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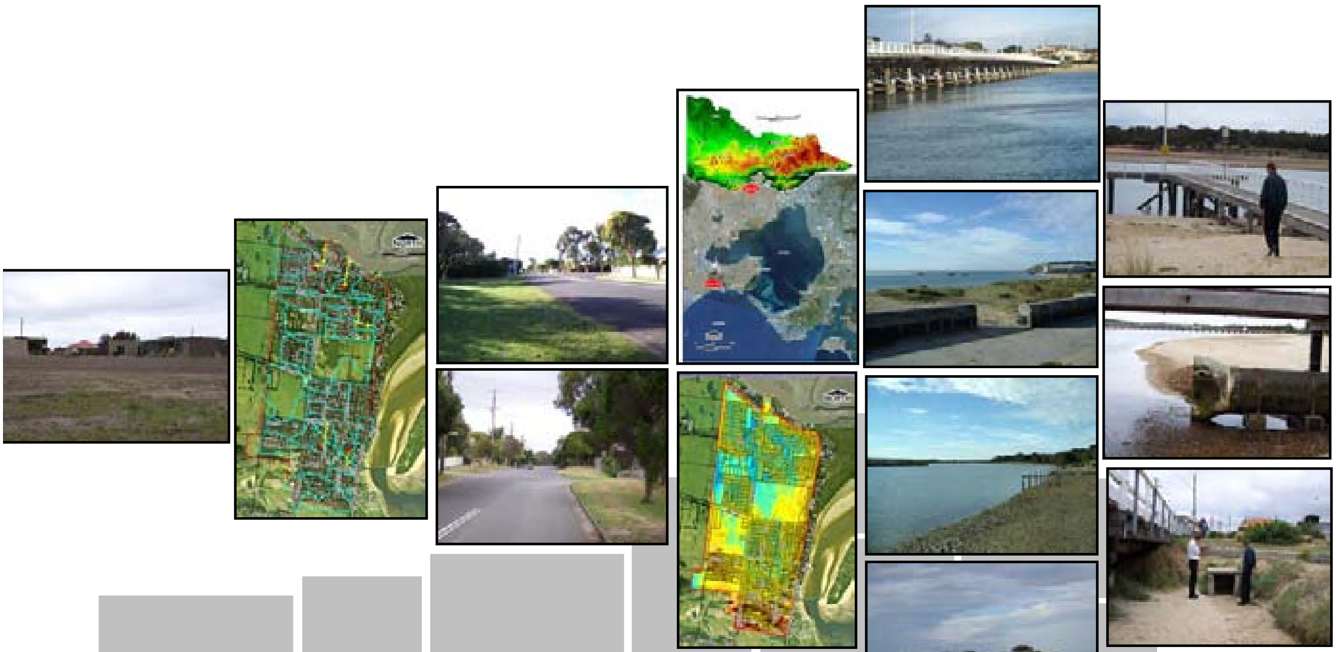
Barwon Heads Drainage Flood Management Plan

Final Report

November 2005



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Barwon Heads Drainage Flood Management Plan Final Report

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	Synopsis:	Final report documenting the findings of a flood study into possible drainage mitigation strategies for Barwon Heads.

REVISION/CHECKING HISTORY

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EXECUTIVE SUMMARY

Study Objective

Barwon Heads experiences relatively serious and frequent drainage-related or "stormwater" flooding. On occasions the flooding has been attributable (at least in part) to pump failures (CoGG, 2002). Low-lying areas often form detention storages in storm events, resulting in flooding of properties and roads at a number of locations. 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. *Data Collection and Review* - All existing data relating to the study area was collected and reviewed. Data included underground pipe networks, pumps, historical flood information, site photos, previous investigations, floor levels, topographic maps and a range of GIS data.

2. *Digital Terrain Data Collection* – Existing photogrammetric data and design elevation models developed for new sub-divisions were available for the study. The data were used to generate a Digital Elevation Model (DEM).

3. *Hydrological and Hydraulic Modelling, and Mapping of the Existing Conditions* - The existing flood characteristics were identified through hydrologic and two-dimensional (2D) hydraulic modelling of the 5, 20 and 100 year average recurrence interval (ARI) flood events. The flood results were mapped using GIS. An assessment of the amount of damage caused by the existing level of risk was calculated 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 in order to develop a shortlist of three (3) alternative flood mitigation schemes to be hydraulically tested and compared with the existing case. Flood damage was calculated for each of the three options tested. A "do nothing" option was also considered.

5. *Selection and Detailed Mapping of the Preferred Option* – The mitigation options were assessed according to their ability to reduce flood damage. The options were ranked according to a range of economic and non-economic factors. A preferred strategy was then selected in consultation with CoGG. The preferred option 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 existing flooding characteristics have been assessed using a 2D hydraulic model. The flood extent of the 1% Annual Exceedance 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 $221,000 per annum (PA). 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.

Table E-1 Number of Properties Inundated Above Floor Level

Design Event	100 year	20 year	5 year
Number of Properties Inundated above Floor Level	61	37	23

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 and pumps 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 Barwon Heads. Through discussion with Council officers, the elements were combined to form three mitigation schemes for detailed modelling and assessment. The 'do nothing' strategy, ie, the existing flood conditions, was also considered.

Scheme 1

- Upgrade Clifford Pde pump station, gravity feeder pipes and rising main
- New 750 mm stormwater gravity pipe along Ozone Rd from Grove Rd to Barwon River to take flow from Clifford Pde pump rising main
- Upgrade Heron Cr pump station, gravity feeder pipes and rising main
- New 825 mm stormwater pipe from corner of Hitchcock Ave and Bridge Rd to Clifford Pde pump station
- Infiltration pits providing 5 year ARI capacity in George St

Scheme 2

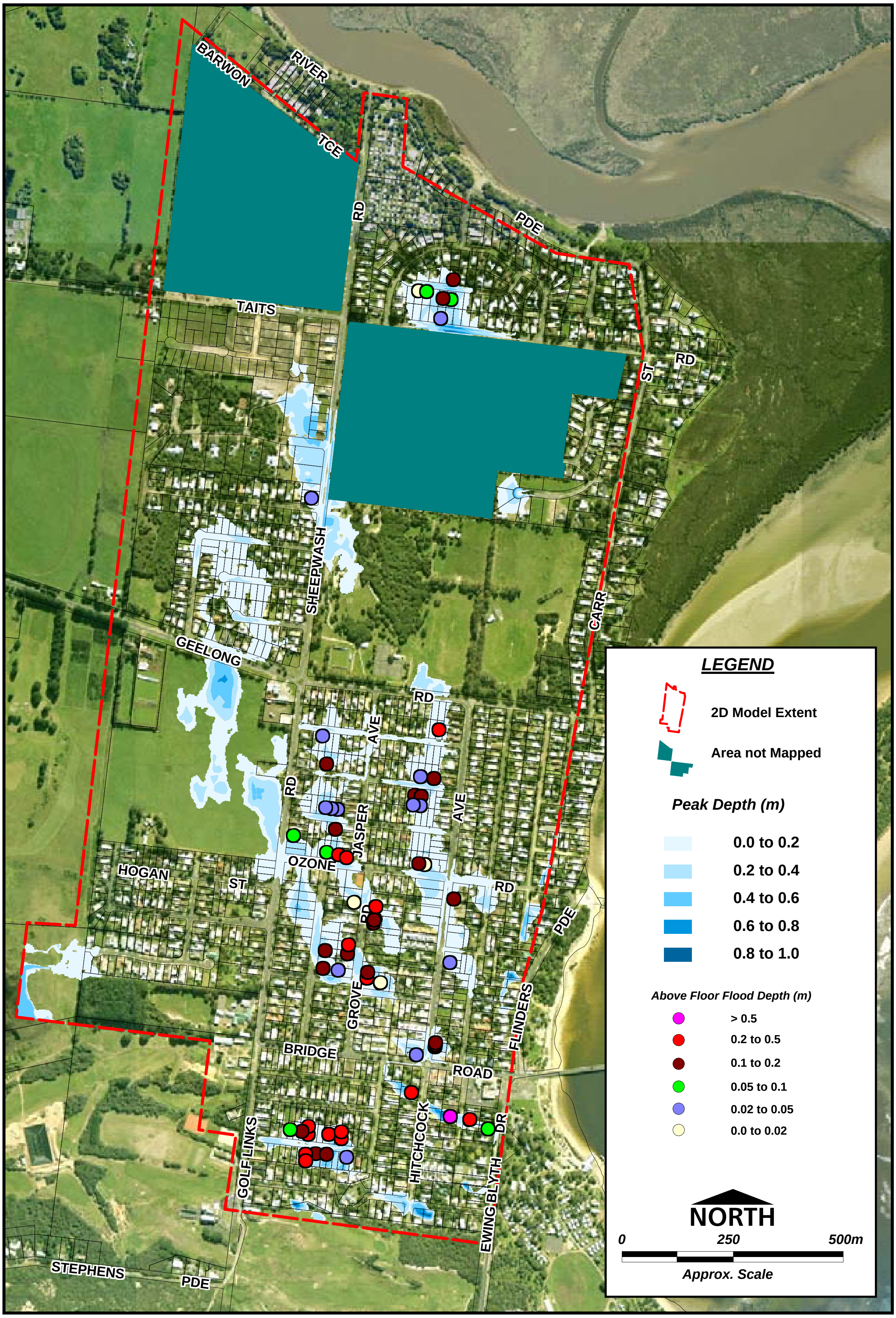
- Scheme 1 works plus upgrade gravity stormwater pipes along Ozone Rd

Scheme 3

- Upgrade gravity stormwater pipes along Ozone Rd
- Upgrade Heron Cr pump station, gravity feeder pipes and rising main
- Infiltration pits providing 5 year ARI capacity in George St
- Purchase two houses in the vicinity of Clifford Pde pump station

Scheme 4

- Do nothing



Existing 100 Year ARI Peak Flood Depth **Figure E-1**

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Each scheme was assessed using the 2D hydraulic model to yield flood characteristics under the differing conditions. 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 option.

Table E-2 Flood Affected Properties

Case	Flood Affected Property Floors**		
	100 Yr	20 Yr	5Yr
Existing	61	37	23
Scheme 1	35	16	10
Scheme 2	31	15	10
Scheme 3	38	21	16
Scheme 4 (Do Nothing)	61	37	23

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

Table E-3 Mitigation Option Economic Summary

Case	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 1	$106,000	$ 115,000	$ 1,427,000	$ 2,121,533	$ 51,000	$ 853,000	$ 2,974,533	**0.48**
Scheme 2	$102,000	$ 119,000	$ 1,477,000	$ 4,345,130	$ 104,000	$1,387,000	$ 5,732,130	**0.26**
Scheme 3	$153,000	$ 68,000	$ 844,000	$ 3,659,709	$ 88,000	$1,124,000	$ 4,783,709	**0.18**
Scheme 4	$ 221,000							

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

+ Pump maintenance costs are included in the net present value (NPV) item, but not the per annum (PA) item, because the maintenance cost basis was not yearly for the pumps.

Preferred Mitigation Strategy

The preferred mitigation strategy was selected based on a number of key indicators including economic, environmental, social and feasibility and performance. Through consultation with the City of Greater Geelong (CoGG), Scheme 1 was selected as the preferred mitigation strategy based on the following:

- it has the highest BCR of the Schemes considered;
- it has the lowest capital cost;
- its potential environmental impact is minimal and similar to the other Schemes;

- the social impacts arising from the scheme are very limited; and
- the feasibility and performance are both good.

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

- Further investigation, with report back to Council, into the feasibility of property-specific measures to manage risk from residual flooding (with Scheme 1 in place). Potential measures include floodproofing 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 during a flood event.
- Development controls via designation of areas as liable to flooding (in accordance with Building Regulations 1994) and use of flood zones/overlays within the Greater Geelong Planning Scheme. Investigation of additional planning scheme amendment (eg Local Planning Policies and Municipal Strategic Statement) to enable further development controls that would limit runoff from land that is currently undeveloped. This should included limiting the fraction impervious for residential areas to 0.5.
- 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.

Preferred Mitigation Scheme (1) Works

Figure E-2

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1 INTRODUCTION

1.1 Background

The City of Greater Geelong (CoGG) engaged WBM Oceanics Australia (WBM) to assess stormwater flooding within Barwon Heads, and to investigate flood management options to manage and minimise the effects of local catchment flooding on the community.

1.2 Catchment Description

Barwon Heads is situated on the southern coast of Victoria on the Bellarine Peninsula, just over an hour's drive south of Melbourne(Figure 1-1). The town is bounded to the north and east by the Barwon River, and to the south by Bass Strait. The town is protected from Barwon River flooding by a levee, so stormwater runoff in the town is from its local catchment.

Topography in the area is undulating, with the majority of the township situated in a low-lying depression, surrounded by ridgelines to the north and east and higher ground to the south. Ground levels range from 1.0 m to 17.0 m AHD (AHD is Australian Height Datum with 0.0 m being approximately mean sea level).

Stormwater runoff within Barwon Heads is generally released to the Barwon River via a network of stormwater pipes and pumps, or it enters the groundwater through natural infiltration or constructed infiltration pits. The stormwater pipe network in the older areas is generally undersized by today's standards. Floodways to convey runoff during larger flood events, when the capacity of the pipe network is exceeded, are not provided in all areas of the town, resulting in above floor flooding in residential and commercial areas.

1.3 History of Flooding

Barwon Heads experiences relatively serious and frequent drainage-related or "stormwater" flooding. On occasions the flooding has been attributable (at least in part) to pump failures (CoGG, 2002). Low-lying areas often form detention storages in storm events, resulting in flooding of properties and roads at a number of locations. The drainage problems of the Barwon Heads catchment are similar to those experienced by many older urban catchments that contain hydraulically constrained and aging stormwater systems. The township contains high levels of development, extensive areas of imperviousness and limited retention of dedicated drainage reserves or open channel systems.

The most recent significant flood event was on 8^{th} February 2002. In the 24 hour period up to 9 am on the 8^{th}, Barwon Heads received 89 mm, or an average of 3.7 mm/hr which is between a 20 year ARI and 50 year ARI rainfall event. However, CoGG (2002) notes that the event was of short duration with rainfall starting over Geelong at 0315 hours and ceasing at 0900 hours. If the rainfall duration was similar at Barwon Heads, the average over 6 hours was about 15 mm/hr, which is greater than the 100 year ARI rainfall intensity of 12 mm/hr.

The most severe flood in living memory was in June 1952 when the Barwon River broke its banks and flowed into Barwon Heads. A levee now protects the town from this type of event, although an assessment of the ARI of the levee was not included in this study. Information provided by the COGG shows that this levee is designed to protect against the flood event of equal magnitude to the 1952 event. The levee has a top level of 4.25 m AHD and provides for 1.75 m freeboard against the estimated Barwon River 1% Annual Exceedance Probability (AEP) flood level of 2.5 m AHD.

1.4 Study Area

The Study Area is the Barwon Heads catchment as shown in Figure 1-2. It is largely bounded to the north and east by the Barwon River ridgeline and to the south by the Golf Course. The western edge of the boundary represents the current extent of urbanised area in Barwon Heads. Two areas that currently have SBO (Special Building Overlay) were excluded from the flood mapping although the catchments and drainage system were modelled to assess overflow into surrounding areas. The Study Area is modelled and mapped in detail using a complex two dimensional flood model.

1.5 Key Objectives

The key objectives of the study were as follows:

1. develop a state-of-the-art computer model of the Barwon Heads local catchment to define the nature and extent of the existing flood hazard;

2. identify and assess potential flood mitigation options to reduce damages associated with flooding impacts;

3. undertake a flood damages assessment to assess the significance of existing flooding impacts and the benefits of any mitigation options; and

4. evaluate and identify opportunities of funding capital and maintenance works associated with the recommendations of the study.

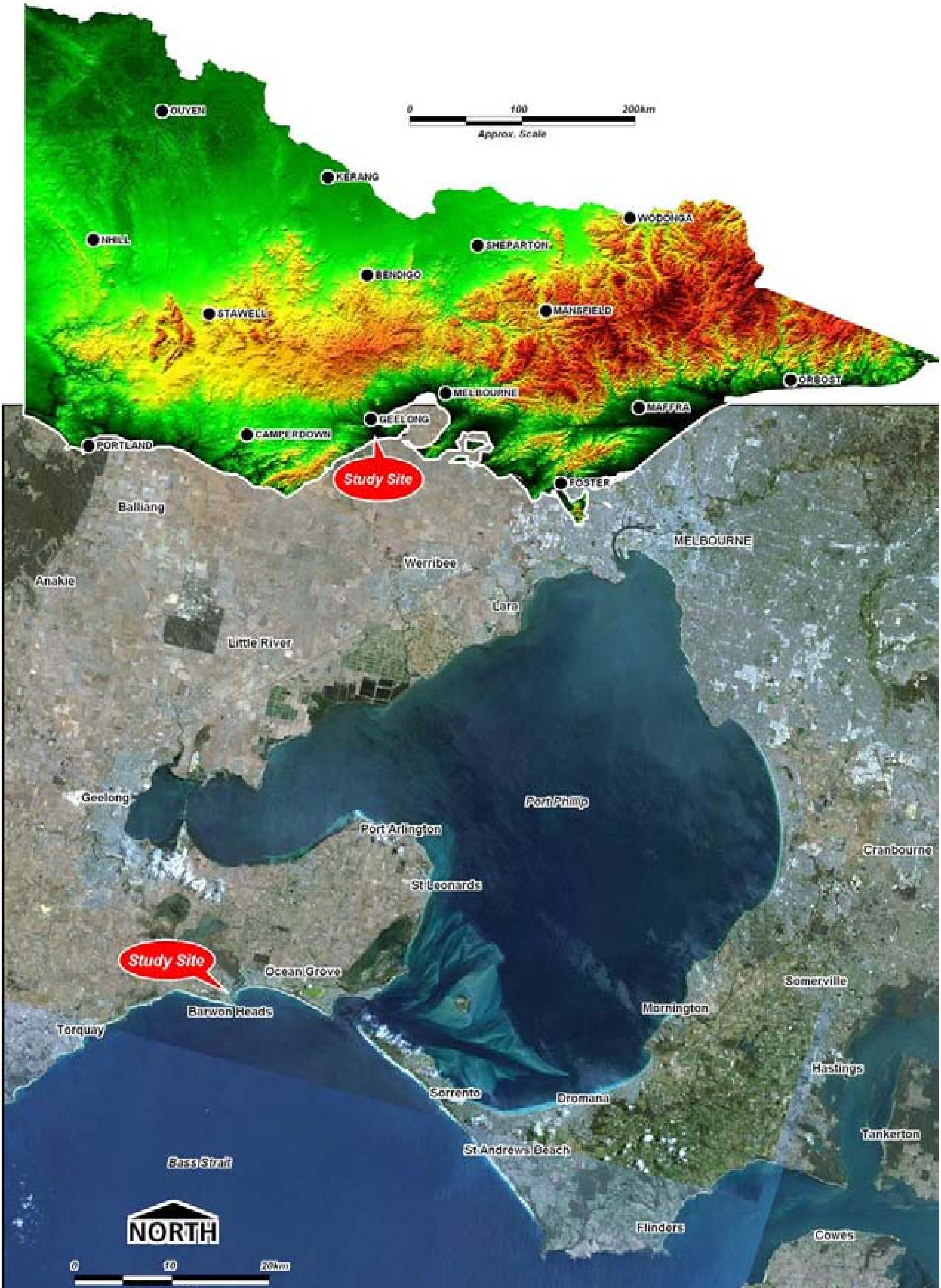


Figure 1-1 Locality Map

Study Area **Figure 1-2**

2 STUDY APPROACH

There were six key stages in the study as follows:

1. data collection;
2. flood model development;
3. flood mapping;
4. flood damages assessment;
5. mitigation options assessment; and
6. 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 Collection

2.1.1 Study Inception and Site Visit

Following commissioning of the study, an inception meeting was held between CoGG representatives and WBM project staff. During this meeting background data was supplied, project documentation was exchanged and the scope of works was discussed and approved. This meeting was followed by a site inspection with Council's representative, where flooding issues throughout the study area were outlined and viewed. During the course of the project, additional site inspections were undertaken by WBM staff to clarify flood and drainage issues.

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.

Topographic survey was required for the development of a Digital Elevation Model (DEM), which is a three-dimensional model of the ground surface. The DEM forms the basis of the hydraulic model. Data for the DEM was obtained from existing photogrammetry as well as design elevation models developed for new sub-divisions constructed since the photogrammetry was undertaken.

Additional project related data was retrieved from Council's SIS group. In particular, the following data were supplied:

- cadastral information over the study area (continuously updated data set supplied by Barwon Water);
- planning scheme zones over the catchment;
- aerial photography; and
- floor heights.

2.2 Flood Model Development

The flood model comprises a hydrological model and a hydraulic model.

The hydrologic model determines the runoff that occurs following a particular rainfall event. The primary output from the hydrologic model is hydrographs at various locations in the catchment. 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 flood waters 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 and pump systems.

Hydrologic modelling of the Barwon Heads catchment was undertaken using XP-RAFTS2000. No calibration data was available for the hydrological model, so for most parameters, typical values appropriate for the catchment characteristics were adopted. The adopted loss model was an initial loss/continuing loss model. The soil type in the catchment is predominantly sand, so the continuing loss is a significant factor in calculating rainfall excess and ultimately peak flood volumes and heights. Therefore, P.J. Yttrup & Associates was commissioned to undertake soil sampling and testing across the catchment to estimate permeability. Although there is no direct correlation between permeability and continuing loss, the permeability was additional background information used in the "engineering judgement" used in assigning the continuing loss.

Hydraulic modelling of Barwon Heads was undertaken using the fully 2D dynamic hydraulic modelling system TUFLOW. The model incorporated both the overland flow paths and the underground trunk drainage system, including pumps. No data was available for calibration, but preliminary results were compared to flood heights in the February 2002 event and CoGG reviewed the results for consistency with their experiences of flooding at Barwon Heads. 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 which 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 100 year ARI flood does not guarantee protection for the next 100 years. Design flood levels were determined for the 100, 20 and 5 year ARI floods.

2.4 Flood Damage Assessment

The design floods were used to make an assessment of the financial losses to residential and commercial 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

Both structural and non-structural floodplain management measures were assessed. Structural measures include options such as alterations to drainage structures, levees and diversion channels. Non-structural measures include options such as property modification and response modification measures. Property modification measures include development controls, voluntary house purchase and voluntary house raising. Response modification measures include flood warning, emergency planning and community awareness. Response modification measures were not considered as part of this assessment.

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 COLLECTION

3.1 Drainage Data

CoGG supplied drainage network data for the catchment in both hard copy and digital (AutoCAD dxf files) file formats. Data included pipe networks (location and size), pump station and rising main locations and size, pump design curves and soakage pit locations. Design drawings for a limited number of the soakage pits were also provided.

3.1.1 Topographic Data

The DEM was developed using the software package 12D. Survey for the DEM was primarily from 1993 photogrammetry data collected by AAM Surveys for Barwon Water. A number of new sub-divisions have been developed after the photogrammetry was completed in 1993. Three of the catchments fall within areas covered by a Special Building Overlay, and as a result do not require flood mapping. Two sub-divisions fall within the area to be mapped, and the available digital design surface information (AutoCAD or Microstation format) was obtained and integrated into the DTM. The resulting DEM is shown in Figure 3-1.

Within the flood mapping area the sampling resolution for the DEM is 0.5m. 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.

Some ground truthing of the DEM was undertaken prior to the commencement of the hydraulic modelling. Figure 3-2 gives a comparison between the surveyed and DEM levels. A positive number indicates that the DEM is high and conversely a negative number indicates that it is low. Over much of the DEM checked there was a good match between the DEM levels and the ground survey. Exceptions were at the southern end of Barwon Heads and through Barwon Heads Village Park where the DEM is high. The CoGG advised that the modelling should continue as the differences were not in areas that would be significant to the study outcomes.

During the course of the study, additional ground survey data for the undeveloped Lot on the corner of Golflinks Rd and Geelong Rd was made available by the developer of that site. This data was not incorporated into the DEM, but the levels in the hydraulic model were adjusted to match the ground survey data.

3.1.2 Floor Levels

Floor level information was supplied to WBM from a number of existing data sets held by CoGG. The data supplied included the address and floor level, but without any geographical location. It was necessary to bring this data into GIS for the study. To do this, each floor level was assigned an x and y coordinate from another database. The floor levels were matched to the coordinates using the address as a common attribute. Once each floor level was assigned a coordinate, a simple process of producing points in the GIS was undertaken. The distribution of floor levels is shown in Figure 3-3.

It must be noted that floor level information was not available for all properties within the area. Existing information was limited to the key flooded areas in the township. As a result, all numbers of flooded properties, damage figures and hence Benefit Cost Ratios, are based on the data set provided.

3.1.3 Soil Permeability

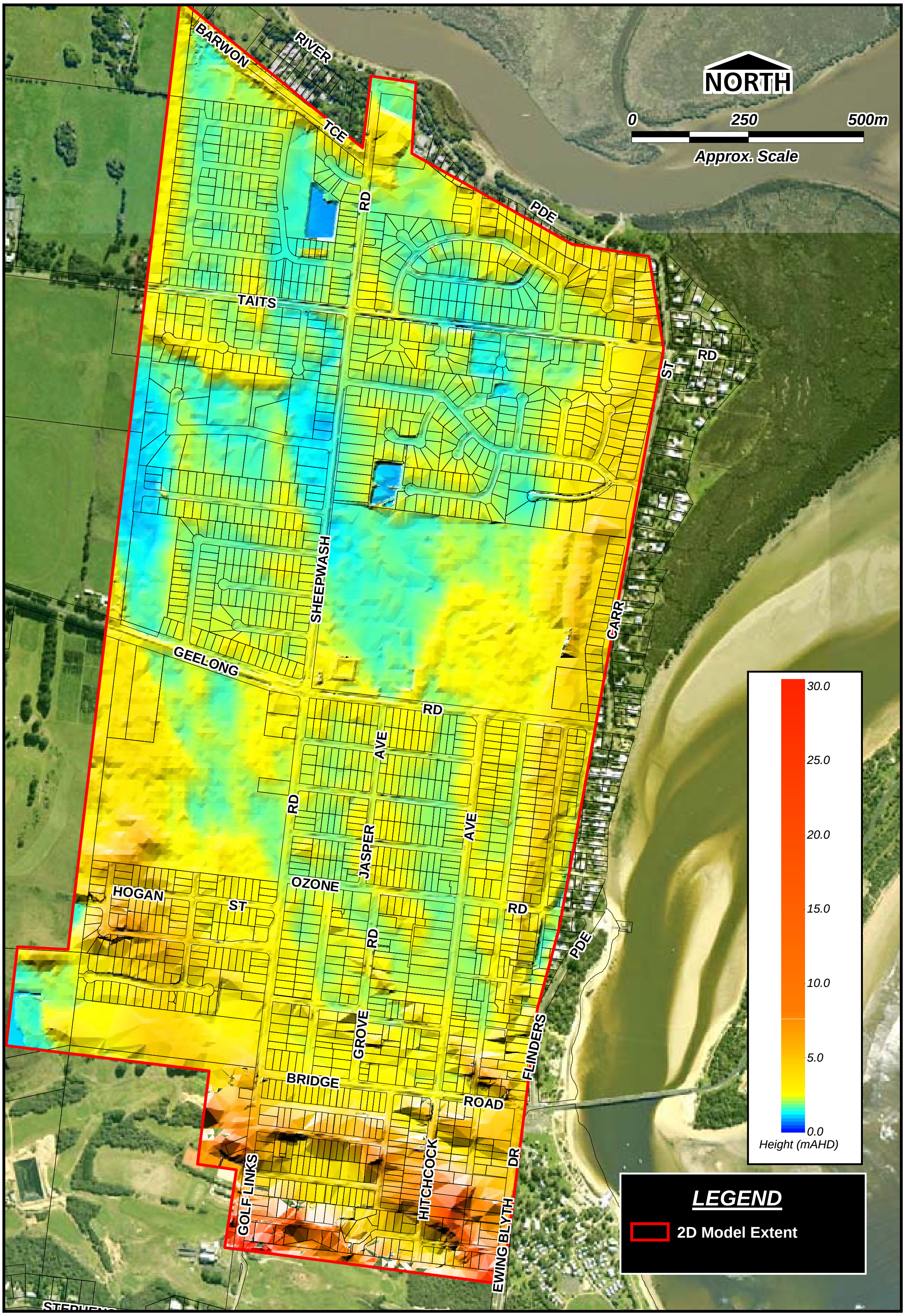
Soil permeability was estimated at 29 sites across Barwon Heads by P.J. Yttrup & Associates. Soil samples were obtained and analysed to give an indication of permeability and its variation across the catchment. The permeability estimates were based on the particle size distribution from sieve analyses and a general relationship provided in Cedergren (1997). Boreholes were also taken at 9 of the sites. The permeability estimates are shown in Figure 3-4 and the test data are in Appendix A.

Significant variation in the permeability was found, with a range of 0.2 m/hr to 15.8 m/hr. The higher values were at sites where there was significant gravel content. The mean and median of all values are 1.7 m/hr and 1.0 m/hr respectively. If the two outliers in the data set are removed (7.9 and 15.8 m/hr) the mean and median values are both 1.0 m/hr. Anecdotal information from Peter Yttrup, who lives at Barwon Heads, indicated very little runoff from the pervious surfaces, ie, there is significant infiltration.

CoGG also provided permeability data that was undertaken for building construction at selected sites around Barwon Heads. These values were typically in the range 0.2 m/hr to 0.5 m/hr. These values are generally consistent with the data derived by P.J. Yttrup & Associates.

The soil tests were also undertaken to investigate spatial variation in the permeability that could then be reflected in a spatial variation in loss rates in the hydrological model. As can be seen in Figure 3-4 there are no obvious patterns in the spatial variation of the permeability. Therefore, it was concluded that the same continuing loss rate would be applied across the catchment.

Continuing loss rates used in hydrological modelling for sandy soils are typically in the range 10 mm/hr to 20 mm/hr. Although there is no known relationship between permeability and infiltration losses, it was considered that the adopted continuing loss rate in the model should be at the upper end of the typical range given the high permeability. Accordingly, a continuing loss rate of 20 mm/hr was adopted for the hydrological modelling.



2D Model Limits and DEM **Figure 3-1**

DEM Ground Truthing

Figure 3-2

Floor Level Distribution **Figure 3-3**

Soil Permeability Estimates **Figure 3-4**

4 FLOOD MODEL DEVELOPMENT

4.1 Hydrological Model

The Barwon Heads catchment is predominantly residential with some rural areas surrounding. Land uses comprise a combination of residential, rural, commercial and special land uses such as a golf course. The Barwon Heads catchment is a little unusual in that it is in fact a series of smaller "self-contained" sub-catchments that drain to the low point in the sub-catchment rather than to a creek or river system. The stormwater drains from the sub-catchments through either natural infiltration or through an underground network of pipes and pumps, kerb and gutter drainage and soakage pits. In this type of system, runoff volume can be more important than peak discharge, particularly in larger flood events that exceed the capacity of the drainage system.

Hydrologic modelling of the Barwon Heads catchment was undertaken using XP-RAFTS2000. The Barwon Heads model was developed for the purpose of extracting total and sub-area hydrographs to be used as boundary conditions for the TUFLOW hydraulic model.

Key tasks for the hydrologic analysis were:

- review available data including rainfall and rainfall losses;
- simulate design rainfall events for a range of return periods and durations using XP-RAFTS2000; and
- derive design flood hydrographs using XP-RAFTS2000 for a range of return periods.

4.1.1 Model Description

XP-RAFTS2000 is a non-linear runoff routing model that develops stormwater runoff hydrographs from actual events or design storms (generated through Intensity-Frequency-Duration data). The Barwon Heads model covers an area of approximately 223ha, including the Barwon Heads study area. The area of Barwon Heads was divided into 70 subcatchments based on an assessment of topography and drainage infrastructure.

4.1.1.1 Loss Parameters

Rainfall losses were accounted for using the Initial Loss/Continuing Loss model in XP-RAFTS2000. Separate loss values were used for impervious and pervious surfaces. Table 4-1 presents the assumed loss values.

Table 4-1 Initial and Continuing Losses

	Initial Loss (mm)	Continuing Loss (mm/h)
Impervious	5	0
Pervious	15	20

4.1.1.2 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 presented in Table 4-2.

Table 4-2 Impervious Fraction for Planning Scheme Zone

Zone	Impervious Fraction
Coastal	0.05
Commercial	0.9
Golf Course	0.1
Major Road	0.9
Mixed Use	0.8
Parks and Recreation	0.1
Public Use	0.5
Residential	0.5
Rural	0.05

RAFTS2000 allows for each sub-catchment to be split into two sub-areas for separate routing. One sub-area was used to model the impervious area and the other the pervious area so that the different loss rates could be applied. Therefore, for each sub-catchment the pervious and impervious areas were calculated using the fraction impervious presented in Table 4-2.

4.1.2 Sub-Catchment Definition

Sub-catchments used in the hydrologic modelling process were defined using a combination of CoGG drainage plans, underground drainage network layout and topographic data. Where drainage scheme data was not available, sub-catchments were defined using topographic data. The sub-catchment breakdown is shown in Figure 4-1. A number of catchments outside of the study area were modelled to ensure that flow from these areas into the study area was accounted for.

4.1.3 Hydrological Model Performance Verification

Due to the lack of historical rainfall and flood height data, calibration of the model to real data was not possible. Verification of results from the hydrological model was undertaken using empirical methods. Peak flows generated by the XP-RAFTS2000 models were verified against values derived using the Rational Method.

The check was done by back calculating the runoff coefficient that would be required in the Rational method to achieve the peak discharge calculated by XP-RAFTS2000. This analysis was undertaken for a range of the sub-catchments with different levels of development. Runoff coefficients in the range of 0.4 to 0.9 were calculated. These are within the range of typical values for the sub-catchments assessed, and it was agreed with CoGG that the results from XP-RAFTS2000 could be adopted for the study.

XP-Rafts2000 Catchment Layout **Figure 4-1**

4.1.4 Design Event Modelling

Design Event Probabilities

Hydrological analysis was undertaken for the 1%, 5% and 20% Average Exceedance Probability (AEP), i.e. the 100, 20 and 5 year Average Recurrence Interval (ARI) or return period, design storm events. Hydrographs were derived by XP-RAFTS2000 to provide external and internal boundary conditions to the hydraulic model at a number of locations throughout the catchment.

Design Rainfall

Temporal patterns and design rainfall intensities were derived from Australian Rainfall and Runoff IFD curves and maps. The process involved the derivation of design rainfall events covering the range of return periods and durations.

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 30 minute duration event may result in the peak discharge in the upper portion of a catchment, while a 2 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 of duration 20 minutes to 3 hours were modelled.

4.2 Hydraulic Model

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 the 2D domain and underground drainage structures were represented as 1D elements dynamically linked to the 2D domain. Pumps were modelled as sink/sources in the 2D domain with flows controlled using a boundary condition derived from the pump characteristic curves. In a catchment such as Barwon Heads where storage and timing of the rainfall inflows in the assessment of the drainage network are important, modelling using flow varying with time (unsteady state) rather then peak flow (steady state) is required. Accordingly, TUFLOW was run in unsteady state.

4.2.1 Model Description

The 2D model domain covers most of the township of Barwon Head 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 Barwon Heads 2D model, the above issues were considered in conjunction with the final objectives of the study. Given the relatively small size of the study area, run times could be kept to an acceptable length using a small grid element size of 3m. A 3m element size over the study area provided a good definition of land shape, key hydraulic controls and waterways.

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. Nine 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 4-3. A Manning's 'n' of 0.013 was adopted for the stormwater pipes. Because of the relatively low velocities in the system, the peak flood levels were not sensitive to the Manning's 'n' or the entry/exit losses in the drainage network.

Table 4-3 2D Domain Manning's 'n' Coefficients

Land use	Manning's 'n'
Roads (whole road reserve)	0.025
Residential	0.20
Commercial/Industrial	0.25
Caravan Park	0.15
Tree and grass reserve (light density)	0.035
Tree and grass reserve (medium density)	0.05
Tree and grass reserve (high density)	0.08
Pasture	0.05
Large Rural Residential blocks	0.06

As discussed previously, the underground stormwater pipes were modelled as 1D components dynamically linked to the 2D domain. Key features of the drainage system, typically pipes with diameter greater than 450mm and pumps, were modelled. Smaller pipes were modelled at some locations after preliminary model runs indicated the need for their inclusion. These components of the model were established using drainage information provided by CoGG. Invert levels were not available for some of the network, so for these pipes, an invert level was derived using the ground level in the DEM at that location. Full interchange of flow between the 1D and 2D domain was allowed, ie, it was assumed that the pits did not restrict the flow of water into the pipes. Sensitivity testing of this assumption demonstrated that a significant restriction applied to the interchange of flow had no significant impact in peak flood levels. This indicated that it is the pipe size, and perhaps limited hydraulic gradient, that is limiting the flow through the drainage network.

The drainage network at Barwon Heads includes a number of soakage pits. Dimensions were available only for a few of the soakage pits. The flow capacity of two of the soakage pits, for which dimensions were available, was calculated using the SWITCH method. This is a conservative method used to design pits and was therefore considered appropriate for providing an indication of the flow capacity of the pits. The calculated flow rates were in the range 0.01 m^3/hour to 0.1 m^3/hour. These calculations indicated that the flow capacity of the pits is not significant in the flood events under consideration in this study. Therefore, in consultation with CoGG, it was concluded not to include these pits in the model.

4.2.2 Boundary Conditions

The hydraulic model covers most of the catchment, which means that there are no external flow boundaries that are normally applied to a hydraulic model. Fifty-five internal local area flow boundaries were used to represent the flow generated from the local catchment. The local area boundary conditions were flow-time boundaries generated using the XP-RAFTS2000 hydrological model. The boundaries were applied over the 2D domain as shown in Figure 4-2.

On consultation with Council representatives, the downstream tail water level in Barwon River was set to 1.45m AHD for all modelled flood events. It resulted in a conservative, but reasonable, estimate of flood conditions at the pipe outlets.

4.2.3 Design Event Modelling

The 5, 20 and 100 year ARI design storm events were modelled in TUFLOW for five storm durations: 20 minutes, 30 minutes, 1 hour, 2 hours and 3 hours. The critical storm duration varied across the catchment, but the 1 and 2 hour storms were the critical duration in most areas. A peak flood height envelope was developed from the five durations and the peak envelope flood surfaces mapped. The mapping is presented in Section 5. These events formed the basis of the assessment of the mitigation options, including the damages assessment.

As no data was available to calibrate the hydraulic model, a sensibility check was undertaken by comparing the flood extents with historical flooding patterns. Preliminary flood extents for each of the design runs were provided to CoGG who reviewed the extents in the context of their experience with historical flooding problems in the study area. The feedback from CoGG was that the flood extents were generally consistent with their experience of flooding at Barwon Heads. One exception was in the southern part of Barwon Heads in the higher dune area where the CoGG felt that the model was indicating flooding worse than they had experienced. In this area the drainage is via gully pits that drain directly into the sand layer. These gully pits were not included in the model because of lack of detailed dimensions of the pits and permeability data for the sand at the base of the pits. Also, as noted in Section 4.2.1, calculations on soakage pit flow capacities elsewhere in the study area indicated that flow capacities might not be significant for this type of drainage system. Therefore, it was agreed in consultation with CoGG that these gully pits would not be included in the system. This means that stormwater runoff in this area does not drain away, rather it continues to build up and hence the levels in the area would be conservative.

In Section 1.3 it is noted that the February 2002 event had an ARI in the vicinity of 100 years, although flooding in some areas was exacerbated by pump failure. Data available for this event indicated properties that were flooded and whether there was above floor flooding or not. This data was compared to the modelled 100 year ARI flood levels to get an indication of whether the model was in the "ballpark." This data is summarised in Table 4-4. Also included in the table are the flood levels for the 100 year 2 hour event with no pumps operating. The comparison indicates that the model is generally consistent with the historical data.

Table 4-4 Design Flood Comparison with February 2002 Flood Data

Complaint	Address	Floor Level (m AHD)	Modelled Flood Level (m AHD)			No Pumps	Comment
			100Yr	20Yr	5Yr	100Y2hr	
Above Floor Level	31 Sheepwash Rd	1.55	1.57	1.51	-	1.67	
	46 Hitchcock Ave	2.42	2.63	2.58	2.54	2.62	
	24 Taits Rd	2.17	-	-	-	-	localised flooding problem
Garage/Porch, but not floor	10 Clifford Pde	2.42	2.43	2.38	2.36	2.44	
	1-3 Warrenbeen Crt	1.71	1.57	1.46	1.42	1.67	
	32 Thorn	2.17	2.29	2.24	2.21	2.29	
Street Flooding	37-39 Sheepwash Rd	1.62	1.57	1.46	1.42	1.67	
	Grandview Pde	2.26 - 4.3	2.2	2.16	2.12	2.2	
	Heron Crs	1.66 - 2.1	1.8	1.7	1.66	1.83	
Other	16 Ewing Blyth	4.28	4.06	-	-	4.05	northwest corner of property only

Tuflow Pipe Network and Flow Boundaries (Existing Case)

Figure 4-2

5 FLOOD MAPPING

This section provides a brief overview of the floodplain mapping process used in the investigation.

TUFLOW produces a geo-referenced data set defining peak water levels throughout the model domain at the corners of its computational cells. The peak flood level from each of the five storm durations was selected for each computational cell to generate an envelope of peak flood level. 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.

Depth of above floor flooding was required for the flood damages assessment, and also to provide an initial indication of the benefit of a mitigation option before proceeding to the economic analysis. Above floor flooding occurs when the height of floodwaters exceeds the height of the floor in habitable rooms within the property. Flooding of garages and carports does not constitute above floor flooding. The depth of above floor flooding was calculated by subtracting the floor level at each property from the flood height at that property for each design event. The number of properties inundated above floor level in each event is shown in Table 5-1.

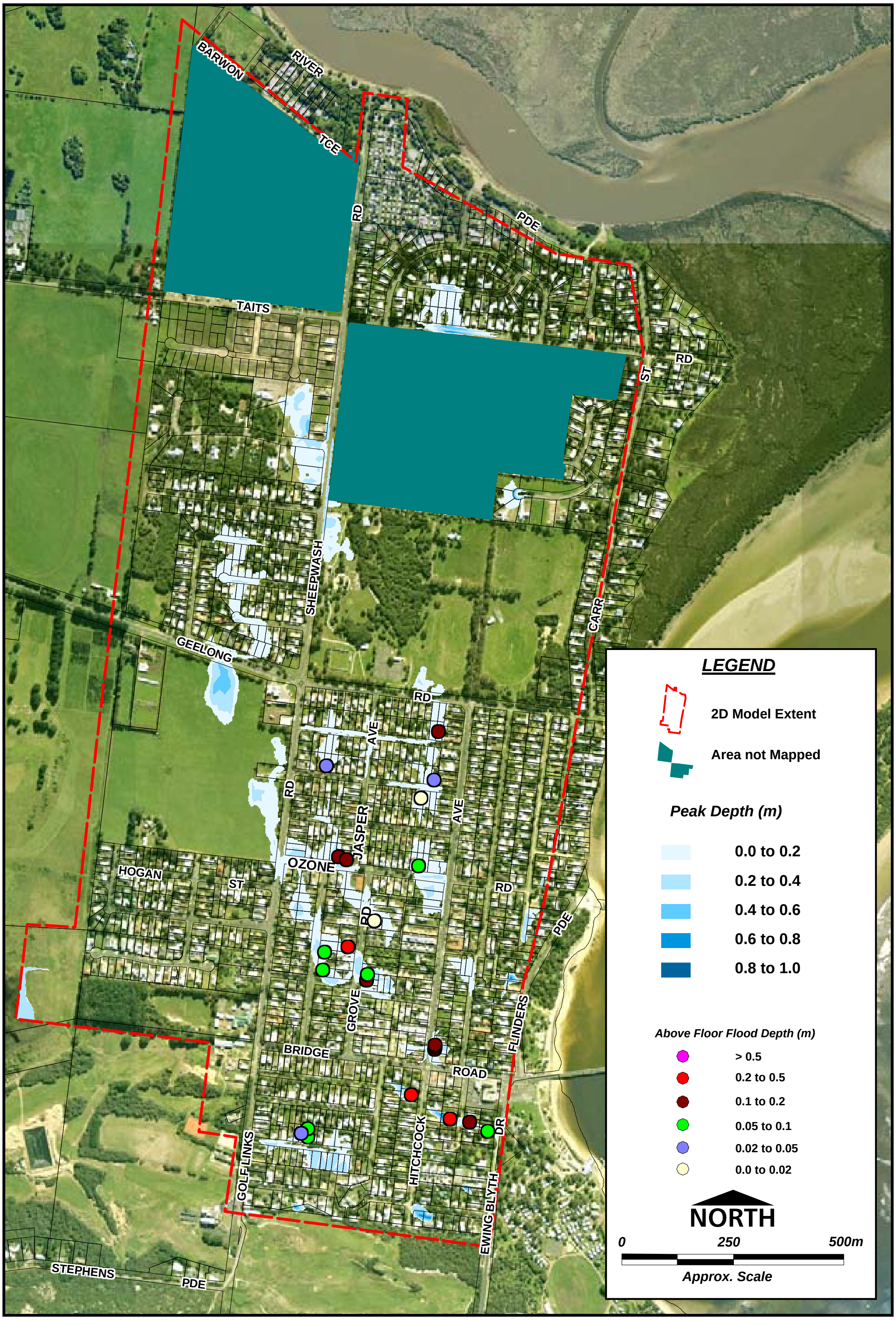
Table 5-1 Number of Flooded Properties

ARI (years)	Number of Flooded Properties	
	Ground Level	Floor Level
100	219	61
20	158	37
5	106	23

The existing condition flood depth and depth of above floor flooding are mapped for the 5 year, 20 year and 100 year ARI events in Figure 5-1 to Figure 5-3 respectively. Peak flood heights were provided digitally to CoGG and in large plots provided separately from this report. A graphical representation of impacts from the mitigation options tested was achieved by plotting the difference between the new surface, as a result of each option, and the existing flood surface without the option. These plots detail the following information:

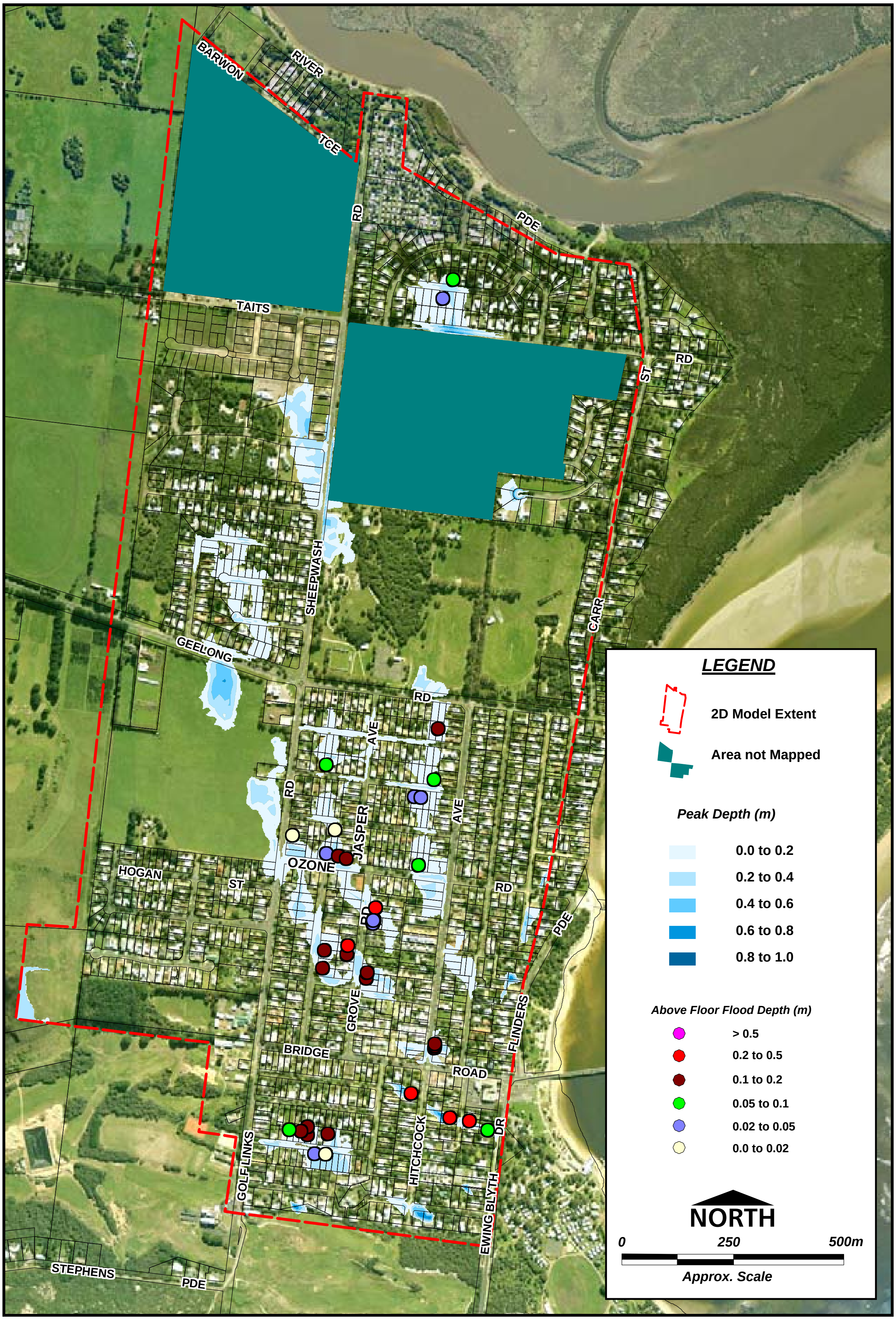
- areas that were previously flooded and are now not flooded;
- areas of reduced flood level;
- areas of limited or no change in flood level;
- areas of increased flood levels; and
- areas that have become flooded as a result of the mitigation option.

The mitigation option maps are presented in Section 7.



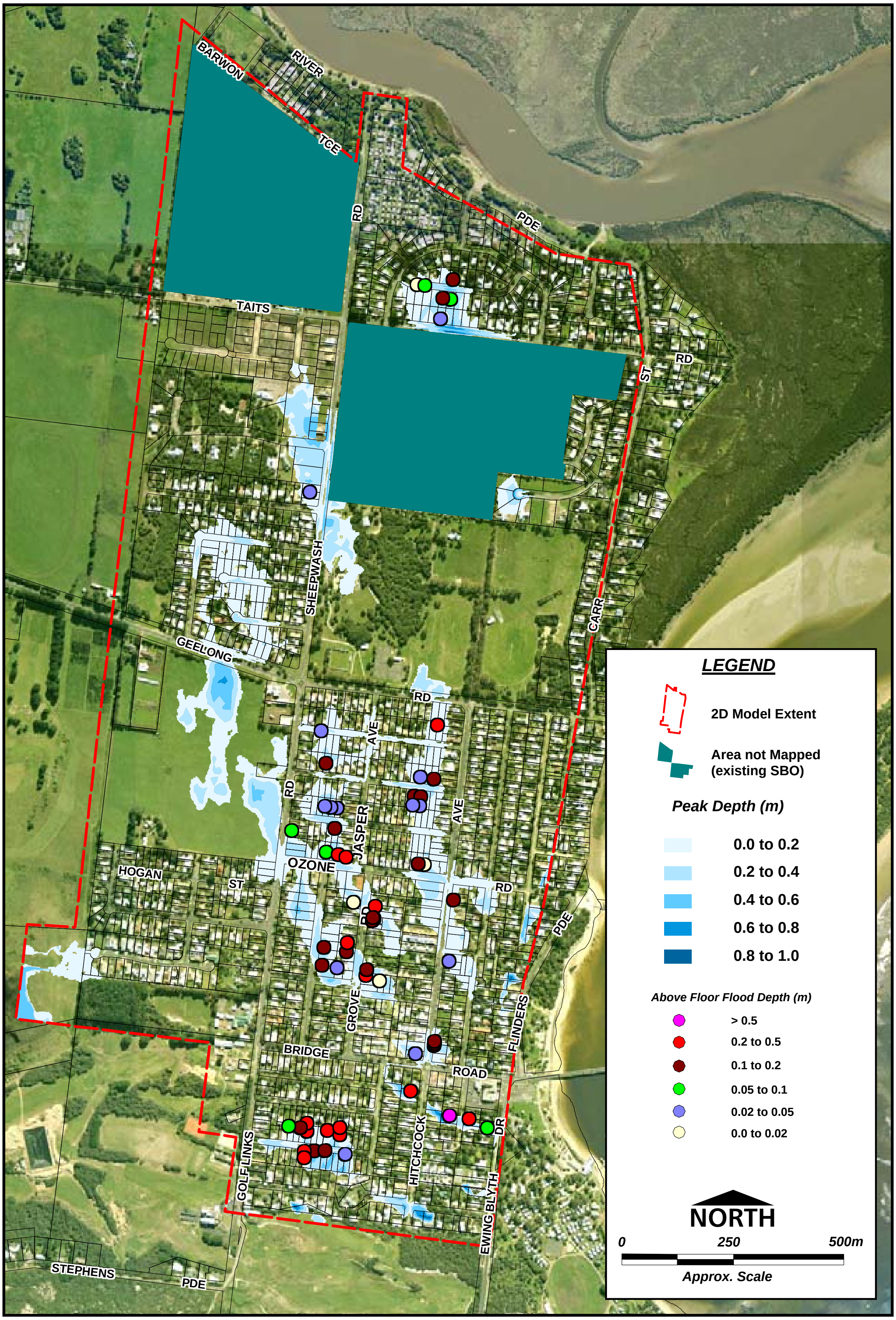
Existing 5 Year ARI Peak Flood Depth

Figure 5-1



Existing 20 Year ARI Peak Flood Depth

Figure 5-2



Existing 100 Year ARI Peak Flood Depth

Figure 5-3

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.

- Identify the areas inundated and the depth of inundation for the range of design flood events (5, 20 and 100 year ARI) modelled using the TUFLOW hydraulic model.
- Determine the damages due to a particular flood event using the assumed floor levels of properties that are flood-affected.
- Calculate the depth of flooding within each property for each ARI event.
- Prepare stage-damage relationships for residential and commercial properties. These relationships will account for such factors as the relative degree of flood preparedness of the community.
- Produce total flood damages for the range of flood events for both residential and commercial/industrial properties.
- Sum damages for all properties for each ARI event and present the results in a probability-damage graph.
- Assume indirect damages are 30% of direct damages as recommended in the RAM (Rapid Appraisal Method) report (NRE, 2000).
- Determine the average annual damages (AAD).

6.1.1 Stage-damage Curves

ANUFLOOD residential stage-damage curves were used for this flood damage assessment. These curves were sourced from NRE (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 curves have all been indexed to 2004 units using appropriate CPI factors sourced from Bureau of Statistics.

ANUFLOOD has 15 non-residential stage-damage curves. For each building size (small, medium and large), there are 5 curves representing 5 value classes. Because the existing building floor level information did not include data on the type, size or condition of each of the buildings considered, the size and condition of each residential buildings was assumed to be medium and average respectively.

The RAM report suggests that the ANUFLOOD curves underestimate flood damages. To address this issue, increases of 60% have been applied to both the residential and non-residential curves, as recommended in the RAM.

Ratios to convert Potential damages to Actual damages were used as per the recommendations from the RAM. That is, for a prepared community with less than 2 hours warning time, a factor (ratio) of 0.8 is used to reduce the potential damages to actual damages. Flood damages were calculated for the 5, 20, and 100 year ARI design flood events.

6.1.2 Outside Buildings

Damages to equipment outside the building are not included in the standard stage-damage curves used. Such damages may include damage to fences, driveways, lower level laundries and outdoor equipment. To account for this, an estimate of "ground equipment damages" was made as a function of ground level inundation. That is, assume a sliding scale from $0 to $1000 with $1000 being the maximum. The full $1000 damage is experienced once the flood level has reached the floor level of the building. The sliding scale works on the difference between the ground level and the floor level (eg a ground level of 1m, floor level of 2m, flood level of 1.5m receives ground equipment damages of $500).

Other damages, such as the loss of plants, lawn and landscaping, is difficult to quantify and is therefore considered in the non-economic assessment.

Ground damages for inundated properties without floor level information have been assumed equal to the average ground damages cost for properties where floor level surveys have occurred.

6.1.3 Damages Calculations

The peak depth of flooding was determined at each property for the 5, 20, and 100 year ARI events and the associated cost 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 very 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 floodplain 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 is included in the AAD analysis, and it is also necessary to assume a flood ARI in which no damages occur. As no flood larger than the 100 year ARI event was modelled, the probability-damages graph was extrapolated, and it was assumed that no damages would occur in the 2 year ARI event.

6.2 Existing Conditions Flood Damages

The total existing conditions damages for each design flood event are presented Table 6-1 and illustrated in Figure 6-1. The existing conditions AAD , also presented Table 6-1, is $221,000.

Table 6-1 Existing Conditions Case Damages Summary

Event		Existing Case			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF+	0.0%			$ 1,465,000	
100	1%	$ 1,020,000	$ 306,000	$ 1,326,000	$ 14,000
20	5%	$ 593,000	$ 178,000	$ 771,000	$ 42,000
5	20%	$ 365,000	$ 110,000	$ 475,000	$ 94,000
2	50%	$ -	$ -	$ -	$ 71,000
Average Annual Damage					**$ 221,000**

+Note – PMF damages are an extrapolation of the 100 year ARI data, ie, they were not calculated using PMF flood levels

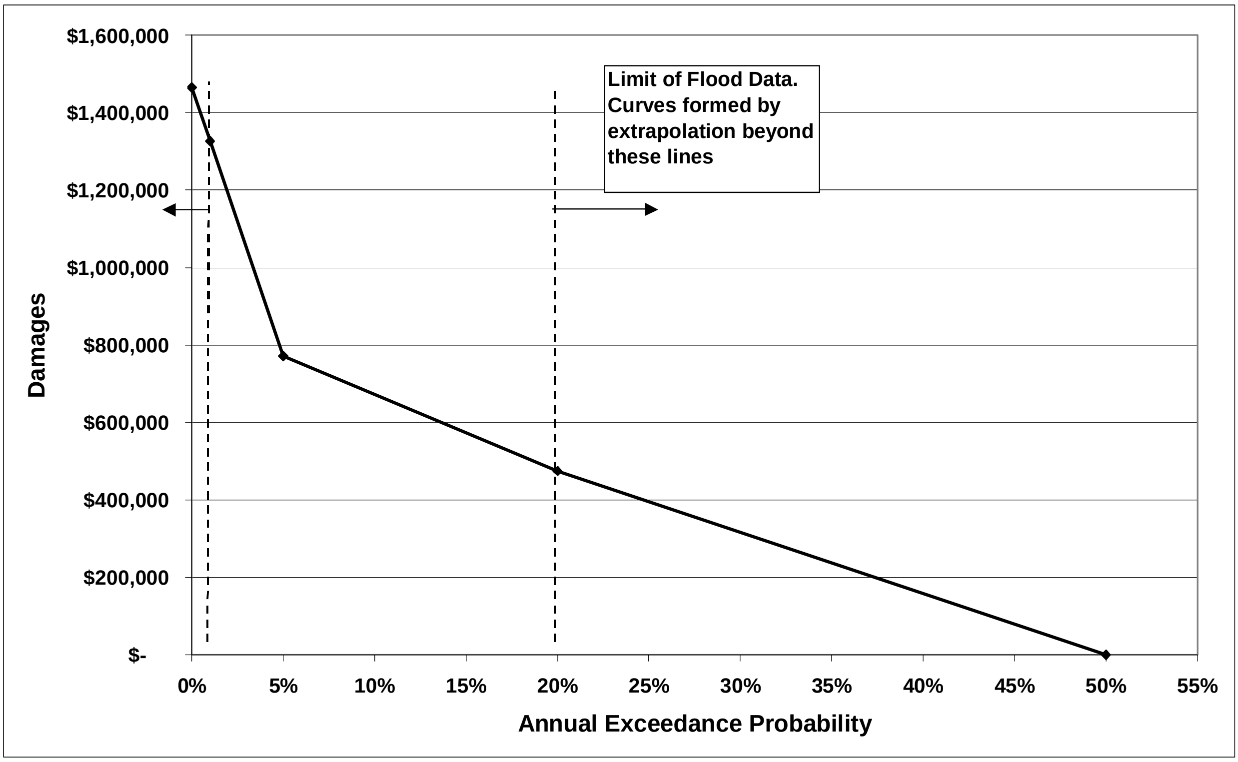


Figure 6-1 Existing Conditions Probability Damages Curve

7 MITIGATION SCHEMES ASSESSMENT

This section outlines and investigates Schemes designed to help alleviate existing flooding: a scheme is a combination of several mitigation options. This section provides details on the formulation and evaluation of each of the mitigation 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 at Barwon Heads, along with anecdotal evidence from historical flooding events, a number of key areas of concern have been determined. These areas are typically characterised by a large number of properties flooded above floor level and the relative damage figures caused by this type of flooding. These were identified from Figure 5-1 to Figure 5-3 and are summarised below:

- commercial precinct in the vicinity of the corner of Bridge Rd and Hitchcock Ave;
- in the vicinity of the Clifford Pde and Grove Rd intersection;
- to the north and south of Ozone Rd;
- in the vicinity of Heron Cr at the northern end of Barwon Heads; and
- George St at the southern end of Barwon Heads.

7.2 Mitigation Option Screening

All possible mitigation options were considered as part of the "first pass" assessment. Options such as levees, floodwalls and floodplain modification were not considered appropriate for the current study area. These predominantly rural structural measures are generally used on a large floodplain where exclusion of floodwaters is the key aim. 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	✓
		Pump Upgrades	Considered	✓
		Soakage Pits	Considered	✓
		Retarding Basin	Not feasible	✗
		Diversions	Considered	✓
		Floodways	Not Feasible	✗
		Open Drain	Limited opportunity	✗
		Channel Improvement	Not appropriate	✗
		Bund Walls / Levees	Not appropriate	✗
		Lot scale infiltration	Considered	✗
		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 Preliminary Assessment

7.3.1 Structural Options

The preliminary assessment of structural measures provided a mechanism for selecting or eliminating options for the detailed analysis. It involved a hydraulic assessment using TUFLOW and one design flood event. An economic analysis was not undertaken for the preliminary assessment.

The mitigation options for which a preliminary assessment was undertaken are listed in Table 7-2. Also listed in the table for each option is the flood benefit and whether it was recommended for detailed assessment.

An option considered, but not assessed following discussions with CoGG, was lot scale infiltration. The intent of this option was to direct flow from roofs into lot scale soakage pits or directly onto grass or gardens rather than draining the roof water onto the streets, which currently occurs at Barwon

Heads in many areas. An assessment was not undertaken because CoGG considered that the difficulties associated with retro-fitting properties would limit the applicability of the option and hence limit its success. In addition, the effectiveness of infiltration systems within low-lying parts of Barwon Heads has been limited.

Table 7-2 Preliminary Mitigation Options

Option ID	Details	Outcomes	Recommended for Detailed Assessment
A1	Duplicated Ozone Rd trunk drain pipes from Hitchcock Ave to outlet.	No significant flood benefit	×
A2	Duplicated Ozone Rd trunk drain pipes from Golflinks Rd to outlet.	No significant flood benefit	×
A3	Quadruple Ozone Rd trunk drain pipes from Golflinks Rd to outlet.	Flood benefit	✓
B1	Pump capacity of Clifford Pde pump station doubled and new ϕ 450mm gravity line along Ozone Rd to take pump discharge.	No significant flood benefit	×
B2	Same as B1, but new gravity line increased to ϕ 600mm.	No significant flood benefit	×
B3	Pump capacity of Clifford Pde pump station quadrupled and new ϕ 750mm gravity line along Ozone Rd to take pump discharge.	No significant flood benefit	×
B4	Same as B3, but added additional existing pipes to model to better represent flows to pump pit.	No significant flood benefit	×
B5	Pump capacity of Clifford Pde pump station increased to approximately 6 times existing (600 *l*/s), triplicate existing ϕ 315mm rising main from Clifford Pde pump, increase capacity of gravity feeder pipes, new ϕ 750mm gravity pipe along Ozone Rd from Grove Rd to River to take flow from Clifford Pde pump rising main, new 200 *l*/s pump station on Grove Rd to the south of Ozone Rd, disconnect pipe that drains northern end of Grove Rd to Clifford Pde pump.	Flood benefit	✓
B6	Tested a range of increases in Heron Cr pump capacity from approximately 2 to 6 times existing capacity, increase capacity of gravity feeder pipes. Preferred option is for an increase in capacity to 210 *l*/s.	Flood benefit	✓
C1	Divert Hogan St development flows from Ozone Rd trunk drain to vacant land to the north of Hogan St.	No significant flood benefit	×
D1	New 825 mm Pipe from corner of Hitchcock Ave and Bridge Rd north along Hitchcock Ave, then west along Clifford Pde into the Clifford Pde Pump Station.	Flood Benefit	✓

7.3.2 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 Barwon Heads where many of the flood affected properties can not be raised. This is due in part to many vulnerable houses being of slab-on-ground construction. Voluntary house purchase was included in one scheme.

Other non-structural measures are discussed in Section 8.2.

7.4 Detailed Assessment

The CoGG required that four mitigation Schemes be assessed, with one of the Schemes being "do nothing". A Scheme is a combination of individual mitigation options. The three Schemes that were assessed are summarised in Table 7-3 and in Figure 7-1 to Figure 7-3. One measure specified in each of the Schemes is the provision of infiltration pits with 5 year ARI capacity in George St. This measure was not analysed during the preliminary assessment phase, but is included in each of the Schemes to reduce above floor flooding in George St. The affect of the pits was simulated by reducing the inflows to the hydraulic model in sub-catchments 65 & 66 (refer Figure 4-1). The inflow hydrographs were adjusted by subtracting up to the peak 5 year ARI flow in these two sub-catchments. If the peak 5 year ARI flow exceeded the flow in the hydrograph at a particular time, the hydrograph was zeroed at that time.

In a separate investigation to this study, CoGG investigated upgrading the existing ϕ300 mm pipe along Bridge Rd to an ϕ825 mm pipe. However, COGG advised that this option was not to be included in the Schemes.

Hydraulic and economic assessments were undertaken for each Scheme.

Table 7-3 Mitigation Scheme Details

Scheme Number	Options used in Scheme (refer Table 7-2 for details of options)
1	B5, B6, D1 and George St infiltration pits to 5 year ARI capacity
2	A3, B5, B6, D1 and George St infiltration pits to 5 year ARI capacity
3	A3, B6, purchase of two houses in the vicinity of the Clifford Pde pump station and George St infiltration pits to 5 year ARI capacity
4	Do nothing

7.4.1 Hydraulic Assessment

The 5 year, 20 year and 100 year ARI design floods were assessed using the same five storm duration events used for the existing case. A peak flood height envelope was then developed for each flood event for each Scheme. 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 Scheme 4 as there were no changes from the existing conditions.

Peak flood height surfaces were used to calculate the number of properties flooded, which was then used in the flood damages assessment for each Scheme.

7.4.1.1 Scheme 1

The change in peak flood height and the properties with above floor flooding for Scheme 1 are mapped in Figure 7-4 to Figure 7-6 for the three flood events assessed. In these figures, no change in flood level within a ± 0.03 m tolerance is mapped as yellow, 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 used to occur 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.

The modelling indicates that the new pipe along Hitchcock Ave and Clifford Pde would eliminate flooding in the 5 year and 20 year ARI events at the intersection with Bridge Rd, and would reduce flood levels in the 100 year ARI event. However, there are only a small number of properties with above floor flooding that would significantly benefit from these works.

The significant increase in the capacity of Clifford Pde pump reduces flood levels in its vicinity, as would be expected, although it does not eliminate the flooding. The addition of the Grove Rd pump eliminates 5 year ARI flooding in its vicinity and reduces flood levels in larger events. The addition of this pump, in combination with the new gravity line to take the pump flows (rather than discharging into the existing Ozone Rd pipe), benefits a number of properties along Grove Rd and Ozone Rd.

The increased capacity of the Heron Cr pump reduces flood levels and benefits a number of properties in its vicinity.

The inclusion of the George St infiltration pit significantly reduces the flood levels in and around George St and benefits a number of properties in its vicinity.

The reductions in flooded grounds and above floor flooding that would occur if Scheme 1 is implemented are summarised in Table 7-4. The grounds of a property were considered flooded when the flood water extent reached the GIS marker for that property. The GIS property markers are shown in Figure 3-3.

Table 7-4 Reduction in Flooded Properties - Scheme 1

ARI (years)	No. Flooded Grounds		Reduction	No. Flooded Floors		Reduction
	Existing	Scheme 1		Existing	Scheme 1	
100	219	181	*38*	61	35	*26*
20	158	110	*48*	37	16	*21*
5	106	67	*39*	23	10	*13*

7.4.1.2 Scheme 2

The change in peak flood height and the properties with above floor flooding for Scheme 2 are mapped in Figure 7-7 to Figure 7-9 for the three flood events assessed. This Scheme is similar to Scheme 1 except that the existing trunk drainage pipe along Ozone Rd was quadrupled. A comparison between the Scheme 1 and Scheme 2 figures shows that the upgrade of the Ozone Rd pipe did not provide a significant improvement over Scheme 1.

The Scheme is the same as Scheme 1 in the George St, Hitchcock Ave, Bridge Rd and Heron Cr areas, and hence, the benefits are the same in both Schemes in these areas.

The reductions in flooded grounds and above floor flooding that would occur if Scheme 2 is implemented are summarised in Figure 7-5. This data indicates that Scheme 2 provides a small improvement over Scheme 1.

Table 7-5 Reduction in Flooded Properties - Scheme 2

ARI (years)	No. Flooded Grounds		Reduction	No. Flooded Floors		Reduction
	Existing	Scheme 2		Existing	Scheme 2	
100	219	175	*44*	61	31	*30*
20	158	108	*50*	37	15	*22*
5	106	72	*34*	23	10	*13*

7.4.1.3 Scheme 3

The change in peak flood height and the properties with above floor flooding for Scheme 3 are mapped in Figure 7-10 to Figure 7-12 for the three flood events assessed. The Scheme is the same as Scheme 1 in the George St and Heron Cr areas, and hence, the benefits are the same in both Schemes in these areas. Elsewhere, the only drainage upgrade over the existing case is to the existing trunk drainage pipe along Ozone Rd, which was quadrupled. This pipe provides minor improvements along Ozone Rd.

The reductions in flooded grounds and above floor flooding that would occur if Scheme 3 is implemented are summarised in Figure 7-5. As expected, this data indicates that Scheme 3 provides smaller flood benefits than the other two Schemes.

Table 7-6 Reduction in Flooded Properties – Scheme 3

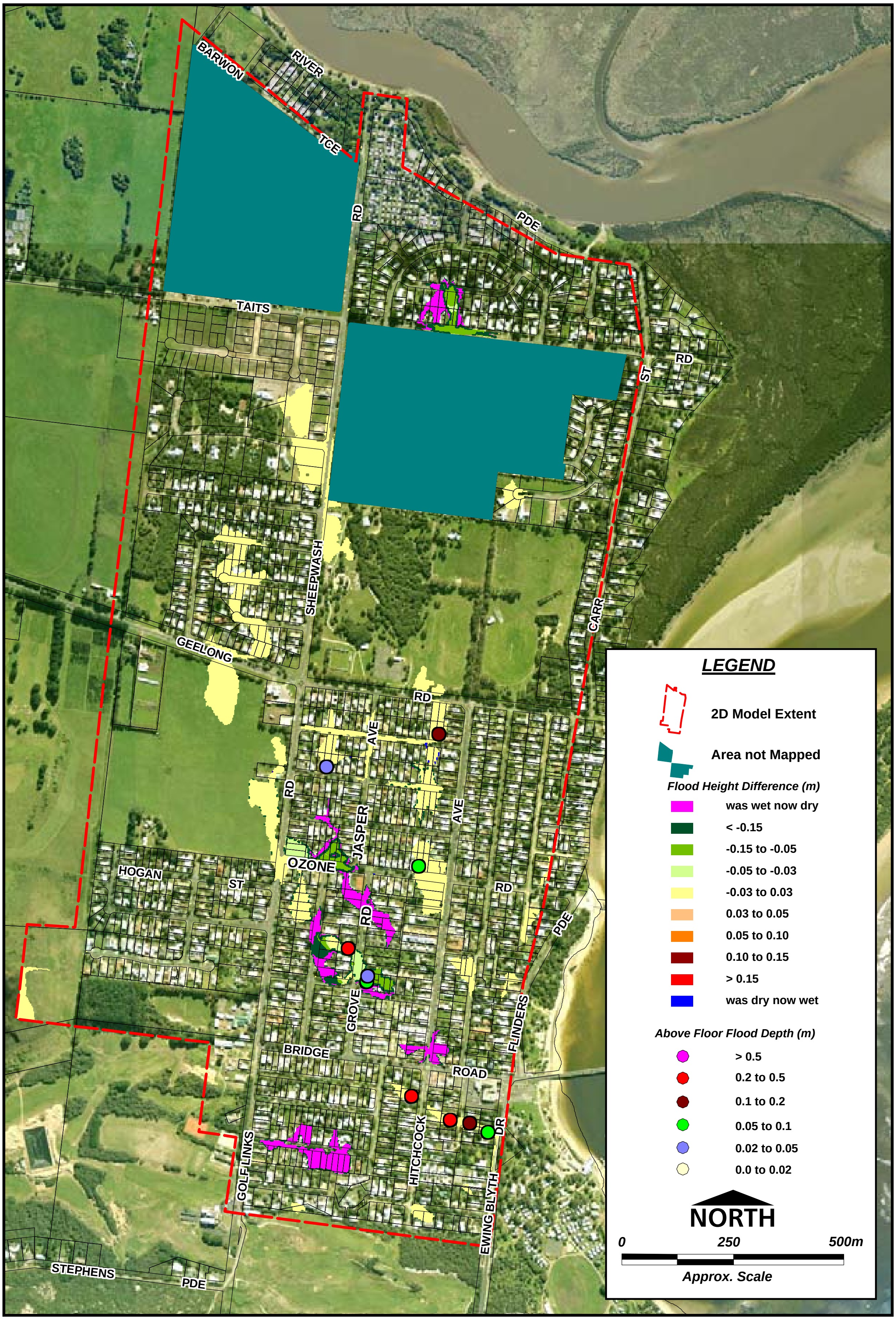
ARI (years)	No. Flooded Grounds		Reduction	No. Flooded Floors		Reduction
	Existing	Scheme 3		Existing	Scheme 3	
100	219	192	*27*	61	38	*23*
20	158	129	*29*	37	21	*16*
5	106	99	*7*	23	16	*7*

Scheme 1 Drainage Works **Figure 7-1**

Scheme 2 Drainage Works

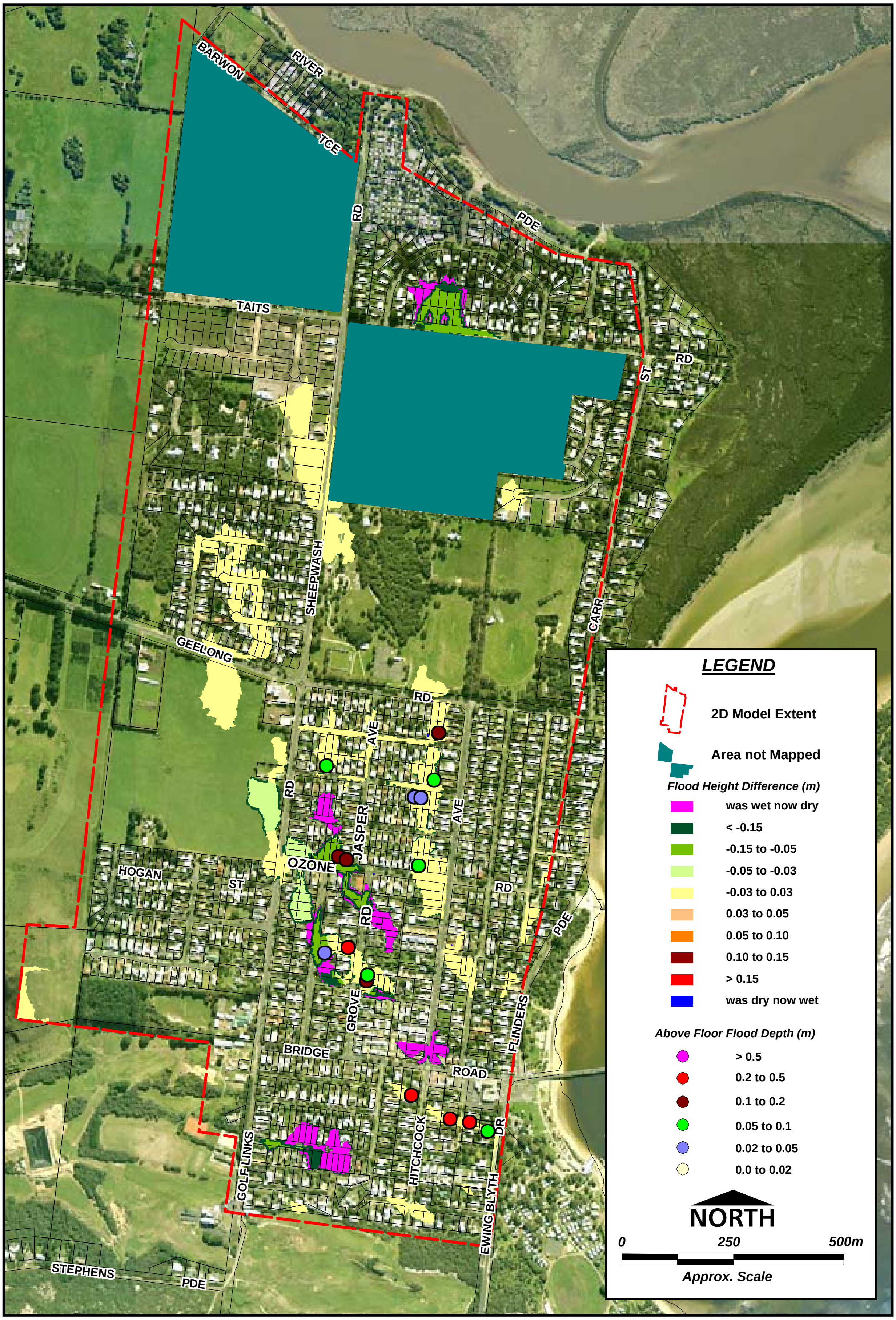
Figure 7-2

Scheme 3 Drainage Works **Figure 7-3**



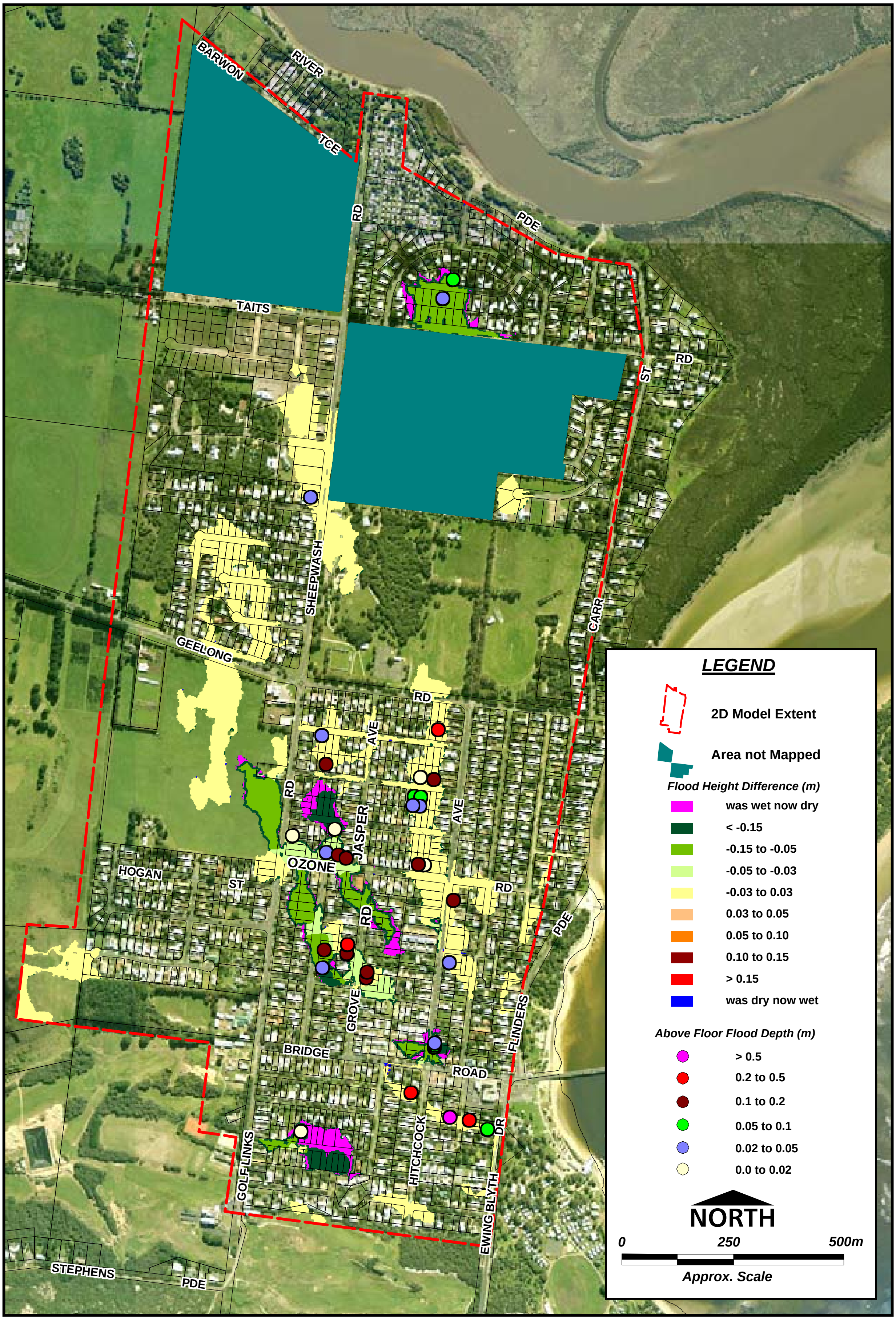
Change in 5 Year ARI Peak Flood Height - Scheme 1

Figure7-4



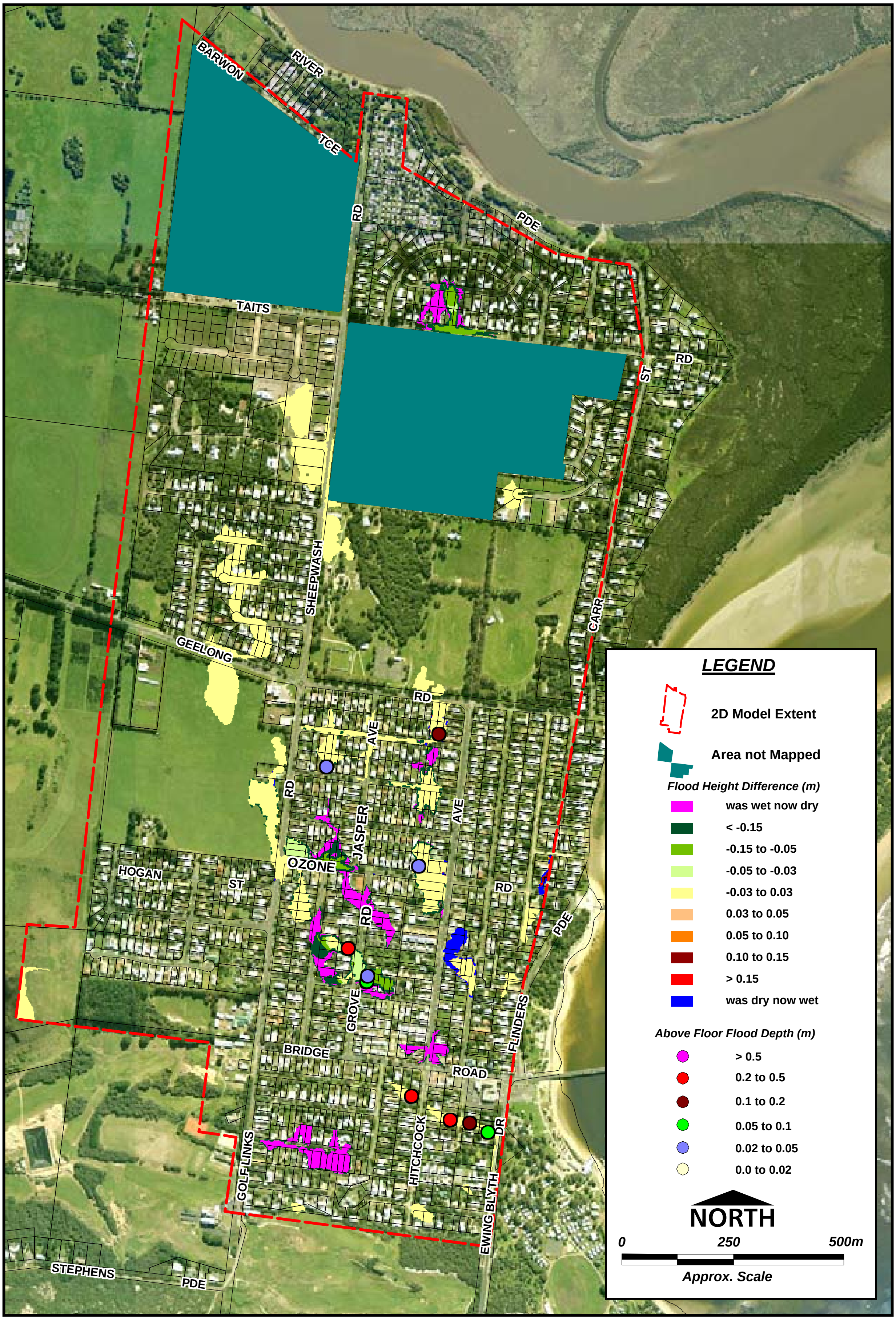
Change in 20 Year ARI Peak Flood Height - Scheme 1

Figure 7-5



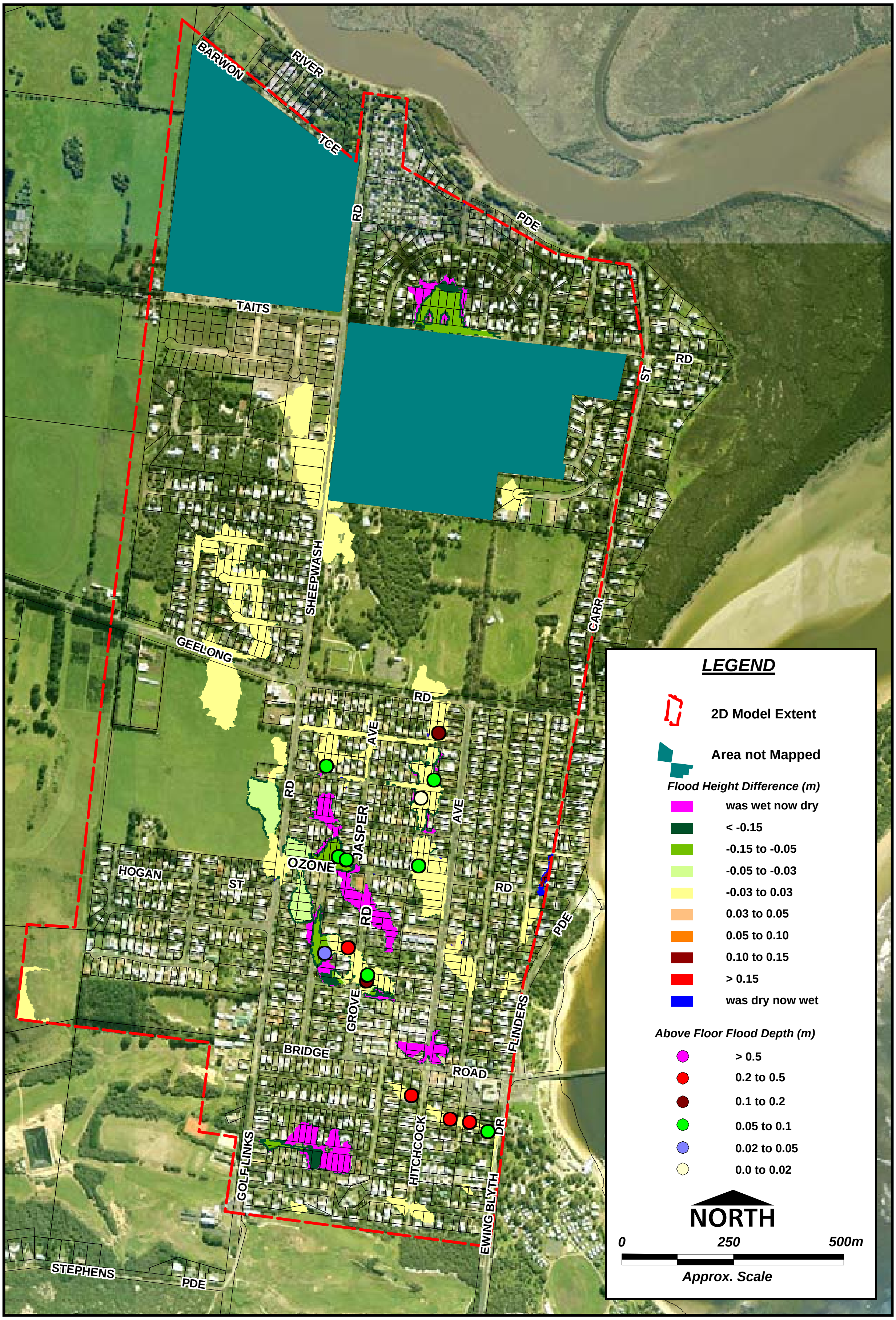
Change in 100 Year ARI Peak Flood Height - Scheme 1

Figure 7-6



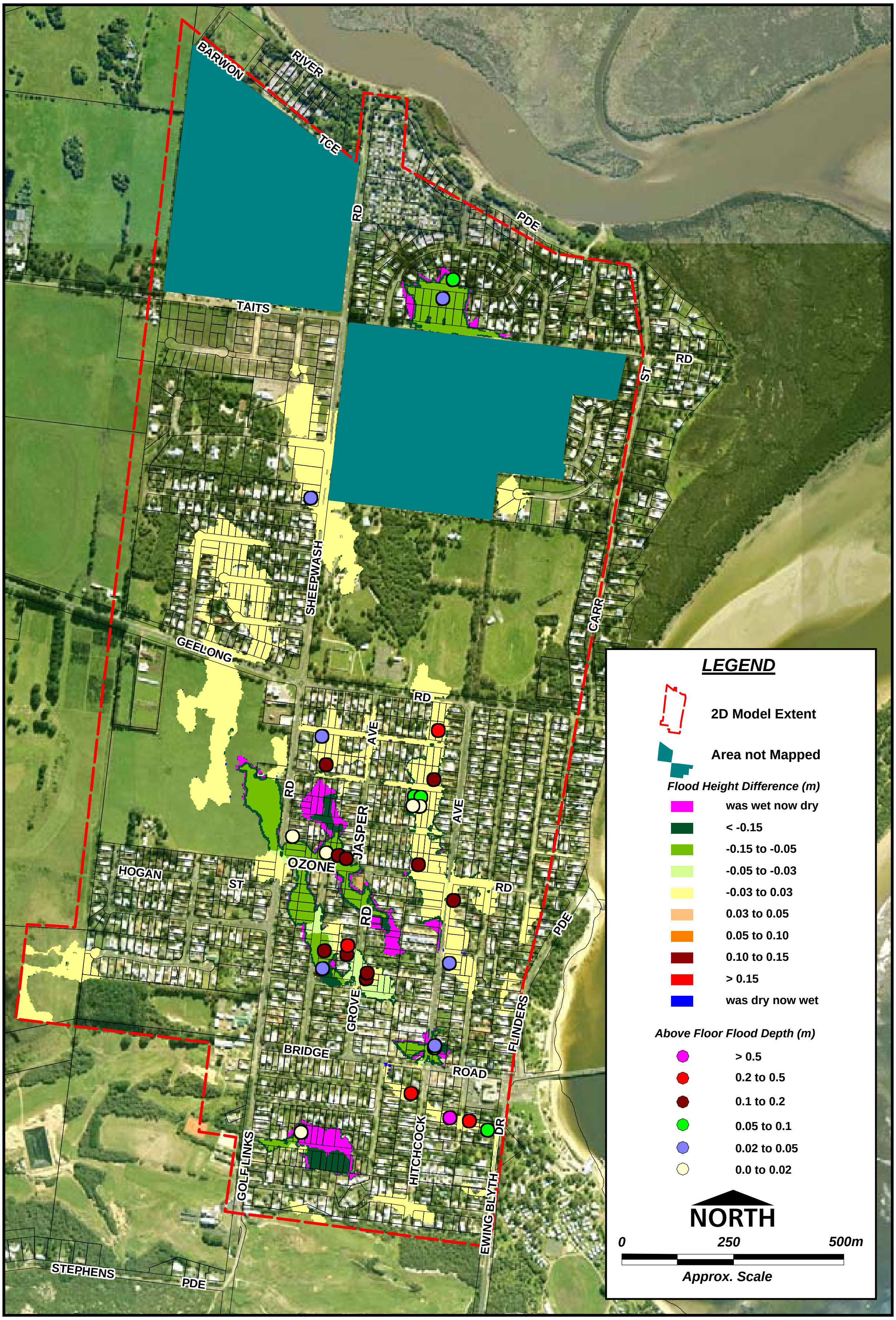
Change in 5 Year ARI Peak Flood Level Scheme 2

Figure 7-7



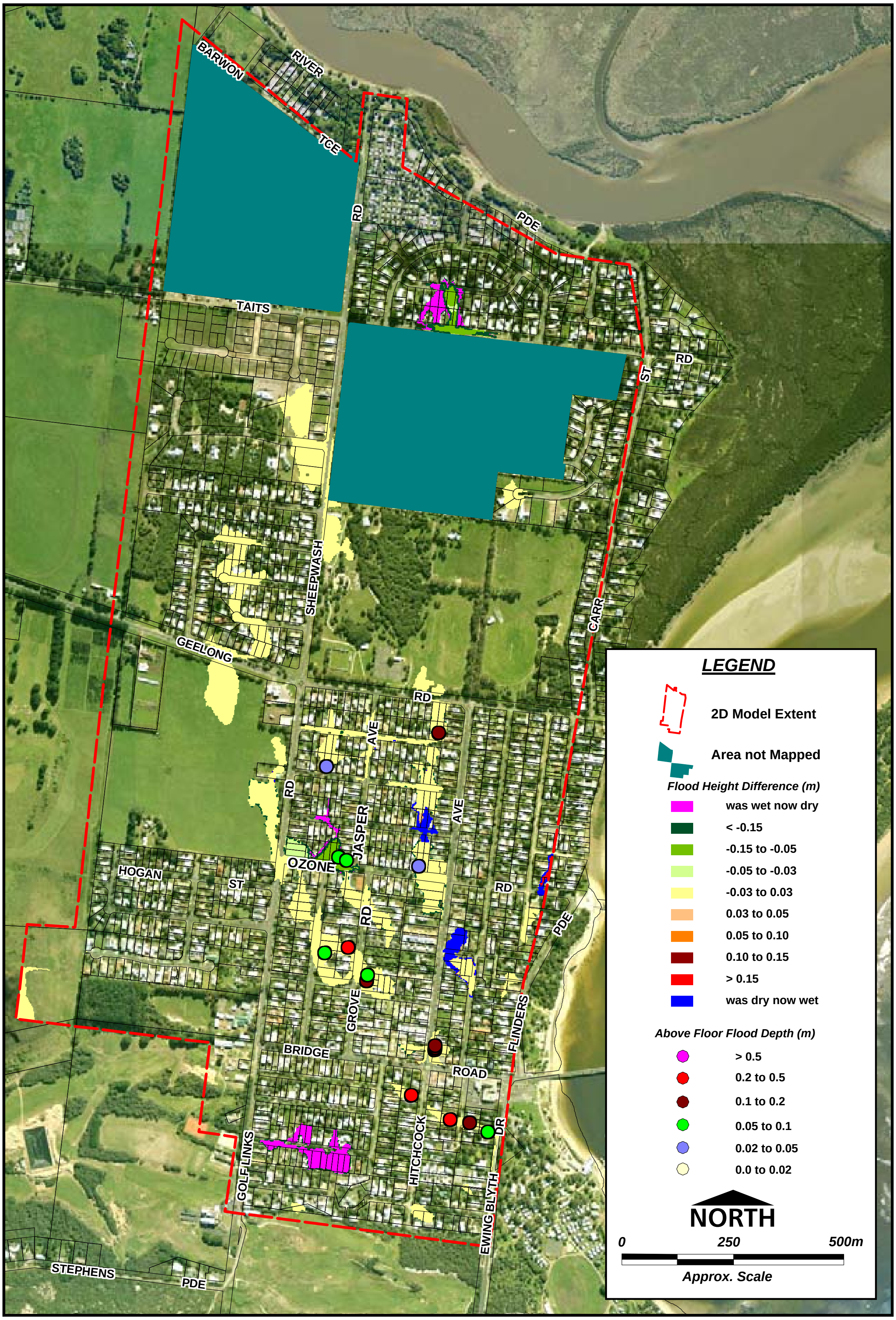
Change in 20 Year ARI Peak Flood Level
Scheme 2

Figure 7-8



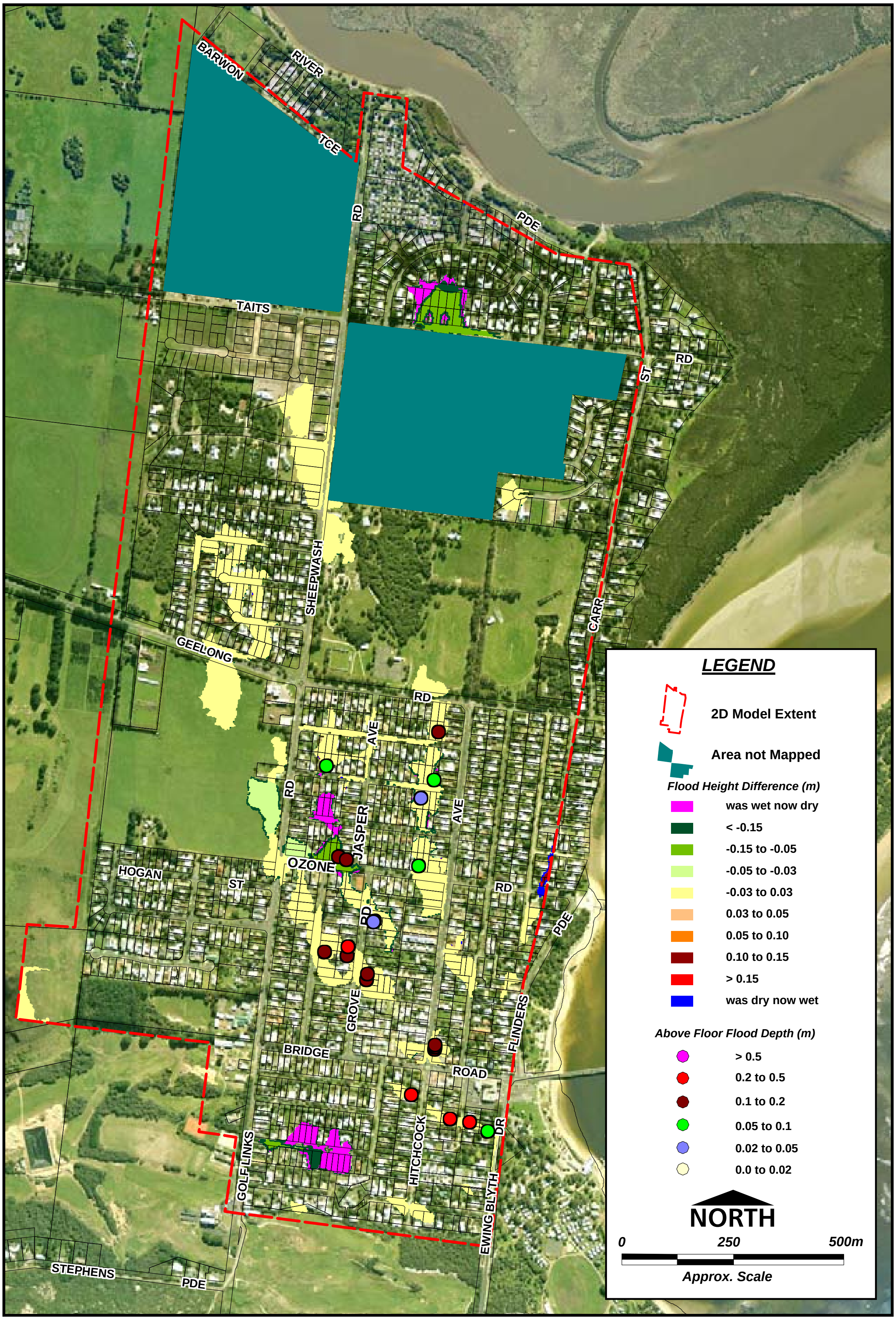
Change in 100 Year Peak Flood Level
Scheme 2

Figure 7-9



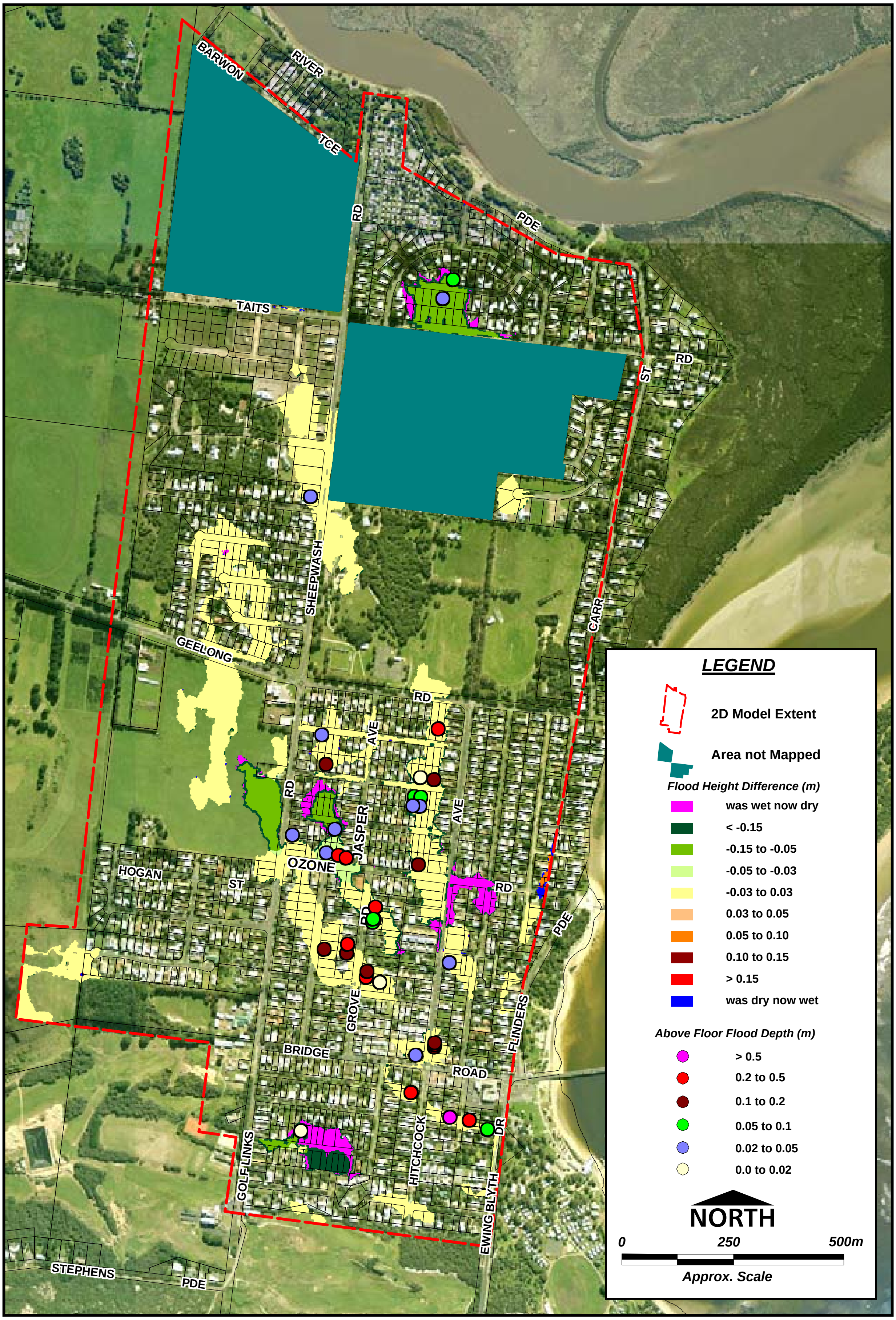
Change in 5 Year ARI Peak Flood Level
Scheme 3

Figure 7-10



Change in 20 Year ARI Peak Flood Level Scheme 3

Figure 7-11



Change in 100 Year ARI Peak Flood Level
Scheme 3

Figure 7-12

7.4.2 Economic Assessment

7.4.2.1 Basis of Assessment

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

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

It is important to note that flood management measures 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 measure.

The overall financial viability of an option 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 measure 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 measure.

In order to calculate the BCR, the annual financial benefits (the change in average annual damages) of a measure needs to be converted to a total benefit over a period of time. This is due to the difficulty in comparing a "lump sum" cost with an "annual" benefit.

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 (ie. 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 7-7 shows the present value of the annual benefit realised at different times over a 50 year period.

Table 7-7 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.

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

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

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

1. Calculate the **average annual benefit** associated with the option (i.e. the reduction in average annual damages) using the method described in Section 6.1.3;
2. Convert the **average annual benefit** to a **total benefit** by multiplying by the **present value factor**;
3. Calculate the **total cost** of the option.

4. 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 retro-fitting additional pumps;
- difficulties associated with upgrading pipes under existing roads;
- difficulties associated with trenching in sand; and
- construction, maintenance and operation costs.

Data from Melbourne Water guidelines and pipe, pump and valve suppliers were used to estimate the total cost of each option. These rates are summarised in Appendix B. The rates for stormwater pipes and rising mains were factored by 1.5 for sections constructed alongside or under minor roads, and by 2.0 for major roads or through developed property. Stormwater pipes were costed on the basis of flush jointed construction with 100% fine crushed rock backfill.

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. WBM have adopted the recommended value of 2.4%. One exception to this general approach was pump maintenance costs for which the cost estimates provided by the supplier were adopted. These costs included replacing the pump every 15 years.

Scheme 3 includes the purchase of two properties. Data on house sales in Barwon Heads for the last 18 months was obtained from www.propertyvalue.com.au. This data included the sale price and an estimate of the September 2004 value of the property. The September 2004 data was used to calculate a median house value for Barwon Heads of $360,000.

7.4.2.2 Scheme 1

The damages under Scheme 1 for each design flood event are summarised in Table 7-9 and illustrated in Figure 7-13. The Scheme 1 AAD , also presented in Table 7-9, is $106,000, which is a reduction of $115,000 from the existing conditions AAD of $221,000. In calculating the AAD, the damages in the PMF were assumed to be the same as the existing case.

A summary of the capital costs for Scheme 1 is presented in Table 7-9 and the benefit cost analysis is summarised in Table 7-10. The BCR for Scheme 1 is 0.48.

Table 7-8 Scheme 1 Damages Summary

Event		Scheme 1			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF[+]	0.0%			$ 1,465,000	
100	1%	$ 523,000	$ 157,000	$ 680,000	$ 11,000
20	5%	$ 272,000	$ 81,000	$ 353,000	$ 21,000
5	20%	$ 164,000	$ 49,000	$ 213,000	$ 42,000
2	50%	$ -	$ -	$ -	$ 32,000
Average Annual Damage					**$ 106,000**

[+]**Note – PMF damages are an extrapolation of the 100 year ARI data, ie, they were not calculated using PMF flood levels**

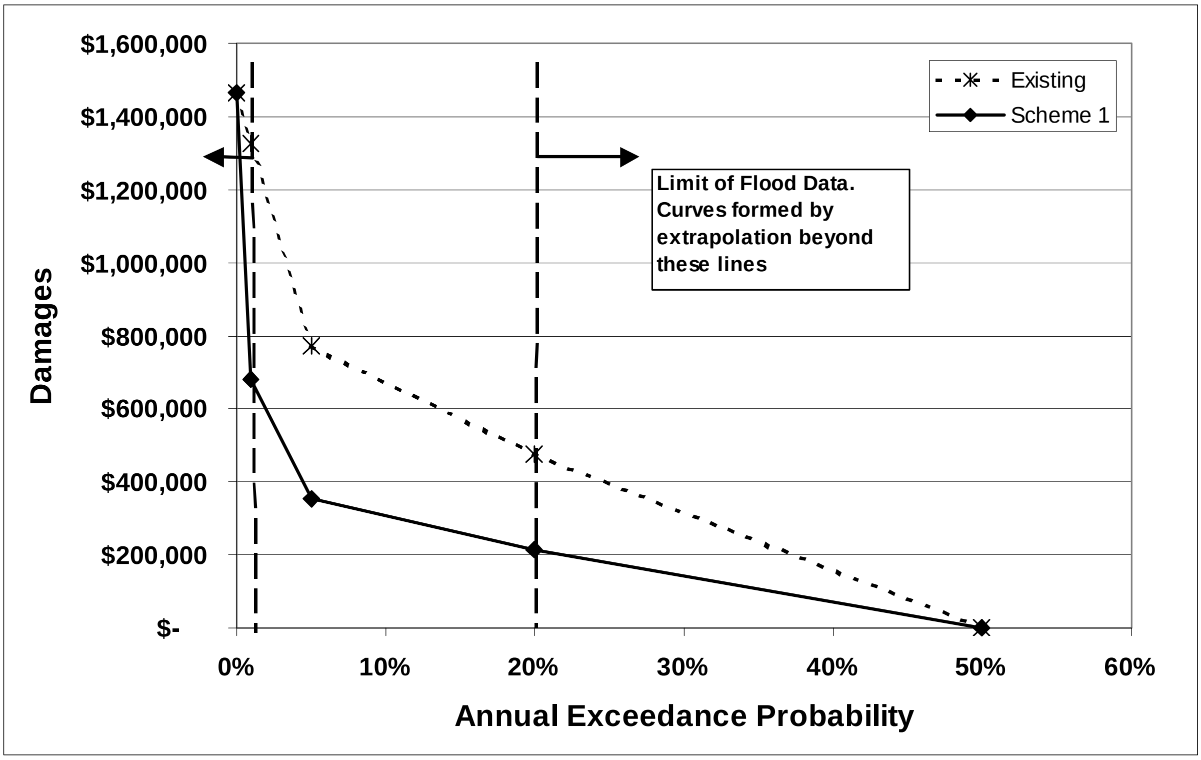


Figure 7-13 Scheme 1 Probability Damages Curve

Table 7-9 Scheme 1 Capital Costs

Item	Capital Cost
Pipe/Culvert Upgrades	$602,000
Tideflex Valve (Ozone)	$20,000
Ozone Outfall Works	$25,000
GPT Upgrade/Installation	$125,000
George St Infiltration Pits	$60,000
Pumps & Associated Works	
Clifford Pde	$326,000
Grove Rd	$149,000
Heron Cr	$157,000
Contingencies (30%)	$439,000
Engineering (15%)	$220,000
Total	**$2,123,000**

Table 7-10 Scheme 1 BCR Summary

	Existing	Scheme 1
Damages (PA)	$221,000	$ 106,000
Benefit (PA)		$ 115,000
Benefit (NPV)		$ 1,427,000
Capital Cost		$ 2,122,000
Maintenance (PA)*		$ 51,000
Maintenance (NPV)*		$ 853,000
Total Option Cost		$ 2,975,000
BCR		**0.48**

***Pump maintenance costs are included in the net present value (NPV) item, but not the per annum (PA) item because the maintenance cost basis was not yearly for the pumps.**

7.4.2.3 Scheme 2

The damages under Scheme 2 for each design flood event are summarised in Table 7-11 and illustrated in Figure 7-14. The Scheme 2 AAD , also presented in Table 7-11, is $102,000, which is a reduction of $119,000 from the existing conditions AAD of $221,000. In calculating the AAD, the damages in the PMF were assumed to be the same as for the existing case.

A summary of the capital costs for Scheme 2 is presented in Table 7-12 and the benefit cost analysis is summarised in Table 7-13. The BCR for Scheme 2 is 0.26. Although Scheme 2 provides slightly greater reduction in the AAD than Scheme 1, its BCR is lower than Scheme 1 because of its higher capital and maintenance costs.

Table 7-11 Scheme 2 Damages Summary

Event		Scheme 2			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF+	0.0%			$ 1,465,000	
100	1%	$ 479,000	$ 144,000	$ 623,000	$ 10,000
20	5%	$ 256,000	$ 77,000	$ 333,000	$ 19,000
5	20%	$ 164,000	$ 49,000	$ 213,000	$ 41,000
2	50%	$ -	$ -	$ -	$ 32,000
Average Annual Damage					**$ 102,000**

+Note – PMF damages are an extrapolation of the 100 year ARI data, ie, they were not calculated using PMF flood levels

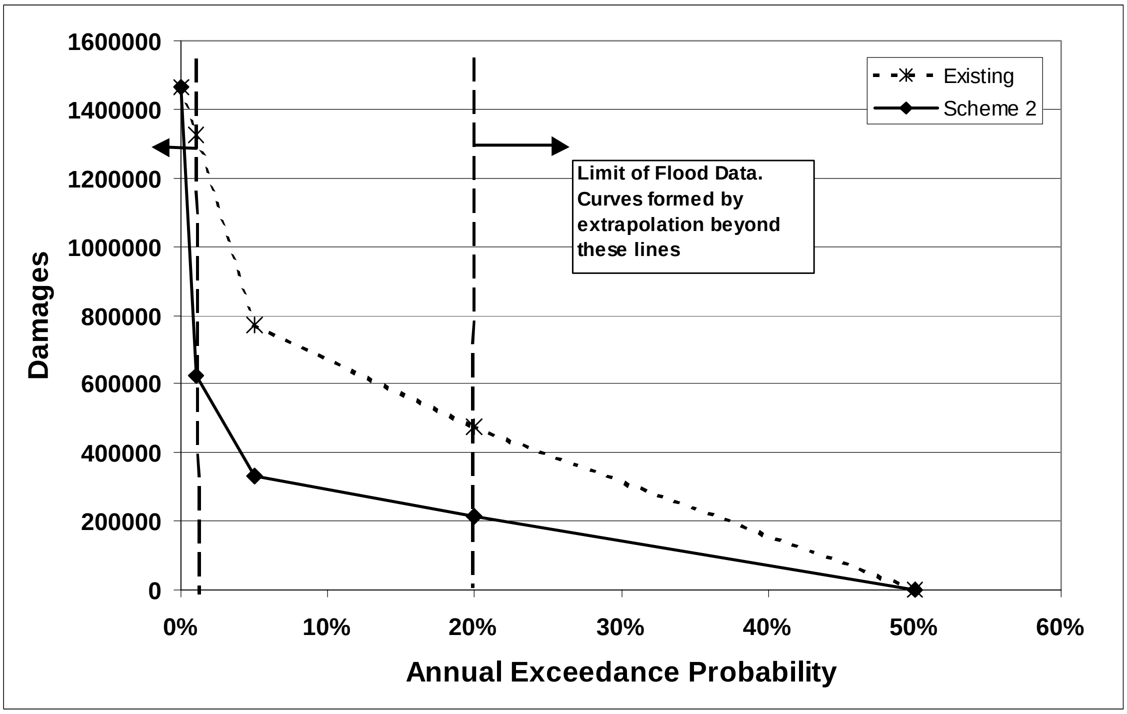


Figure 7-14 Scheme 2 Probability Damages Curve

Table 7-12 Scheme 2 Capital Costs

Item	Capital Cost
Pipe/Culvert Upgrades	$1,816,000
Tideflex Valve (Ozone)	$199,000
Ozone Outfall Works	$75,000
GPT Upgrade/Installation	$125,000
George St Infiltration Pits	$60,000
Pumps & Associated Works	
Clifford Pde	$326,000
Grove Rd	$149,000
Heron Cr	$157,000
Contingencies (30%)	$872,000
Engineering (15%)	$567,000
Total	**$4,346,000**

Table 7-13 Scheme 2 BCR Summary

	Existing	Scheme 2
Damages (PA)	$221,000	$ 102,000
Benefit (PA)		$ 119,000
Benefit (NPV)		$ 1,477,000
Capital Cost		$ 4,345,000
Maintenance (PA)*		$ 104,000
Maintenance (NPV)*		$ 1,387,000
Total Option Cost		$ 5,732,000
BCR		**0.26**

***Pump maintenance costs are included in the net present value (NPV) item, but not the per annum (PA) item because the maintenance cost basis was not yearly for the pumps.**

7.4.2.4 Scheme 3

The damages under Scheme 3 for each design flood event are summarised in Table 7-14 and illustrated in Figure 7-15. The Scheme 3 AAD , also presented in Table 7-11, is $153,000, which is a reduction of $68,000 from the existing conditions AAD of $221,000. In calculating the AAD, the damages in the PMF were assumed to be the same as the existing case.

A summary of the capital costs for Scheme 3 is presented in Table 7-15 and the benefit cost analysis is summarised in Table 7-16. The BCR for Scheme 3 is 0.18, which is the lowest of the three Schemes investigated.

Table 7-14 Scheme 3 Damages Summary

Event		Scheme 3			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF+	0.0%			$ 1,465,000	
100	1%	$ 634,000	$ 190,000	$ 823,000	$ 9,000
20	5%	$ 374,000	$ 112,000	$ 486,000	$ 26,000
5	20%	$ 280,000	$ 84,000	$ 364,000	$ 63,000
2	50%	$ -	$ -	$ -	$ 55,000
Average Annual Damage					**$ 153,000**

+Note – PMF damages are an extrapolation of the 100 year ARI data, ie, they were not calculated using PMF flood levels

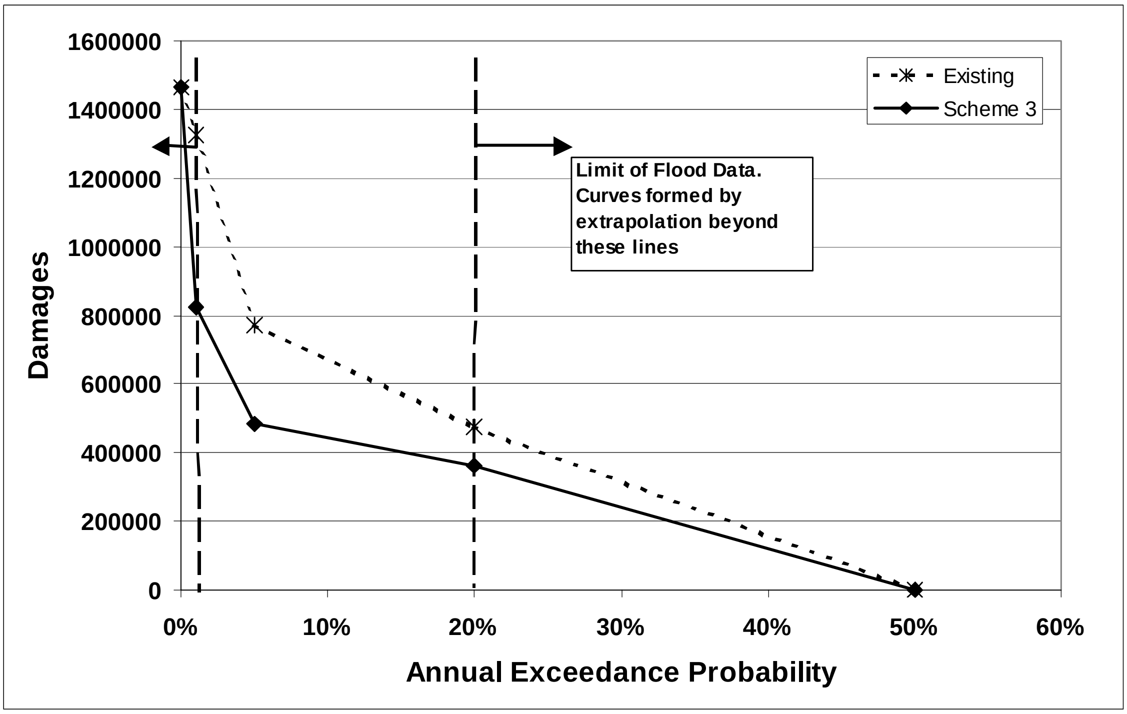


Figure 7-15 Scheme 3 Probability Damages Curve

Table 7-15 Scheme 3 Capital Costs

Item	Capital Cost
Pipe/Culvert Upgrades	$1,282,000
Tideflex Valve (Ozone)	$ 180,000
Ozone Outfall Works	$ 50,000
George St Infiltration Pits	$ 60,000
House Purchase	$ 720,000
Pumps & Associated Works	
Heron Cr	$ 157,000
Contingencies (30%)	$ 734,000
Engineering (15%)	$ 477,000
Total	**$3,660,000**

Table 7-16 Scheme 3 BCR Summary

	Existing	Scheme 3
Damages (PA)	$221,000	$ 153,000
Benefit (PA)		$ 68,000
Benefit (NPV)		$ 844,000
Capital Cost		$ 3,660,000
Maintenance (PA)*		$ 88,000
Maintenance (NPV)*		$ 1,124,000
Total Option Cost		$ 4,784,000
BCR		**0.18**

***Pump maintenance costs are included in the net present value (NPV) item, but not the per annum (PA) item because the maintenance cost basis was not yearly for the pumps.**

7.4.3 Environmental Impacts

Environmental impacts, associated with the construction and operation of each flood mitigation option, are discussed in this section.

Table 7-17 details each option, including the “do nothing” approach, and presents details regarding the impacts on all aspects of the environment in the area. The “do nothing” approach would have less impact than any of the other measures investigated, as it does not change the catchment characteristics.

It is not anticipated that any of the Schemes will have long-term environmental impacts. Schemes 1 to 3 will slightly decrease the quantity of stormwater infiltrating to the groundwater because there will be less water ponded in the catchment. This will result in a small increase in the quantity of stormwater directly entering the Barwon River. Given that the Barwon River is well flushed, it is not expected that this will have a significant ecological impact. A preliminary ecological assessment may be warranted to confirm this assumption.

7.4.4 Social, Feasibility and Performance Indicators

Table 7-18 and Table 7-19 outline the social, feasibility and performance implications related to each flood mitigation Scheme. A key issue noted in these tables is the community's perception of the impacts of the upgrade of the outfalls on the aesthetic and recreational values of the beaches.

Table 7-17 Environmental Implications

ISSUE	FLOOD MITIGATION SCHEME			
	Scheme 1	Scheme 2	Scheme 3	Scheme 4 "Do Nothing" (Existing Case)
Ecological impact.	Minimal impact. Upgrade to Ozone Rd outfall may cause minor disturbance of beach during construction. Long term small increase in stormwater discharge to river. Similar comment applies to Heron Cr pump outfall. River is well flushed, so impacts should be minimal, but an ecological review may be required.	Minimal impact, but greater than Scheme 1. Upgrade to Ozone Rd outfall may cause minor disturbance of beach during construction. Long term small increase in stormwater discharge to river. Similar comment applies to Heron Cr pump outfall. River is well flushed, so impacts should be minimal, but an ecological review may be required.	Minimal impact, but less than Scheme 1 & 2. Upgrade to Ozone Rd outfall may cause minor disturbance of beach during construction. Long term small increase in stormwater discharge to river. Similar comment applies to Heron Cr pump outfall. River is well flushed, so impacts should be minimal, but an ecological review may be required.	No Change.
Noise.	Limited noise impacts. Some noise associated with construction of new pipes and pumps. Some increase in noise during rainfall events due to additional pumps.	Limited noise impacts. Some noise associated with construction of new pipes and pumps. Some increase in noise during rainfall events due to additional pumps.	Limited noise impacts. Some noise associated with construction of new pipes and pumps, although less than Schemes 1 & 2 because of fewer pipe upgrades. Some increase in noise during rainfall events due to additional pumps, although less than Scheme 1& 2 because fewer pumps.	No Change.
Receiving Water Quality.	Minor impact. Erosion in construction phase increase in stormwater discharge to River. Manage via construction management plan. Receiving water is well flushed, so impacts should be minimal, but an ecological review may be required.	Minor impact, but greater than Scheme 1. Erosion in construction phase increase in stormwater discharge to River. Manage via construction management plan. Receiving water is well flushed, so impacts should be minimal, but an ecological review may be required.	Minor impact, but less than Scheme 1 & 2. Erosion in construction phase increase in stormwater discharge to River. Manage via construction management plan. Receiving water is well flushed, so impacts should be minimal, but an ecological review may be required.	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.

Table 7-18 Social Indicators

ISSUE	FLOOD MITIGATION SCHEME			
	Scheme 1	Scheme 2	Scheme 3	Scheme 4 "Do Nothing" (Existing Case)
Recreation and aesthetic.	Low impact. Community may be concerned about the aesthetics of upgraded outfalls. Upgraded outfall should not significantly impact on recreational aspects of beaches because there are existing outfalls.	Low impact. Community may be concerned about the aesthetics of upgraded outfalls. Upgraded outfall should not significantly impact on recreational aspects of beaches because there are existing outfalls.	Low impact. Community may be concerned about the aesthetics of upgraded outfalls – concerns would be less than Schemes 1& 2 because Ozone Rd not being upgraded. Upgraded outfall should not significantly impact on recreational aspects of beaches because there are existing outfalls. Land purchased could be used for new park.	No Change.
Cultural Heritage.	Not known	Not known	Not known	No Change.
Public Safety.	Would be minimal in the local streets being constructed in. Manage risk with appropriate traffic management.	Would be minimal in the local streets being constructed in. Manage risk with appropriate traffic management.	Would be minimal in the local streets being constructed in. Manage risk with appropriate traffic management.	No Change.

Table 7-19 Feasibility and Performance Indicators

ISSUE	FLOOD MITIGATION SCHEMES			
	Scheme 1	Scheme 2	Scheme 3	Scheme 4 "Do Nothing" (Existing Case)
Maintenance costs.	Upgraded pumps and new pump will increase maintenance costs over existing conditions. Increases associated with new pipes.	Upgraded pumps and new pump will increase maintenance costs over existing conditions. Increases associated with new pipes.	Upgraded pump will increase maintenance costs over existing conditions, although less than Schemes 1 & 2. Additional maintenance costs if purchased land is converted to a park.	Maintenance regime of existing pumps should be reviewed given history of failures.
Constructability.	Difficulties will include construction in sand of new/upgraded pipes, construction along existing roads and duplicated Heron Cr rising main through residential areas.	Difficulties will include construction in sand of new/upgraded pipes, construction along existing roads and duplicated Heron Cr rising main through residential areas.	Difficulties will include construction in sand of new/upgraded pipes, construction along existing roads and duplicated Heron Cr rising main through residential areas.	Not applicable.
Funding and feasibility.	Reasonable probability of attracting funding.	Very low probability of attracting funding.	Very low probability of attracting funding.	Not applicable.
Public acceptability.	May be some issues relating to disruptions during construction and upgrade of beach outfalls.	May be some issues relating to disruptions during construction and upgrade of beach outfalls.	May be some issues relating to disruptions during construction and upgrade of beach outfalls..	Issues relating to Council being seen to be doing nothing about the problem.

8 PREFERRED MITIGATION STRATEGY

8.1 Description of Preferred Scheme

Scheme 1 has been selected in consultation with CoGG officers as the preferred option for flood mitigation. It involves the following structural measures:

- upgrade of Clifford Pde pump station to 600 *l*/s along with upgrades to gravity feeder pipes and rising main;
- new ϕ 750mm gravity pipe along Ozone Rd from Grove Rd to Barwon River to take flow from Clifford Pde pump rising main;
- new 200 *l*/s pump station on Grove Rd;
- disconnect existing gravity stormwater pipe that drains northern end of Grove Rd to Clifford Pde pump station;
- upgrade Heron Cr pump station to 210 *l*/s with upgrade to gravity feeder pipes and rising main;
- new ϕ825 mm stormwater pipe from corner Hitchcock Ave and Bridge to Clifford Pde pump station; and
- infiltration pits with 5 year ARI capacity in George St.

The above measures are also shown schematically in Figure 7-1. Additional non-structural components are recommended in Section 8.2.

8.2 Non-Structural Components

In addition to the structural works associated with Scheme 1, a number of additional recommendations are made in regard to the protection of individual buildings and property not provided with flood immunity by the preferred strategy. The following section outlines some of the additional components that have been recommended for use in conjunction with Scheme 1.

8.2.1 Individual Floodproofing

Floodproofing individual, or groups of properties, may be an option for some areas of Barwon Heads. Where floodwaters are relatively shallow, the landowners could prevent floodwaters entering buildings thereby reducing damage, by adopting a number of flood exclusion techniques. Techniques such as the use of exterior sealants, floodwalls, floodgates and flood closures and panels (lift out and removable) can all provide sound flood protection. An education and awareness program (Section 8.2.2) would need to be developed to demonstrate the likely flood depths on any property and to show the benefit that floodproofing would bring to the individual property owner. The related property-specific measure of property buy-back with on-sell following modifications (where feasible) may be an option for some properties. Such properties would be on-sold with conditions known to purchaser.

8.2.2 Education and Awareness

Educating landowners to the risk of flooding and providing sufficient flood information would allow landowners to put plans in place to minimise the magnitude of damage in a flood event. An education program forms an important component of the recommended strategy. This process would include not only the dissemination of flood information gained from this study process, but also the steps that individual landowners could take to reduce flood damage. Simple measures such as storage of vulnerable materials and equipment above ground or floor level, and preferably above the 100 year flood level, can help to reduce damages significantly.

8.2.3 Development Controls

Council is able to designate areas as being liable to flooding in accordance with Sub Regulation 6.2 of the Building Regulations 1994. Such a designation gives effect to the provision of the Building Regulations that require building permits to specify minimum floor levels (generally 300mm above the estimated 1% flood level).

In addition, the Victorian Planning Provision and the CoGG Planning Scheme provide a number of mechanisms, via zones and overlays, for the control of development in flood prone areas. The zones and overlays that relate to flooding include:

- Urban Floodway Zone (UFZ);
- Floodway Overlay (FO);
- Rural Floodway Overlay (RFO);
- Land Subject to Inundation Overlay (LSIO); and
- Special Building Overlay (SBO).

In addition to zonings, overlays are shown on the planning scheme with associated additional provisions to those of the underlying zones. The application of the appropriate overlay or zone is set out in the Geelong Planning Scheme documentation as follows.

Applying Zones and Overlays:

- *applying the Urban Floodway Zone to locations in the urban areas that are high hazard and active floodways and where strict control over land use is required;*
- *applying the Floodway Overlay to locations in the urban areas that are high hazard and active floodways;*
- *applying the Rural Floodway Overlay to locations in the rural areas that are high hazard and active floodways;*
- *applying the Land Subject to Inundation Overlay to locations in both the urban and rural areas that are subject to periodic inundation but which are not high hazard nor active floodplains; and*

- *applying the Special Building Overlay to land in urban areas that are subject to inundation by surcharge flows from urban drainage systems, such as Barwon Heads and Corio.*

In the Barwon heads study area these planning provisions can be used by Council to control the development of new land where flooding problems have been identified. It is recommended that Council amend its Planning Scheme to require that all redevelopment in Barwon Heads does not increase the fraction impervious above 0.5: the flood levels determined by this study are based on a fraction impervious for residential areas of 0.5. If development that increases the fraction impervious above 0.5, the flooding problems identified in this report will worsen.

As further development within the Barwon Heads catchment has the potential to increase flood risk to people and property, assessment of rezoning proposals should include the application of the principle of zero adverse flood impact on adjacent, upstream and downstream areas. Assessment of development and subdivision applications (planning permit) should include application of best practice guidelines for development within or upstream of flood-prone areas. Best practice environmental management for stormwater runoff should also be encouraged as part of development and subdivision applications in order to reduce runoff and improve water quality.

8.3 Flood Mapping of Preferred Strategy

Flood mapping has been undertaken for the preferred strategy for each flood event. Large scale A1 plans show detailed mapping of flood extent for each of the 100, 20 and 5 year events, along with flood depth, flood impacted properties and flood height contours. These have been provided to CoGG as part of the data delivery in hard copy and digital GIS formats.

Figure 7-4 to Figure 7-6 show the flood affected properties for the preferred scheme, for each of the flood events analysed.

8.4 Funding of Preferred Scheme

Funding mechanisms available to Council for the upgrade of drainage infrastructure typically fall into one of two categories:

- ***Private Benefit*** for which a user-charge typically applies associated with a direct link between the infrastructure provided and the benefit received.
- ***Public Benefit*** is related to infrastructure that provides a benefit to the wider community throughout the municipality.

Clearly, augmentation works undertaken within the catchment of Barwon Heads are for the direct benefit of those residents with an existing flooding problem or threat. There also exists an indirect benefit to those residents within the catchment associated with increased trafficability of roads subject to flooding, as well as public health and safety issues and other non-economic benefits. Benefit may also be deemed to apply to residents with properties that are not flood effected but discharge stormwater within the catchment. This principle of catchment wide benefit within drainage schemes has been successfully implemented under legislation previous to the Local Government act 1989.

Special Rates and Charges are the typical mechanism for funding of drainage works under user charges. Section 163 of the Local Government Act 1989 sets out the provisions for the application of a special rate, charge or combination of these. The purpose of the rate or charge is to recoup costs associated with the provision of infrastructure. The charge is typically a one-off payment while a rate is generally an annual payment made over a number of years.

Recent decisions handed down at VCAT or AAT suggests a more confined application of special rates and charges particularly in relation to main drainage augmentation schemes. In essence the Ball decision (Appeal No 1993/37685) concluded:

- A special rate or charge can only be levied where a *special benefit* is received
- The special benefit must be received by the land owners (rather than the property)
- In this context, a special benefit was recognised by the Tribunal as an increase in property values.

That is, according to the Tribunal, while every property in the catchment receives, to a greater or lesser degree, a benefit from the main drainage augmentation works, that benefit does not translate into an increase in property values and is therefore not a *special benefit*. Thus, according to the tribunal, funding via special rates and charges is not applicable.

Furthermore, the Tribunal ruled that where:

> *… properties are already drained to lawful points of discharge and the provision of additional capacity in the main drainage system, although obviously required to drain the entire catchment, will not provide a special benefit to them as owners of their land.*

Appeal No 1993/37685 pg 7

This would indicate that the main drainage augmentation works within an area with made and kerbed streets is not considered by the Tribunal to provide a specific benefit to property owners in the catchment. Therefore the ruling would imply that in the case of the Barwon Heads area, funding via special rates and charges may be problematic due to potential legal uncertainty and social resistance.

It is recommend that Council seek independent legal advice to confirm the rationale of a test case involving a special rates and charges scheme.

8.5 Strategy for Implementation

It is recommended that the implementation of the preferred strategy should be undertaken over a period of seven years. This period will allow sufficient time for the determination and arrangement of funding sources, designation of flood levels and application of flood zones/overlays, the dissemination of flood information to the community, the design and construction of drainage works and the implementation of individual floodproofing of properties by landowners where appropriate.

An approximate schedule of implementation is shown in Table 8-1.

Table 8-1 Implementation Schedule

Item	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Determine Funding Source(s) and Prepare Business Case.							
Detailed Design of Scheme 1							
Construction of Scheme 1							
Designation and Dissemination of Flood Information.							
Planning Scheme Amendment (Flood Zones/Overlays).							
Individual Floodproofing.							
Education and Awareness Program.							

9 PUBLIC CONSULTATION PROCESS

The Draft Final Report of the Barwon Heads Drainage Flood Management Plan and associated flood mapping was placed on public exhibition with an invitation for submissions. The general public was advised of the exhibition via a public notice, and owners of properties affected by the 100 year ARI flood event within the study area (approximately 440 no. properties) received individual letters with explanatory fact sheets.

Sixteen written submissions and five verbal submissions were received. The major issues of concern and the City's responses are listed in Appendix C. There were 21 submissions but some had the same concerns, hence the list of concerns has only 18 items.

10 REFERENCES

Cedergren (1997). *Seepage, Drainage and Flow Nest*, John Wiley & Sons, Figure 2.5 page 31

CoGG (2002). *Report: Rain Event 8th February 2002*, Kevin Garde, City of Greater Geelong, Geelong 2002.

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

APPENDIX A: SOIL TEST RESULTS

APPENDIX B: UNIT RATES

Melbourne Water Greenfield Stormwater Pipe Rates

Nominal pipeline diameter (mm)	Category 1	Category 2	Category 3	Category 4
	Rate for Interlocking / Flush Jointed pipes with 20% FCR backfill ($/m)	Rate for Rubber Ring Jointed pipes with 20% FCR backfill ($/m)	Rate for Interlocking / Flush Jointed pipes with 100% FCR backfill ($/m)	Rate for Rubber Ring Jointed pipes with 100% FCR backfill ($/m)
300	83	95	107	123
375	95	118	126	157
450	110	137	149	185
525	127	158	175	217
600	146	182	204	254
675	168	209	236	294
750	192	238	272	339
825	218	291	312	417
900	246	331	355	478
1050	309	414	450	603
1200	381	512	559	751
1350	463	620	682	914
1500	562	754	843	1,131
1650	729	978	1,034	1,387
1800	923	1,238	1,247	1,674
1950	1,144	1,540	1,483	1,997
2100	1,391	1,789	1,741	2,239

RCBC Unit Rates

Dimensions (mm)		Rates ($/m)	
Width	**Height**	**Delivered**	**Installation (Greenfields)**
600	300	185	90
600	450	206	90
750	300	211	140
750	600	255	140

APPENDIX C: PUBLIC SUBMISSIONS AND COGG RESPONSES

The major issues of concern raised by owners of affected properties, community organizations or authorities during the consultation process are listed below with the relevant responses:

1. I believe flooding of my property is due to blocked drains and pits.

Response:

Flooding is due mainly to lack of hydraulic capacity within older drainage systems that were designed to the lower standards that were applicable at that time. The City's Infrastructure Operations Unit will endeavour to check critical council drainage assets for blockages, in order to maximise use of capacity that may be available.

2. Will the proposed subdivision south west of Geelong Rd/Golf Links Rd worsen the drainage/flooding problems?

Response:

No. This subdivision is to have significant detention storage with stormwater runoff directed to golf course for reuse via irrigation.

3. How can my property be considered subject to flooding when it has never flooded (eg February 2005 storm event or 1952 flood event)?

Response:

It cannot be assumed that flooding has not previously or will not occur at any given property, on the basis that there are no records of flooding or flooding to the extent identified by the mapping of the 1 in 100 year overland flows.

The February 2005 storm event was not a critical or major storm event for drainage system at Barwon Heads, being a long duration and low intensity storm. Critical storms that generate flooding at Barwon Heads are shorter duration with higher intensities.

Flooding at Barwon Heads in 1952 was due to riverine flooding (Barwon River) rather than stormwater or drainage related flooding due to runoff from local catchment exceeding capacity of drainage systems.

4. Is the information being gathered by Council going to affect property values or saleability?

Response:

It is important to note that designation of an area as liable to flooding does not cause or change the likelihood of flooding, but recognises the existing condition of land.

The designation will not be described on title, but will be disclosed in Land Information Certificates issued under the Local Government Regulations, and for building permits under the Building Regulations.

The value of any property is determined by the complex interplay of many different factors such as location, streetscape and amenity, and it is difficult to assign what effect if any, the identification of land as liable to flooding may have on the value of a property. Devaluation of properties (identified as being liable to flooding) is considered unlikely at Barwon Heads once flood management plan is explained and limited lot supply situation is taken into account.

5. Will the designation affect my house insurance?

Response:

The Insurance Council of Australia has advised Melbourne Water that most insurance policies, which provide coverage for storm damage, include cover for damages resulting from overland flows. The preferred mitigation strategy includes further investigation into feasibility of property specific measures to manage risk from residual flooding, as well as an education & awareness program.

6. Will the flooding information and planning scheme overlay controls (Special Building Overlay) stop redevelopment of my property?

Response:

Generally not. The information will only be used to ensure that any future development of your property is carried out in a manner that recognises the location of areas that may be subject to flooding. Requirements for any proposed development will depend upon the flooding characteristics of the land such as depth and velocity, and the nature of the development proposed. Both Corangamite Catchment Management Authority and Council officers can provide preliminary advice on any likely requirements that will need to be met.

It should be noted that development controls, apart from minimum floor levels, are only applicable in a statutory context once flood overlay (SBO) is created within planning scheme. Creation of SBO requires planning scheme amendment where again submissions from public are invited.

7. I am concerned about timing of proposed works and potential adverse impact on businesses, residents and public.

Response:

Timing of works would take interests of businesses into account and adverse impact on residents and public would be minimised.

8. Why was flood overlay not applicable to my property prior to purchase?

Response:

Flood overlay on planning scheme (Special Building Overlay) is future planning scheme amendment, as recommended in flood management plan.

9. Why are there no structural flood mitigation measures proposed in my area (north west of Geelong Rd/Sheepwash Rd)?

Response:

Structural mitigation measures not justifiable in this area due to shallow flooding and lack of internal flooding of dwellings.

10. Mitigation Scheme 2 is preferred in submission, rather than Scheme 1 preferred in Draft Final Report, due to increased social benefits.

Response:

Cost of Scheme 2 is significantly greater than Scheme 1 with limited increase in social benefits.

11. Proposed seven year implementation schedule for flood management plan is too long.

Response:

The proposed schedule reflects the typical timeframe required for such a costly and complex flood mitigation project, which includes consultation with various parties and approval from other authorities.

12. Will consultation be undertaken with relevant authorities on design of proposed mitigation works?

Response:

Flood Management Plan would be implemented with appropriate consultation with relevant authorities.

13. Can't the George St area be serviced with a reticulated drainage system with outfall to Barwon River, rather than proposed localised soakage system?

Response:

A reticulated drainage system would require an expensive pumped system or deep gravity drains draining to adjoining catchment. George Street is located within an area with sandy soils where infiltration is considered to be best practice and a cost effective stormwater disposal method.

14. Will the proposed mitigation works be coordinated with proposed streetscape works (Hitchcock Av) and provision of gas?

Response:

Opportunities to coordinate the various works will be investigated.

15. Shouldn't the City fix up the drainage system rather than spend money on study?

Response:

Limited funds expended on study would have little or no beneficial impact if diverted to improving drainage system, given costs involved. Study is also required to identify effective mitigation measures in a holistic manner for the complex drainage system, rather than wasting funds on ineffective works or transferring problems from one location to another.

16. Can't further development be stopped in Barwon Heads if drainage infrastructure is inadequate?

Response:

Rezoning of further residential land is unlikely at Barwon Heads (as indicated in Structure Plan and Urban Growth Strategy). Flood Management Plan recommends improvements to drainage system with development controls and assessment of development and subdivision applications to include application of best practice guidelines for development within or upstream of flood-prone areas.

17. Can't wording on Land Information Certificates be altered to indicate 1 in 100 year flood event is 'extreme' event?

Response:

Wording used on Land Information Certificates reflects State Government legislative requirements.

18. Why were existing Special Building Overlay (SBO) areas NW and SE of Taits Rd/Sheepwash Rd not flood mapped as part of study?

Response:

Existing SBO areas have development controls in place (SBO was created as part of design of subdivisions), which should prevent internal flooding during 1 in 100 year flood event. Funds for study were limited so existing SBO areas were not studied again.