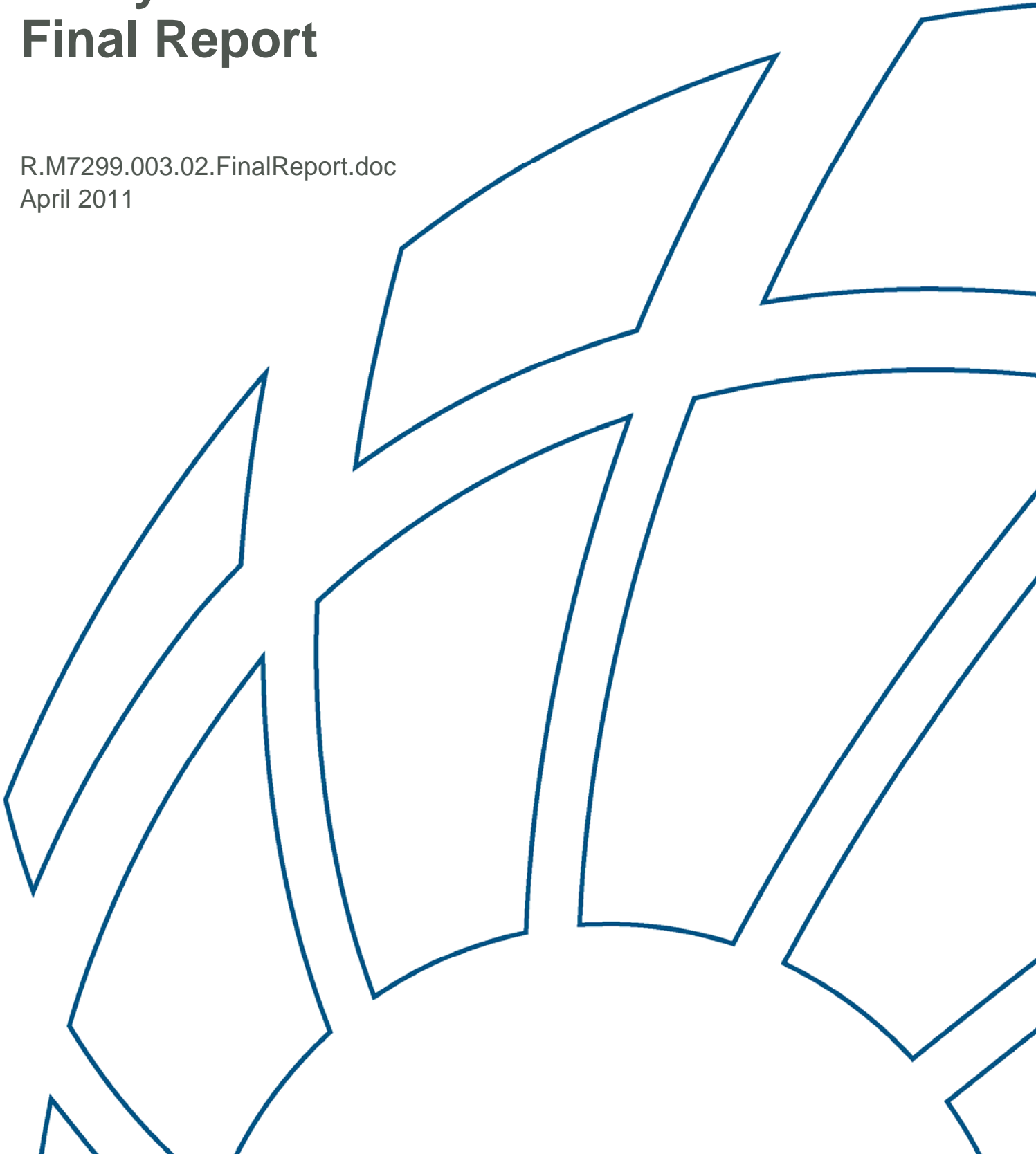


# **Kosciusko Avenue Main Drain Catchment Drainage / Flood Study Final Report**

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April 2011



# Kosciusko Avenue Main Drain Catchment Drainage / Flood Study Final Report

Prepared For: City of Greater Geelong

Prepared By: BMT WBM Pty Ltd (Member of the BMT group of companies)

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<b>Title :</b>	Kosciusko Avenue Main Drain Catchment Drainage / Flood Study Final Report
<b>Author(s) :</b>	Yannick Michel and Michael Turnley
<b>Synopsis :</b>	This report documents the methodology and results for the Kosciusko Avenue Main Drain Catchment Drainage / Flood Study.

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## EXECUTIVE SUMMARY

### Study Objective

The Kosciusko Avenue Main Drain (MD) catchment has some of the most serious and frequent drainage-related or “stormwater” flooding within the municipality. Like many areas of similar age, the stormwater pipe network within the Kosciusko Avenue MD catchment is generally ageing and hydraulically constrained by today’s standards. There are only limited open channel flow systems or overland floodways to convey runoff during larger flood events, so when the capacity of the network is exceeded, it results in above floor flooding in the residential areas. The primary objectives of this study were to characterise existing flooding and to develop an appropriate flood management strategy to mitigate stormwater flooding in the area.

### Study Methodology

The study was carried out under the following core elements.

1. *Preliminary Tasks* – These were project initiation, including an inception meeting and initial site inspection, along with a data collation and review exercise. The data collation and review phase included an analysis of previous drainage investigations, council policy, aerial photography of the area, topography, GIS datasets, digital plans and design information.
2. *Digital Terrain Model* – Photogrammetry of the study area was commissioned and supplied by Photomapping Services. LiDAR data of the study area was also provided by the City of Greater Geelong (CoGG) and used to assist in the hydrological model development. Additional continuous elevation strings representing features of hydraulic importance were sourced for use in the modelling.
3. *Hydrological and Hydraulic Modelling, and Mapping of the Existing Conditions* – The hydrologic and hydraulic modelling was undertaken using the traditional approach of applying flow boundaries from the hydrological model (RORB) to the two-dimensional (2D) hydraulic model (TUFLOW). The existing flood characteristics were identified through hydrologic and hydraulic modelling of the 20%, 5% and 1% average exceedence probability (AEP) flood events. The flood results were mapped using GIS. An assessment of flood damage was undertaken using the stage-damage curve approach.
4. *Mitigation Option Assessment and Mapping* – A wide range of potential structural and non-structural flood mitigation measures were screened, from which a shortlist of three (3) alternative flood mitigation schemes were selected and tested using the hydraulic model. Flood damage, scheme cost and benefit-cost ratios were determined for each of the schemes tested. A “do nothing” option was also considered.
5. *Selection and Detailed Mapping of the Preferred Mitigation Scheme* – The mitigation schemes were assessed according to their ability to reduce flood damage. The schemes were ranked according to a range of economic and non-economic factors. A preferred strategy was then selected in consultation with CoGG. The preferred scheme was mapped using GIS, with hardcopy plans of flood extent and flood levels produced.

The key results from the investigation are summarised in the following sections.

## Existing Flooding Characteristics

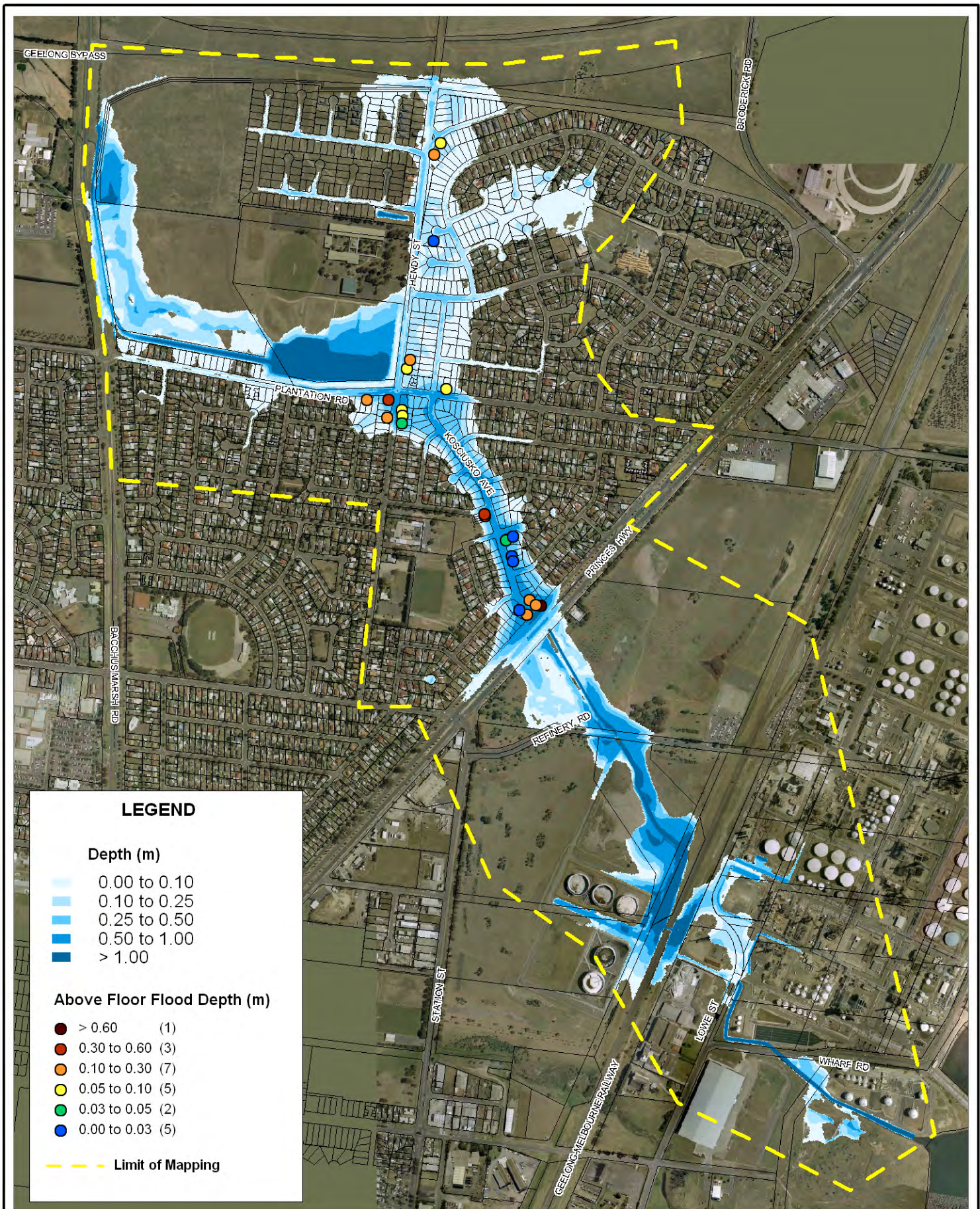
The flood extent of the 1% Annual Exceedence Probability (AEP) flood, i.e. the 100 Year Average Recurrence Interval (ARI) flood, is shown in Figure E-1. The number of flood-affected properties was identified and the average annual flood damage (AAD) was calculated at \$40,000. Table E-1 shows the total number of properties that have floor level information available and are inundated to above floor level in the range of flood events analysed. An analysis was also undertaken to determine the number of properties within the study mapping area, ie, not the full catchment, that have flooding within the property boundaries in the 1% AEP event. This information is also detailed in Table E-1.

Hazard mapping was undertaken using the methodology prescribed in the Melbourne Water document *Guidelines for Development in Flood-prone Areas*. The analysis is designed to determine if it is safe for people to move about on a property during a flood event. Safety is defined in terms of the depth, velocity and velocity-depth product. The existing 1% AEP hazard mapping for the study area is shown in Figure E-2. There are sections of the main overland drainage paths that are classified as unsafe in a 1% AEP event such as table drains, open channels and retarding basins. In addition to these main overland flowpaths experiencing unsafe overland flow in a 1% AEP flood are Hendy St, Kosciusko Ave and the intersection of Kosciusko Ave and the Princes Hwy service road. During the 20% AEP flood, areas considered unsafe are generally located where flood water is 'ponding' and include Bacchus Marsh Rd table drain, the Plantation Rd retarding basin and the intersection of Kosciusko Ave and the Princes Hwy service road.

**Table E-1 Number of Flooded Properties**

AEP	Number of Flooded Properties	
	Kosciusko Ave MD	
	Within Property	Above Floor*
1%	477	23
5%	366	10
20%	251	4

\* Results based on properties surveyed by CoGG. Refer to Section 3.6 (of the Main Report).

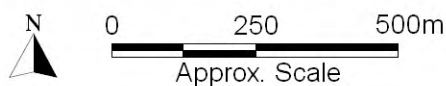


Title:  
**Existing 1% AEP Peak Flood Depth**

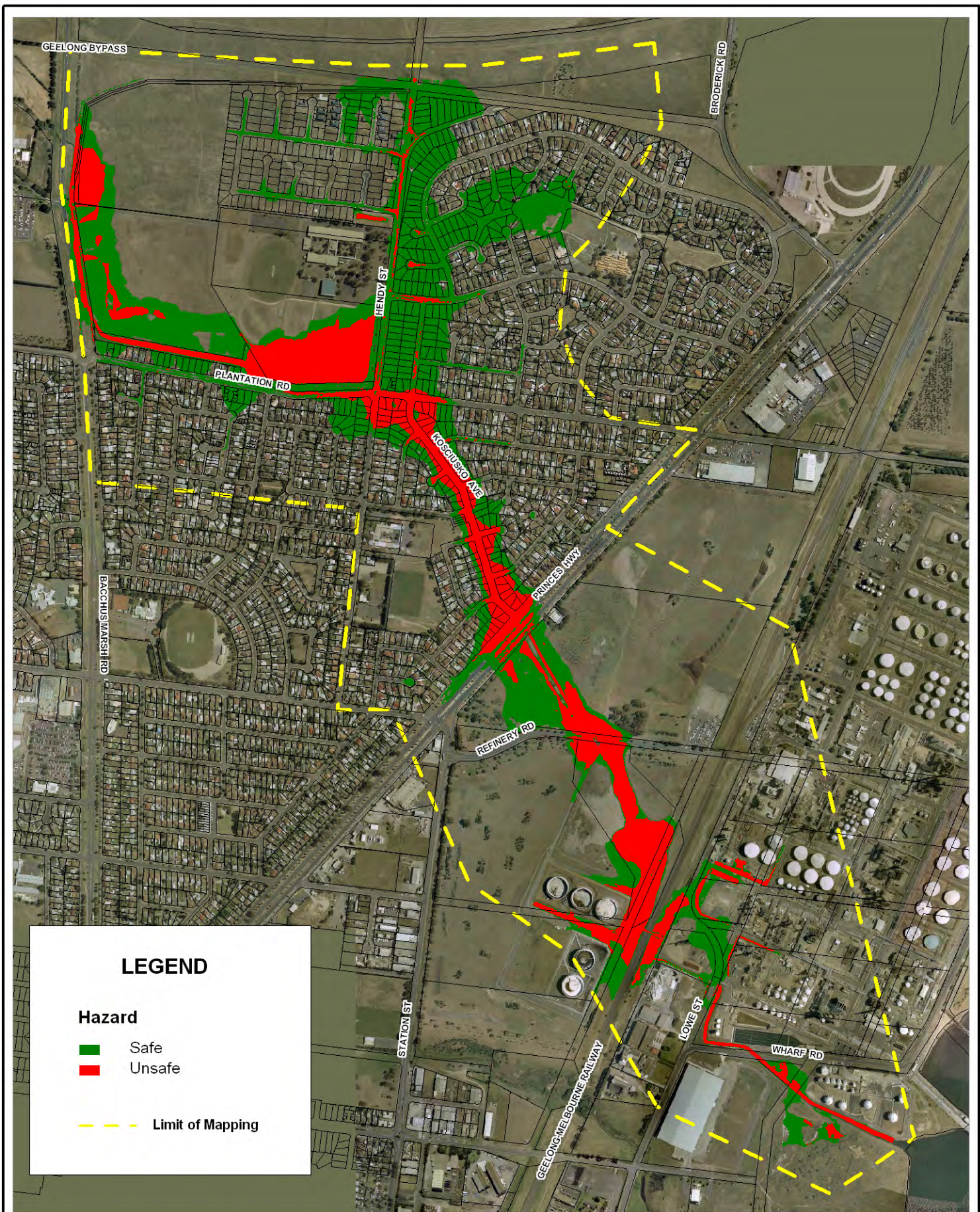
Figure:  
**E-1**

Rev:  
**B**

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**LEGEND**

**Hazard**

- Safe
- Unsafe

- - - Limit of Mapping

Title:  
**Existing 1% AEP Flood Hazard**

Figure:  
**E-2**

Rev:  
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## Mitigation Option Assessment

A full range of structural and non-structural flood mitigation elements were considered when developing the three mitigation schemes. The elements considered ranged from upgrading underground pipe systems through to planning scheme amendments and education and awareness programs. These elements were screened to provide a list of elements that were considered suitable for use in the Kosciusko Ave MD drainage catchment. Through discussion with Council officers, the elements were combined to form the mitigation schemes for detailed modelling and assessment. The 'do nothing' strategy, ie, the existing flood conditions, was also considered.

Each scheme was assessed using the hydraulic model for each flood event. Table E-2 shows the number of flooded properties under each scenario. Table E-3 outlines the benefit (as a result of reduced flooding), the capital and on-going costs and Benefit to Cost Ratio (BCR) of each scheme.

**Table E-2 Flood Affected Properties**

Option	Flood Affected Property Floors **		
	1% AEP	5% AEP	20% AEP
Existing	23	10	4
Scheme One	17	8	4
Scheme Two	9	7	4
Scheme Three	8	6	4
Scheme Four (Do Nothing)	23	10	4

\*\* Flood Affected Property Floors are defined as those with flood levels above the surveyed floor level

**Table E-3 Mitigation Option Economic Summary**

Options	Annual Damages	Average Annual Benefit	Total Benefit (NPV)	Capital Cost	Ongoing Costs over 30 Years (PA)	Ongoing Costs over 30 Years (NPV)*	Total Option Cost	BCR
Scheme One	\$32,000	\$8,000	\$99,000	\$2,220,000	\$53,000	\$658,000	\$2,878,000	0.03
Scheme Two	\$26,000	\$14,000	\$174,000	\$5,565,000	\$134,000	\$1,663,000	\$7,228,000	0.02
Scheme Three	\$20,000	\$20,000	\$248,000	\$10,578,000	\$254,000	\$3,152,000	\$13,730,000	0.02
Scheme Four	\$40,000							

\* NPV – Net Present Value discounted at 7% over 30 years

## Preferred Mitigation Scheme

Scheme Two is the preferred scheme for the Kosciusko Ave MD drainage catchment. Details of the scheme are shown in Figure E-3. Through consultation with the CoGG, the preferred scheme was selected as it focused on mitigation of overland flows and flood depths to reduce flood hazard within the urban areas of Kosciusko Ave MD. The impact of the preferred scheme on 1% AEP flood levels is shown in Figure E-4, and

the hazard mapping for the preferred scheme is shown in Figure E-5. A comparison with the existing case hazard map (Figure E-2) shows a significant reduction in the extent of the areas classified as unsafe, particularly in the areas of concern previously mentioned.

Scheme Two has a higher capital cost and a marginally lower BCR. The scheme results in reductions of flood levels along most of the major flow paths and reduces the overall flood extent along Kosciusko Ave, resulting in a reduction of flood affected properties. Although regions of high hazard still exist within the catchment, these areas are dramatically reduced by the preferred scheme.

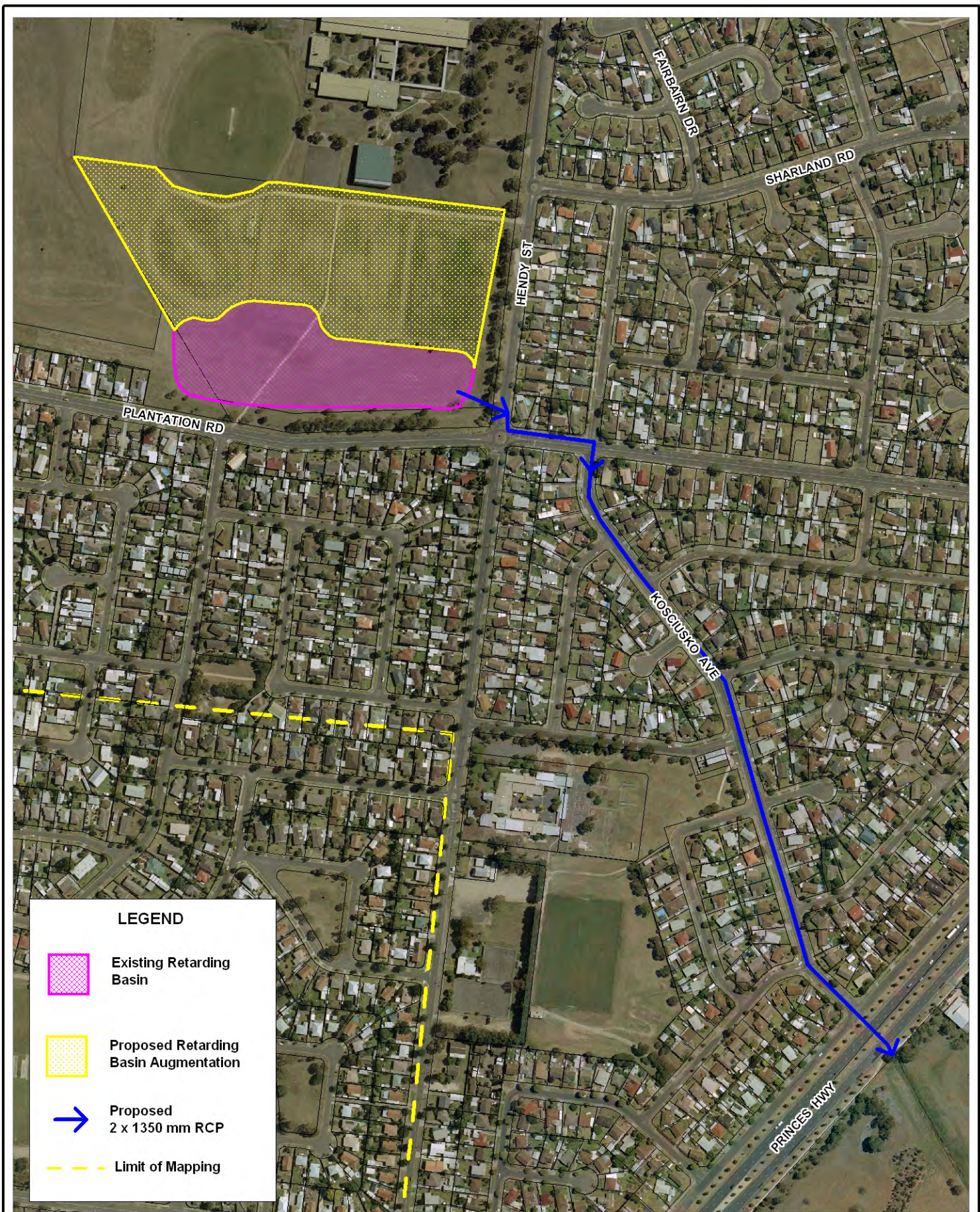
Further reductions in the number of flood affected properties under Scheme Two may be achieved through localised works. It is recommended that the City investigate the feasibility of localised flood mitigation measures, such as lifting footpaths &/or underground drainage augmentation, in order to reduce the flood risk for properties at the intersection of Streeton Close & McCubbin Court.

Also considered in the selection of the preferred scheme were key indicators such as environmental, social, feasibility and performance. This analysis in regard to the preferred scheme, when compared to the other schemes, is summarised as follows:





- its potential environmental impact is minimal and similar to the other schemes;
- the social impacts arising from Scheme Two are very limited; and
- the feasibility and performance are comparable to the other schemes.

A number of non-structural components are recommended for implementation in conjunction with the structural measures. These additional measures are summarised below.

- Further investigation into the feasibility of property-specific measures to manage risk from residual flooding (with Scheme Two in place). 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. This may be a feasible and economical alternative considering that house values are approximately \$200,000 to \$300,000 in the area whereas the capital cost per floor saved in the 1% AEP event for Scheme Two is approximately \$398,000.
- Education and awareness program to inform landowners how to minimise the magnitude of damage during 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 (planning permit) 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.



**LEGEND**

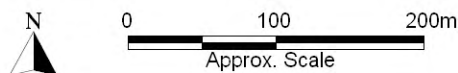
-  Existing Retarding Basin
-  Proposed Retarding Basin Augmentation
-  Proposed 2 x 1350 mm RCP
-  Limit of Mapping

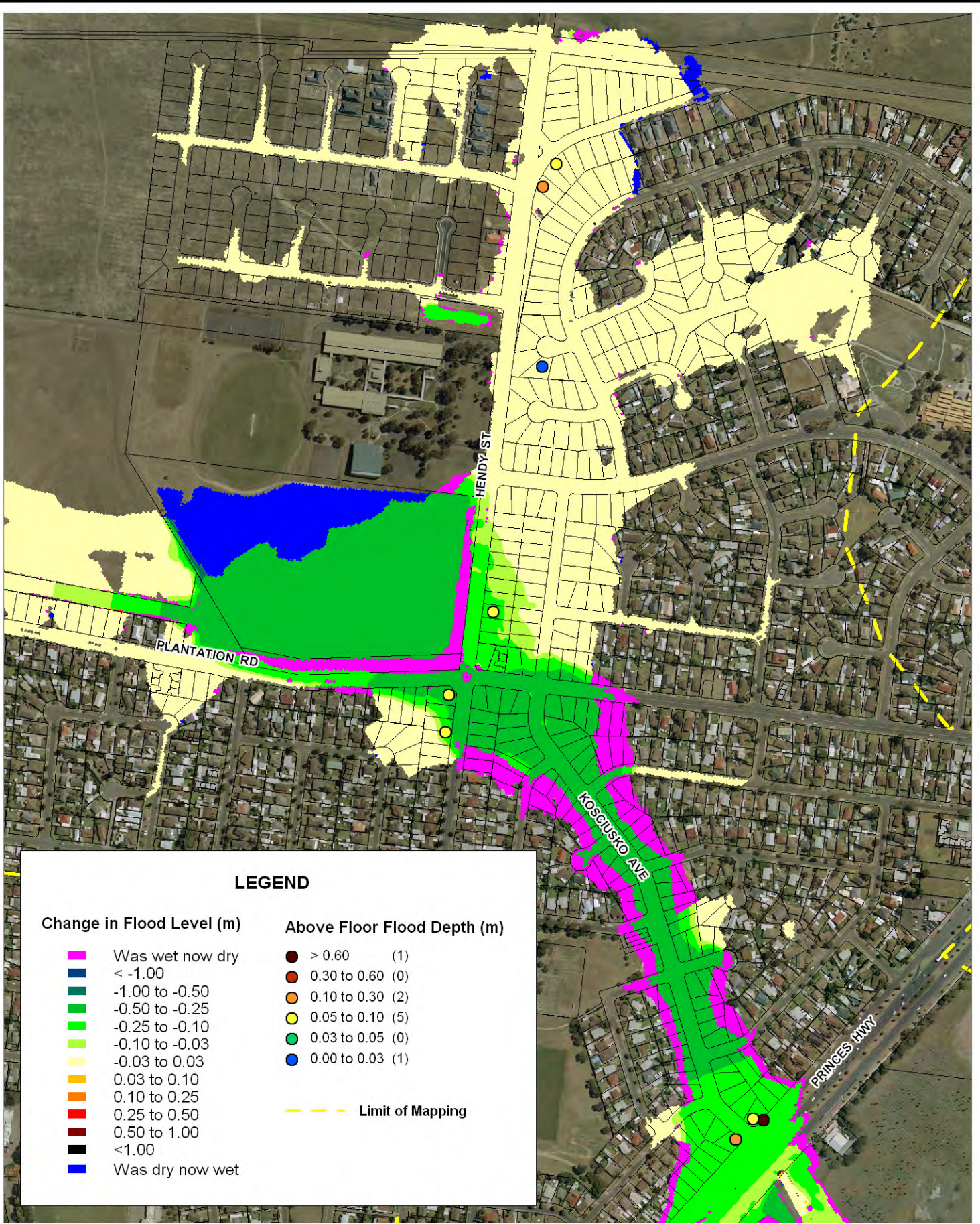
Title:  
**Preferred Scheme  
 Proposed Mitigation Works**

Figure:  
**E-3**

Rev:  
**A**

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**LEGEND**

**Change in Flood Level (m)**

- Was wet now dry
- < -1.00
- -1.00 to -0.50
- -0.50 to -0.25
- -0.25 to -0.10
- -0.10 to -0.03
- -0.03 to 0.03
- 0.03 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- 0.50 to 1.00
- <1.00
- Was dry now wet

**Above Floor Flood Depth (m)**

- > 0.60 (1)
- 0.30 to 0.60 (0)
- 0.10 to 0.30 (2)
- 0.05 to 0.10 (5)
- 0.03 to 0.05 (0)
- 0.00 to 0.03 (1)

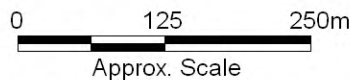
- - - Limit of Mapping

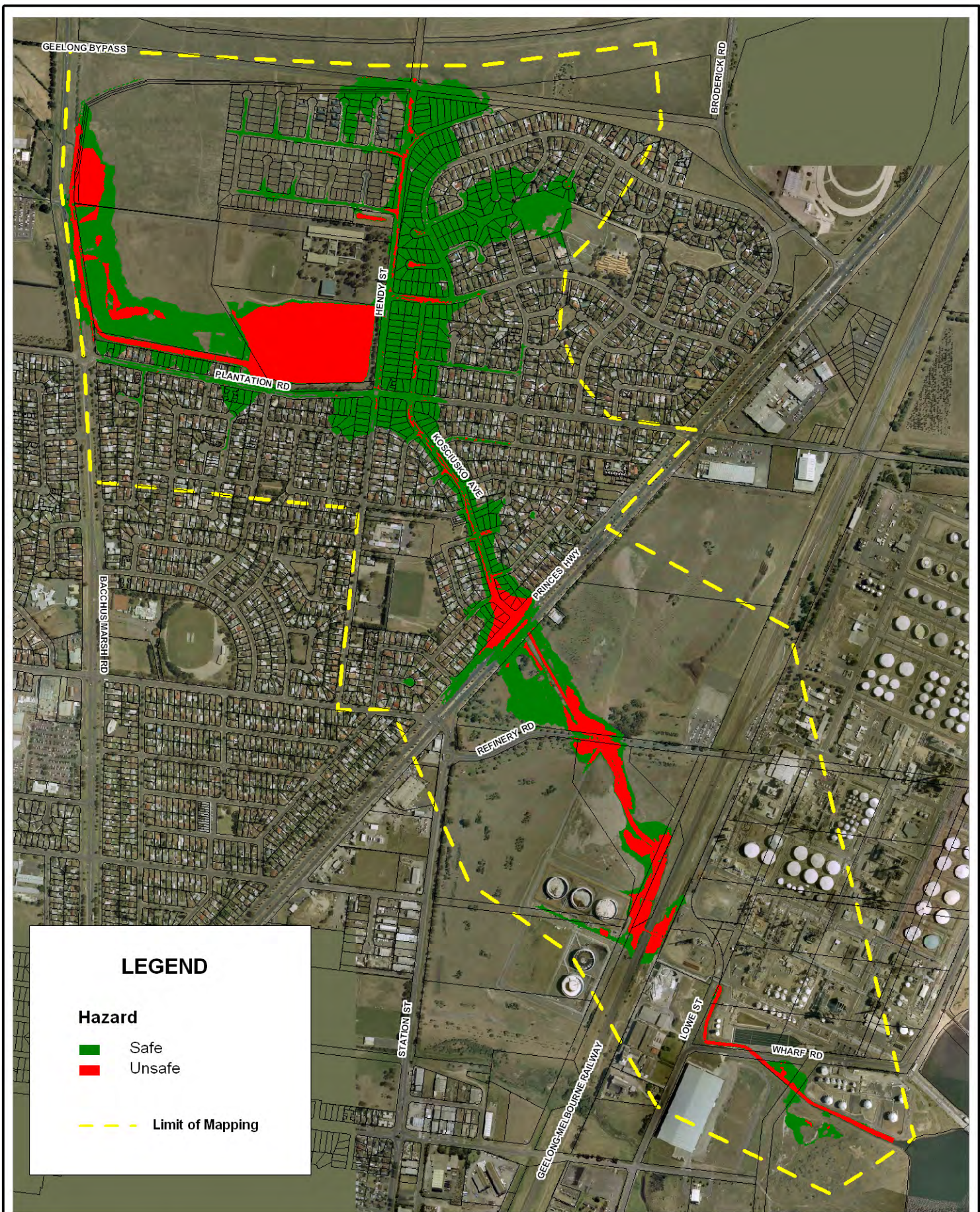
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**Preferred Scheme**  
**1% AEP Peak Flood Impact**

Figure:  
**E-4**

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**LEGEND**

**Hazard**

- Safe
- Unsafe

- - - Limit of Mapping

Title:  
**Preferred Scheme**  
**1% AEP Flood Hazard**

Figure:  
**E-5**

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# 1 INTRODUCTION

The City of Greater Geelong (CoGG) has engaged BMT WBM Pty Ltd (BMT WBM) to undertake an assessment of stormwater flooding within the Kosciusko Avenue Main Drain (MD) catchment (C156), and to investigate flood management options to manage and minimise the effects of flooding on the community.

## 1.1 Catchment Description

Kosciusko Avenue MD catchment is approximately 10 km drive north from the centre of Geelong (Figure 1-1). The catchment is predominantly located in Corio, with the upper reaches overlapping into Lara and Lovely Banks.

The catchment drains approximately 9.6 km<sup>2</sup> of rural and urbanised areas into Corio Bay via a series of constructed open channels, pipes and overland flowpaths. The catchment is an irregular shape narrowing downstream of the intersection of Plantation Road and Hendy Street. Figure 1-2 illustrates the bottom half of the catchment and Figure 4-1 shows the full extent of the catchment. West of Bacchus Marsh Road is predominantly zoned rural living. The area bound by Bacchus Marsh Road, Geelong Bypass and Heales Road is zoned as Industrial. This area is currently undeveloped, however will become the location of the Heales Road Industrial Estate (HRIE). The area bound by the Geelong Bypass and Princes Highway is predominantly zoned as urban residential. South to south east of Princes Highway is predominantly zoned as commercial or industrial.

Whilst within the urban areas drainage infrastructure is in place, the existing drainage network is generally undersized and therefore contributes to localised 'stormwater' flooding. Like many drainage systems in areas of a similar age, the Kosciusko Avenue MD drainage network has a limited capacity for the size of the catchment.

Three dry bottom retarding basins have also been constructed within the catchment and a new basin is proposed within the HRIE. The largest of the existing basins is located at 93 Hendy Street (corner of Plantation Road and Hendy Street), designed to mitigate flows from the upstream rural and rural residential areas. This retarding basin has a significant catchment area of approximately 5.4 km<sup>2</sup> and a storage volume of approximately 44,500m<sup>3</sup>. The two other retarding basins, located at 170 Tower Hill Drive and 19-21 Streeton Close (Corner of Nigella Avenue), are smaller in size with storage capacities of approximately 8085 m<sup>3</sup> and 1450 m<sup>3</sup> respectively. The Tower Hill Drive and Streeton Close retarding basins have been constructed to mitigate flows from recent rural living and residential subdivisions.

## 1.2 History of Flooding

The Kosciusko Avenue catchment is subject to some of the most frequent and serious flooding within the CoGG. Low capacity pre-1980 drainage infrastructure in conjunction with minimal clear overland flow paths, as a result of urban development, has resulted in conditions conducive to flooding through the urban areas.

## 1.3 Study Area

The Kosciusko Avenue MD study area is detailed in Figure 1-2. The upstream study area extents are defined by Bacchus Marsh Road to the west and Geelong Bypass to the north. The downstream extent is Corio Bay, the discharge point for the catchment.

The study area is modelled in detail using both hydrologic and complex two-dimensional hydraulic models to simulate the flood behaviour within the area. The area that is to be flood mapped is also shown in Figure 1-2.

## 1.4 Key Objectives

The key objectives of this study are to:

1. develop a Digital Terrain Model (DTM) of the study catchment from digital data supplied by Photomapping Services Pty Ltd (Photomapping Services);
2. determine the flood extents, depths and associated hazard of the critical 1%, 5% and 20% annual exceedance probability (AEP) flood events through the use of hydrologic and hydraulic models for existing conditions;
3. identify and assess potential mitigation strategies to reduce damages associated with flooding;
4. determine the flood extents, depths and associated hazard of the critical 1%, 5% and 20% annual exceedance probability (AEP) flood events through the use of hydrologic and hydraulic models for the preferred mitigation strategy; and
5. produce a report and flood maps detailing the methodology and results from the above four tasks.

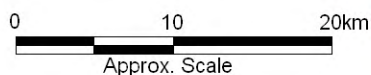


Title:  
**Locality Map**

Figure:  
**1-1**

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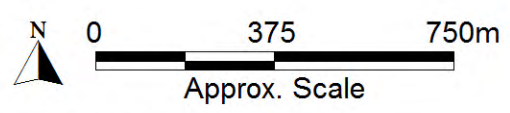
**LEGEND**

— 2D Model Extent

- - - Area to be Flood Mapped

Title:	Figure:	Rev:
<b>Study Area and Flood Mapping Limit</b>	<b>1-2</b>	<b>A</b>

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## 2 STUDY APPROACH

There were six key stages in the study as follows:

- Data collection;
- Flood model development;
- Flood mapping;
- Flood damages assessment;
- Mitigation options assessment; and
- Reporting.

The remainder of Section 2 outlines the adopted approach for each of these stages. A detailed description of some of the stages is given in subsequent sections of the report.

### 2.1 Data Collation

#### 2.1.1 Study Inception and Site Visit

Following commissioning of the study, an inception meeting and site visit were held between representatives from CoGG and BMT WBM. The principal objectives were to confirm project approach, obtain data and to discuss known flooding issues on site.

#### 2.1.2 Drainage, Topographic and GIS Data Sets

All relevant data for the drainage systems was obtained from the CoGG. The data was comprehensively reviewed to identify any significant data gaps and to gain a complete understanding of issues in the study area. Where required, field survey was commissioned to address gaps in available data.

### 2.2 Flood Model Development

The flood model was developed using the traditional approach of utilising hydrologic and hydraulic computer models. The hydrologic model determines the runoff hydrographs that occur following a particular rainfall event. The hydrographs describe the quantity, rate and timing of the runoff that results from rainfall events. These hydrographs then become a key input into the hydraulic model. The hydraulic model simulates the movement of floodwaters through overland flow paths, storage areas, and hydraulic structures. The hydraulic model calculates flood levels and flow patterns and also models the complex interactions between overland flow paths and underground drainage.

The hydrologic modelling of the catchment was undertaken using RORB. A new RORB hydrological model of the catchment was developed for this flood study. As discussed further in Section 4.1.1, although three retarding basins, with one more proposed, exist within the Kosciusko Avenue MD catchment, only those basins located outside the hydraulic model extent have been included in the RORB model, with the remaining basins included in the hydraulic model. No calibration data was available for the hydrological model, so for most parameters, typical values appropriate for the catchment characteristics were adopted and the model was then verified against the Rational Method

and previous studies within the catchment. The adopted loss model was an initial loss/runoff coefficient model.

Hydraulic modelling of the catchment was undertaken using the 2D/1D dynamic hydraulic modelling system TUFLOW. The model incorporated both the overland flow paths and the underground trunk drainage system. No data was available for calibration so typical values based on experience and the site inspections were applied. TUFLOW was run as an unsteady flow model to ensure reliable representation of the storage within the system and the complex timing and interaction of flows in the drainage network.

## 2.3 Flood Mapping

Flood maps showing flood extent, depth and height were produced for each design flood analysed. Design floods are hypothetical floods used for planning and floodplain management investigations. A design flood is defined by its probability of occurrence. It represents a flood that has a particular probability of occurring in any one year. For example, the 1% Annual Exceedance Probability (AEP) or 100 year Average Recurrence Interval (ARI) flood is a best estimate of a flood magnitude which has 1 chance in 100 of being exceeded in any one year. It should be noted that planning for the 1% AEP flood does not guarantee protection for the next 100 years. Design flood levels were determined for the 1%, 5% and 20% AEP floods.

## 2.4 Flood Damage Assessment

The design floods were used to make an assessment of the financial losses to residential properties and public infrastructure. These financial losses were then used as a basis to do an economic assessment of potential mitigation options.

## 2.5 Mitigation Options Assessment

A range of options designed to mitigate the existing flood impact and associated damages were considered and analysed for effectiveness. The financial impacts of each scenario were compared in order to ascertain the most suitable outcome.

## 2.6 Reporting

Several meetings were held with CoGG during the course of the study to present findings before proceeding to the next stage. The findings of the study are presented in this Flood Study Report.

## 3 DATA COLLATION

### 3.1 Site Inspection

Following commissioning of the study, a site inception was undertaken by BMT WBM project staff. The site inspection provided the opportunity to gauge an understanding of how the system drains and the hydraulic roughness values (Manning's 'n') that would be suitable for the modelling.

### 3.2 GIS Data

All relevant data for the drainage systems were obtained from the CoGG. The data was comprehensively reviewed to identify any significant data gaps and to gain a complete understanding of issues in the study area.

Additional project related GIS data was sourced from Council's GIS system. In particular, the following data were supplied:

- cadastral information over the study area;
- planning scheme zones over the catchment; and
- aerial photography.

### 3.3 Drainage Data

CoGG supplied drainage network data for the catchment in digital formats (as GIS datasets and pdf copies of drainage plans). Data included pipe networks (location and size), open channel locations and pit locations. Gaps in the pipe data were identified and in-filled where possible by interpolation of inverts from upstream and downstream information. Areas that were unable to be interpolated were determined through field survey, undertaken by All General Survey Pty Ltd (AGS).

### 3.4 Topographic Data

Photomapping Services Pty Ltd was commissioned to undertake the photogrammetric terrain survey. The data was supplied in AutoCAD (DWG) format, and was subsequently converted to a Triangulated Irregular Network (TIN), which was imported into MapInfo Professional. The resulting DEM is shown in Figure 3-1.

The DEM was subsequently reviewed and augmented as required. Due to the timing of the Geelong Bypass construction works and the photogrammetry, it was necessary to obtain data on the table drain and road embankments near the corner of Bachuus Marsh Road and the Bypass. This work was undertaken by AGS. The area covered by the survey is shown in Figure 3-1.

Within the flood mapping area the grid resolution of the DEM is 0.2 m. Based on our past experience, we have found that this level of detail is well suited to simulating the topography of urbanised environments for hydraulic modelling.

BMT WBM was supplied LiDAR data of the catchment by CoGG to facilitate the hydrological analysis. The data assisted the catchment and sub-catchment boundary definition.

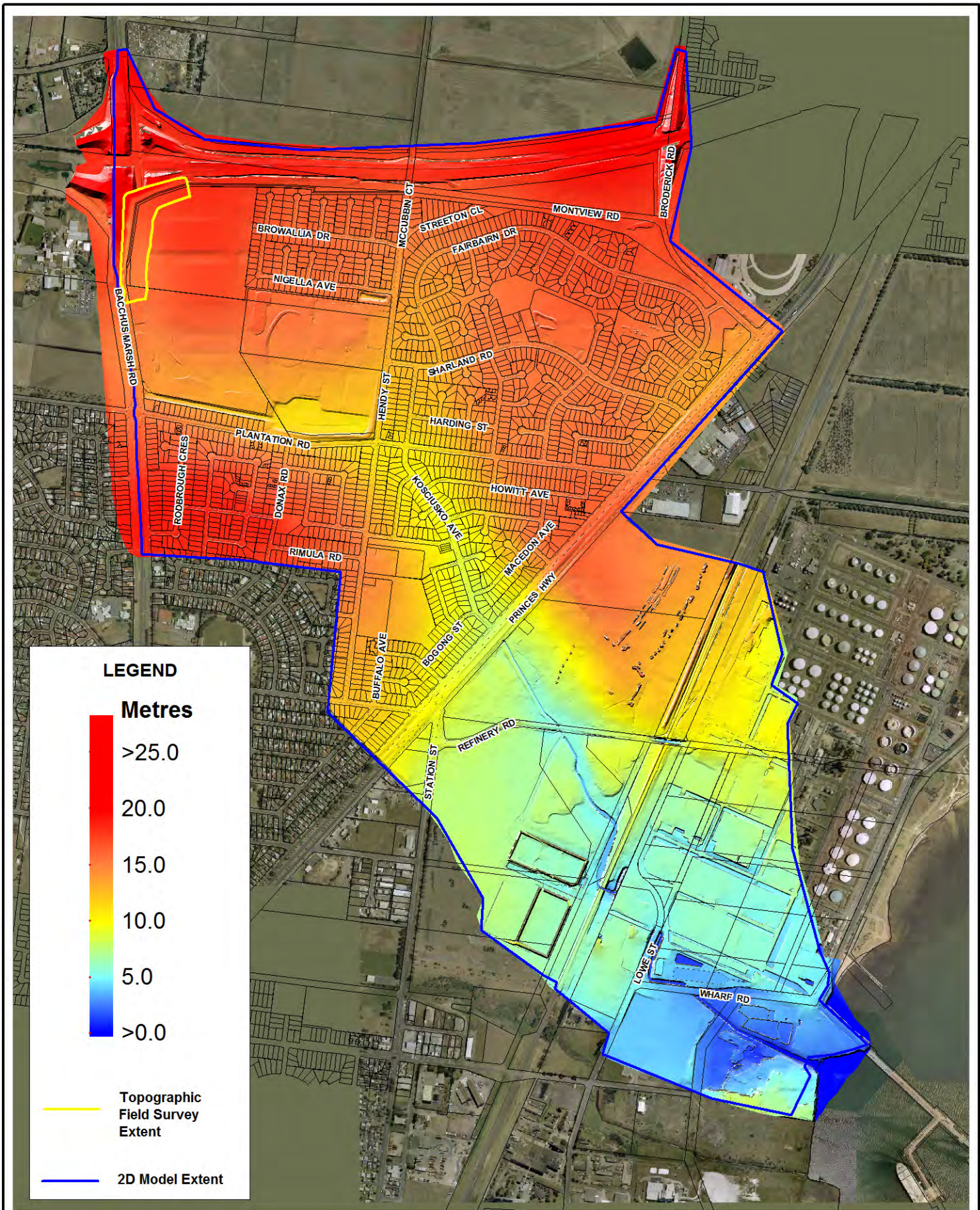
### 3.5 Field Survey

Field survey was required to capture missing data and to provide detailed data of drainage structures and features that could not be reliably captured using aerial survey techniques. AGS Pty Ltd was commissioned to capture missing pipe inverts, details of the Bacchus Marsh Road and Geelong Bypass interchange, details of culvert crossings, cross sections of the table drain along Bacchus Marsh Road, and details of the various Shell Refinery structures crossing the open channel main drain. This data was provided as electronic AutoCAD format and will be supplied on the data handover CD.

### 3.6 Floor Levels

Floor level information was supplied to BMT WBM from new survey commissioned by CoGG. The data supplied included the floor level and ground levels with associated location (as x,y coordinates). The location of surveyed floor levels is shown in Figure 3-2.

The extent of floor level survey was determined by CoGG and does not exist for all properties within the study area. As a result, all numbers of flooded properties, damage figures and hence Benefit Cost Ratios, are based on the data set provided.

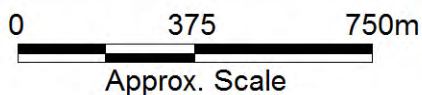


Title:  
**Photogrammetry DEM and Field Survey Patch**

Figure:  
**3-1**

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**LEGEND**

- Surveyed Floor Levels
- - - Limit of Mapping

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**Surveyed Floor Levels**

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**3-2**

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## 4 FLOOD MODEL DEVELOPMENT

### 4.1 Hydrological Model

Hydrologic modelling of the study catchment was undertaken using RORB. A RORB model of the catchment was established for the purpose of extracting total and sub-area hydrographs to be used as boundary conditions for the TUFLOW hydraulic model. The RORB modelling process and results are discussed in the following sections.

#### 4.1.1 RORB Model

RORB simulates the linkages between sub-catchments as reach storages with the storage discharge relationship defined by the following equation;

$$S = 3600kQ^m$$

Where 's' represents the storage ( $m^3$ ), 'Q' is the discharge ( $m^3/s$ ), 'm' is a dimensionless exponent and 'k' is non-dimensional empirical coefficient. 'k' is defined by the product of the catchment value ' $k_c$ ' and the individual reach  $k_i$ . Both m and  $k_c$  are defined as calibration parameters. Based on industry best practice, in the absence of calibration events, an 'm' value of 0.8 was adopted.

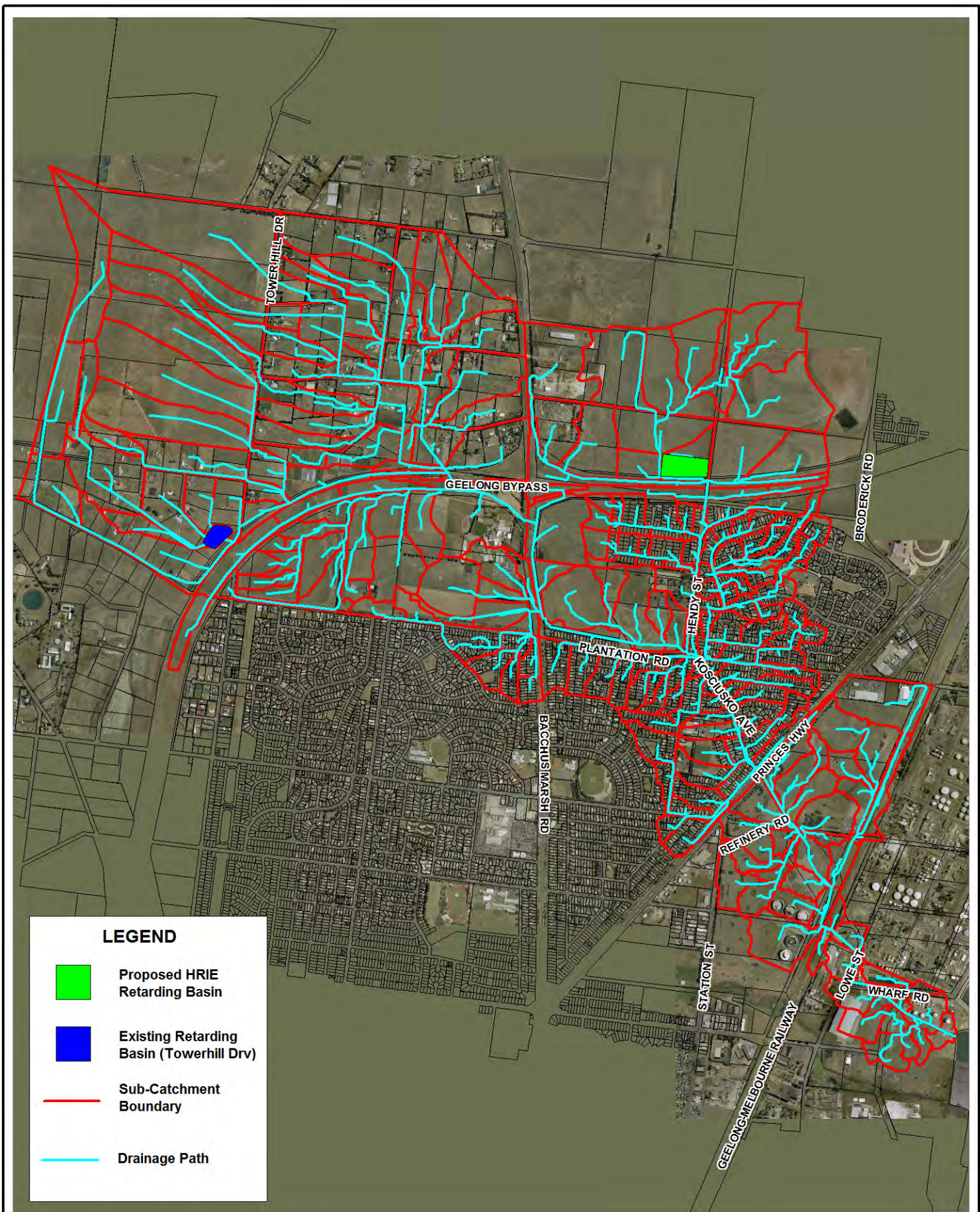
##### 4.1.1.1 Model Description

The RORB model incorporates the entire Kosciusko Avenue MD catchment area. The model has 265 sub-catchments where each sub-catchment has a conceptual reach (approximate overland flow path) defined. Although four retarding basins exist within the Kosciusko Avenue MD catchment, Plantation Road/Hendy Street and Streeton Close retarding basins have been omitted from the RORB hydrologic model. These retarding basins are located within the extents of the TUFLOW hydraulic model and hence, the modelling of the storage effects of each of the basins will be done within the hydraulic model. The Tower Hill Drive and HRIE retarding basins have been included in the hydrological model and discussed in Section 4.1.1.7.

The hydrological model extends to the catchment outlet at Corio Bay, which is also the downstream boundary of the hydraulic model.

##### 4.1.1.2 Sub-Catchment Definition

The catchment and sub-catchment boundaries were determined using the results of an initial assessment of the catchment using the software package CatchmentSIM. The CatchmentSIM software defines flow paths, catchment and sub-catchment boundaries using a DTM. The DTM used in the assessment was primarily based on the LiDAR topographic data (supplied by CoGG) in addition to the photogrammetry collected for this study. The representation of the catchment produced by CatchmentSIM was then reviewed and rationalised based on the road and drainage layouts, as well as the locations for which hydrographs were required for the hydraulic model. The resulting schematic layout of the RORB model is shown in Figure 4-1.



**LEGEND**

- Proposed HRIE Retarding Basin
- Existing Retarding Basin (Towerhill Drv)
- Sub-Catchment Boundary
- Drainage Path

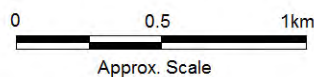
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**RORB Catchment Layout**

NOTE: The Plantation Rd/Hendy St and Streecon CIs/Nigella Ave retarding basins are modelled hydraulically

Figure:  
**4-1**

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#### 4.1.1.3 Global Parameters

RORB model parameters for the Kosciusko Avenue drainage catchment are summarised in Table 4-1 and discussed further in Sections 4.1.1.4 to 4.1.1.7.

**Table 4-1 RORB Parameters**

RORB Parameter	Value
Storm Data	Kosciusko Avenue
Catchment Area	9.56 km <sup>2</sup>
Initial Loss	10.0 mm
Run off coefficient (1% AEP)	0.60
m	0.80
k <sub>c</sub>	4.22
Fraction Impervious	Varies, as per land use (Table 4-4)
Reach Type	Types 2 & 3
Peak Flow Events	Varies (typically 2 hr or 9 hr)

#### 4.1.1.4 IFD Parameters

Storm data was based on IFD parameters sourced from the Bureau of Meteorology which are based on Figures 1.8 to 6.8 and 7d to 9 of Australian Rainfall and Runoff (AR&R) Volume 2. The adopted values for the catchment are presented in Table 4-2.

**Table 4-2 IFD Parameters**

IFD Parameter		Adopted Value
Rainfall Intensity (mm/hr)	2 Year ARI, 1 Hour Duration	17.9
	2 Year ARI, 12 Hour Duration	3.42
	2 Year ARI, 72 Hour Duration	0.8
	50 Year ARI, 1 Hour Duration	35.8
	50 Year ARI, 12 Hour Duration	6.47
	50 Year ARI, 72 Hour Duration	1.78
Skew Coefficient		0.40
Geographical Factor F2		4.29
Geographical Factor F50		14.85
Zone		1

#### 4.1.1.5 Loss Parameters

The loss model adopted was the “initial loss/volumetric runoff coefficient” loss model. This modelling approach is consistent with previous flood studies. RORB generates runoff by subtracting losses at each timestep from the rainfall occurring in that time period. The adopted initial loss was 10mm and the runoff coefficients for pervious areas were adopted as per Melbourne Water recommendations, as summarised in Table 4-3. For impervious areas, RORB has a “hardwired” initial loss of 0 mm and runoff coefficient of 0.9.

**Table 4-3 Runoff Coefficients for different AEPs**

AEP	Runoff Coefficient
20%	0.25
5%	0.45
1%	0.60

#### 4.1.1.6 Fraction Impervious

The fraction of the catchment that is impervious is a key input to the hydrologic modelling. Impervious fractions for various planning scheme codes were based on advice from CoGG, values contained within Council’s design guidelines, inspections of aerial photographs, and values presented in Australian Rainfall and Runoff (1987). Key impervious fractions adopted are reproduced in Table 4-4.

**Table 4-4 Impervious Fraction for Planning Scheme Zone**

Zone	Impervious Fraction
Residential (< 300 m <sup>2</sup> )	0.95
Residential (300 to 400 m <sup>2</sup> )	0.6
Residential (400 to 600 m <sup>2</sup> )	0.5
Residential (600 to 1 000 m <sup>2</sup> )	0.42
Residential (1 000 to 2 000 m <sup>2</sup> )	0.4
Residential (2 000 to 4 000 m <sup>2</sup> )	0.3
Rural Living (>4 000 m <sup>2</sup> )	0.05
Commercial/Business	0.95
Industrial	1
Hospitals	1
Farming Zone	0
Open Space / Sports Grounds/Public Parks	0.15
Schools with large sports fields / Developed Parks	0.5
Schools with few fields	0.75
Major Roads	1
Minor Roads	0.8

The planning scheme data was used to establish an area-weighted average of the impervious fractions for each sub-catchment used in the hydrologic model.

#### 4.1.1.7 Retarding Basins

The Plantation Road/Hendy Street and Streeon Close retarding basins are located within the TUFLOW hydraulic model extent. The 2D hydraulic model will determine the storage and discharge characteristics of the basins based upon the underlying topography and outlet structures, and therefore do not need to be included in the RORB hydrologic model. For the majority of sub-catchments within the hydraulic model extent, only local sub-area inflows are applied, not total hydrographs. Therefore the routing of flows through these retarding basins and other storages do not require modelling in RORB.

Tower Hill Drive and the proposed HRIE retarding basins are located outside the hydraulic model extent and therefore are only incorporated into the hydrological model. Topographic LiDAR data was used to determine the stage-storage relationship for the Tower Hill Drive retarding basin. The outlet structure and configuration were based on design drawings of the retarding basin, supplied by Council.

Details of the proposed HRIE retarding basin were based on Council's XP-RAFTS model. Council's model contained a defined stage-storage and stage-discharge relationship, as well as details of the spillway and pipe outlet. The stage-storage relationship defined in Council's model was adopted in the RORB model, along with the outlet details. The stage-discharge relationship automatically derived by RORB was used to determine discharge from the RB. The results showed that the XP-RAFTS model had a higher peak discharge of 2.6m<sup>3</sup>/s compared to 1.7m<sup>3</sup>/s in RORB, although the overall discharge from the HRIE catchment for the key events were approximately equal.

A comparison of the RORB and XP-RAFTS retarding basin results and parameters are shown in Table 4-5.

**Table 4-5 HRIE Retarding Basin RORB Parameters for the 1% AEP Event**

Parameter	RORB	XP-RAFTS
Maximum Storage Volume	51,300 m <sup>3</sup>	68,173 m <sup>3</sup>
Peak 1% AEP Discharge	1.7 m <sup>3</sup> /s	2.6 m <sup>3</sup> /s
Peak 1% AEP depth	2.51 m*	2.97 m*
Nominal Spillway Crest Level	2.9 m*	
Nominal Culvert Outlet	1 No. DN900 (Existing pipe)	

\* Arbitrary Datum

#### 4.1.2 Hydrological Model Verification

Due to the lack of historical rainfall and flood height data, calibration of the model to recorded data was not possible. Verification of results from the hydrological model was therefore undertaken using empirical methods.

The Rational Method was used to verify the RORB model. The Rational Method approach does not directly account for the impact of storage (such as retarding basins), therefore it was necessary to verify the RORB model with all its storages omitted. The RORB model was initially run using a  $k_c$  value derived from the Melbourne Water relationship between  $k_c$  and catchment area:

$k_C = 1.19A^{0.56}$ , where A is catchment area in square kilometres.

The  $k_C$  value of 4.22 derived from the above relationship was initially used to run the RORB model. The resulting peak flow at Princes Highway and the catchment outlet (Corio Bay) were compared against the Rational Method calculations to check the applicability of the routing parameters to the particular catchment. Comparisons showed that the peak outflows from the RORB model were within 10 percent of those using the Rational Method approach. The comparisons suggested that the flows from the RORB model were within acceptable limits at the catchment outlet and therefore the RORB  $k_C$  value of 4.22 was adopted.

Table 4-6 documents the peak RORB outflows from the catchment and compares them to the peak flow calculated using the Rational Method.

**Table 4-6 Comparison of Rational Method and RORB (without retarding basins)**

Location	Peak Flow (m <sup>3</sup> /s)		% Difference
	Rational Method	RORB	
Princes Highway	62.7	57.9	-7.7%
Catchment Outlet (Corio Bay)	65.3	63.0	-3.5%

### 4.1.3 Design Event Modelling

#### 4.1.3.1 Design Event Probabilities

Hydrological analysis was undertaken for the 1%, 5% and 20% AEP design storm events. Hydrographs were derived by RORB to provide external and internal boundary conditions to the hydraulic model at a number of locations throughout the catchment.

#### 4.1.3.2 Design Rainfall

Intensity – Frequency – Duration (IFD) parameters for the Kosciusko Avenue MD were derived using the maps from Volume Two of Australia Rainfall and Runoff (AR&R). These IFD parameters are an input for RORB and are used to generate design rainfall intensities and depths using standard AR&R procedures. The IFD parameters are presented in Table 4-2.

Filtered temporal patterns were used to derive the design storm events. Aerial Reduction Factors (ARF) were not applied due to the catchment's small size. The resulting design storms were run through the RORB model of the catchment and the results summarised to determine the critical durations.

#### 4.1.3.3 Critical Duration Derivation

For each design probability, the peak discharge at various locations within the drainage system may be generated by events of different durations. Therefore, consideration of peak discharges for a range of durations is important. For example, a 2 hour duration event may result in the peak discharge in the upper portion of a catchment, while a 9 hour duration event could result in the peak discharge at the bottom of a catchment. Alternatively, the peak flood level may be more related to

volume than discharge, and a high volume event may be more appropriate for consideration. Accordingly, to assess the peak discharges and volumes over the catchment, events ranging from a 10 min duration to a 72 hour duration were modelled using RORB. A range of events representing the critical durations were selected to run in the hydraulic model.

#### 4.1.4 Peak Inflows

The peak inflows into the 2D model area are summarised in Table 4-7. The locations of the inflows referred to in Table 4-7 are shown in Figure 4-2. There are additional local inflows into the hydraulic model downstream of these external inflows.

**Table 4-7 Peak Inflows**

Location	Peak Inflow (m <sup>3</sup> /s)		
	20% AEP	5% AEP	1%AEP
Bacchus Marsh Road Culvert	6.5 *	14.5 *	22.1 *
Bacchus Marsh Road / Plantation Road Intersection	2.0	3.8	7.0
HRIE at Geelong Bypass **	2.8	4.0	5.5

\* Flows are from the hydraulic model which accounts for the impact of storage upstream of the Geelong Bypass

\*\* Flows are from the total catchment including sub-catchments not routed through the HRIE retarding basin

## 4.2 Hydraulic Model

The drainage system in Kosciusko Ave MD catchment comprises underground stormwater pipes, open channels and overland flow paths. Overland flow paths are controlled to a greater or lesser extent by “hydraulic controls” such as road embankments and retarding basins. TUFLOW, a fully 2D hydraulic modelling package with the ability to dynamically nest 1D elements, was adopted for this study. Overland flow paths and storages were modelled in 2D whilst the table drains, open channel main drain, Council's pipe network (DN450 and greater) and stormwater entry pits were modelled as 1D elements dynamically linked to the 2D domain.

In a catchment such as the Kosciusko Avenue MD, where storage and timing of the rainfall inflows in the catchment are important, modelling using flow varying with time (unsteady state) rather than peak flow (steady state) is required. Accordingly, TUFLOW was run in unsteady state.

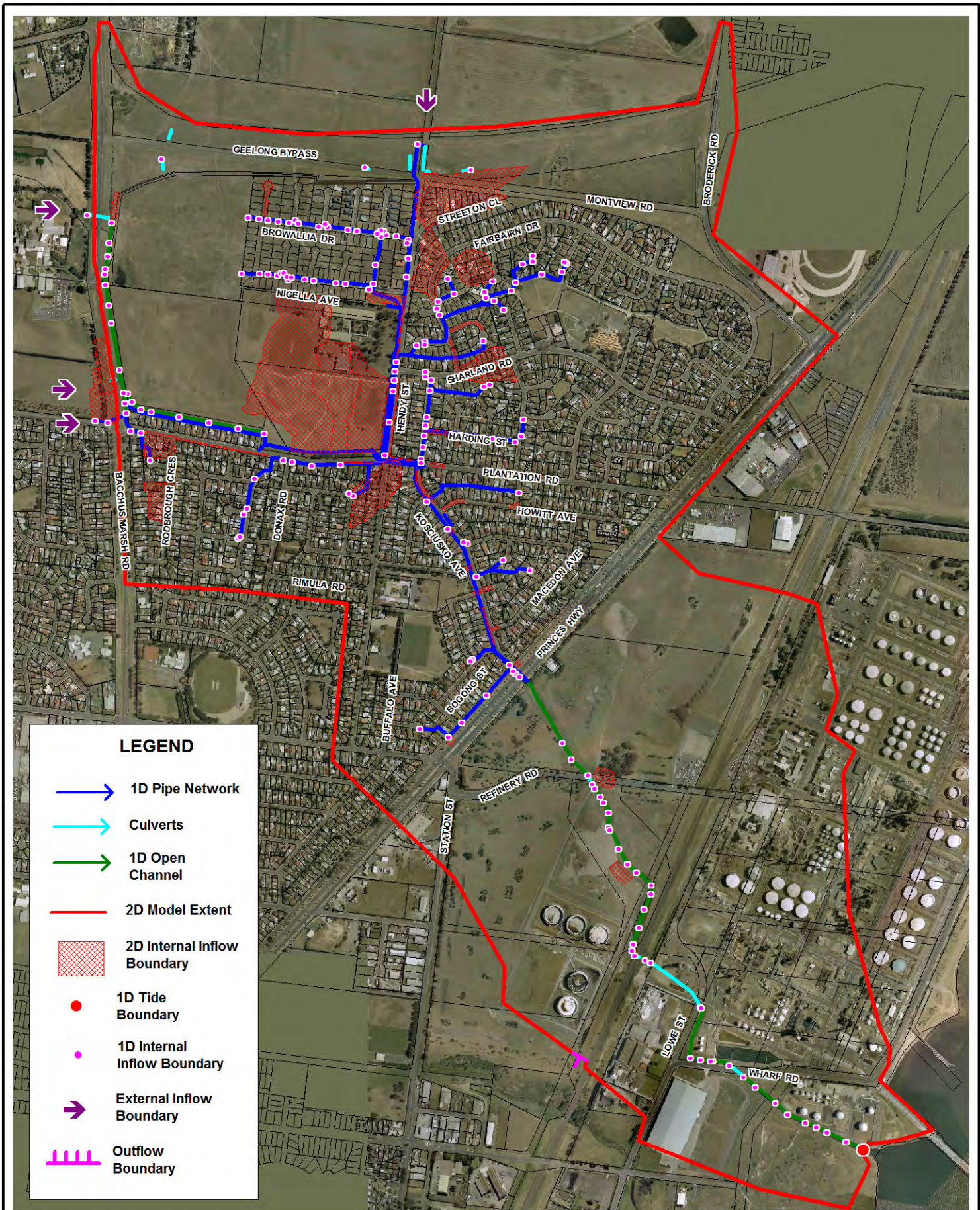
### 4.2.1 Model Description

The 2D model domain extends beyond the area to be flood mapped and covers approximately 4.5 km<sup>2</sup> of the Kosciusko Avenue MD drainage catchment (as shown in Figure 4-2). The geometry of the 2D model was established by constructing a uniform grid of square elements. One of the key considerations in establishing a 2D hydraulic model relates to the selection of an appropriate grid element size. Element size affects the resolution, or degree of accuracy, of the representation of the physical properties of the study area as well as the size of the computer model and its resulting run

times. Selecting a very fine grid element size will result in both a higher resolution and longer model run times.

In adopting the element size for the Kosciusko Avenue catchment, the above issues were considered in conjunction with the final objectives of the study. Given the size of the study area, run times could be kept to an acceptable length using a small grid element size of 3 metres across the entire model domain. 1D elements representing open channels, pipes and culverts are embedded into the 2D model to improve the modelling of the catchment. The modelling of these 1D elements will ensure that the capacity and conveyance of these systems are accurately represented.

Each square grid element contains information on ground topography sampled from the DEM at 1.5 m spacing, surface resistance to flow (Manning's 'n' value) and initial water level. Areas of different land-use type, determined from planning maps, aerial photography and site inspections, were identified for setting Manning's 'n' values. These are summarised in Table 4-8.



Title:  
**TUFLOW Model Setup**

Figure:  
**4-2**

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**A**

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0 250 500m  
Approx. Scale



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**Table 4-8 2D Domain Manning's 'n' Coefficients**

Land use	Manning's n
Residential	0.3
LDRZ	0.045
RLZ	0.045
Commercial/Industrial	0.3
Schools (No ovals/fields)	0.2
Railway Easement	0.045
Open Space – Maintained Grass	0.03
Open Space - Paddocks	0.045
Corio Bay	0.02
Road Reserve	0.022

#### 4.2.2 Boundary Conditions

The TUFLOW model has been developed using a fixed water level of 1.12 m AHD for the downstream boundary condition. This level was adopted based on discussions between BMT WBM and CoGG regarding a suitable tailwater condition. The level is based on the Highest Astronomical Tide (HAT) for Williamstown (0.52 m AHD) and an allowance for increased tide levels caused by climate change (0.6 m).

Following the submission of the Draft Hydrology Report (BMT WBM (2009), reference R.M7299.001.00.Hydrology.doc), the downstream boundary was moved from Corio Bay to the entrance of the estuary. This was undertaken to improve model performance at the boundary. The change was sensitivity tested and determined to have no impact on water levels in the urbanised areas.

#### 4.2.3 Design Event Modelling

The 1%, 5% and 20% AEP design storm events were modelled in TUFLOW for 11 storm durations: 15 minute, 20 minute, 25 minute, 1 hour, 1.5 hours, 2 hours, 3 hours, 4.5 hours, 6 hours, 9 hours and 12 hours.

The critical storm duration varied across the catchment. The 2 hour, 3 hour and 9 hour storms were the critical durations along the main drain, while the 25 minute and 1 hour events were critical for Hendy Street and Plantation Road. The 12 hour storm was included to ensure peak flood levels were obtained in areas where the flood is likely to 'pond' such as the Plantation Road/Hendy Street Retarding Basin, Princes Highway and at the railway crossing near the Shell refinery. A peak flood height envelope was developed from the 11 durations and the peak envelope for each AEP event was mapped. The mapping is presented in Figure 5-1 to Figure 5-3. These flood events also formed the basis of the hazard assessment as discussed in Section 5.

As no data was available to calibrate the hydraulic model, a sensibility check was undertaken by comparing the flood extents with historical flooding patterns. Flood extents for each of the design runs were provided to CoGG in BMT WBM (2009). CoGG reviewed the extents in the context of their experience with historical flooding problems in the study area and advised that the flooding patterns indicated by the model were consistent with their understanding of historical flooding in the catchment.

#### 4.2.4 Sensitivity Testing

Sensitivity testing of the models was required as a result of differences between the current study's findings and a previous VicRoads Planning investigation study for the Geelong Bypass (WaterTech 2004). The flows at the Geelong Bypass culvert (located upstream of the main Bacchus Marsh Road culvert) and the Bacchus Marsh Road culverts (immediately south of the Geelong Bypass, and north of McCubbin Court) were significantly lower than those initially modelled in this investigation. Both analyses are fundamentally different in their adopted hydrological modelling method. The VicRoads analysis used a hydraulic direct rainfall model to generate estimates of flows (and flood levels), while a hydrological runoff routing model (RORB) was used to generate flows to apply to a hydraulic model (TUFLOW) to generate flood levels for the current investigation. The latter is considered a 'traditional' modelling approach, while the direct rainfall model is a relatively recent approach and ideally requires 'calibration' to recorded data or results from a proven alternative methodology.

A range of hydrological models were run in RORB in order to assess the sensitivity of the model. The sensitivity tests showed that short of replicating the same modelling approach used in the VicRoads study (ie. direct rainfall modelling), the flows shown in Table 4-9 are the lowest achievable flows based on reasonable assumptions. The fraction impervious values for the rural living zone north of the Geelong Bypass and west of Bacchus Marsh Road were reduced from 10%, which is typically adopted based on the planning scheme, to 5% based on observations from aerial photos. The hydraulic model was extended to include the area west of Bacchus Marsh Road and north of the Geelong Bypass to directly account for the impacts of storage and routing on peak flows. The RORB model flows were then applied upstream of the main Bacchus Marsh Road culvert allowing flows to be routed and stored based on the underlying LiDAR topographic data in the hydraulic model. The flows are shown in Table 4-9.

**Table 4-9 VicRoads and Kosciusko Avenue MD Flow Comparisons**

Location	Peak 1% AEP Flows (m <sup>3</sup> /s)	
	VicRoads Investigation	Kosciusko Avenue MD Investigation (From TUFLOW Model)
Bypass Culvert <i>(upstream of the main Bacchus Marsh Road culvert)</i>	15.1	22.2
Main Bacchus Marsh Road Culvert <i>(north of McCubbin Court)</i>	16.8	22.1

## 5 FLOOD MAPPING

This section provides the methodology for the floodplain mapping process used in the investigation and the flood extent and hazard map for each of the AEP events is presented.

TUFLOW produces a geo-referenced data set defining peak water levels throughout the model domain at the corners of its computational cells. For a given AEP flood event, the peak flood level from each of the eleven storm durations was selected for each computational cell to generate an envelope of peak flood levels. These data were imported into GIS to generate a digital model of the flood surface. Contours of flood height (relative to AHD) were extracted directly from the flood surface.

Flood depths were calculated by subtracting the ground level from the flood surface. The GIS was used to carry out the calculation at a horizontal resolution identical to that of the DEM. The digital model of inundation depth was then contoured to map inundation depths over the model domain.

The existing condition flood depth is mapped for the 20%, 5% and 1% AEP events in Figure 5-1 to Figure 5-3 respectively. The flooding within the Kosciusko Avenue MD catchment is generally characterised by shallow sheet flow across most of the catchment with deeper flows along the engineered floodway, Kosciusko Avenue and the open watercourse to Corio Bay.

There are a number of embankments crossing the main flow path resulting in flood storage and flood peak attenuation. These locations are Bacchus Marsh Road, Plantation Road/Hendy Street Retarding Basin, Princes Highway and the railway embankment.

The existing conditions flood modelling for the 100 year ARI event has indicated that cross-catchment flows occur at the intersection of the catchment boundary and the railway embankment at the southern end. This cross-catchment flooding behaviour was not further investigated as part of this study. It is recommended that Council undertake an investigation of cross-catchment flows to understand the implications of flooding from adjacent catchments.

Hazard mapping was undertaken using the methodology prescribed in the Melbourne Water document *Guidelines for Development in Flood-prone Areas*. The analysis is designed to determine if it is safe for people to move about on a property during a flood event. Safety is defined in terms of the depth, velocity and velocity-depth product as follows:

- depth should be no more than 0.35m; and
- velocity should be no more than 1.5 m/s; and
- the product of depth and velocity should be no more than 0.35 m<sup>2</sup>/s.

Hazard maps of the Kosciusko Avenue MD catchment for the three flood events are presented in Figure 5-4 to Figure 5-6. As expected, the majority of the main overland flow path through the catchment is classified as unsafe in a 1% AEP event, extending from the Bacchus Marsh Road culverts through to Corio Bay. Within the residential area, properties subject to flooding classified as unsafe are only in the vicinity of Plantation Road and Hendy Street intersection and along Kosciusko Avenue during the 1% AEP event. Elsewhere within the residential area, unsafe flooding is contained

within the road reserves. In addition to these main overland flowpaths, Plantation Road/Hendy Street and Nigella Estate Retarding Basins are classified as unsafe in a 1% AEP flood.

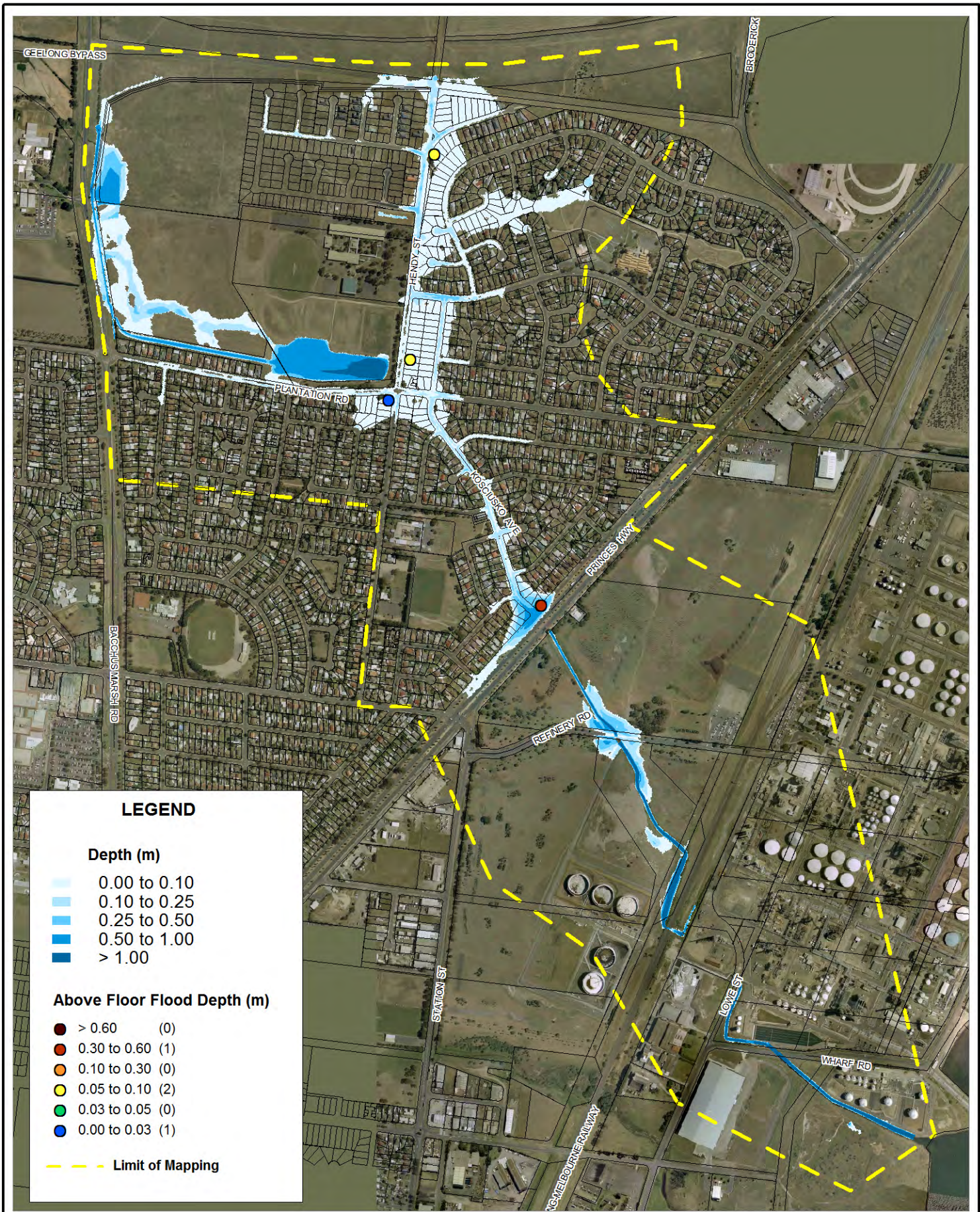
During the 20% AEP flood, areas considered unsafe are generally located where flood water is 'ponding' and include the Plantation Road/Hendy Street and Nigella Estate Retarding Basins, Princes Highway and the open channel from Princes Highway to Corio Bay.

The number of properties with flooding within the property boundaries and above floor flooding for existing conditions is shown in Table 5-1.

**Table 5-1 Number of Flooded Properties**

AEP	Number of Flooded Properties	
	Within Property	Above Floor*
1%	477	23
5%	366	10
20%	251	4

\* Results based on properties surveyed by CoGG.

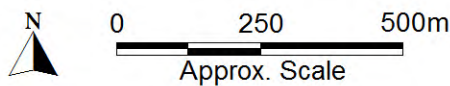


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**Existing 20% AEP Peak Flood Depth**

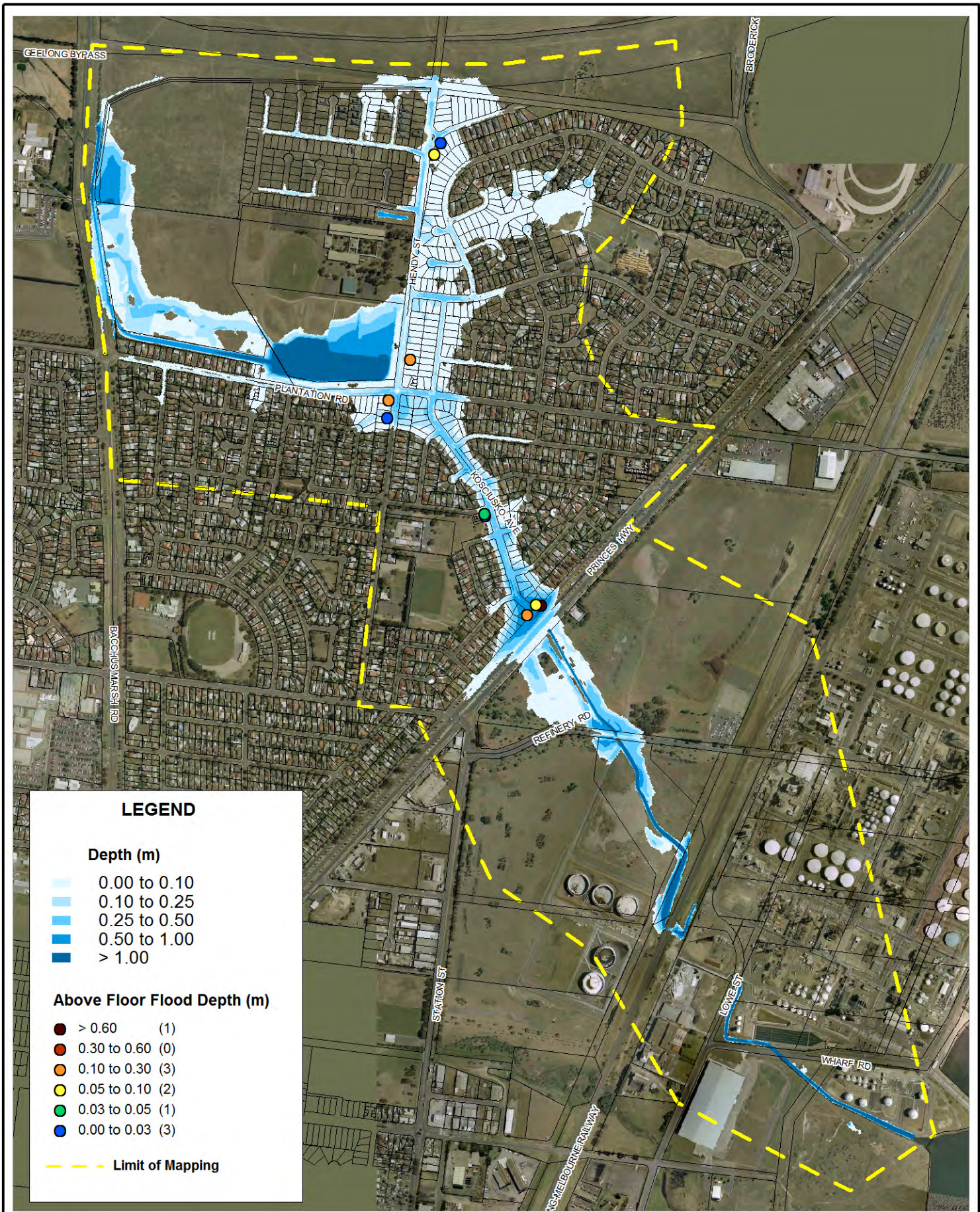
Figure:  
**5-1**

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**B**

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Filepath : T:\M7299.MT.Kosciusko\_FS\Mapinfo\Drawings\Final\Fig5-1\_20%\_Extent\_RevB.WOR



Title:  
**Existing 5% AEP Peak Flood Depth**

Figure:  
**5-2**

Rev:  
**B**

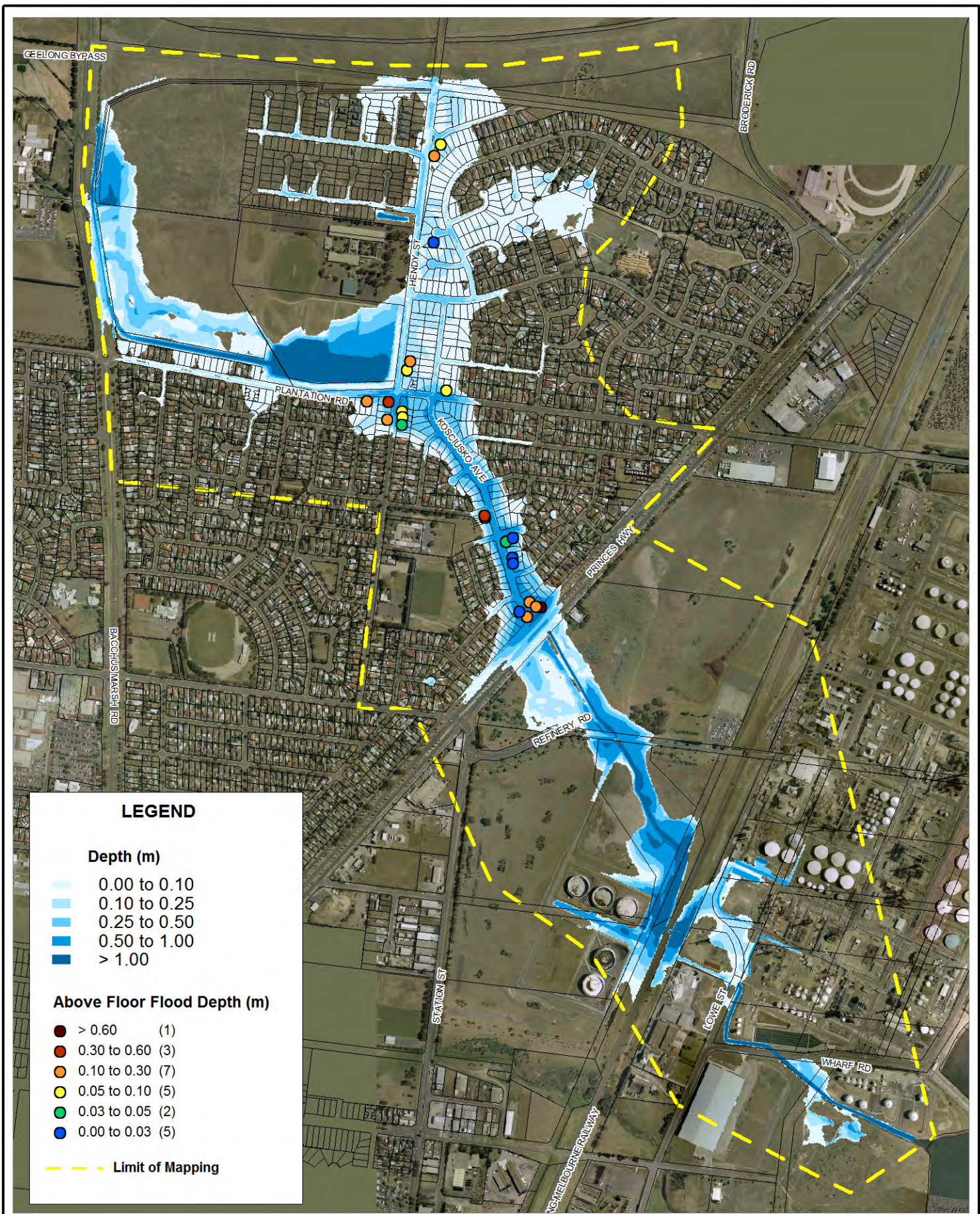
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0 250 500m  
 Approx. Scale



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Title:  
**Existing 1% AEP Peak Flood Depth**

Figure:  
**5-3**

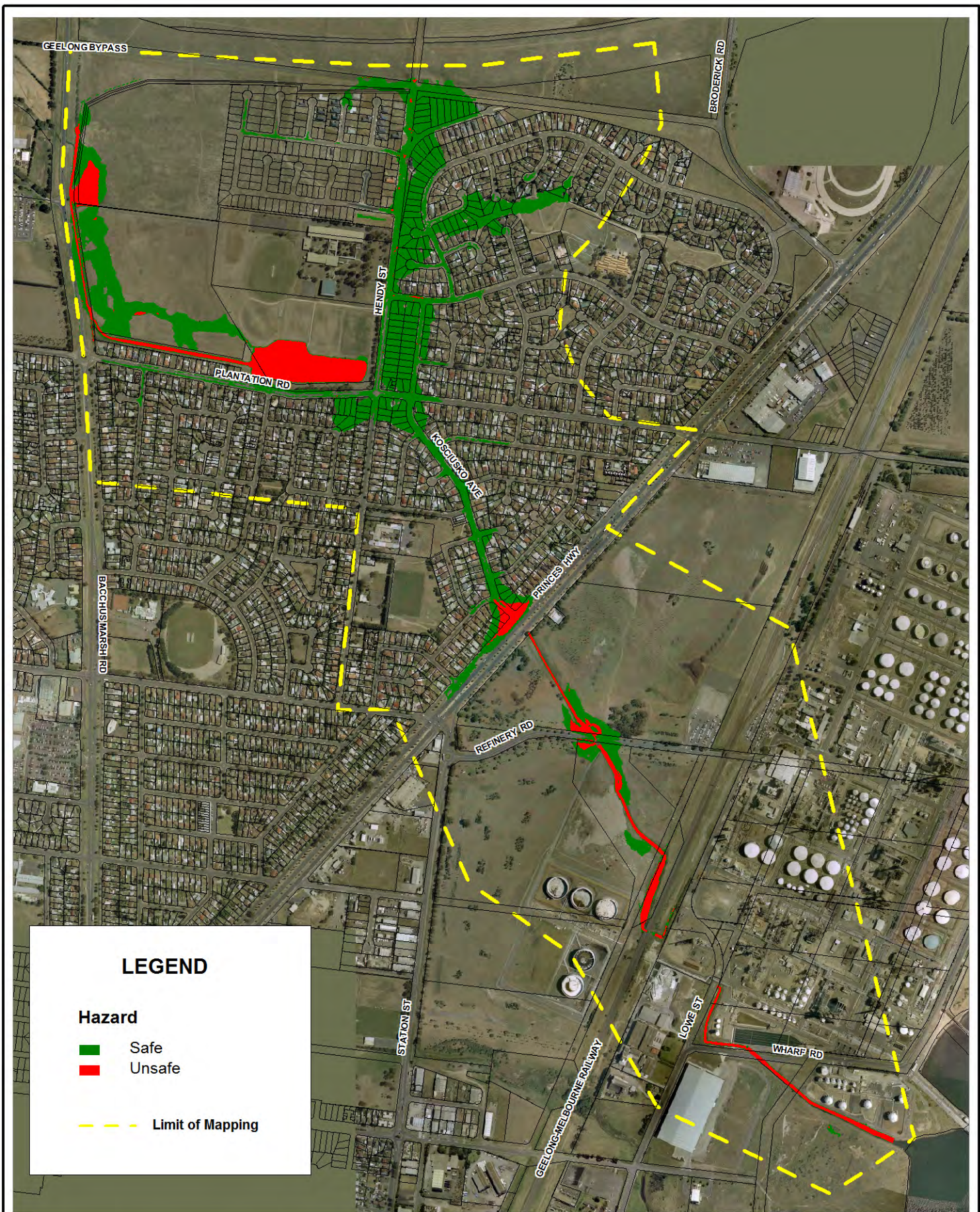
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**B**

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0 250 500m  
 Approx. Scale



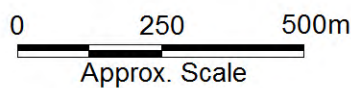


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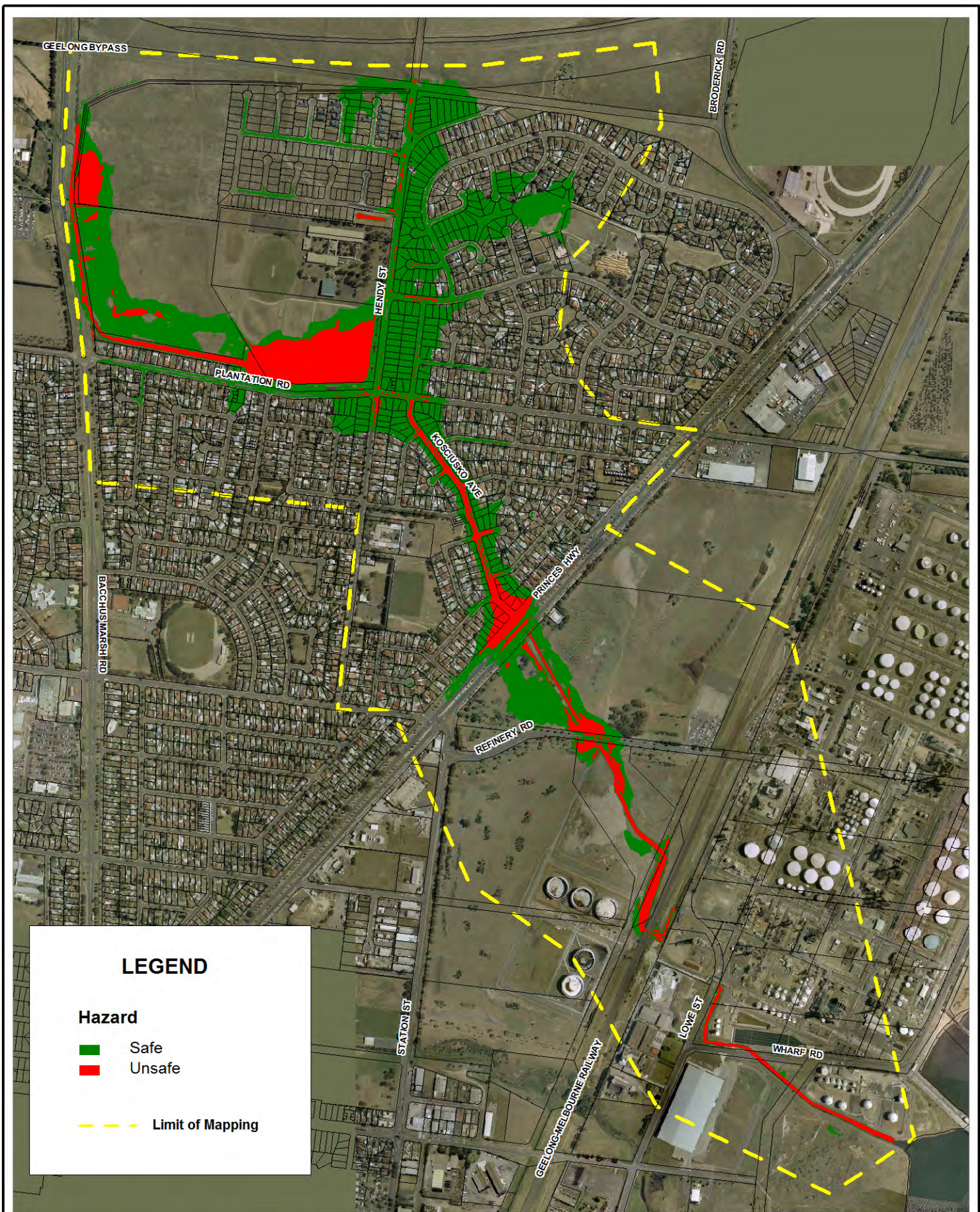
Figure:  
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**B**

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**LEGEND**

**Hazard**

- Safe
- Unsafe

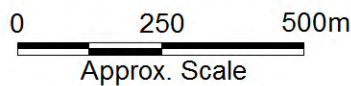
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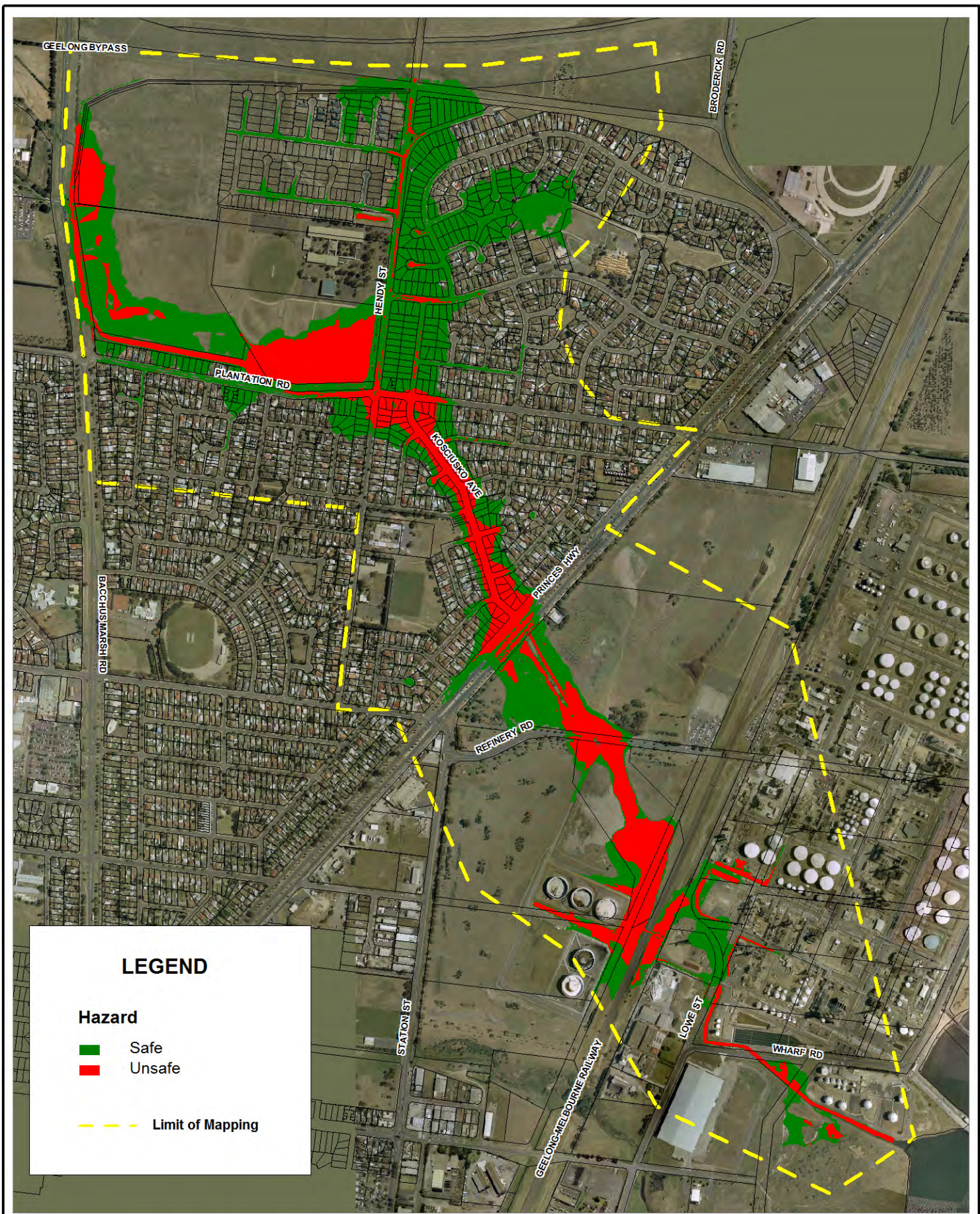
Figure:  
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**LEGEND**

**Hazard**

- Safe
- Unsafe

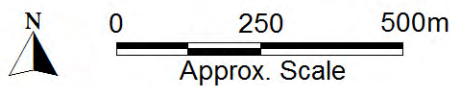
- - - Limit of Mapping

Title:  
**Existing 1% AEP Flood Hazard**

Figure:  
**5-6**

Rev:  
**B**

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