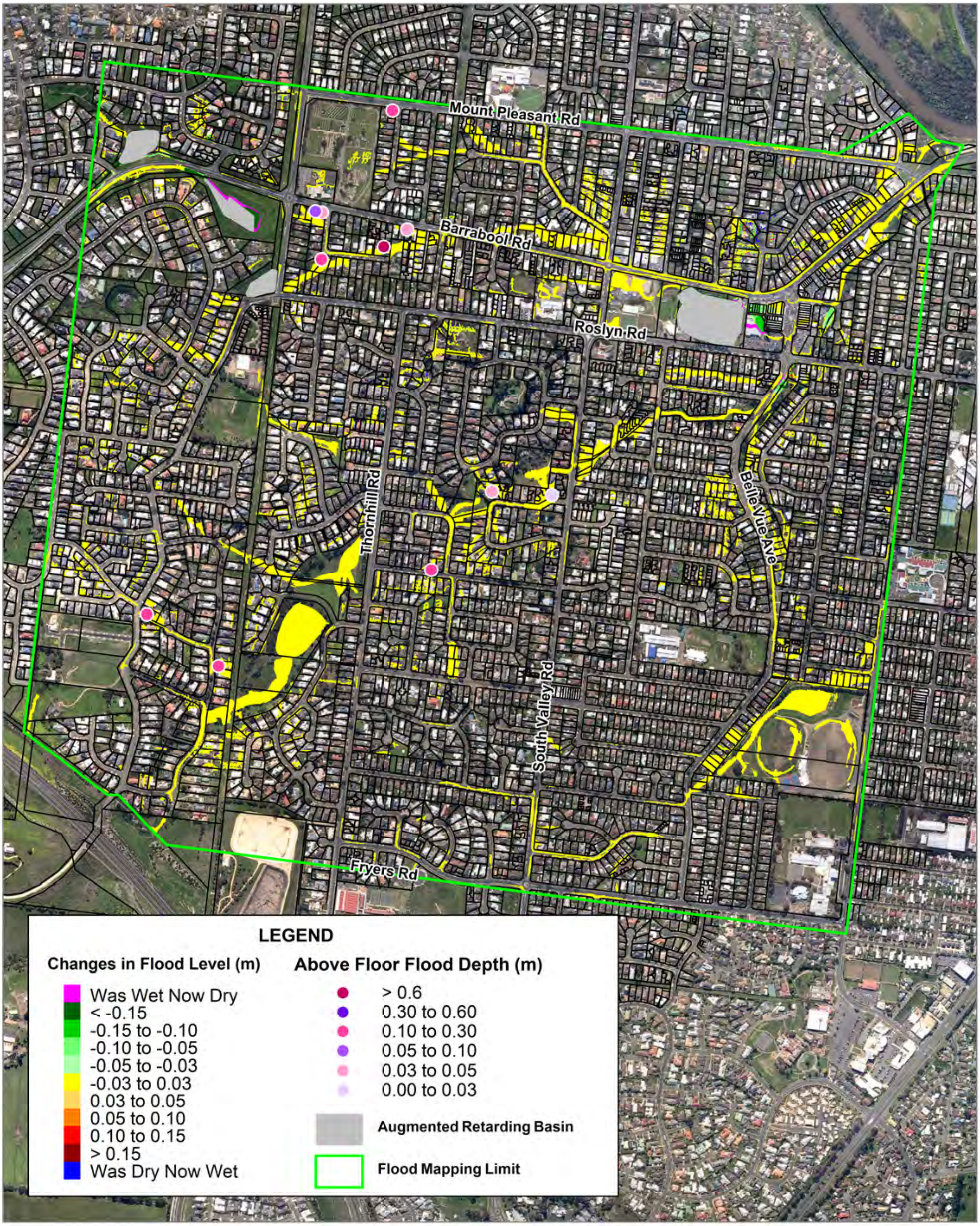

Title:

Mitigation Scheme Three
20% AEP Peak Flood Impacts

Figure: 7-12

Rev: B

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0 250 500m
Approx. Scale

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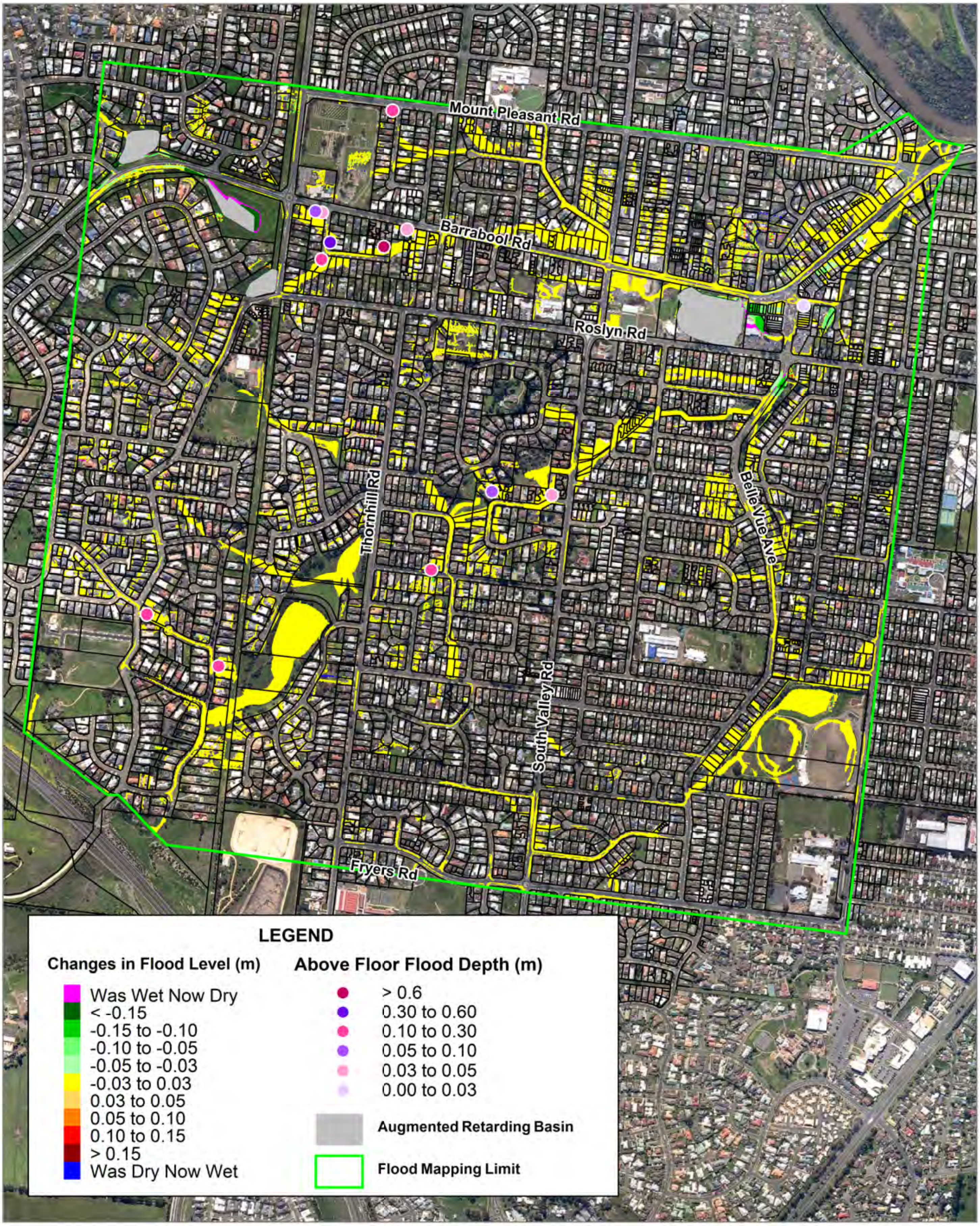

Title:

Mitigation Scheme Three
10% AEP Peak Flood Impacts

Figure: **7-13**

Rev: **B**

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Approx. Scale

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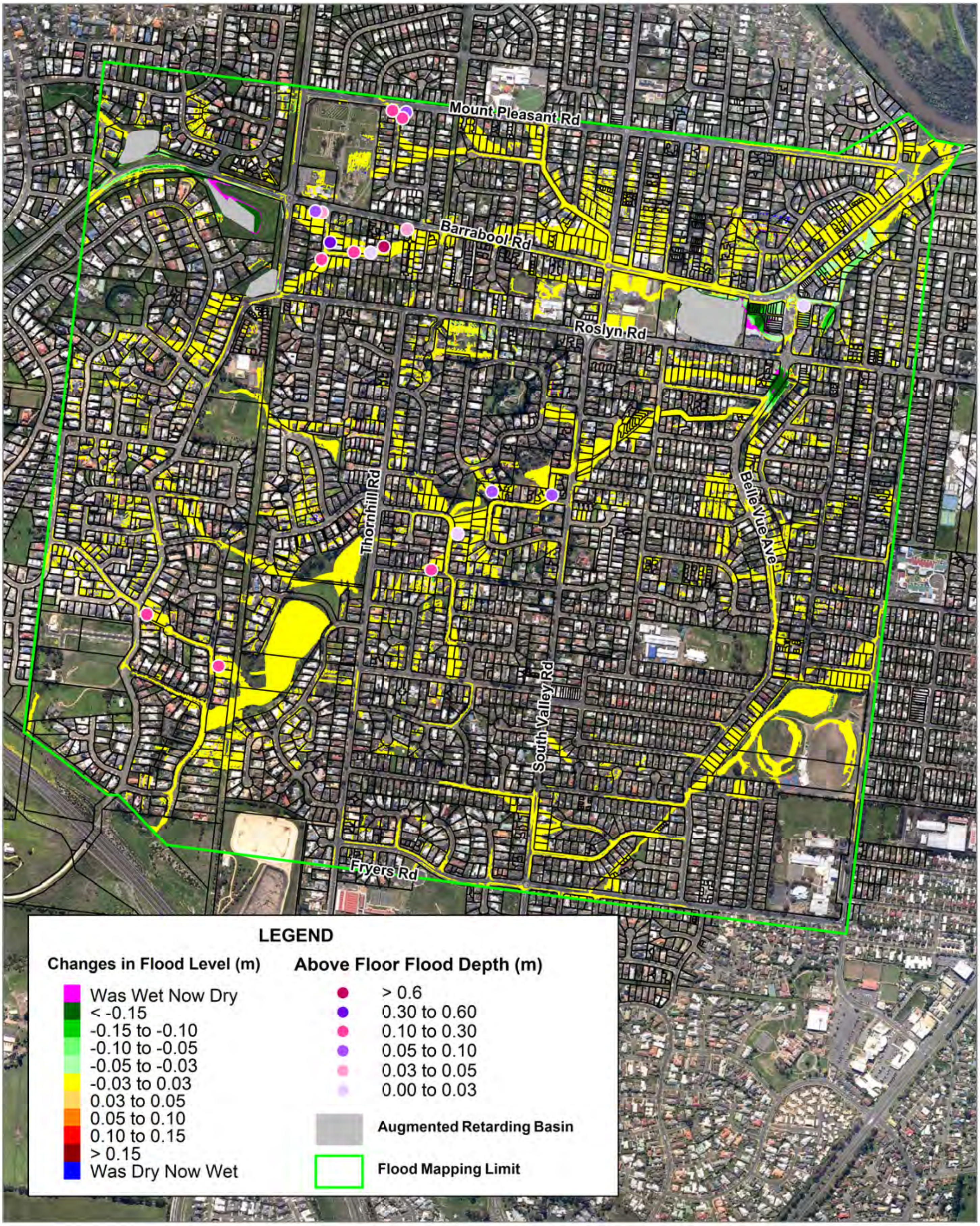

Title:

Mitigation Scheme Three
5% AEP Peak Flood Impacts

Figure: 7-14

Rev: B

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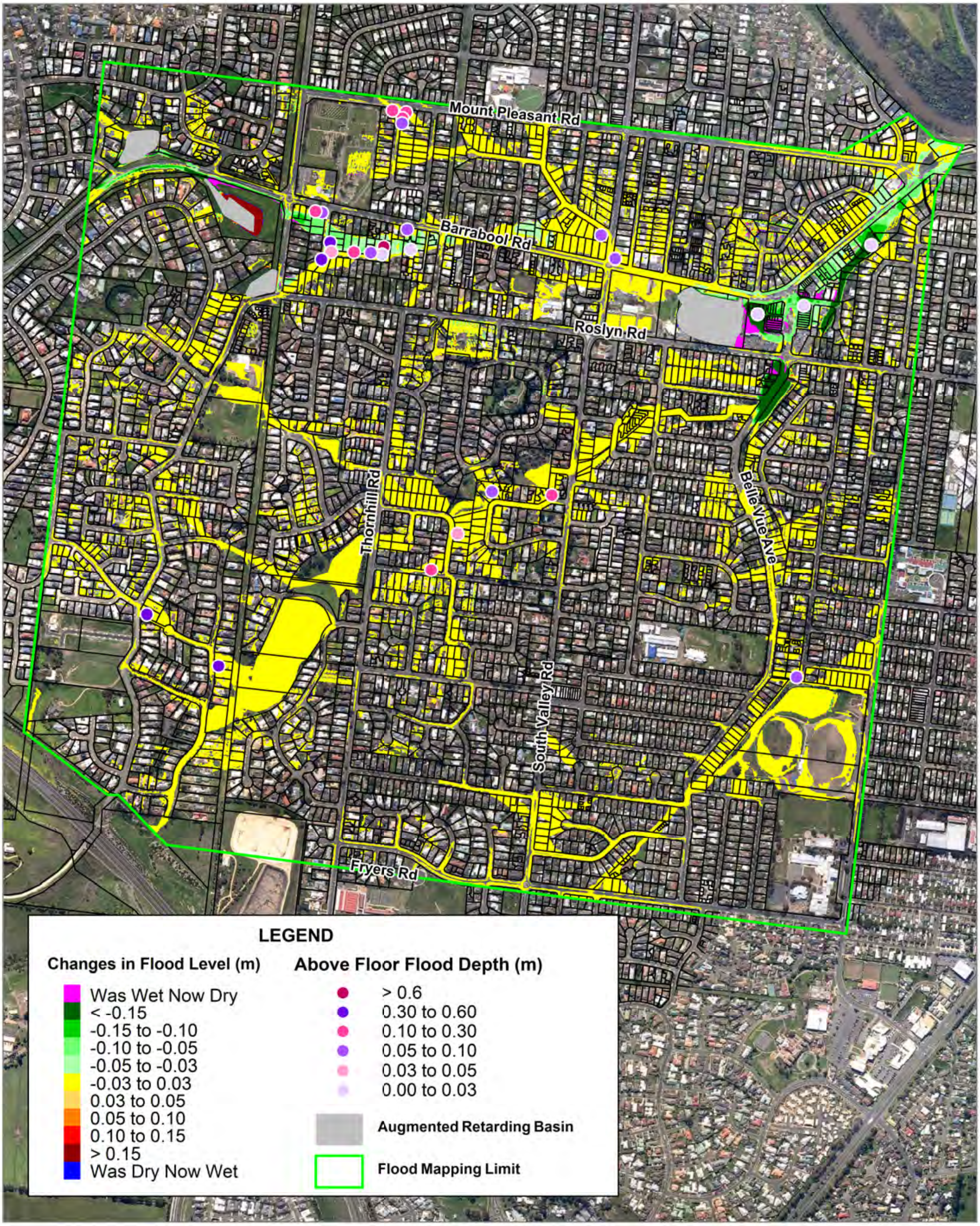

Title:

Mitigation Scheme Three
1% AEP Peak Flood Impacts

Figure: **7-15**

Rev: **B**

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Approx. Scale

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8 MITIGATION OPTION ASSESSMENT

8.1 Economic Assessment

8.1.1 Basis of Assessment

In general, the benefits of the construction of flood management schemes are as follows:

- increased flood immunity of properties protected by the scheme;
- increased flood immunity of roads protected by the scheme and thus improved mobility of the community during flooding events;
- decreased cost of flood damage to properties protected by the scheme;
- decreased potential for loss of life during a flood event within the area protected by the scheme; and
- decreased emotional, social and psychological trauma experienced by residents in times of flooding.

It is important to note that flood management schemes can have the effect of increasing flood levels in other areas, thereby resulting in increased flood damages to properties elsewhere.

Of the factors listed above, the change in flood damages is the only one that can be easily quantified in monetary terms. In Section 6, the flood damages for the existing study area were calculated. The reductions (or increases) in these damages have been calculated to quantify the monetary benefit of each scheme.

The overall financial viability of a scheme is initially assessed by calculating the monetary benefit-cost ratio (BCR). These ratios are used to evaluate the economic potential for the option to be undertaken. A monetary benefit-cost ratio of 1.0 indicates that the monetary benefits are equal to the monetary costs. A ratio greater than 1.0 indicates that the benefits are greater than the costs while a ratio less than 1.0 indicates that the costs are greater than the benefits. The change in infrastructure damage as a result of implementing the scheme is not included in the benefit-cost analysis.

In floodplain management, a BCR substantially less than 1.0 may still be considered viable because the economic analysis does not include the intangible benefits of a flood mitigation scheme.

In order to calculate the BCR, the annual financial benefit (the change in average annual damages) of a scheme is summed over the financial project life and converted to present value.

A financial project life of 30 years was chosen for this study. This does not imply that the projected structural life of the scheme is only 30 years. In fact, some measures should be effective in reducing the frequency of flooding for centuries to come.

It is not correct to simply multiply a long term average annual benefit by the financial project life of 30 years to derive a total worth of the benefits. To do so would ignore the important point that the benefits from this scheme (i.e. reduced flood damages) will occur over time and in the future.

For example, a benefit of $2.3 million to be gained in 10 years' time is not worth $2.3 million now but only $1.2 million now. This is because $1.2 million could be invested now and appreciate at say 7% p.a. over and above inflation for 10 years. This would then be equivalent to $2.3 million in 10 years' time. This is called the Present Value of the benefit. It is a universally accepted economic theory and used in all major project economic analyses. The adopted rate of 7% is called the discount rate and is the middle of the range 6 to 8% typically considered for assessing public works.

As an example, Table 8-1 shows the present value of the annual benefit realised at different times over a 50 year period.

Table 8-1 Present Value of Annual Benefits

Year	Average Annual Benefit ($ million)	Present Value ($ million)
0	2.3	2.3
1	2.3	2.2
10	2.3	1.2
25	2.3	0.4
50	2.3	0.1

If the present value benefits for each year are totalled for the 50 years, the total present value (or total benefit) of the benefits is $31.7 million. The calculation of the total benefit can be simplified through the use of a Present Value Factor. Rather than calculating the present value for each year and summing to calculate the total benefit, a Present Value Factor can be used when the average annual benefit is identical in each year. The Present Value Factor is calculated using equation (1). The Present Value Factor is multiplied by the average annual benefit to calculate the total benefit. The Present Value Factor is 13.8 for a 50 year period and a discount rate of 7%.

It is interesting to note that if a longer financial project life of say, 100 years was chosen then the total present value of the benefits is only $1.1 million more at $32.8 million. This is due to the fact that the present value of the benefits to be accrued in the second 50 year period is low because of the length of time until the benefits are realised.

$$\frac{\left\lfloor 1-\left(\frac{1}{(1+i)^{n}}\right)\right\rfloor}{i} \qquad (1)$$

where
n is the number of years
i is the discount rate(%)

The procedure for calculating benefit-cost ratios is outlined below:

- calculate the average annual benefit associated with the option (i.e. the reduction in average annual damages) using the method described in Section 6;
- convert the average annual benefit to a total benefit by multiplying by the present value factor; and
- calculate the total cost of the option.

Calculate the monetary **benefit-cost** ratio:

$$Benefit - Cost\ Ratio = \frac{Total\ Benefit}{Total\ Cost}$$

It is important to recognise that the monetary benefit-cost ratios represent only one of the issues that must be considered in respect to the viability of an option. Other issues such as social and psychological impacts, although difficult to quantify, must be included in the complete assessment.

Benefit-cost ratios may be sensitive to variations and/or inaccuracies in the following:

- difficulties associated with upgrading pipes under existing roads;
- service conflicts;
- difficulties associated with trenching near buildings and power poles; and
- construction, maintenance and operation costs.

Data from Melbourne Water's Land Development Manual and Melbourne Water rate estimates for drainage works were used to estimate the total cost of each option. These rates are summarised in Appendix A. The rates for stormwater pipes and rising mains were factored by 1.5 for sections constructed alongside or under roads. Stormwater pipes were costed on the basis of flush jointed construction with 100% fine crushed rock backfill. An allowance for engineering and contingencies of 15% and 20% has been allowed for in the proposed works with an Administration allowance of 9% (applied to the cost estimate inclusive of the engineering allowance).

Maintenance costs were calculated based on recommendations made in the CoGG publication, Report on Asset Maintenance Benchmarking (GHD, 1997). Table Two of this report shows that CoGG are currently spending 0.4% of asset value on maintenance of drainage assets and recommends expenditure be increased to 2.4% of asset value. BMT WBM has adopted the recommended value of 2.4%.

8.1.2 Scheme One

The damages under Scheme One for each design flood event are summarised in Table 8-2 and illustrated in Figure 8-1. The Scheme One AAD, also presented in Table 8-2, is $381,000, which is a reduction of $8,000 from the existing conditions AAD of $389,000 per annum.

A summary of the capital costs for Scheme One is presented in Table 8-3 and the benefit cost analysis is summarised in Table 8-4. The BCR for Scheme One is 0.01. Based on the figures presented in Table 7-3 and Table 8-3, the capital cost of Scheme One per property floor saved from flooding during a 1% AEP flood event is $3,347,000.

Table 8-2 Scheme One Damages Summary

Event		**Scheme One**				
(Years ARI)	**AEP**	**Residential Damages**	**Commercial / Industrial Damages**	**Total Indirect Damages**	**Total Damages**	**Incremental Average Annual Damages**
PMF*	0.0%				$3,189,000*	
100	1%	$2,137,000	$72,000	$663,000	$2,872,000	$30,000
20	5%	$1,189,000	$45,000	$370,000	$1,604,000	$90,000
10	10%	$807,000	$28,000	$251,000	$1,086,000	$67,000
5	20%	$525,000	$16,000	$162,000	$703,000	$89,000
2	50%					$105,000
Average Annual Damage						**$381,000**

+ Note – PMF damages are an extrapolation of the 1% AEP data, i.e., they were not calculated using PMF flood levels

Table 8-3 Scheme One Capital Cost Estimates

Item	**Capital Cost**
Works	$4,649,000
Contingencies (20%)	$930,000
Engineering (15%)	$697,000
Administration (9%)	$418,000
Total	**$6,694,000**

Table 8-4 Scheme One BCR Summary

Item	**Existing**	**Scheme One**
Damages (PA)	$389,000	$381,000
Benefit (PA)		$8,000
Benefit (NPV)		$99,000
Capital Cost		$6,694,000
Maintenance (PA)		$161,000
Maintenance (NPV)		$1,998,000
Total Option Cost		$8,692,000
BCR		**0.01**

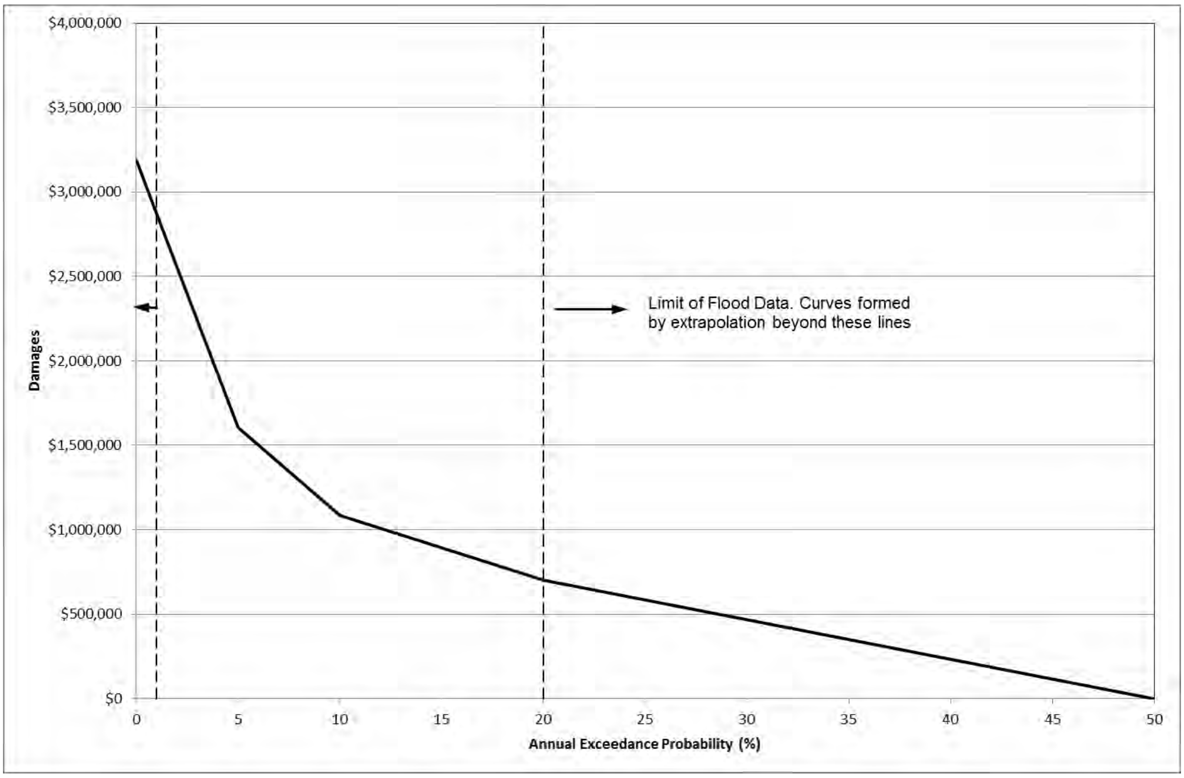

Figure 8-1 Scheme One Probability Damages Curve

8.1.3 Scheme Two

The damages under Scheme Two for each design flood event are summarised in Table 8-5 and illustrated in Figure 8-2. The Scheme Two AAD, also presented in Table 8-5, is $362,000, which is a reduction of $27,000 from the existing conditions AAD of $389,000.

A summary of the capital costs for Scheme Two is presented in Table 8-6 and the benefit cost analysis is summarised in Table 8-7. The BCR for Scheme Two is 0.01. From the figures presented in Table 7-4 and Table 8-6, the capital cost of Scheme Two per property floor saved from flooding during a 1% AEP flood event is $4,220,000.

Table 8-5 Scheme Two Damages Summary

Event		Scheme Two				
(Years ARI)	AEP	Residential Damages	Commercial / Industrial Damages	Total Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF*	0.0%				$2,987,000*	
100	1%	$2,067,000	$7,000	$622,000	$2,696,000	$28,000
20	5%	$1,178,000	$2,000	$354,000	$1,534,000	$85,000
10	10%	$799,000	$2,000	$240,000	$1,041,000	$64,000
5	20%	$514,000	$0	$154,000	$668,000	$85,000
2	50%					$100,000
Average Annual Damage						**$362,000**

+Note – PMF damages are an extrapolation of the 1% AEP data, i.e., they were not calculated using PMF flood levels

Table 8-6 Scheme Two Capital Costs

Item	Capital Cost
Pipe Works	$14,654,000
Contingencies (20%)	$2,931,000
Engineering (10%)	$2,198,000
Administration (9%)	$1,319,000
Total	**$21,102,000**

Table 8-7 Scheme Two BCR Summary

Item	Existing	Scheme Two
Damages (PA)	$389,000	$362,000
Benefit (PA)		$27,000
Benefit (NPV)		$335,000
Capital Cost		$21,102,000
Maintenance (PA)		$506,000
Maintenance (NPV)		$6,279,000
Total Option Cost		$27,381,000
BCR		**0.01**

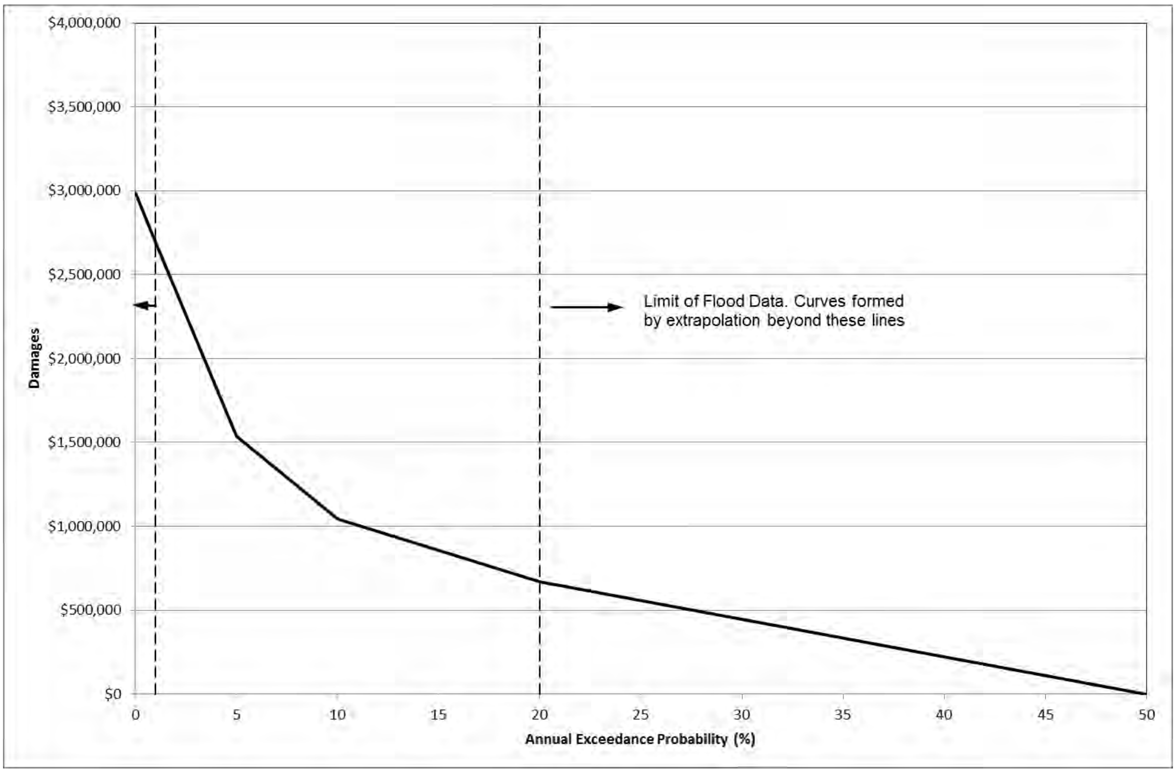

Figure 8-2 Scheme Two Probability Damages Curve

8.1.4 Scheme Three

The damages under Scheme Three for each design flood event are summarised in Table 8-8 and illustrated in Figure 8-3 The Scheme Three AAD, also presented in Table 8-5, is $363,000, which is a reduction of $26,000 from the existing conditions AAD of $389,000.

A summary of the capital costs for Scheme Three is presented in Table 8-9 and the benefit cost analysis is summarised in Table 8-10. The BCR for Scheme Three is 0.01. From the figures presented in Table 7-5 and Table 8-9, the capital cost of Scheme Three per property floor saved from flooding during a 1% AEP flood event is $4,542,000.

Table 8-8 Scheme Three Damages Summary

Event		**Scheme Three**				
(Years ARI)	**AEP**	**Residential Damages**	**Commercial / Industrial Damages**	**Total Indirect Damages**	**Total Damages**	**Incremental Average Annual Damages**
PMF*	0.0%				$2,819,000*	
100	1%	$1,964,000	$7,000	$591,000	$2,562,000	$27,000
20	5%	$1,178,000	$2,000	$354,000	$1,534,000	$82,000
10	10%	$812,000	$2,000	$244,000	$1,058,000	$65,000
5	20%	$524,000	$0	$157,000	$681,000	$87,000
2	50%					$102,000
Average Annual Damage						**$363,000**

+Note – PMF damages are an extrapolation of the 1% AEP data, i.e., they were not calculated using PMF flood levels

Table 8-9 Scheme Three Capital Costs

Item	**Capital Cost**
Pipe Works	$18,925,000
Contingencies (20%)	$3,785,000
Engineering (10%)	$2,839,000
Administration (9%)	$1,703,000
Total	**$27,252,000**

Table 8-10 Scheme Three BCR Summary

Item	**Existing**	**Scheme Three**
Damages (PA)	$389,000	$363,000
Benefit (PA)		$26,000
Benefit (NPV)		$323,000
Capital Cost		$27,252,000
Maintenance (PA)		$654,000
Maintenance (NPV)		$8,116,000
Total Option Cost		$35,368,000
BCR		**0.01**

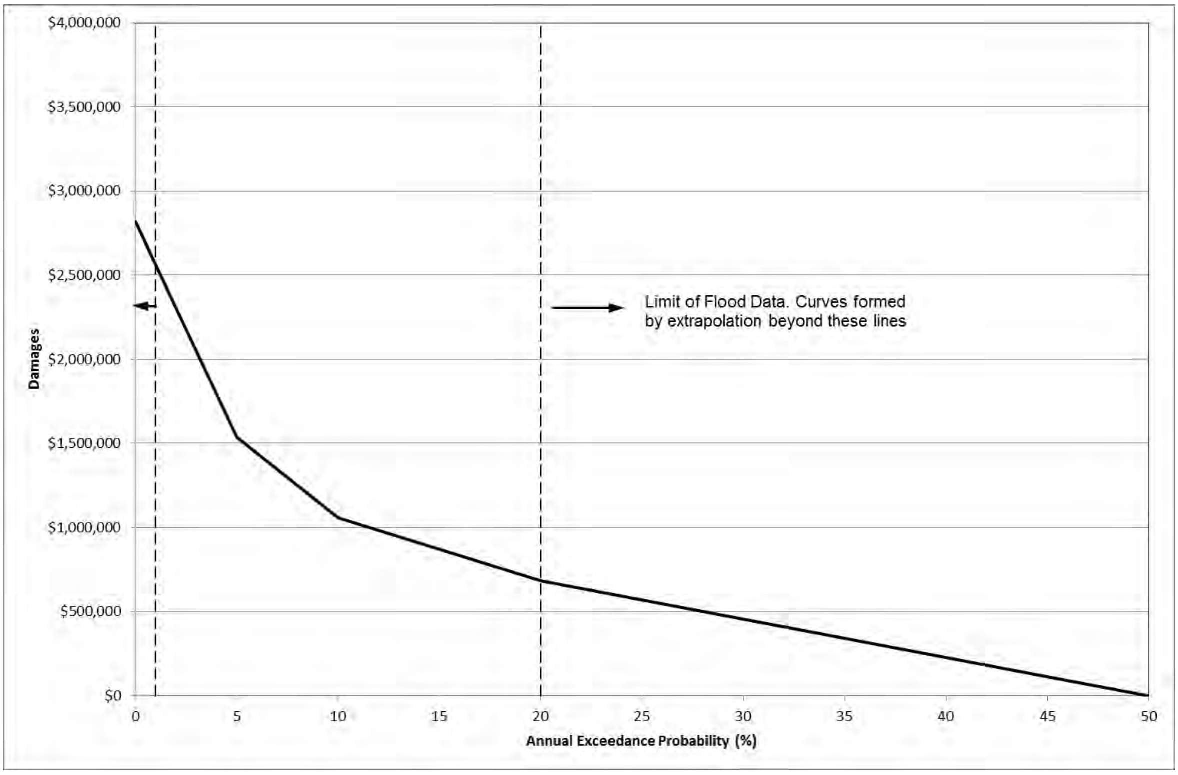

Figure 8-3 Scheme Two Probability Damages Curve

8.2 Environmental Assessment

Environmental impacts, associated with the construction and operation of each flood mitigation option, are discussed in this section. Table 8-11 presents details regarding the environmental implications for each scheme in the study area. It is not anticipated that any of the schemes will have long-term environmental impacts.

Table 8-11 Environmental Indicators

Issue	FLOOD MITIGATION SCHEMES			
	Scheme One	Scheme Two	Scheme Three	Scheme Four "No Structural Works" (Existing Case)
Ecological impact.	No Change	No Change	No Change	No Change.
Noise.	Minor impacts associated with the construction of the works.	Minor impacts associated with the construction of the works.	Minor impacts associated with the construction of the works.	No Change.
Receiving Water Quality.	No Change.	Increased rate of runoff into the Barwon River from the Belle Vue Avenue bypass pipe. This piped runoff may contain a higher concentration of pollutants than previously due to the inherent treatment that occurred previously as the water flowed overland through vegetated properties. Following further investigation stormwater water quality works may be required to mitigate environmental impacts and meet stormwater management legislation.	Same as Scheme Two.	No Change.
Air.	Minimal impact. Manage via construction management plan.	Minimal impact. Manage via construction management plan.	Minimal impact. Manage via construction management plan.	No Change.

8.3 Social Assessment

Table 8-12 outlines the social implications related to each flood mitigation scheme proposed for the study area.

Table 8-12 Social Indicators

Issue	FLOOD MITIGATION SCHEMES			
	Scheme One	**Scheme Two**	**Scheme Three**	**Scheme Four** **"No Structural Works" (Existing Case)**
Recreation and Aesthetic.	No Change.	The playing field within the Highton Recreation Reserve and associated sporting facilities will require re-configuration as a result of excavation and will become inundated when storage is initiated. Through appropriate design of the retarding basin, including playing field drainage systems, there should not be a significant impact on the community due to the presence of water on the playing fields.	Same as Scheme Two	No Change.
Cultural Heritage.	Manage via Cultural Heritage Management Plan (if required).	Same as Scheme One.	Same as Scheme One.	No Change.
Public Safety.	Moderate risk due to potentially deep excavation. Manage risk with appropriate construction phase management plans as applicable. Some potential risk from large drainage structures. Manage with best practice design.	Same as Scheme One.	Same as Scheme One.	No Change. Areas of unsafe flooding would remain.

8.4 Feasibility and Performance Indicators

Table 8-13 presents the feasibility and performance indicators for the study area. The main inhibitors to both schemes are the capital costs and relatively low BCR values; however Scheme One is more favourable than Scheme Two for these two indicators.

Table 8-13 Feasibility and Performance Indicators

Issue	FLOOD MITIGATION SCHEMES			
	Scheme One	Scheme Two	Scheme Three	Scheme Four “No Structural Works” (Existing Case)
Maintenance costs.	Limited increase in annual maintenance cost as proposed pipe would only make up a small percentage of the drainage infrastructure within the study area. Retarding basin works are located in existing reserves that are already maintained in the required manner by council.	Same as Scheme One.	Same as Scheme One.	No Change

Issue	FLOOD MITIGATION SCHEMES			
	Scheme One	**Scheme Two**	**Scheme Three**	**Scheme Four "No Structural Works" (Existing Case)**
Ease of Construction	Difficulties associated with the laying of new pipes, particularly under Mount Pleasant Road, whilst minimising disruption to traffic flow. Unknown geology of excavation area may pose difficulties in construction and increase costs. Potential for other utilities such as sewerage, potable water and gas to be located within the area.	Difficulties associated with the laying of new pipes, particularly under Barrabool Road and Belle Vue Avenue, whilst minimising disruption to traffic flow. Difficulties associated with retro-fitting new pit and connector pipe configuration with already established development/drainage network. Unknown geology of excavation areas may pose difficulties in construction and increase costs. Potential for other utilities such as sewerage, potable water and gas to be located within the area.	Same as Scheme Two.	Not applicable.
Funding and feasibility.	Very high capital cost and a low BCR of 0.01 would make funding difficult. Capital cost of Scheme per property floor saved from flooding during a 1% AEP flood event is $3,347,000.	Very high capital cost and a low BCR of 0.01 would make funding difficult. Capital cost of Scheme per property floor saved from flooding during a 1% AEP flood event is $4,220,000.	Very high capital cost and a low BCR of 0.01 would make funding difficult. Capital cost of Scheme per property floor saved from flooding during a 1% AEP flood event is $4,542,000.	Not applicable.

Issue	FLOOD MITIGATION SCHEMES			
	Scheme One	Scheme Two	Scheme Three	Scheme Four “No Structural Works” (Existing Case)
Public acceptability.	There would be issues related to this scheme as works are proposed to be undertaken on existing road infrastructure disturbing transportation.	There would be issues related to this scheme as works are proposed to be undertaken on existing road infrastructure disturbing transportation. There may be issues related to loss of access to Highton Recreation Reserve during construction and the layout post construction.	Same as Scheme Two.	Issues relating to Council being seen to be doing nothing structurally about the problem.

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9 PREFERRED MITIGATION SCHEME

9.1 Description of Preferred Scheme

Scheme Four “No Structural Works” is the preferred mitigation scheme for the study area. Through consultation with the CoGG, the preferred scheme was selected as the mitigation works adopted in Schemes One to Three have very low benefit cost ratios (BCRs). As documented in previous sections, and summarised below in Table 9-1, the very low BCRs reflect the high capital costs per floor level saved, to the order of $4M in capital cost.

Whilst each of the schemes delivers benefits in reducing the above floor flooding, the nature of the flooding within the catchment has meant that large numbers of properties are still inundated during the modelled flood events. The bulk of the calculated flood damages are a result of property inundation rather than above floor flooding, and consequently despite reductions in the above floor flooding, commensurate reductions in the calculated AAD have not been realised.

Table 9-1 Comparison of Scheme One and Scheme Two

Scheme	AAD	Capital Cost	BCR	Flooded Floors Saved in 1% AEP Flood Event*	Capital Cost per floor saved (1% AEP Flood Event)
One	$381,000	$6,694,00	0.01	2	$3,347,000
Two	$362,000	$21,102,000	0.01	5	$4,220,000
Three	$363,000	$27,252,000	0.01	6	$4,542,000
Four	$389,000	-	-	-	-

* Results based on properties surveyed by CoGG.

In response to the preferred scheme being “No Structural Works”, CoGG will continue to investigate a number of flood mitigation options ‘in-house’ to assess whether options can be implemented that will result in a reduction to the flooding and flood damages experienced by the Highton community. Additionally, CoGG will implement a number of non-structural mitigation measures within the catchment, including:

- Further investigation into the feasibility of localised flood mitigation measures, such as lifting footpaths and/or underground drainage augmentation, in order to reduce the flood risk for properties that have been the subject of previous drainage/flooding requests for service that have identified capacity deficiencies rather than blockages. These investigations would be undertaken in accordance with the priority ranking established by applying the City's prioritisation method for drainage investigation/design work.

- Further investigation into the feasibility of property-specific measures to manage flood risk. Potential measures include flood-proofing of individual or groups of buildings/properties by landowners, and property buy-back with on-sell following modifications (where feasible) with conditions known to purchaser.

- Education and awareness program to inform landowners how to minimise the magnitude of damage in a flood event.

- Development controls via designation of areas as liable to flooding in accordance with Building Regulations 2006 and use of flood zones/overlays within the Greater Geelong Planning Scheme.

- Recognition that further development within the catchment has the potential to increase flood risk to people and property. Assessment of rezoning proposals to include application of principle of zero adverse flood impact on adjacent, upstream and downstream areas. Assessment of development and subdivision applications to include application of best practice guidelines for development within or upstream of flood-prone areas.

- Best practice environmental management for stormwater runoff to be encouraged as part of development and subdivision applications in order to reduce runoff and improve water quality, where not a statutory requirement.

10 PUBLIC CONSULTATION PROCESS

The Highton Drainage/Flood Study will be placed on display for public consultation. The public consultation period will allow local residents and stakeholders to query and make comments regarding the information contained within this report. Following the public consultation, any submissions received from the public will be addressed by Council, with details provided in Appendix C.

11 REFERENCES

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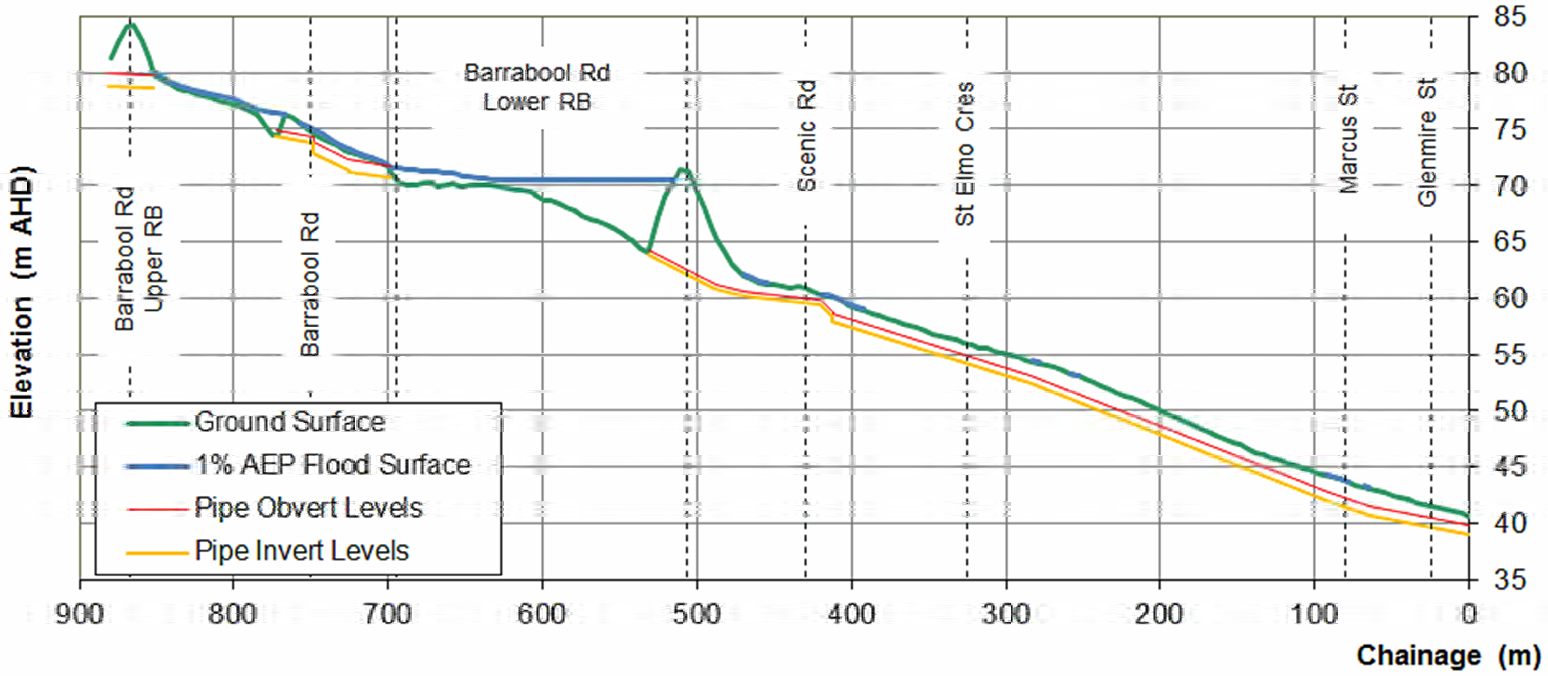
DNRE 2000, Department of Natural Resources and Environment 2000, *Rapid Appraisal Method (RAM) for Floodplain Management*, Department of Natural Resources and Environment, Victoria.

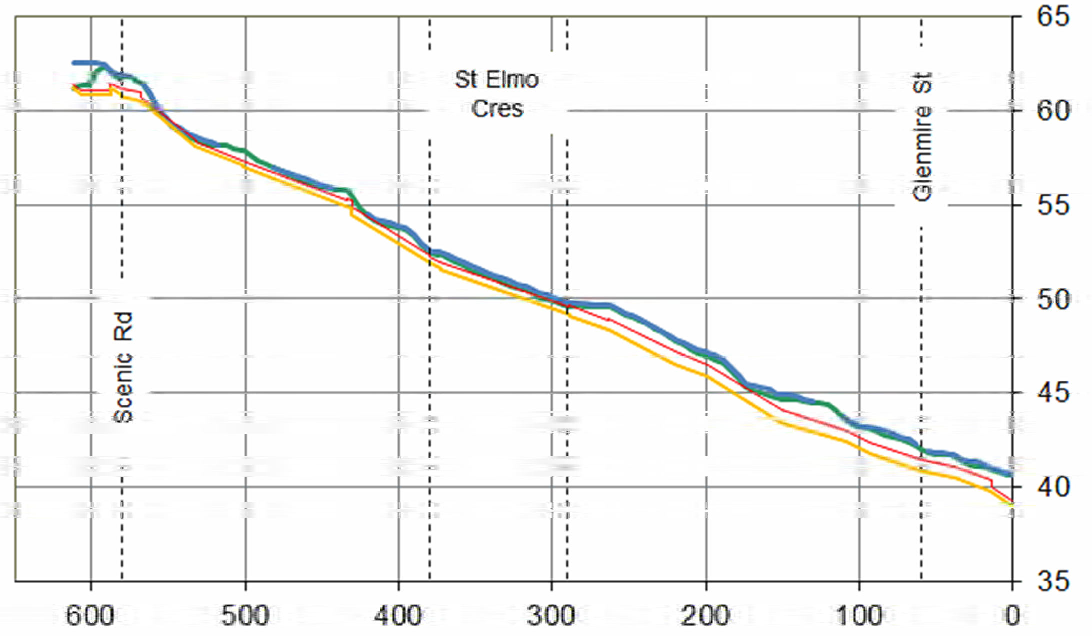
Smith, D 1994, 'Flood Damage Estimation – A review of urban stage-damage curves and loss functions', *Water SA*, vol. 20, pp. 231-238.

APPENDIX A: CONSTRUCTION RATES

West Region Pipeline Rates ($ per m)			
Nominal pipe diameter (mm)	Interlocking / Flush Jointed pipes	Adopted rates for pipes in road reserves	'Jacking' Rates
	100% FCR backfill	100% FCR backfill	
300	129	194	271
375	156	234	328
450	188	282	395
525	218	327	458
600	249	374	523
675	276	414	580
750	309	464	649
825	343	515	720
900	378	567	794
1050	460	690	966
1200	570	855	1197
1350	696	1044	1462
1500	841	1262	1766
1650	1,013	1520	2127
1800	1,244	1866	2612
1950	1,538	2307	3230
2100	1,901	2852	3992
2250	2,452	3678	5149
2400	3,061	4592	6428

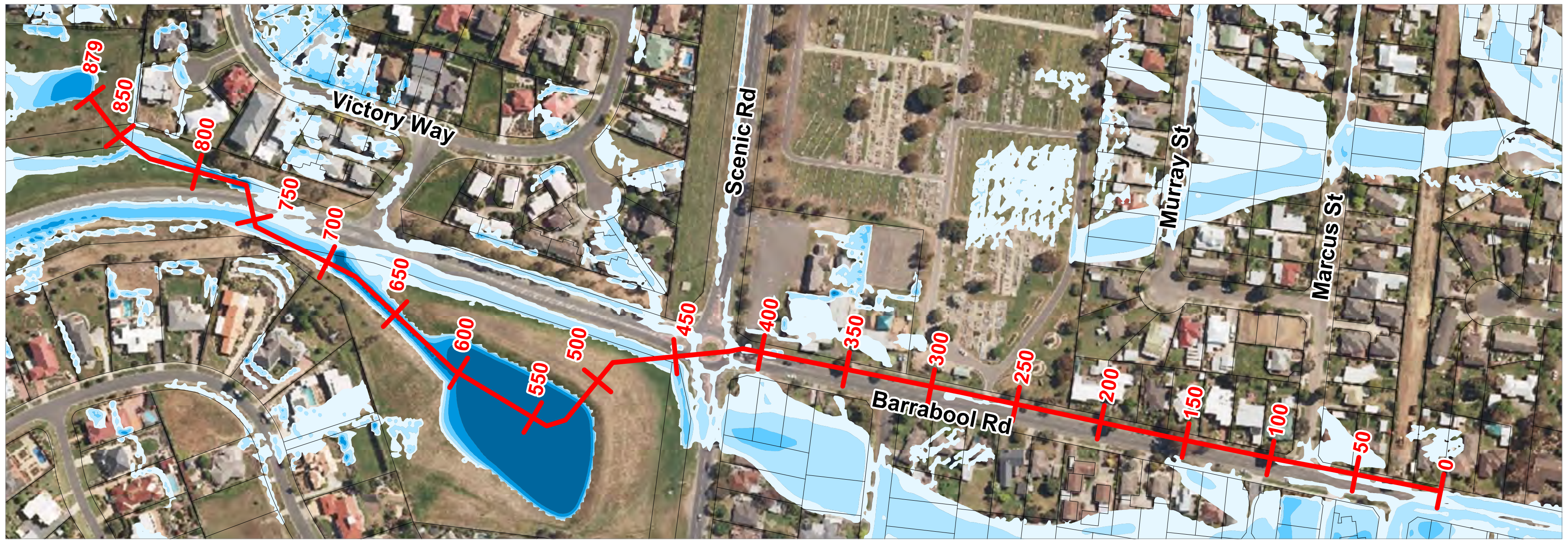
APPENDIX B: LONGITUDINAL PROFILE PLOTS

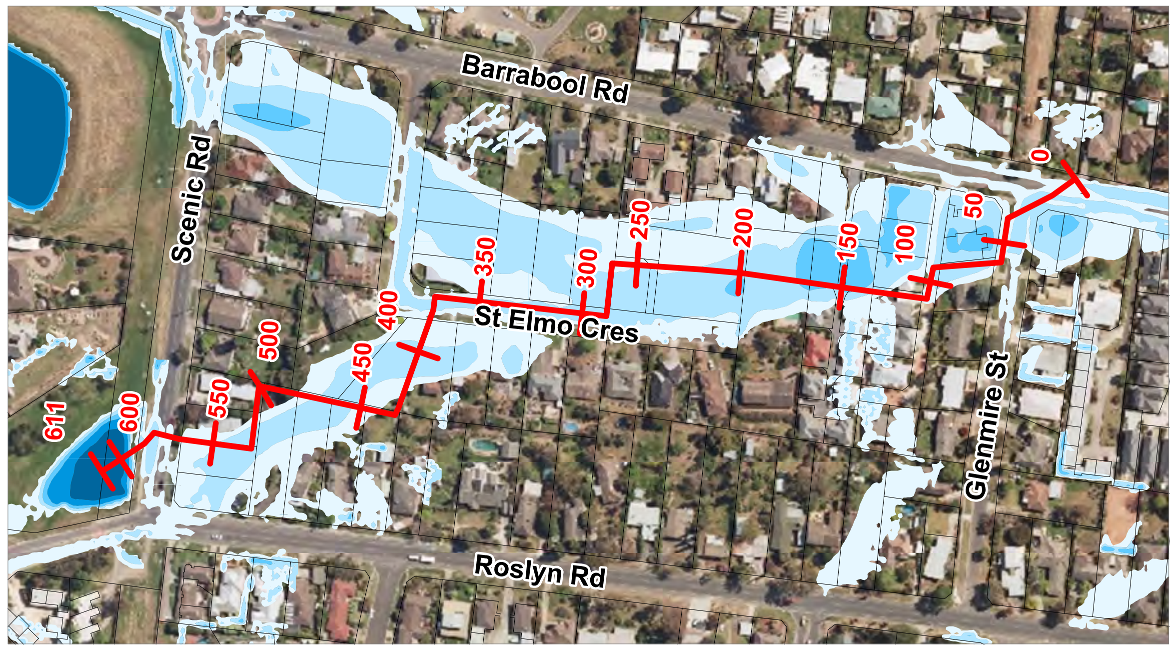




Ground Surface (m AHD)	81.33	79.79	77.29	74.89	71.79	69.48	68.80	65.93	70.01	61.18	59.34	57.00	55.05	52.91	50.03	47.06	44.53	42.50	40.60
Flood Surface (m AHD)	81.20	80.06	77.71	75.17	71.90	70.86	70.47	70.47		61.18	59.38								40.64
Chainage (m)	879	850	800	750	700	650	600	550	500	450	400	350	300	250	200	150	100	50	0

61.19	61.35	59.45	57.82	55.97	53.78	51.44	49.91	49.07	46.94	44.63	43.19	41.74	40.60
62.57	62.57	59.54		56.02	53.91	51.66	50.13	49.18	47.19	44.93	43.23	41.80	40.64
611	600	550	500	450	400	350	300	250	200	150	100	50	0





Title:

1% AEP Existing Conditions Flood Surface Longitidinal Profile Barrabool Rd Upper RB and Wandana Dr RB to Glenmire St

Figure: **B-1**

Rev: **B**

N

0 75 150m

Approx. Scale

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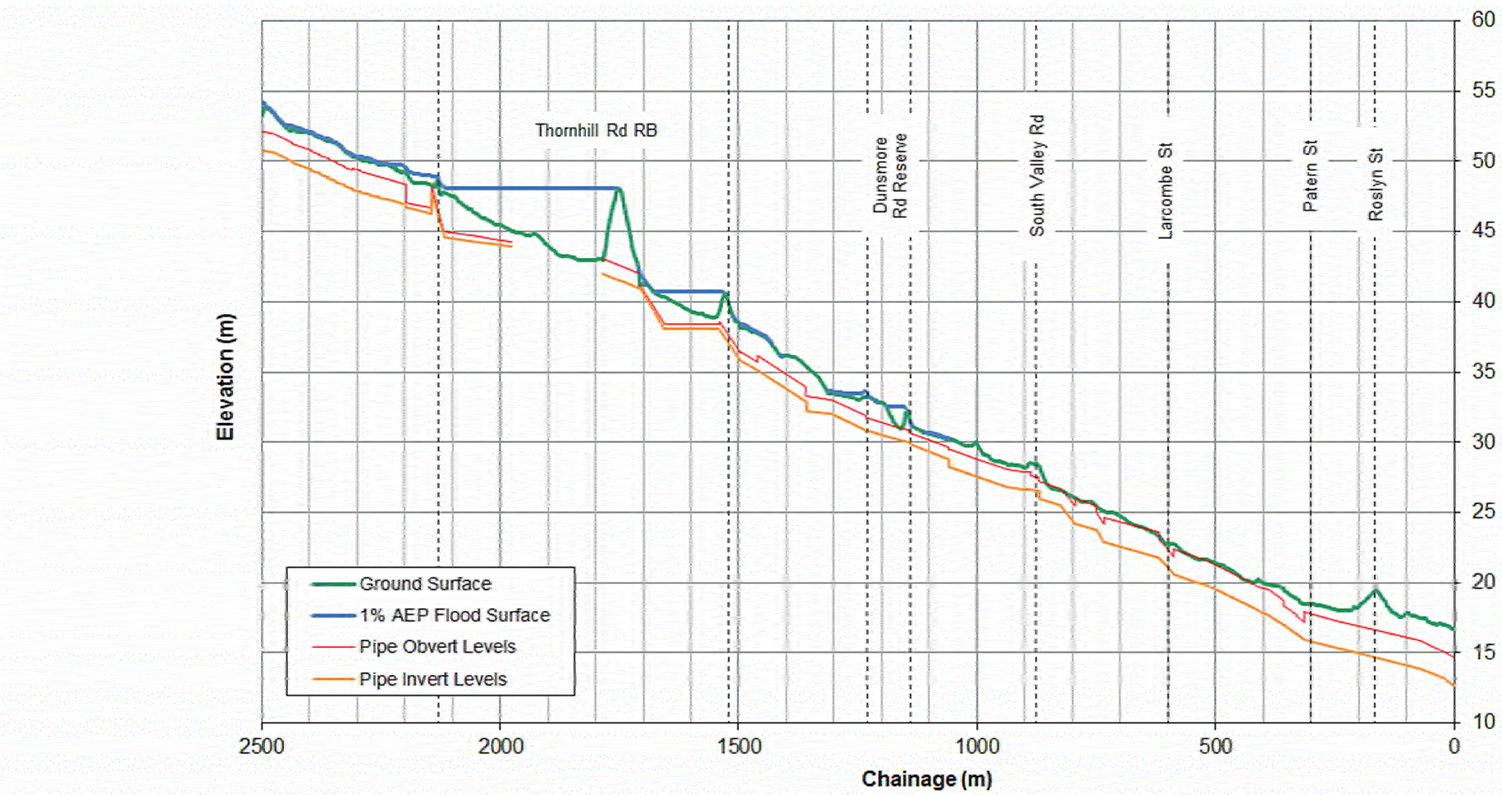
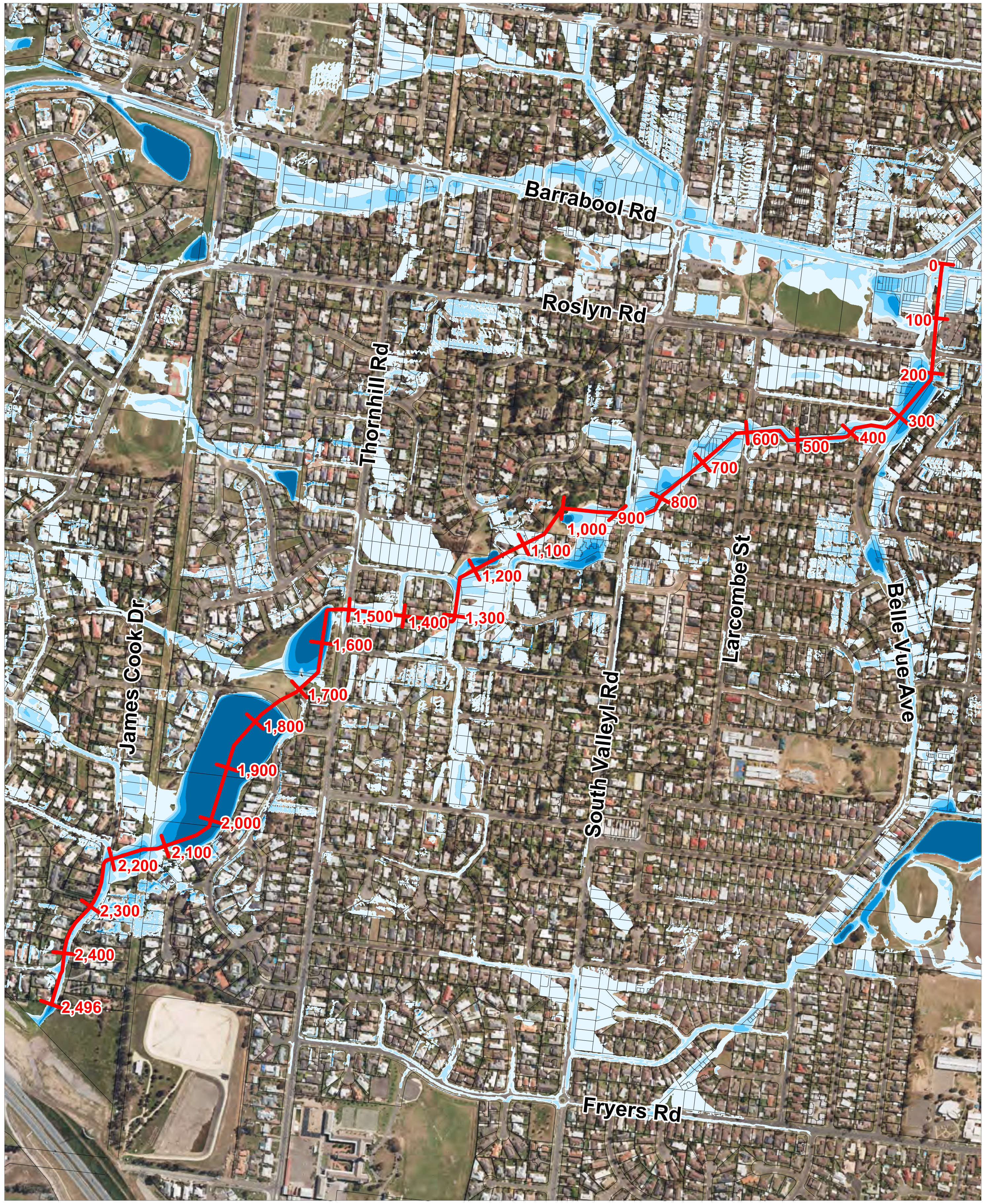
Filepath : T:\M8094.JL.Highton_DFS\MapInfo\Drawings\Report_Final\FigB-1_Exg_LongSectA_RevB.WOR



Ground Surface (m AHD)	53.29	52.06	50.29	49.29	47.56	45.48	44.08	42.97	41.26	39.36	38.56	36.16	33.45	32.86	30.59	30.05	28.21	26.14	24.73	22.60	21.43	19.97	18.51	18.25	17.83	16.69
Flood Surface (m AHD)	54.20	52.14	50.38	49.69	48.07	48.07	48.07	48.07	41.77	40.73			33.62		30.68		28.61	26.41	24.90	23.07	21.77	20.20	18.89	18.89		16.85
Chainage (m)	2496	2400	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	900	800	700	600	500	400	300	200	100	0



Title:

1% AEP Existing Conditions Flood Surface Longitidinal Profile James Cook Dr to Barrabool Rd

Figure: B-2

Rev: B

N

0 200 400m

Approx. Scale

BMT WBM

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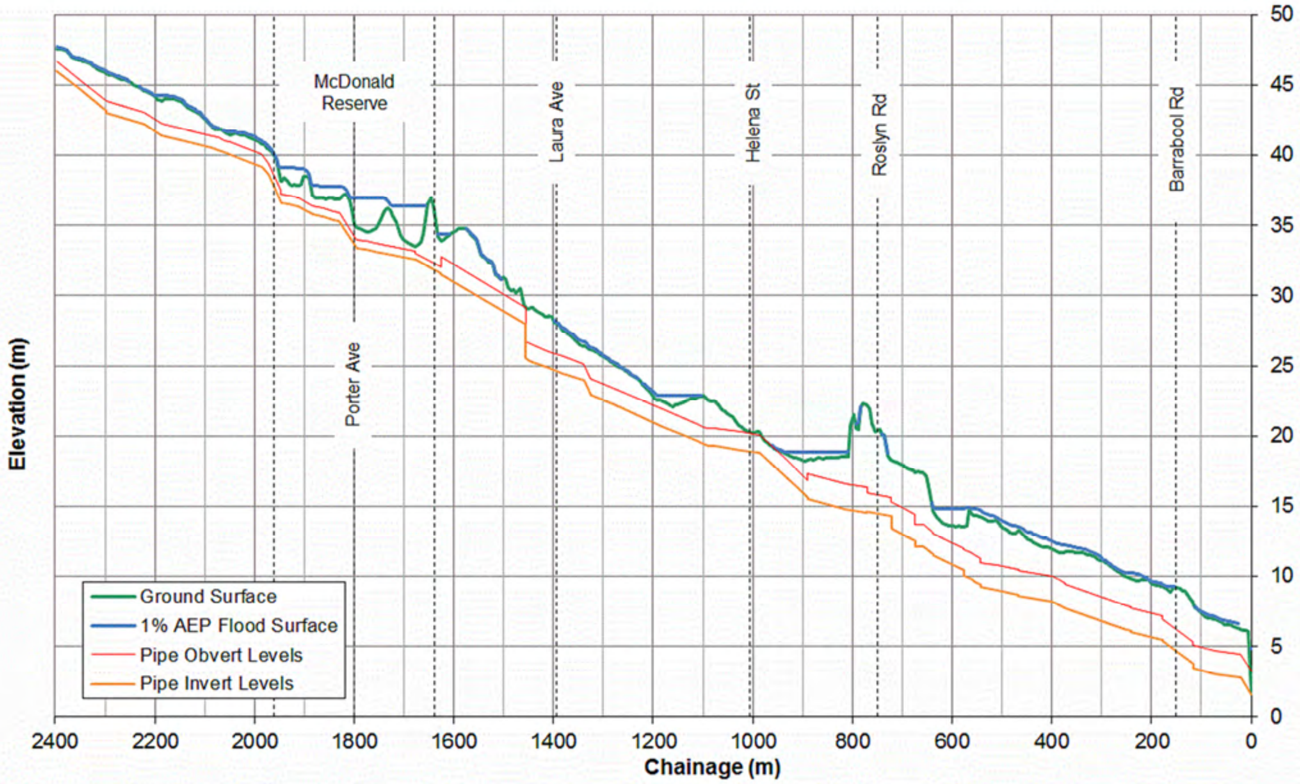
Filepath : T:\M8094.JL.Highton_DFS\MapInfo\Drawings\Report_Final\FigB-2_Exg_LongSectB_RevB.WOR



Ground Surface (m AHD)	47.55	45.92	44.31	42.69	41.18	38.52	35.05	33.93	34.57	31.33	28.26	25.66	22.84	22.87	20.25	18.29	21.53	17.93	13.60	13.55	12.00	11.12	9.50	7.38	1.69
Flood Surface (m AHD)	47.70	46.06	44.34	42.77	41.37	38.99	36.98	36.41			28.28	25.79	23.14			18.89			14.87	14.00	12.54	11.33	9.65	7.52	4.85
Chainage (m)	2395	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	900	800	700	600	500	400	300	200	100	0

Title:

1% AEP Existing Conditions Flood Surface Longitidinal Profile Fryers Rd to Barwon River

Figure: **B-3**

Rev: **B**

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

0 200 400m

Approx. Scale

BMT WBM

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Filepath : T:\M8094.JL.Highton_DFS\MapInfo\Drawings\Report_Final\FigB-3_Exg_LongSectC_RevB.WOR

APPENDIX C: PUBLIC SUBMISSIONS AND RESPONSES

This Appendix has been intentionally left blank and will be completed by Council following the public consultation period for the Highton Drainage/Flood Study.

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