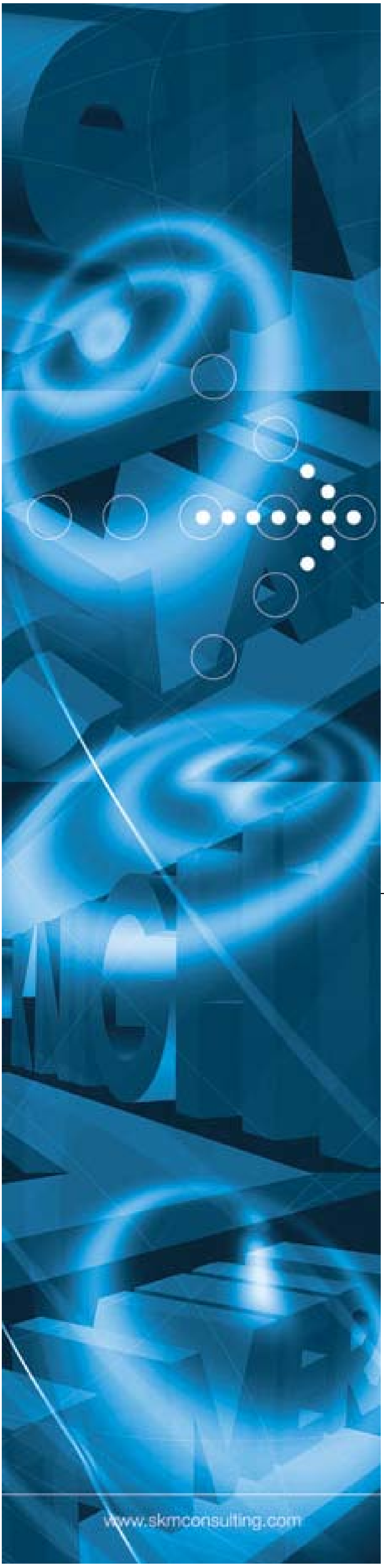

Shepparton Mooroopna Floodplain Management Study

Floodplain Management Plan

Executive Summary

October 2002

LAWSON AND TRELOAR PTY LTD
Coastal, Ocean and Water Resources Consulting Engineers

SINCLAIR KNIGHT MERZ

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Contents

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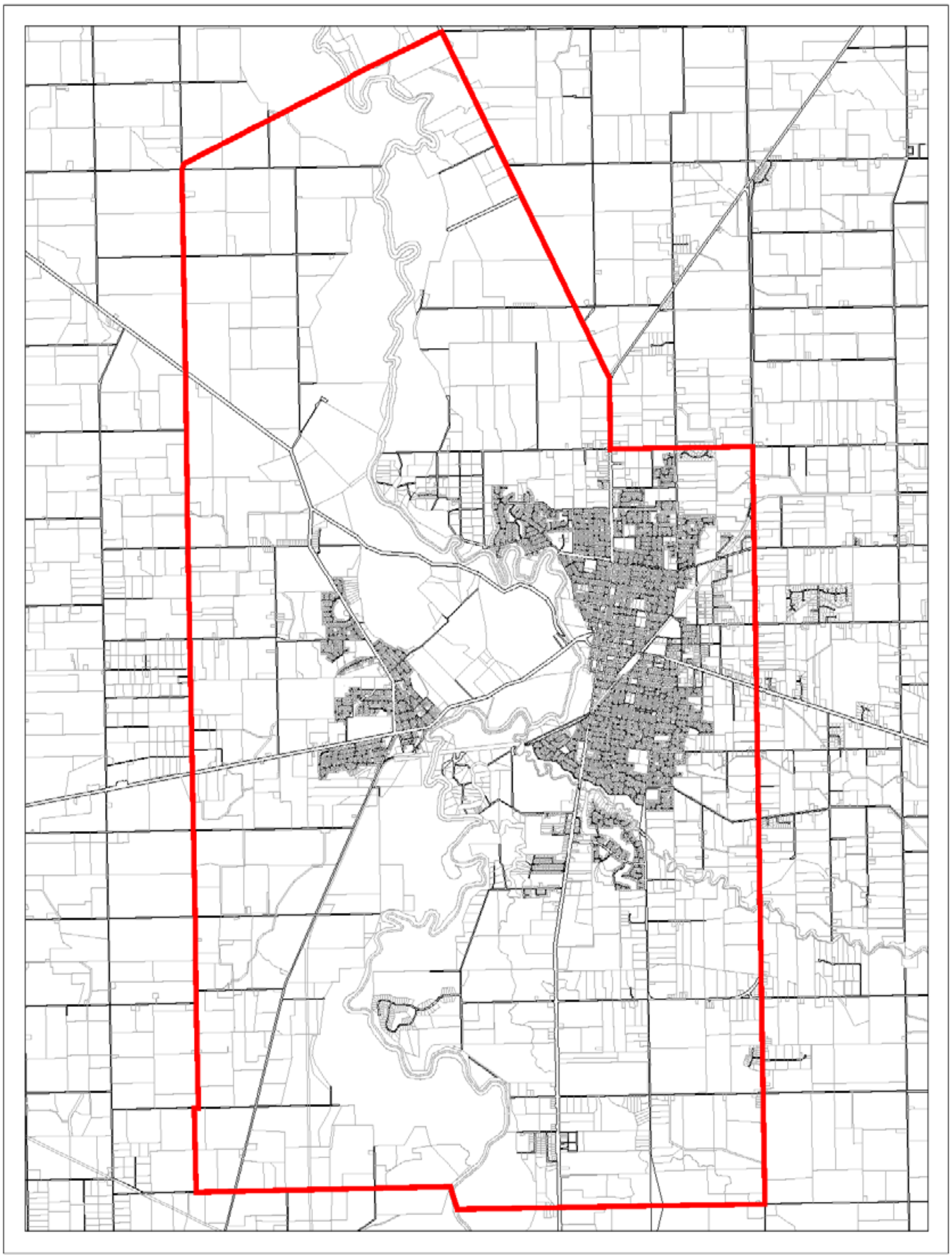
1. Introduction

This document provides a summary of the development of a floodplain management plan for Shepparton-Mooroopna. The study area covered by the floodplain management plan is shown in **Figure 1-1**. Further details can be found in **Stage 1** and **Stage 2** Technical Documents (SKM, 2002a; 2002b).

- **Figure 1-1 Shepparton-Mooroopna Floodplain Management Plan Study Area**



The main objective of the floodplain management plan is to minimise the economic and social impacts of flooding on the community, whilst protecting environmental values of the study area. This has been achieved by investigating and documenting the existing nature of flooding and also by considering a range of flood mitigation measures for Shepparton-Mooroopna. The mitigation measures investigated included both structural (eg. levees, floodways) and non-structural options (land use planning, emergency response), although structural options were assessed by the technical steering committee and community reference group as unsuitable.

The key benefits of the plan are therefore:

- Improved community awareness of flood risks
- Improved development management through new land-use mapping
- Improved emergency management and response through new flood inundation maps and listings

In June 1999, the Greater Shepparton City Council (GSCC) commissioned Sinclair Knight Merz to undertake a comprehensive floodplain management study for Shepparton-Mooroopna to assist in the development of this plan. The Goulburn Broken Catchment Management Authority (GBCMA) has also played a lead role in managing this study.

2. Conduct of Study

The study was coordinated and guided by a technical steering committee (TSC) comprising representatives from relevant agencies. The committee met throughout the course of the study. Its role was to review work to-date, provide guidance to the consultant, and make resolutions regarding the consultant's findings and study outcomes. A community reference group (CRG) consisting of residents nominated by the community played a pivotal role of providing feedback on the study direction and outputs during the course of the study.

The plan has been developed in two stages to enable the application of risk management principles. The use of the risk management framework is in line with best practice principles as outlined in the Victoria Flood Management Strategy (DNRE/DoJ 1998). Key elements of the two stages are as follows:

- **Stage 1** - Investigation of flooding, determining the likelihood and consequences for existing conditions.
  - Data collection – collection of data relevant to study (eg. topographic information, historical flood levels, etc),
  - Community consultation - providing information to and seeking flood related information from the community,
  - Hydrologic analysis – analysis of streamflow information to assess the likelihood of the floods of a given size occurring (ie, flood peaks and volume),
  - Hydraulic analysis – computer modelling of flood behaviour to estimate flood extents and levels resulting from a given flood under existing conditions.
  - Flood damage assessment – assessment of economic damages to the community from flooding under existing conditions,
  - Flood mapping for emergency response – mapping on a cadastral base of a range of flood events (output from the hydraulic analysis) to enable improved emergency management and response during floods,
  - Planning scheme information – providing GSCC and GBCMA with suitable outputs to aid the revision of the planning scheme related to flooding under existing conditions.

- **Stage 2** – Investigation of measures to reduce economic and social consequences from flooding
  - Community consultation - providing information to and seeking feedback from the community on the existing flooding risks (likelihood and consequences), and possible measures to reduce economic and social consequences from flooding,
  - Preliminary identification and assessment of possible mitigation measures – broad assessment of flood mitigation measures identified through community consultation,
  - Detailed assessment of mitigation measures – assessment includes hydraulic, economic, environmental and social impacts due to mitigation measures,
  - Development of a floodplain management plan for Shepparton Mooroopna.

3. Stage 1 - Investigation of Existing Flood Risk

3.1 Community Consultation in Stage 1

Community consultation was a significant component of the study process in Stage 1. The community consultation was conducted via the resident survey (ie. questionnaire), community reference group briefing sessions and media releases.

A resident survey/questionnaire was distributed in October 1999 to gather known flood information and preliminary feedback on the study outputs. The questionnaire was distributed to 18,000 properties with a target of approximately 12,000 residents. Responses were received from 941 residents (8% of total target).

As part of the questionnaire, residents were asked to provide information regarding the location of historical flood marks within the study area. Approximately 300 references to flood marks were provided. Where possible these flood marks were surveyed as part of the data collection phase.

In addition, resident interviews were carried out which provided flood descriptions including flood photography and video information.

As part of the first questionnaire, residents were asked to nominate suitable persons for a Community Reference Group (CRG). In total around 135 nominations were received.

There have been five briefing sessions conducted with the CRG during the study (both **Stage 1** and **Stage 2**).

3.2 Data Collection

The study began with the collection and collation of new and pre-existing data. New data collected included a photogrammetric survey, field topographic survey and property data survey. Pre-existing data included previous topographic survey, historical flood marks and previous study reports.

The photogrammetry and field topographic survey were used to construct a digital terrain model (DTM) of the study area. The DTM was used in the hydraulic analysis and flood inundation mapping.

Historical flood marks identified in responses to the questionnaire were surveyed where possible. This flood level data were used in the calibration of the hydraulic model (refer to **Section 3.4**)

The property data contained details for each property in the study area affected by the then estimated 100 year ARI flood. The data collected included:

- address,
- location,
- building floor level,
- building type, size and condition.

This data was collected for approximately 9,500 properties. This data was central to the flood damage assessment and flood inundation mapping. In addition this property data is a valuable resource for emergency management by VICSES and GSCC, and to assist GBCMA in evaluating land use planning and development applications.

3.3 Hydrologic Analysis

Hydrologic analysis was undertaken to estimate the likelihood of floods of any given size occurring. The likelihood of flood of a given size occurring is referred to as the Average Recurrence Interval (ARI). The ARI is the time *on average* between flood events exceeding a given size. For example the 10 year ARI flood is on average likely to be exceeded ten times in 100 years. It is also possible, however, that two such floods could occur, for example, in consecutive years.

Theoretical floods with given ARIs are termed design floods. Rigorous analyses of available streamflow records were undertaken to estimate the design floods. The primary outputs of the analysis were design floods (5 to 500 year ARI) for the Goulburn River and the Broken River and Seven Creeks at the upstream limit of the study area. Design floods were also estimated for the Goulburn River at Shepparton. **Table 3-1** shows the design floods determined as part of the hydrologic analysis.

- **Table 3-1 Design Floods**

ARI (years)	Peak Flow (ML/d)			
	Goulburn River at Upstream Limit	Broken River at Upstream Limit	Seven Creeks at Upstream Limit	Goulburn River At Shepparton
5	53,800	21,400	21,200	73,400
10	71,400	27,400	27,400	102,000
20	91,300	32,900	42,000	137,000
50	120,000	39,000	57,800	180,000
100	142,000	43,500	69,900	219,000
200	168,000	48,300	89,400	261,000
500	205,000	53,600	120,000	336,540

To put the above design floods into perspective, the ARIs and peak flow for three major historical floods at the Shepparton gauge are listed in **Table 3-2.**

- **Table 3-2 Historical Floods at Shepparton**

Date of Historical Flood	ARI (years)	Peak Flow (ML/d)
October 1993	35	150,000
May 1974	75	192,000
September 1916	160	233,000

Flooding in Shepparton Mooroopna is a result of the interaction of floods in the Goulburn River, Broken River and Seven Creeks. Further analysis of available streamflow records was performed to determine the nature of the interaction.

The design flood combinations were determined for two scenarios, a Goulburn River dominant flood event and a Broken River/Seven Creeks dominant flood event. For a Goulburn River dominant event, the ARI of the design flood in the Goulburn River at the upstream study limit was set to the required ARI of the design flood at Shepparton. The design floods for the Broken River and Seven Creeks at the upstream study limit were then determined to result in a flood at Shepparton with the ARI required. Similarly for a Broken River/Seven Creeks dominant flood, the ARI of design floods for the Broken River and Seven Creeks were set to the required ARI of the design flood at Shepparton. The design floods for the Broken River and Seven Creeks at the upstream study limit were then determined to result in a flood at Shepparton with the ARI required.

Combinations of design floods in the three streams resulting in floods of a given ARIs at the Shepparton gauge were determined and are displayed in **Table 3-3**.

- **Table 3-3 Design Flood Combinations**

ARI at Shepparton Gauge (years)	ARI of Floods in Contributing Streams* (years)		
	Goulburn River (at study boundary)	Broken River (at study boundary)	Seven Creeks (at study boundary)
10	**10**	5	5
	5	**10**	**10**
20	**20**	10	10
	10	**20**	**20**
35	**35**	17	17
	17	**35**	**35**
50	**50**	20	20
	20	**50**	**50**
100	**100**	50	50
	50	**100**	**100**
200	**200**	100	100
	100	**200**	**200**
500	**500**	200	200
	200	**500**	**500**

*Dominant contributing stream(s) for each map shown in bold.

Table 3-3 shows both Goulburn River dominant and Broken River/Seven Creeks dominant floods (shown in upper and lower lines respectively against each Shepparton gauge height). For example, a flood with 100 year ARI at the Shepparton gauge can result from either:

1. Goulburn dominant event - 100 year ARI in Goulburn River in combination with 50 year ARI floods in both the Broken River and Seven Creeks, or
2. Broken/Seven dominant event - 100 year ARI floods in the Broken River and Seven Creeks in combination with a 50 year ARI flood in the Goulburn River.

The design event combinations were used as an input to the hydraulic analysis.

3.4 Hydraulic Analysis for Existing Conditions

Hydraulic analysis was undertaken to estimate flood levels within the study area. The modelling was undertaken (by Lawson and Treloar) using the 2-dimensional hydraulic computer model, MIKE 21. The model used inflows derived from the hydrologic analysis (in the various design flow combinations outlined in **Table 3-3)** to determine flood levels and extents throughout the study area for historical and design flood events under existing conditions. The models were calibrated using the 1974 and 1993 flood events. Outputs from the hydraulic model were used in the flood damage assessment and flood inundation mapping.

3.5 Flood Damages Assessment

The flood damage assessment was undertaken using a Geographic Information Systems (GIS) based flood damages model. The flood damage model contained embedded flood damage data and an assessment methodology based on the ANUFLOOD program (Smith and Greenaway, 1992) and NRE's Rapid Appraisal Method (RAM) (DNRE, 2000).

The model compares flood levels (estimated from the hydraulic model) with property data to estimate the number of buildings affected above floor, the number affected below floor and the total damages expected for that event.

For this study the ratio of actual flood damages to potential flood damages was set to 0.7. This ratio is a measure of the community experience with flooding and the amount of warning time provided. A ratio of 0.7 is appropriate for an inexperienced community but with warning time greater than 12 hours (DNRE, 2000). Improvements in flood warning and flood emergency response planning can result in a lower ratio and hence a reduction in flood damages (refer to **Section 4.4.2**).

The flood damage assessment was used to determined existing flood risk and the benefits (ie. reduction in risk) of various mitigation options (refer to **Section 4.3**)

3.6 Existing Flood Risk

The impact of flooding on a community can be usefully summarised in terms of flood risk. Flood risk is defined as the product of likelihood of flooding (ie. flood ARI) and consequence of flooding (ie. flood damages). That is:

*Flood Risk = Likelihood * Consequence*

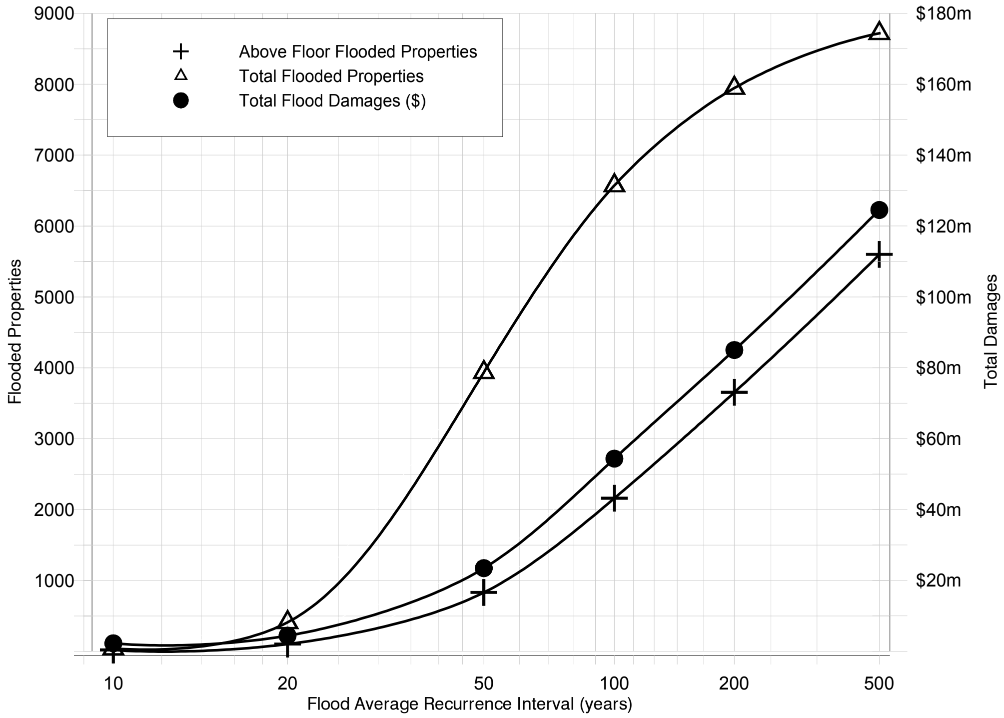
The likelihood of flooding for Shepparton-Mooroopna has been determined via hydrologic and hydraulic modelling. **Table 3-4** provides a summary of existing consequences for the total study area for a Goulburn River dominant event.

- **Table 3-4 Existing Consequences of Flooding**

Flood Damage Data	ARI (years)					
	10	20	50	100	200	500
Properties Flooded Above Floor	20	103	831	2,160	3,654	5,599
Properties Flooded Below Floor	21	307	3,106	4,412	4,292	3,120
Total Flooded Properties	**41**	**410**	**3,937**	**6,572**	**7,946**	**8,719**
TOTAL DAMAGES (DRF at 0.7)	**$2.25 mil**	**$4.42 mil**	**$23.4 mil**	**$54.3 mil**	**$85.0 mil**	**$125 mil**

Figure 3-1 shows graphical representation of consequences, including properties flooded above floor, total flooded properties flooded and damages for the entire study area, for a Goulburn River dominant event.

■ **Figure 3-1 Existing Consequences of Flooding (Goulburn River Dominant)**



Flood risk, as a function of likelihood *and* consequence, can be determined for a given flood or can be integrated over a range of floods, to provide a single indicator of the risk to the community. This indicator is known as Average Annual Damage (AAD) and represents the cost to the community each year due to flooding. Average annual damage is calculated as the area under a curve of total monetary damages versus flood ARI (in **Figure 3-1**). The AAD or flood risk for Shepparton-Mooroopna under existing conditions is estimated at **$1.09 million** (ie, $1.09 million/annum), to a 100 year ARI event and **$1.75 million** to a 500 year ARI event.

Understanding and quantifying flood risk becomes invaluable in assessing the economic merit of mitigation options. Mitigation options reduce flood risk and AAD. A comparisons of AAD for existing conditions with AAD of a given mitigation option represents the benefit (ie. reduction in AAD) of the option. Comparing the benefit with the cost of implementation of the option provides a benefit-cost ratio, which assists in assessing and ranking of options on economic grounds. Discussion and assessment of mitigation options for Shepparton-Mooroopna is provided in **Section 4**).

3.7 Flood Inundation Mapping and Property Listings for Emergency Response

A comprehensive set of flood inundation maps for Shepparton-Mooroopna has been produced for emergency management and response. Flood inundation maps were produced for the design event combinations shown in **Table 3-3** for ARIs of 10 years or greater at Shepparton. Both Goulburn River dominant and Broken River /Seven Creeks dominant flood scenarios have been considered.

Two map sheets have been produced for each gauge height. A map sheet at 1:25,000 scale covers the entire study area and a map sheet at 1:10,000 scale covers the inner urban area of Shepparton-Mooroopna. **Table 3-5** summarises the gauge height at Shepparton for which maps have been produced. There are a total of 28 map sheets (ie. 7 events/gauge heights x 2 flood scenarios x 2 sheets).

- **Table 3-5 Shepparton Gauge Heights for Flood Inundation Maps**

Shepparton Gauge Height (m)	Shepparton Gauge Elevation (m AHD)	ARI (years)
11.3	111.42	10
11.6	111.72	20
11.8	111.92	35
12.0	112.12	50
12.2	112.32	100
12.3	112.42	200
12.5	112.62	500

For each mapped Shepparton gauge height, correlations to gauge heights on the Goulburn River at Murchison, Broken River at Orrvale and Seven Creeks at Kialla West have been determined. These gauge heights are documented on each flood inundation map. They provide a means of identifying flood magnitudes in the contributing stream expected to result in the gauge height (and flood depths and extents) shown on each map. Accompanying the map sheets are listings of properties affected both below and above floor level for a range of Shepparton gauge heights.

The intention of the maps is that once warning of an impending flood of a particular height is received, the appropriate map and its listing are used to assist in emergency response.
The maps show flood levels, flood depths, flood extents and flood affected properties. The associated listings provide detailed data on each flood and all properties affected by that flood.

For the 100 year ARI event, velocity maps have also been produced for the two design scenarios and two map areas. These show shaded flow speed zones and indicative flow direction arrows.

Also, incremental flood inundation maps have been produced by layering the flood extents of each of the seven mapped events, for both dominant flood scenarios. These maps provides a visual summary of the increase in flood extent with increasing flood magnitude and thereby indicates the nature of flood breakouts and their encroachment on roads, property and critical areas (eg for access) generally across the study area.

The flood inundation maps and associated incremental maps and property listings can be found on the Project CD-ROM.

3.8 Planning Scheme Information

Flooding delineation option maps have been produced to assist GSCC and GBCMA in the definition of new land use flood zones and overlays, and the designation of flood levels. The maps have been prepared for existing conditions for Shepparton-Mooroopna. From these option maps, CoGS and GBCMA have developed the planning maps in accordance with the Victorian Planning Provisions Practice Notes – Applying the Flood Provisions in Planning Schemes (DoI 2000). The flooding delineation maps are bound in a separate volume.

The flood zone and overlays of relevance to this study are the Urban Floodway Zone (UFZ), Floodway Overlay (FO) and Land Subject to Inundation Overlay (LSIO). Both UFZ and FO identify active and important flood conveying areas. Areas zoned as UFZ carry with them restrictions on land use and development. FO areas are largely discretionary with developments assessed on performance based criteria. The Land Subject to Inundation Overlay identifies remaining flood prone areas.

Floodways can be defined by a number of hydraulic, planning, environmental and other criteria. Key criteria used in this study are the 10 year ARI flood extent (representing high frequency flood risk), an extent based on depth and velocity in a 100 year ARI flood event (representing high hazard flood risk) and an absolute flood depth of 0.5 m. A combination (eg. envelope) of these is usually appropriate and has been applied in this case. The remaining flooded areas inundated in a 100 year ARI flood event were classified as Land Subject to Inundation.

The designated flood levels were derived by enveloping the peak flood levels from the two design flood combinations listed in Table 3-3 that result in a 100 year ARI flood at the Shepparton gauge, ie. the 100 year ARI Goulburn River/50 year ARI Broken River and Seven Creeks flood enveloped with the 100 year ARI Broken River and Seven Creeks/50 year ARI Goulburn River flood.

The GBCMA as the floodplain management authority has declared the flood levels in accordance with the requirements of Water Act, 1989.

4. Stage 2 - Investigation of Measures to Reduce Flood Risk

4.1 Community Consultation in Stage 2

Similarly to Stage 1, a resident questionnaire was distributed in June 2001 to explain the nature of flooding detailing the flood risks (ie. likelihood and consequences). With this information in mind, the questionnaire was designed to gather feedback on risk treatments (or more commonly known as mitigation measures) of a both structural and non structural nature. As per Stage 1, the questionnaire was distributed to 18,000 properties with a target of approximately 12,000 residents. Responses were received from 663 residents (6% of total target).

Two questions related to the nature of flood mitigation measures preferred by the community. Question 2 asked the community to rank eight structural and non-structural measures. The results, in order of importance to the community, were as follows:

1) Floodways
2) Waterway capacity works
3) Levees or flood walls
4) Land use planning controls
5) Improved flood warning
6) Flood proofing or raising
7) Community Education
8) Land acquisition

Question 4 was aimed at obtaining the community's suggestions of possible mitigation measures/schemes.

A number of comments were made in the questionnaire responses which required addressing via feedback to the general community through the CRG. The issues raised and responses are shown in **Table 4-1.**

- **Table 4-1 Issues Raised and Response to Stage 2 Questionnaire**

Issues	Response
Existing environmental values not to be adversely impacted by any mitigation measure/scheme	Clearly communicate assessment of environmental impacts will be undertaken
Impacts on flooding due to the Goulburn Valley Highway bypass	Clearly communicate VicRoads will be required to demonstrate the floodplain impacts of the bypass
Levees can lead to a false sense of security	Clearly communicate levee are designed for a given flood magnitude and will overtop for larger events
Local flooding due to stormwater drainage	Clearly communicate this study is concerned with mainstream flood.
Flood response plans – sandbagging, evacuation procedures, etc	Clearly communicate a comprehensive flood response plan will be reviewed as part of this study.

From the feedback obtained a list of mitigation measures for preliminary assessment was developed. The preliminary assessment of mitigation measures is outlined in **Section 4.2**. Part of this assessment included identification of measures warranting detailed assessment.

Further consultation with the CRG was undertaken during the detailed assessment of structural mitigation options (See **Section 4.3**).

4.2 Preliminary Identification and Assessment of Flood Mitigation Measures

A preliminary assessment of the feasibility of mitigation measures suggested was made considering the cost, practicality and effectiveness. From this assessment measures/schemes requiring further investigation were identified. **Table 4-2** outlines the results of this preliminary assessment.

- **Table 4-2 Preliminary Assessment of Flood Mitigation Measures**

Measure Suggested	Type of Measure	Issues affecting feasibility	Warrants further investigation
Mooroopna Floodway - constructed floodway between Mooroopna and Goulburn River north of the Causeway	Structural	- Size of floodway & in turn cost to achieve reduction in flood levels - Any social and environmental impact on adjacent land	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Levee banks along Goulburn River in South Mooroopna - levee adjacent to Archer Street and Toolamba Road	Structural	- Levee height versus costs to achieve benefit - Availability of land to site the levee - Upstream and downstream adverse hydraulic impact - Any social and environmental impact on adjacent land/ landholders - Local drainage from behind levee	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Levee banks along Goulburn River in North Mooroopna - levee adjacent to Mooroopna Wyuna Road between McFarlanes Lane to Paisley Crescent	Structural	- Levee height versus costs to achieve benefit - Availability of land to site the levee - Upstream and downstream adverse hydraulic impact - Any social and environmental impact on adjacent land/ landholders - Local drainage from behind levee	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Levee banks along Broken River in South Shepparton - levee adjacent to Lincoln Drive and Broken River Drive	Structural	- Levee height versus costs to achieve benefit - Availability of land to site the levee - Upstream and downstream adverse hydraulic impact - Any social and environmental impact on adjacent land/landholders - Local drainage from behind levee	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Levee banks along Goulburn River in Boulevard Area - levee adjacent to Boulevard	Structural	- Levee height versus costs to achieve benefit - Availability of land to site the levee - Upstream and downstream adverse hydraulic impact - Any social and environmental impact on adjacent land/ landholders - Local drainage from behind levee	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Realignment of No. 12 irrigation supply channel to create a floodway	Structural	- Change to existing infrastructure - Cost associated with realignment compared with reduced flood damage (ie reduce flood levels)	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Increased Capacity of Railway and/or Causeway openings	Structural	- Costs associated with widening opening compared to reduced flood levels and benefits - Environmental impacts due to change flow regime	**Yes** - Hydraulic, economic, social & environmental impact assessment required
Improved Land Use Planning	Non-structural	- Existing developments - Development pressure	**Yes** - Land-use planning map completed
Remove/change operation Loch Garry	Structural	- Distance downstream of study area - Impact on downstream properties	**No** - Investigated in **Stage 2** shows no impact within the study area

Measure Suggested	Type of Measure	Issues affecting feasibility	Warrants further investigation
Clearing vegetation from waterways	Structural	- Environmental impacts would be significant - Ongoing maintenance would be significant	**No** **-** Significant environmental impacts
Improved Flood Warning/ Emergency Response	Non-structural	- Lack of flood awareness - Comprehensive flood response plan	**Yes** - Economic & social impact assessment required - Review flood response plan - Flood response maps
Construction of Upstream storages on the Goulburn River and/or Broken River	Structural	- High costs - Significant social and environmental impacts	**No** - Significant cost and environmental impacts
Diversion of Goulburn River to Waranga Basins or along Eastern Goulburn Main Channel	Structural	- Flood volumes significantly larger than existing channel capacity - High costs - Significant environmental impacts	**No** - Significant cost and environmental impacts
High Capacity Pumps located near confluence of Goulburn and Broken with pipeline to downstream	Structural	- Flood volumes significantly larger than pump capacity - High costs - Significant environmental impacts	**No** - Significant cost and environmental impacts

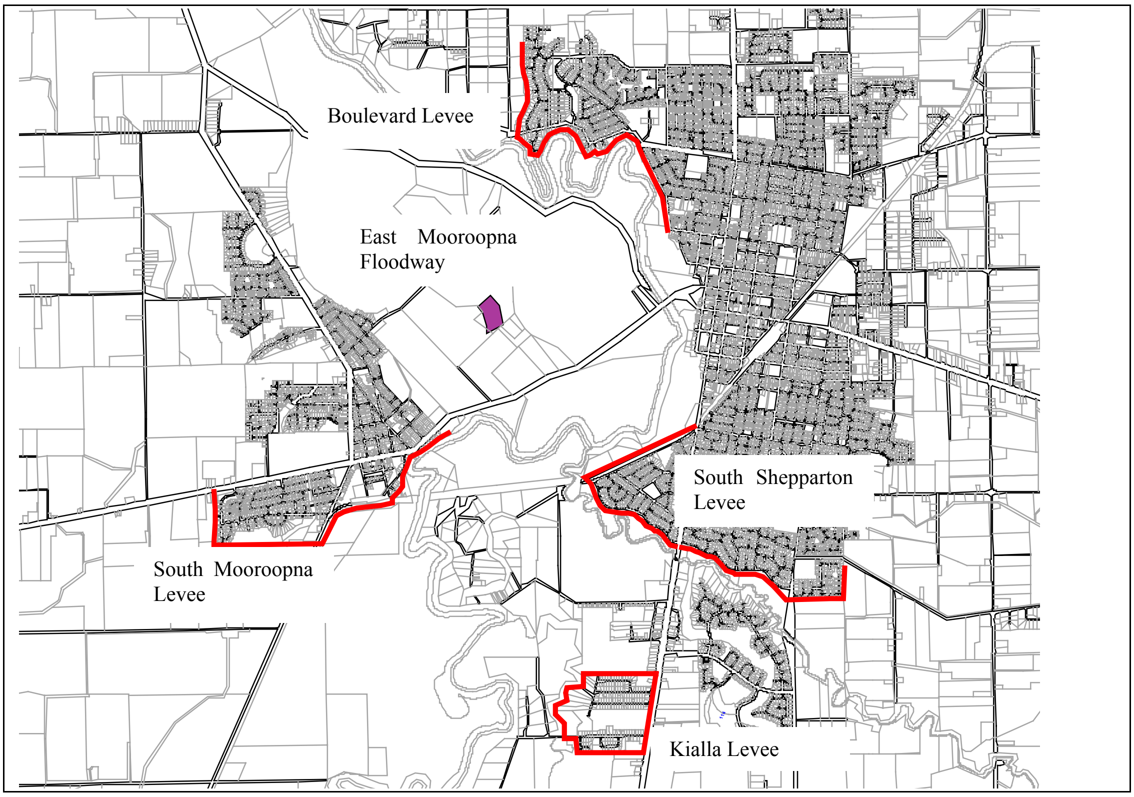
4.3 Detailed Assessment of Structural Flood Mitigation Options

The detailed flood mitigation assessment involved the development and comparison of eight structural flood mitigation options, derived from various mitigation measures. The eight options are as follows:

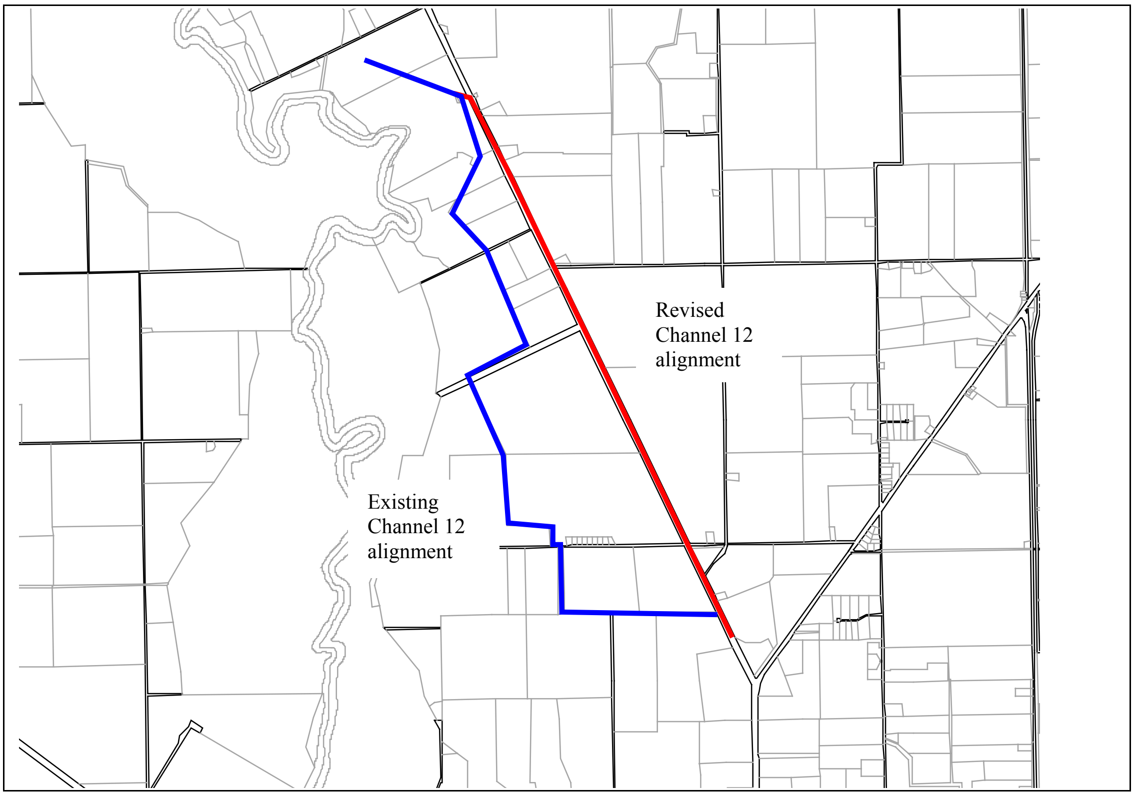
- Option 1 – Kialla Levee
- Option 2 – South Shepparton Levee
- Option 3 – South Mooroopna Levee
- Option 4 – Boulevard Levee
- Option 5 – Combination of the above levee options
- Option 6 – East Mooroopna Floodway
- Option 7 – Realignment of Channel 12
- Option 8 – Increased waterway opening in causeway and railway line crossing.

Figure 4-1 shows the indicative levee alignments for Options 1 to 5 and the floodway alignment for Option 6. **Figure 4-2** shows both the existing and revised Channel 12 alignment under Option 7. These alignments have been used for evaluation purposes. They are not final alignments if options are to be incorporated in the floodplain management plan.

- **Figure 4-1 Mitigation Options 1 to 6**



- **Figure 4-2 Mitigation Option 7 - Channel 12 Realignment**



For each option, the assessment generally involved determining its flooding impacts using the hydraulic model, its construction and maintenance costs, its economic benefit (eg. reduction in AAD, benefit cost ratio) and its environmental and social impacts or benefits. In this assessment economic and hydraulic (and to some extent social) impacts have been the initial indicators of the merits of options. In most cases, decisions to abandoned options were made on these economic and hydraulic grounds (and related social impacts) alone. Hence, environmental assessment in particular was not necessary for these options.

For economic analysis, a 30 year project life and 6% discount rate were assumed.

The levee Options 1 to 5 were evaluated assuming a 100 year ARI design standard. The levee height included a freeboard of 600 mm above the 100 year ARI design flood level. This freeboard allowance is in line with standard design practice. The provision of levees with a lower design standard (eg. 20 year ARI) would not be feasible given that total monetary flood damages only start to become significant above a 20 year ARI event.

In all assessments, a Goulburn River dominant flood scenario was used. A Broken River/Seven Creeks dominant scenario would yield slightly different property damage estimates, but have little effect on the benefit/cost of each mitigation option.

4.3.1 Option 1 - Kialla Levee

This option involved the construction of a ring levee encompassing Vickers Street, Furphy Avenue and Balmoral Street. The levee would prevent flooding of properties contained within. Details of the levee assessment are as follows:

- Length ~ 2.70 km
- Average height ~ 2.10 m
- Estimated costs ~ $1.2 million
- Reduction in AAD ~ $70,000
- Benefit/Cost ~ 0.8

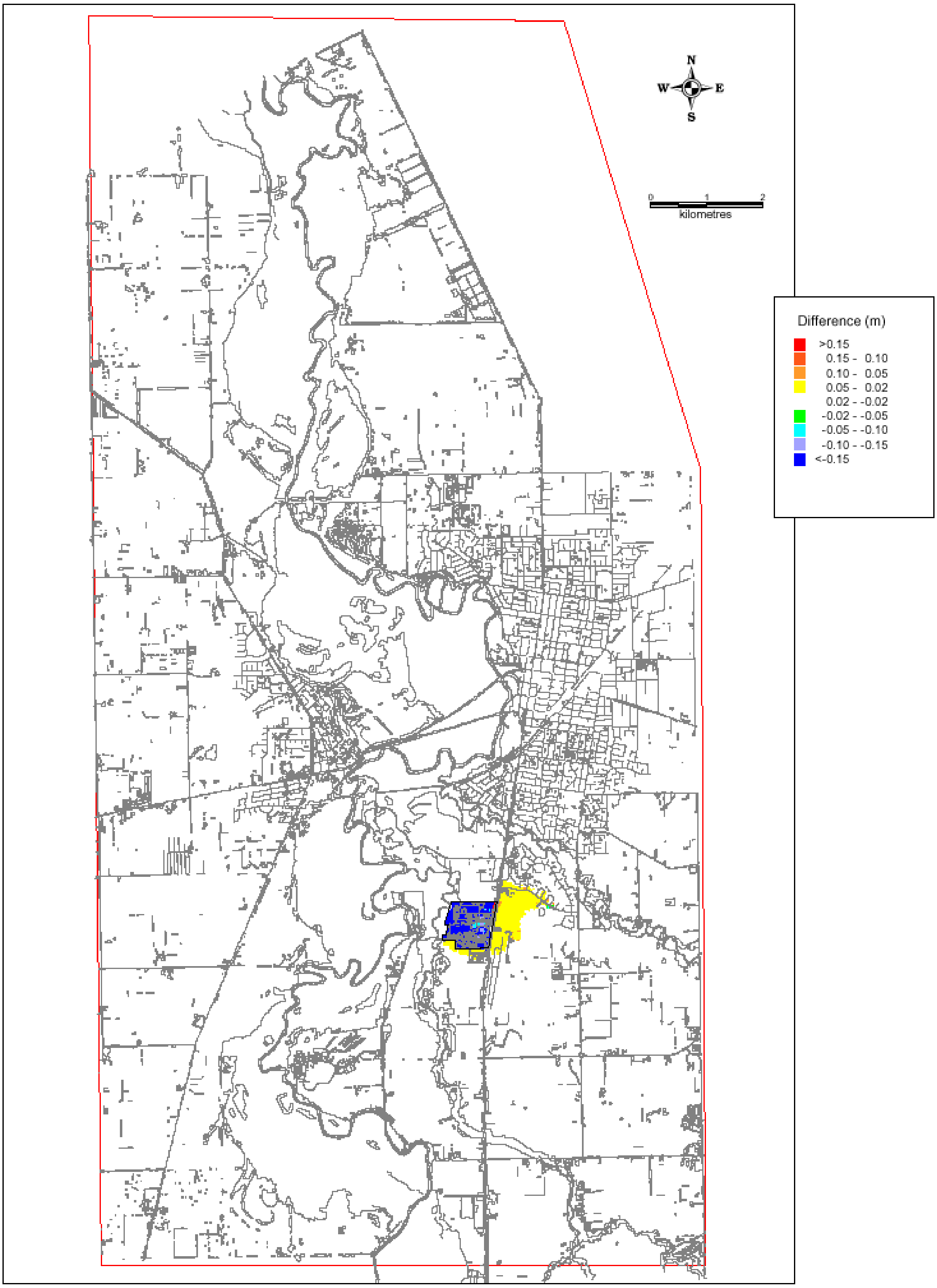
A hydraulic assessment of the flooding impacts for the 100 year ARI flood showed the levee increased water levels east of the Goulburn Valley Highway by 20 mm to 50 mm**.** **Figure 4-3** shows the *difference* in the 100 year ARI water surface levels between Option 1 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

Table 4-3 shows the effect of Option 1 on the number of properties affected, both above floor levels and total, for the 100 year ARI event over the entire study area.

Table 4-3 Option1 Kialla Levee – Properties Affected (100 year ARI event)

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	2,126	6,451
Reduction in number of properties	**34**	**121**

- **Figure 4-3 Option 1 Kialla Levee – Water Surface Level Difference (100 year ARI event)**



4.3.2 Option 2 – South Shepparton Levee

This option involved the construction of levee along Lincoln Drive, Broken River Drive. In addition, a low level bund is required along the northern side of the railway line from the Broken River to Goulburn Valley Highway. This bund prevents backwater flooding from the Goulburn River. Some stormwater works are required to prevent flooding through the stormwater drainage system. These works would prevent properties in the Shepparton South area flooding from the Broken River and backwater flooding from the Goulburn River.

Details of the levee assessment are as follows:

- Length ~ 4.8 km (includes railway bund)
- Average height ~ 1.50 m
- Estimated costs ~ $1.4 million
- Reduction in AAD ~ $130,000
- Benefit/Cost ~ 1.3

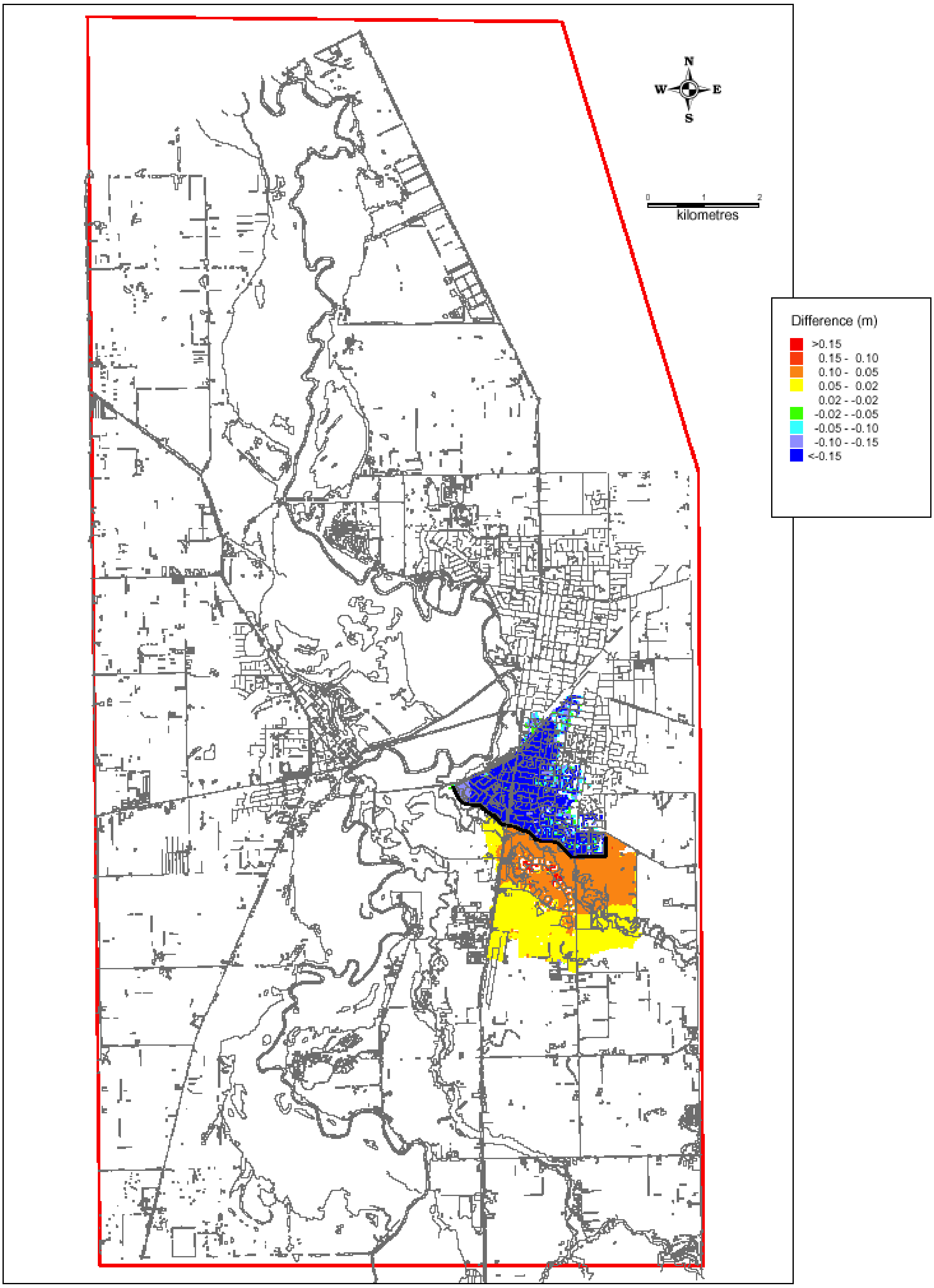
A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the levee increased water levels in the Kialla Lakes Residential Estate (south of Broken River) and adjoining properties by 50 mm to 100 mm. **Figure 4-4** shows the *difference* in the 100 year ARI water surface levels between Option 2 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

Table 4-4 shows the effect of Option 2 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

■ Table 4-4 Option 2 Shepparton South Levee - Properties Affected (100 year ARI event)

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	1,814	5,896
Reduction in number of properties	**346**	**676**

■ **Figure 4-4 Option 2 Shepparton South Levee – Water Surface Level Difference (100 year ARI event)**



4.3.3 Option 3 – South Mooroopna Levee

This option involved the construction of a levee along southern edge of the Mooroopna township from the Midland Highway (western edge of Mooroopna) to Toolamba Road. From Toolamba Road the levee continues north along the railway line then along the back of the Archer Street properties to the Midland Highway (eastern edge of Mooroopna). Some rural drainage works are required to divert the Ardmona Drain to the west of Mooroopna. This option prevents the breakout of the Goulburn River across the railway line through Mooroopna. For this option backwater flooding will still occur in Mooroopna via the Mooroopna golf course area.

Details of the levee assessment are as follows:

- Length ~ 3.9 km
- Average height ~ 1.40 m
- Estimated costs ~ $3.0 million
- Reduction in AAD ~ $330,000
- Benefit/Cost ~ 1.50

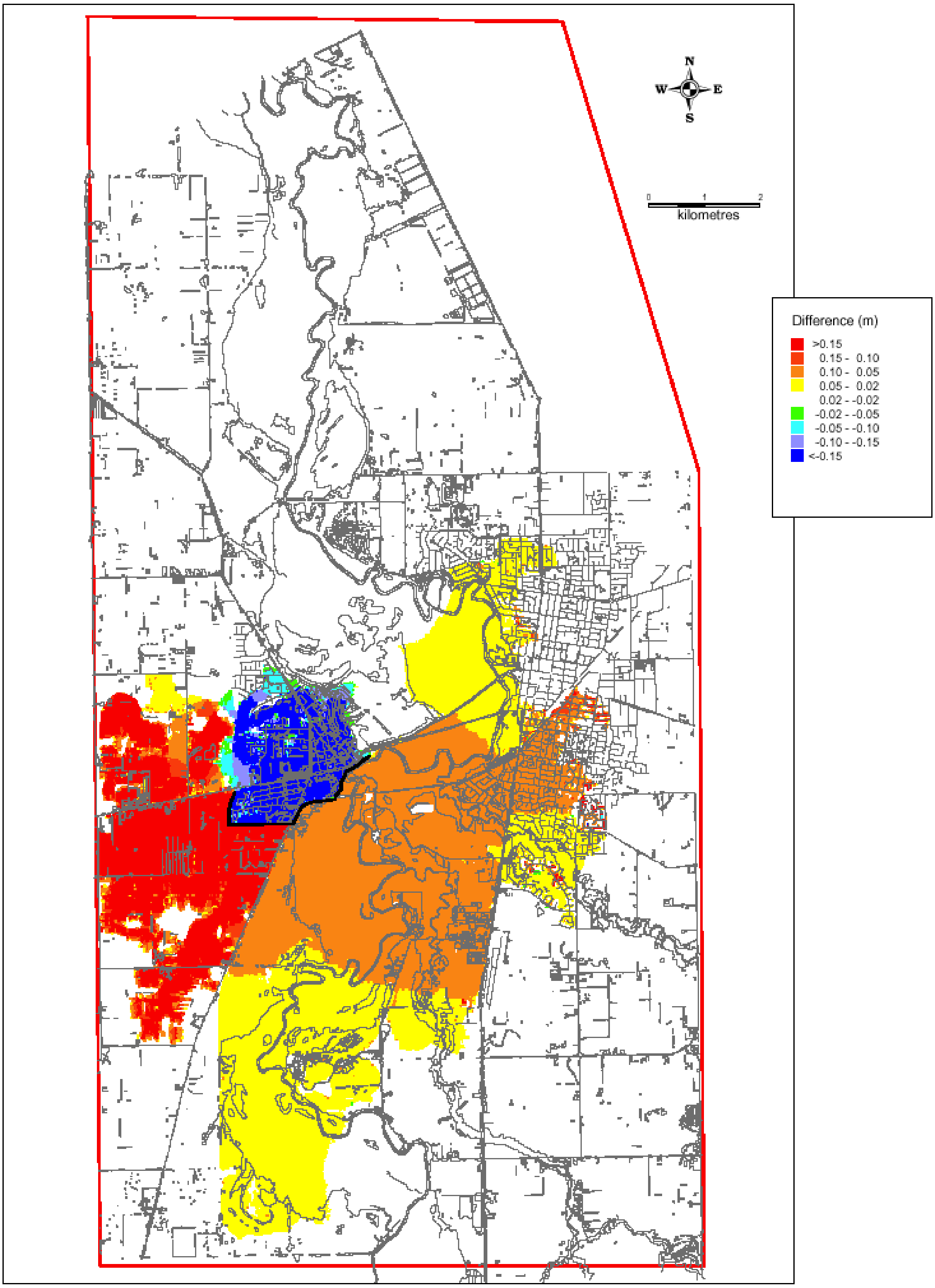
A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the levee increased water levels upstream of the levee significantly. Increases in the water levels through the Kialla Lakes, Kialla and South Shepparton areas are between 50 mm to 100mm. **Figure 4-5** shows the *difference* in the 100 year ARI water surface levels between Option 3 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

Table 4-5 shows the effect of Option 3 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

■ Table 4-5 Option 3 Mooroopna South Levee – Properties Affected (100 year ARI event)

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	1,468	5,816
Reduction in number of properties	**692**	**756**

■ **Figure 4-5 Option 3 Mooroopna South Levee – Water Surface Level Difference (100 year ARI event)**



4.3.4 Option 4 – Boulevard Levee

This option involved the construction of a levee from adjacent to the northern end of the De Lisle Avenue south to the north bank of the Goulburn River. The levee continues along the north bank of the Goulburn River behind the existing properties to the corner of the Boulevard and Knight Street. This option prevents the breakout from the Goulburn River across the Boulevard and through the existing residential area. Some backwater flooding will still occur along the existing floodway parallel to Hovell Crescent.

Details of the levee assessment are as follows:

- Length ~ 3.6 km
- Average height ~ 1.40 m
- Estimated costs ~ \$1.0 million
- Reduction in AAD ~ \$100,000
- Benefit/Cost ~ 1.50

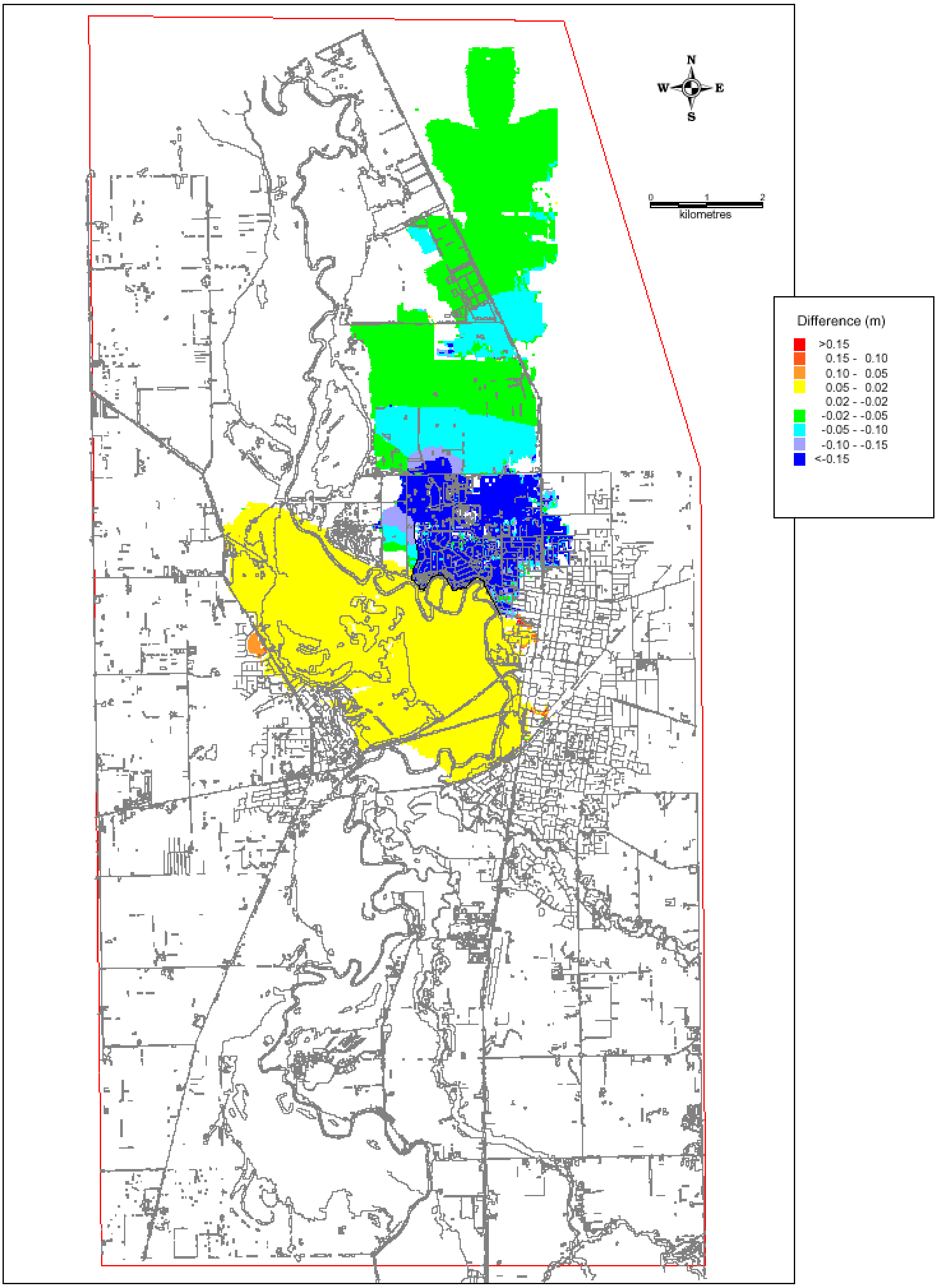
A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the levee increased water levels upstream of the levee. Increases in the water levels of 20 mm to 50 mm occur within the floodplain adjacent to Gemmills Swamp. **Figure 4-6** shows the *difference* in the 100 year ARI water surface levels between Option 4 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

Table 4-6 shows the effect of Option 4 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

■ Table 4-6 Option 4 Boulevard Levee – Properties Affected (100 year ARI event)

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	2,050	4,993
Reduction in number of properties	**110**	**1,579**

■ **Figure 4-6 Option 4 Boulevard Levee – Water Surface Level Difference (100 year ARI event)**



4.3.5 Option 5 – Combined Levees

This option combined the levees outlined in Options 1 to 4.

Details of the levees assessment are as follows:

- Total Length ~ 15 km
- Estimated costs ~ $6.6 million
- Reduction in AAD ~ $560,000
- Benefit/Cost ~ 1.10

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the levees increased water levels over the area upstream of the Boulevard levee. Significant increases in the water levels of 100 mm to 150 mm occur in the residential areas of Kialla and Kialla Lakes. **Figure 4-7** shows the *difference* in the 100 year ARI water surface levels between Option 4 and existing conditions. A positive number indicates an increase in water level due to the proposed levee.

Table 4-7 shows the effect of Option 5 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

- **Table 4-7 Option 5 Combined Levees – Properties Affected (100 year ARI event)**

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	831	3,937
Reduction in number of properties	**1,329**	**2,635**

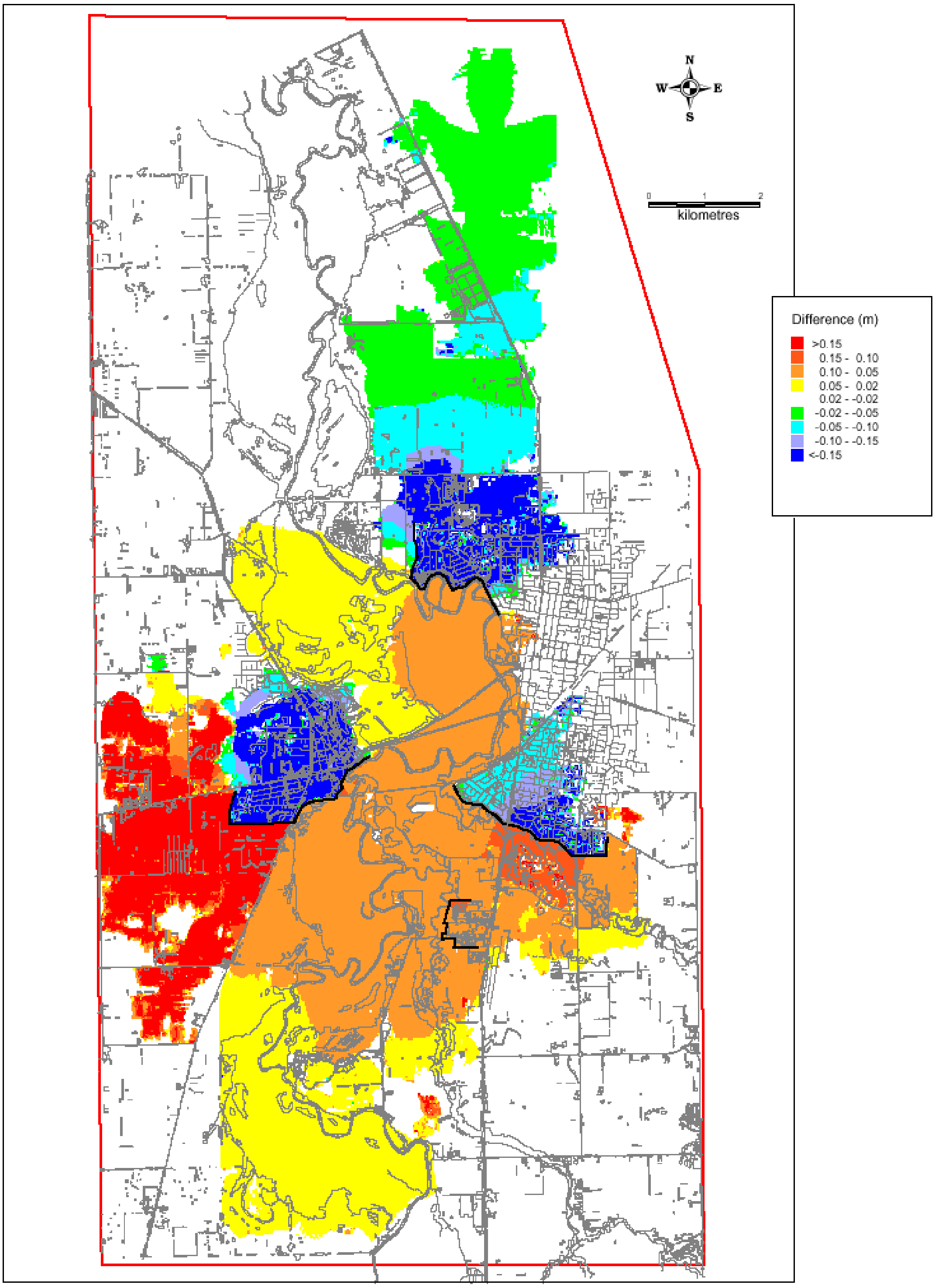
4.3.6 Levee Options - Conclusions

The levee options (Options 1 to 5) were presented to both the TSC and the CRG in April 2002, where it was considered that the increases in the water surface levels (see **Figure 4-3** to **Figure 4-7**) would be unacceptable to adjacent affected landholders. On this basis, levee options have not been considered further.

In addition, the construction of the South Mooroopna and Boulevard levees would involve siting the levees in close proximity to existing residential properties. Adverse social impacts would arise from the levee locations and include the visual impacts and inconvenience.

Given the adverse flooding impacts and community feedback via the CRG, Options 1 to 5 are not recommended for inclusion in the floodplain management plan. As a result and as noted in **Section 4.3**, environmental assessment of these options was not necessary.

■ **Figure 4-7 Option 5 Combined Levees - Water Surface Level Difference (100 year ARI event)**



4.3.7 Option 6 – East Mooroopna Floodway

This option involved the construction of a floodway through a ridge adjacent to the Ibis piggery. The floodway exploits the significant difference in flood level between the old Mooroopna Hospital and Gemmill's Swamp. To improve the efficiency of the floodway the widening of the Geraghty's Bridge opening in the causeway by 25 m (approximately doubling the existing opening) were considered as part of the works. This option removes an obstruction to the flow on the western floodplain.

Details of the floodway assessment are as follows:

- Length ~ 330 m
- Width ~ 200 m
- Depth of excavation ~ 0.9 m average; ~ 1.5 m maximum
- Volume excavated ~ 64 000 m^3
- Widening of Geraghty's Bridge by 25 m
- Estimated Cost ~ $1 .8 million
- Reduction in AAD ~ $75,000
- Benefit/Cost ~ 0.6

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the floodway decreased water levels in the floodplain from the causeway to the Boulevard by 20 mm to 50 mm. Localised increases in the water levels of 20 mm to 50 mm occurred at the floodway outlet adjacent to Gemmill's Swamp (Note: increases do not occur in the vicinity of existing properties). **Figure 4-8** shows the *difference* in the 100 year ARI water surface levels between Option 6 and existing conditions. A positive number indicates an increase in water level due to the proposed floodway.

Table 4-8 shows the effect of Option 6 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

- **Table 4-8 Option 6 East Mooroopna Floodway – Properties Affected (100 year ARI event)**

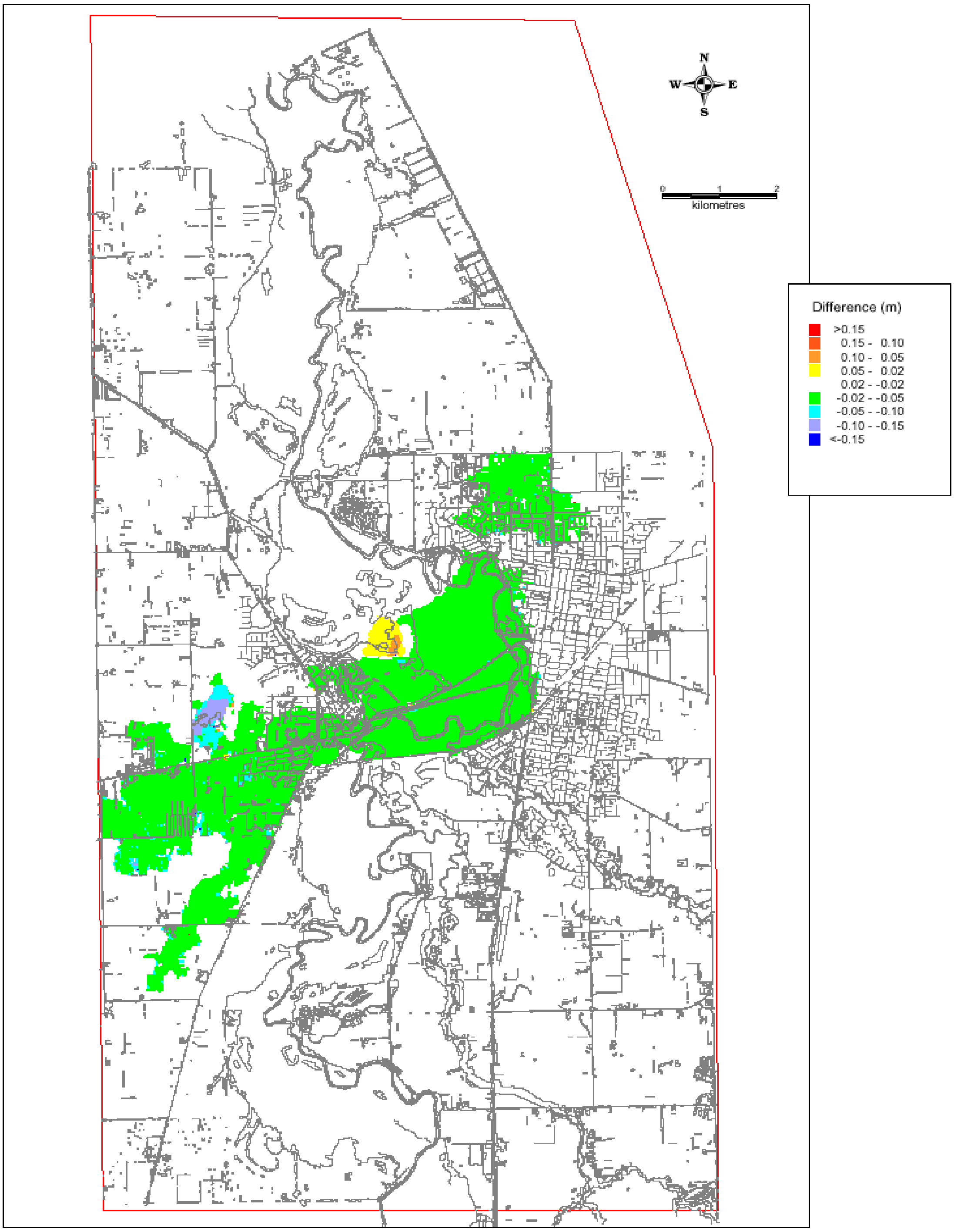
Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	2,061	6,447
Reduction in number of properties	**99**	**125**

The floodway is located on a portion of the floodplain which is inundated in flood events greater than 20 years ARI. For flood events with ARIs less than 20 year the floodway has no effect on flood behaviour. Given this relatively low frequency when the floodway will operate it is considered the environmental impact on Gemmill's Swamp will be minimal.

For the 100 year ARI event peak flow velocities through the floodway are about 1 m/s. These velocities are unlikely to result in scouring of a grassed floodway. As indicated above the floodway will not operate in flood events with an ARI less than 20 years. Due to the low frequency of inundation and the significant distance from the floodway to the Goulburn River, the risk of avulsion (ie, a change in river course) of the Goulburn River along the floodway is considered low.

Due to the low benefit cost ratio, the East Mooroopna Floodway is considered uneconomic and is not recommended for inclusion in the Floodplain Management Plan.

■ **Figure 4-8 Option 6 East Mooroopna Floodway - Water Surface Level Difference (100 year ARI event)**



4.3.8 Option 7 – Realignment of Channel 12

This option involves the realignment of the Channel 12 along the western side of the Barmah Shepparton Road. Currently the banks of Channel 12 form a barrier to the flood flow in the area to the south of the Sewerage Treatment plant. Channel 12 is used for the distribution of irrigation water by Goulburn Murray Water.

Details of the floodway assessment are as follows:

- Length of channel to realignment ~ 5.6 km
- Estimated Cost ~ $1.2 million
- Reduction in AAD ~ $40,000
- Benefit/Cost ~ 0.5

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the realignment of Channel 12 decreased water levels in the area north of Wanganui Road to the existing Channel 12 alignment by up to 150 mm. Smaller decreases of 20 mm to 50 mm are seen in the area south of Wanganui Road to the Boulevard. Increases in the water levels occur downstream of the existing alignment adjacent to the Sewerage Treatment Plant. **Figure 4-9** shows the *difference* in the 100 year ARI water surface levels between Option 7 and existing conditions. A positive number indicates an increase in water level due to the proposed realignment.

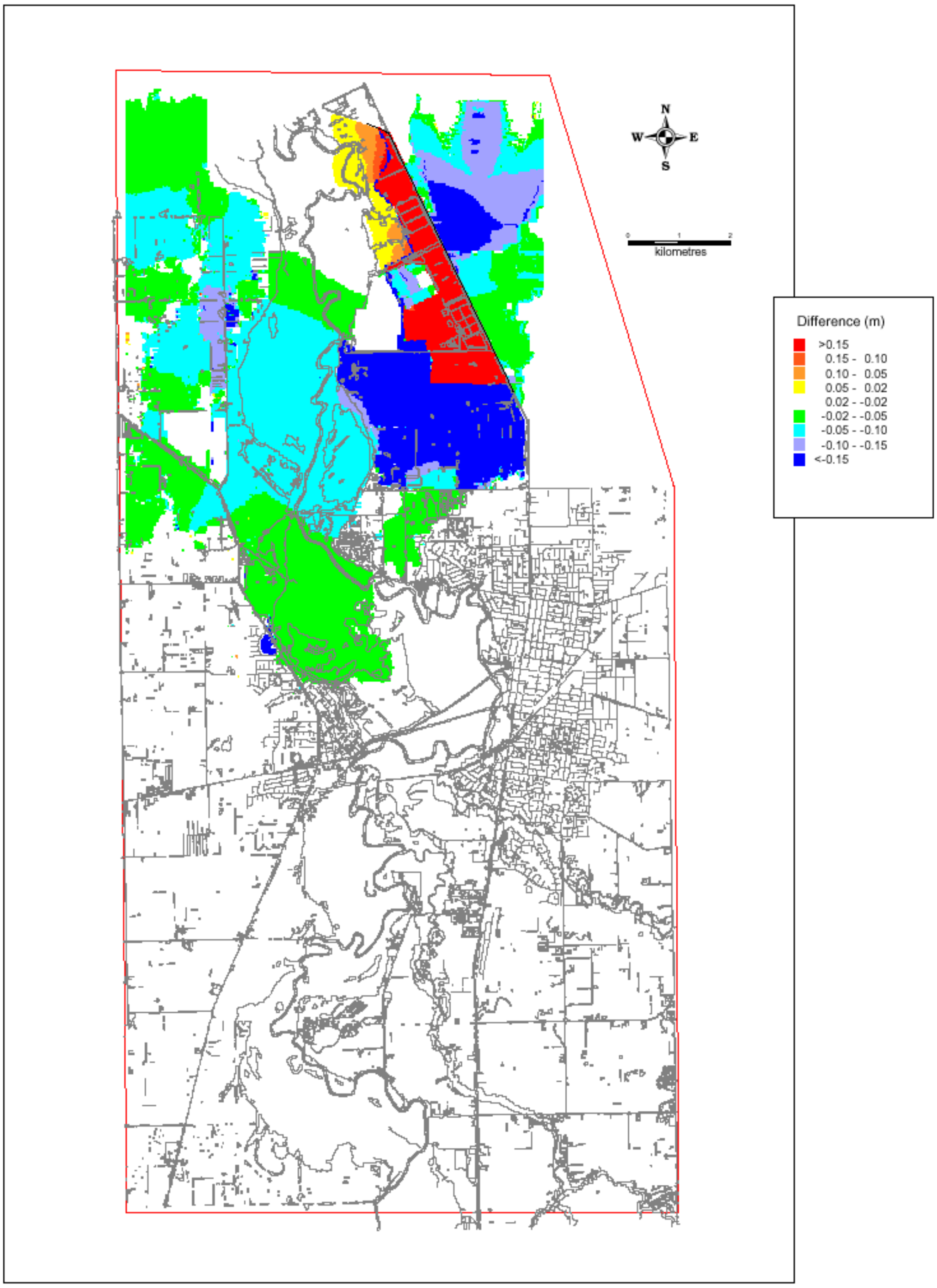
Table 4-9 shows the effect of Option 7 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

- **Table 4-9 Option 7 Channel 12 Realignment – Properties Affected (100 year ARI event)**

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	2,140	6,492
Reduction in number of properties	**20**	**80**

Due to the low benefit cost ratio the Channel No. 12 realignment is considered uneconomic and the option is not recommended for inclusion in the Floodplain Management Plan.

- **Figure 4-9 Option 7 Channel 12 Realignment - Water Surface Level Difference (100 year ARI event)**



4.3.9 Option 8 – Increased Bridge Openings in Causeway and Railway Line

This option involves increasing the bridge openings through both the causeway and the railway line. The hydraulic analysis for existing conditions has shown that both the causeway and railway cause a significant increase in flood levels immediately upstream of both structures. These increases are due to the constriction to the flood flow formed by the two structures. This option aims to reduce the increases in upstream flood levels by increasing waterway openings.

This option considered a doubling of the bridge openings in both the causeway and railway line. This would involve the replacement of existing bridges with new extended bridge structures. The details of the increased openings are as follows:

- Causeway (openings number west to east)
  - Geraghty's Bridge - increased by 25m
  - Ah Wong's Bridge - increased by 50m
  - Boolbadah Floodway Bridge - increased by 75m
  - Daish's Bridge - increased by 25m
  - McGuire's Bridge - increased by 100m
  - Dainton's Bridge (Goulburn River) increased by 75m.
- Railway
  - Goulburn River - increased by 175m
  - Broken River - increased by 75m

Details of the causeway and railway openings are as follows:

- Preliminary Cost ~ $20 million
- Reduction in AAD ~ $240,000
- Benefit/Cost ~ 0.16

A hydraulic assessment of the flooding impacts for the 100 year ARI flood event showed the widening of causeway and railway opening decreased water levels in the area between the causeway and railway by 100 mm to 150 mm. Larger decreases in water levels occur immediately south of the railway. North of the causeway, increases in water levels of 20 mm to 50 mm occur in the Boulevard area. Immediately downstream of the causeway increases in water levels are between 50 mm to 100 mm. **Figure 4-10** shows the *difference* in the 100 year ARI water surface levels between Option 8 and existing conditions. A positive number indicates an increase in water level due to the proposed wider openings.

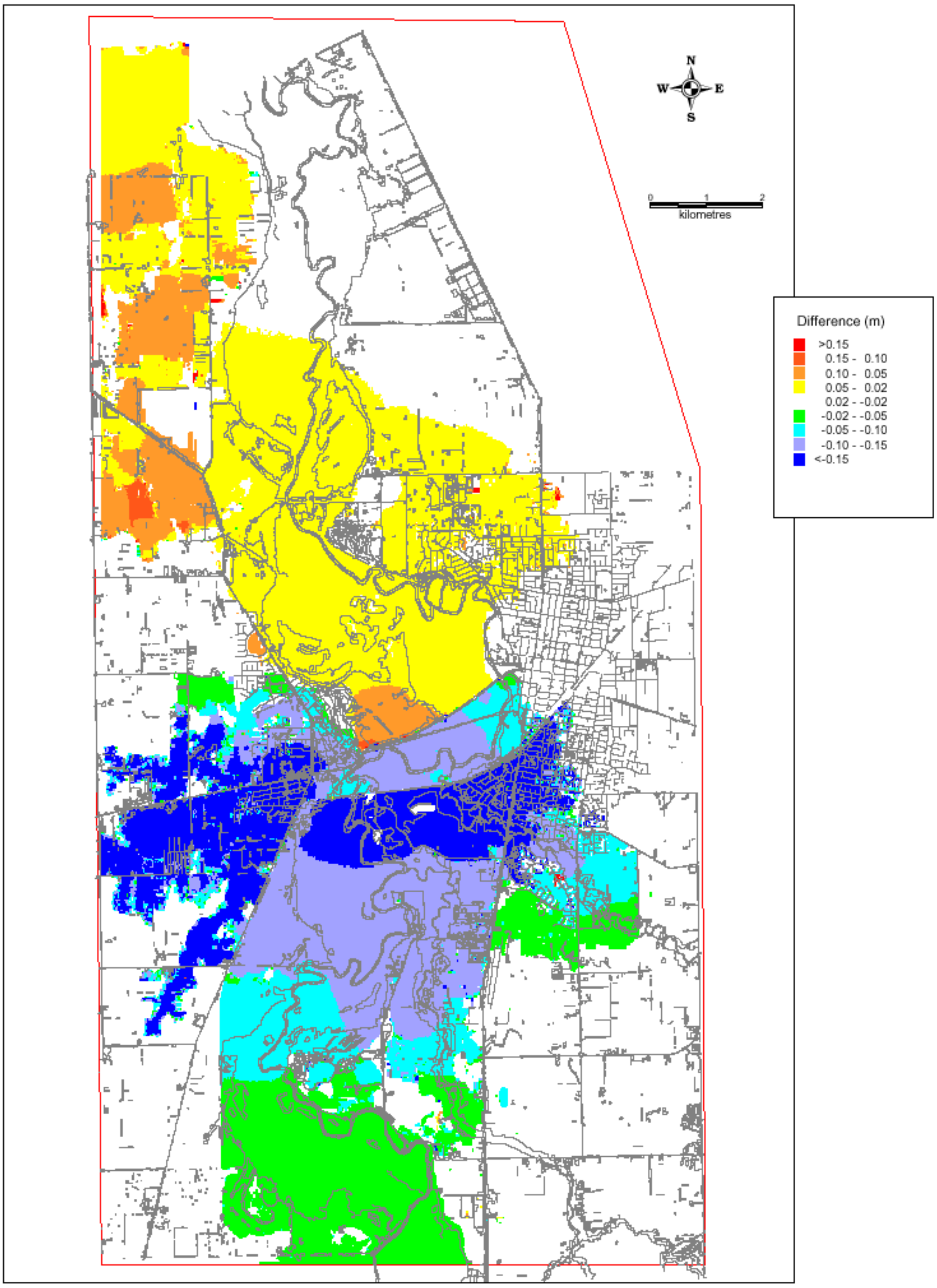
Table 4-10 shows the effect of Option 8 on the number of properties affected, both above floor and total, for the 100 year ARI event over the entire study area.

- **Table 4-10 Option 8 Causeway and Railway Opening – Properties Affected (100 year ARI event)**

Scenario	Flooded Above Floor Level	Total Flooded
Existing	2,160	6,572
Proposed Option	1,322	5,917
Reduction in number of properties	**838**	**655**

This option results in a significant reduction in properties flood affected and incurring flood damages. However due to the high capital cost the benefit cost ratio is low. On this basis increasing bridge causeway and railway openings is considered uneconomic. The option is not recommended for inclusion in the Floodplain Management Plan.

■ **Figure 4-10 Option 8 Causeway and Railway Increased Waterway Openings - Water Surface Level Difference (for 100 year ARI event)**



4.4 Assessment of Non-structural Flood Mitigation Measures

4.4.1 Planning Scheme Amendments (Land Use Planning)

Amendments to the current planning scheme are aimed to ensure that future land use and development are compatible with flooding risks as identified by the study. **Section 3.8** outlines the approach adopted by this study in providing improved planning information to the GSCC and GBCMA.

Improved land use planning does not immediately reduce flood damages for existing properties/infrastructure, but does provide an effective means of reducing flood damages in the longer term.

In addition, the improved information for land use planning would facilitate more effective assessment of applications.

4.4.2 Emergency Response and Flood Warning

As outlined in **Section 3.7**, flood inundation maps and property listings have been developed for a range of gauge heights at Shepparton (as shown in **Table 3-5**). The flood inundation maps show the flood extents, flood depths, flood elevations contours and properties inundated above floor level and the property listings identified the address of properties inundated above floor for a range of gauge heights at Shepparton.

The flood response plan for Shepparton–Mooroopna (Flood sub-plan of the Municipal Emergency Management Plan) has been reviewed as part of this study. The revised flood response plan incorporates the flood inundation maps and property listings.

The revised flood response plan will represent a significant improvement over current emergency management and response by providing detailed information about infrastructure (roads, etc) and properties affected for a given gauge height at Shepparton. As a consequence it is likely that there will be a reduction in flood damages experienced, as authorities/residents will be able to take appropriate preparatory actions (ie lifting of valuable property above flood level, sand bagging, etc).

The benefit of improved flood response/warning can be assessed by adjusting the ratio – the Damage Reduction Factor (DRF) - of actual damages to potential damages. As outlined in **Section 3.5** the ratio was set to 0.7 to evaluate the flood damages for existing conditions.

The RAM (NRE, 2000) provides some guidance on appropriate DRFs under improved emergency response/flood warning. It is considered reasonable that a DRF of 0.6 be adopted to evaluate the effectiveness of the revised flood response plan.

Based on the revised DRF the average annual damages (AAD) reduces from $1.09 million under existing conditions to $990,000 with the implementation of the revised flood response plan.

The flood inundation maps for emergency response, outlined in **Section 3.7**, have been based on inflows from the Goulburn River, Broken River and Seven Creeks. To utilise these flood inundation maps requires flood forecasts for the three streams at locations immediately upstream of the study area.

The Bureau of Meteorology (BoM) in consultation with Goulburn-Murray Water (G-MW) currently provides quantitative flood forecasts (flood height and timing of peak) at the following gauges relevant to this study:

- Goulburn River at Murchison
- Goulburn River at Shepparton

Through consultation with BoM (A Baker, *pers comm*. 2002), the Murchison gauge on the Goulburn River is considered too far upstream of the study area to be fully effective. It is therefore recommended a telemetered stream gauge be installed near the upstream limit of the study area. A gauge at this site would also have the advantage of capturing inflows from the Castle, Creightons and Pranjip Creek catchments. It may be possible to re-establish the discontinued gauge on the Goulburn River at Kialla West.

A basic service for Orrvale is provided but this can be inaccurate in larger flood events as a result of the unknown magnitude of breakouts between Casey's Weir and Orrvale. Further investigations are required to quantify these breakouts with an aim to improve the accuracy of forecasts at Orrvale.

Additional quantitative flood forecasts (flood height and timing of peak) would be required for the Seven Creeks at Kialla West. The additional forecast for Seven Creeks at Kialla West could be made by using information for Seven Creeks at Euroa and relationship developed as part of this study's hydrological analysis. A small amount of extra investigation is required to assess the suitability of this developed relationship for flood warning purposes. Alternatively, the existing Euroa URBS Flood Forecasting model could be extended to Kialla West (A Baker, *pers comm*. 2002).

BoM is currently finalising the development of an URBS runoff routing model for flood prediction for Goulburn Catchment to Seymour. This model could be extended to Shepparton and then include quantitative prediction at all gauges relevant to the Shepparton Mooroopna study. The existing models for the Broken River to Benalla and Seven and Castle Creeks to Euroa would be incorporated into this lower Goulburn model.

To complement the URBS model development, BoM recommends that telemetry at a number of gauging stations be upgraded. The Goulburn River at Murchison and, Goulburn River at Shepparton and the Broken River at Orrvale gauges have older style telephone telemetry (telemark) which requires manual interrogation. Sevens Creeks at Kialla West has a modem interface which allows automatic interrogation of the gauge at the preset times. It is recommended that all critical gauges (Shepparton, Murchison, Kialla West and Orrvale) be upgraded to Event Radio Reporting Telemetry Systems (ERTS). It is further recommended that a new ERTS based stream gauge be commissioned on the Goulburn River at the upstream limit of the study area. Communications infrastructure at the new Yarrawonga radar site could be used to transfer data in real time to the BoM Flood Warning Centre in Melbourne. ERTS telemetry is preferred to telephone telemetry because there are no telephone polling or rental costs and greater resolution data is provided. Data from all relevant rain and stream levels sites would be displayed on the BoM's publicly accessible website (A Baker, *pers comm*. 2002).

BoM would be willing to contribute toward the capital costs of upgrading the existing sites subject to ongoing costs being met by local beneficiaries (ie: GSCC, GBCMA and G-MW). Also, BoM can assist with radio path testing to determine the suitability of the suggested telemetry upgrade approach for the existing four sites and the proposed new site. Ongoing maintenance procedures at the new site should include the development of high stage rating tables. It is likely that a small amount of hydraulic modelling work would be required at the two new sites to develop synthetic rating tables. These relationships would be required for the interim period until measured rating relationships are developed.

Opportunities to use FM88 and automated mass dialling to aid in flood warning have been explored (N McPherson, *pers comm.*, 2002). FM88 radio exists in the Shepparton-Mooroopna area although it is assumed an upgrade of station facilities to accommodate the flood warning process is necessary. Automated mass dialling, whilst appealing in principle, is more problematic as suitable systems have not yet been developed.

Importantly, it is believed beneficial to use only one means of mass-communication for flood warning to ensure consistency of flood warning messages. On this basis a focus on FM88 is recommended, although opportunities and developments in automated dialling are worth tracking and exploring.

Flood warning arrangements will be documented as part of the flood response plan (Flood sub-plan of the Municipal Emergency Management Plan).

5. Floodplain Management Plan

5.1 Outline of Recommended Plan

The investigations in this study have been brought together as the Floodplain Management Plan for Shepparton-Mooroopna. This study has been conducted in line with best practice principles using a risk management framework (DNRE/DoJ 1998).

The recommended plan is in line with the Goulburn Broken CMA Regional Floodplain Strategy (SKM 2002c) and contains the following elements:

- *Planning Scheme Amendment*
  - It is recommended the Greater Shepparton City Council amend its planning scheme to include the revisions to the planning zones and overlays as outlined in **Section 3.8**.
  - It is recommended the Goulburn Broken Catchment Management Authority declare the 100 year ARI flood levels outlined in **Section 3.8**.

- *Flood Warning Arrangements*
  - It is recommended that BoM in conjunction with G-MW continue to provide quantitative flood forecasts for the Goulburn River at Murchison and Shepparton.
  - It is recommended the future role of G-MW in providing forecasts for Shepparton and other locations be resolved.
  - It is recommended that a new gauging station be established on the Goulburn River adjacent to the upstream study limit and BoM provide quantitative flood forecasts for this gauge.
  - It is recommended that the accuracy of the current flood forecasts for the Broken River at Orrvale be improved by further investigation of Broken River breakout between Casey's Weir and Orrvale.
  - It is recommended that BoM provide additional quantitative flood forecasts for the Sevens Creeks at Kialla West and the proposed new site on the Goulburn River at the upstream limit of the study area.
  - It is recommended that the communication infrastructure for gauges at Murchison, Shepparton, Kialla West and Orrvale be upgraded to Event Radio Reporting Telemetry Systems.
  - It is recommended that GSCC review existing roles and investigate further opportunities for Emergency Radio FM88 to assist in flood warning arrangements.
  - It is recommended that GSCC explore the viability of automatic telephone dialling as an alternative to deliver flood warnings to individual properties.

- *Flood Response and Recovery*
  - It is recommended the Greater Shepparton City Council revise its flood response plan (which requires amendment of the Municipal Emergency Management Plan - flood sub plan). This flood response plan outlines:
    - the roles and responsibilities of the relevant authorities,
    - means of disseminating flood warnings,
    - emergency works and actions (eg. evacuation, sand bagging, road closures, etc),

    - performance monitoring of emergency response and management (evacuations, road closures, injuries etc),
    - arrangements for flood recovery,
    - arrangements for counselling to address social trauma,
    - arrangements for financial flood relief.

  - The flood response plan should also be cognisant of the "Greater Shepparton Public Health Plan."

- *Flood Monitoring*
  - It is recommended that the Greater Shepparton City Council and the Goulburn Broken CMA establish an agreement to cover the following flood monitoring aspects:
    - triggers and methods for data collection of rainfall, peak flood flows, peak flood levels, flood extents (including on ground survey, aerial photography and satellite imagery) and flood damages (includes damage to bed and bank, structural damages etc),
    - procedures for the storage of flood data collected during flood events.

    Note: This agreement will be based on the existing Flood Assessment Manual prepared for GBCMA Flood Response Action Plan (SKM 2002d).

- *Flood Preparedness and Community Awareness*
  - It is recommended the Greater Shepparton City Council in conjunction with the Goulburn Broken CMA develop a program to increase community awareness of existing flood risks, flood emergency response and flood warning arrangements. The program should consist of the following elements:
    - Community flood guide outlining contact phone numbers, context of local flooding issues, flood warning arrangements and useful tips for reducing damage and enhancing safety.
    - Contribution to media articles regarding flood issues.
    - Public exhibition of this study's outcomes in Council's foyer.

- *Information Management Systems*
  - It is recommended the Greater Shepparton City Council in conjunction with the Goulburn Broken CMA develop information management systems to facilitate the access and use of the flood information from previous studies, this current study and collected during flood events. The information management systems may include the following elements:
    - Customised GIS database/interface to facilitate the collation and access to the topographic, property, flood data collected as part of this study. All spatial study outputs (flood inundation maps etc) should also be included in the GIS database.
    - Training for GSCC and GBCMA staff in the use of the GIS database.
    - Establishment of a central location for hard copies of reports and maps.

This floodplain management plan recognises the principles of the VicHealth document "Leading the Way - Councils creating healthier communities", particularly the principle of integrated planning. In this regard, the floodplain management plan should call on provisions of the municipal public health plan when establishing flood recovery methods and more generally by providing a sense of improved personal safety in times of flood.

It should be noted that following the detailed assessment of structural mitigation options, no structural mitigation works are recommended for the plan.

From the assessment in **Section 4.4.2**, the flood warning arrangements and flood response elements alone would reduce the average annual damage (AAD) from $1.09 million to $990,000. This represents a benefit of $100,000 per year. It is reasonable to expect that the other elements of the recommended plan would also lead to further reductions in flood damages.

5.2 Costs Associated with Recommended Plan

The cost breakdown of the recommend plan, as outlined in **Section 5.1**, is shown in **Table 5-1**. Also provided is an indication of the priority of the recommended plan's elements.

- **Table 5-1 Recommended Floodplain Management Plan – Costs**

Element	Cost	Priority
Planning Scheme Amendment - Adopt Planning overlays and zones - Declare 100 year ARI flood levels	 $6,000 $3,000	 Very high Very high
Flood Warning Arrangements - Clarify arrangements with G-MW - Establish gauging station on the Goulburn River adjacent to the upstream limit of the study area. - Improve accuracy of forecast at Orrvale - Provide quantitative flood forecast for Sevens Creeks at Kialla West - Upgrade communication infrastructure for Murchison, Shepparton, Orrvale and Kialla West - Emergency Radio, FM88 - Automatic Telephone Dialling Viability	 $2,000 $50,000 $10,000 pa $7,000 $10,000 $30,000 $12,000 $3,000	 Very high High High High High High Medium
Flood Response - Develop flood response plan - Link to municipal public health plan	$10,000	Highest
Flood Monitoring - Develop/review monitoring plan - Data collection as required	 $3,000 $10,000 (indicative)[1]	 High High
Flood Preparedness and Community Awareness - Develop community flood response plan - Printing and distribution of community flood response plan	 $7,000 $10,000	 Medium Medium
Information Management System - GIS development - Training	 Part of current Study $3,000	 Very high High
Total **- Capital cost (excl. data collection)** **- Recurrent cost**	 **$156,000** **$10,000 p.a**	

1. Cost is dependent on size of flood events.

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