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Study Report

Flood Risk Management Study – Lower Barwon River and Lower Moorabool River

Corangamite CMA

01 March 2019

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01 March 2019

Geoff Taylor
Floodplain Manager
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Via email: geoff.taylor@ccma.vic.gov.au

Dear Geoff,

Flood Risk Management Study – Lower Barwon River and Lower Moorabool River

Please find below the draft report for the Lower Barwon River and Lower Moorabool River Flood Study. We would welcome any feedback or questions regarding the report. Please note that the flood warning review and planning report will be included early in January 2019 as those reports become available.

Yours sincerely

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Senior Engineer

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CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Overview

Corangamite CMA in partnership with the City of Greater Geelong and Golden Plains Shire Council engaged Water Technology to undertake the Lower Barwon and Lower Moorabool Rivers Flood Risk Management Study. The overall objective of this project is to review and revise existing flooding information and produce detailed flood mapping for a range of flood modelling scenarios within the study area. The project has involved a definitive flood investigation for the floodplain reaches within the study area, including collation of available relevant data, a comprehensive hydrological assessment, and determination of robust flood levels, velocities, depths and extents for a range of design floods. The project will develop an improved understanding of flood behaviour to enable improved land use planning and emergency response.

This document is the fourth and final of a series of technical reports which will be prepared during the study. This report forms a draft study report and documents the flood intelligence information for emergency response, damage assessment, mitigation analysis and other key findings from the study.

2 BACKGROUND

The study area is defined by the lower reaches of the Barwon River and the Moorabool River to the mouth of the Barwon River including Waurn Ponds Creek and a number of small tributaries (Figure 2-1). The study area extends upstream to the Batesford streamflow gauge on the Moorabool River and the Pollocksford streamflow gauge on the Barwon River.

FIGURE 2-1 STUDY AREA

The floodplains of the Barwon and Moorabool Rivers have faced significant riverine floods noted in 1852, 1880, 1909, 1951, 1978, 1995, 2001 and 2011. Fortunately given the long and frequent history of flooding along the Barwon and Moorabool Rivers much of the residential development through Geelong and the wider catchment is located outside of the areas know to be subject to flooding. Consequently, much of the floodplain is now occupied for recreational uses with some land still occupied by industrial businesses.

Numerous flooding investigations of the Barwon and Moorabool Rivers, as well as a number of important tributaries including the Leigh River, Waurn Ponds Creek and Armstrong Creek have occurred over the past 50 years, the most significant of these include:

- Geelong Flood Plain Management Study, GHD (J1982)
- Geelong Flood Mitigation Strategy Final Report, GHD (1997)
- Moorabool and Barwon River Regional Flood Mapping Project, GHD (2016)

The project has produces flood mapping and improves the flood intelligence for the major waterways in and around the city of Geelong within the study area shown in Figure 2-1.

3 HYDROLOGY AND HYDRAULICS SUMMARY

3.1 Hydrology Summary

3.1.1 Overview

An overview of the hydrological analysis for the study is provided below. For further detail regarding the analysis the hydrology report should be consulted (Water Technology 2018).

The primary aim of the hydrological analysis undertaken for this project included:

- Determining design event peak flows and hydrographs for input to the hydraulic model at the model boundaries primarily the Barwon River from Pollocksford, the Moorabool River at Batesford, Waurn Ponds Creek and a number of small local tributaries.
- Design Events included the 50%, 20%,10%, 5%, 2%, 1%, 0.5%, 0.2% AEP flood events, probable Maximum flood (PMF) and climate change scenarios.
- Determine historic flows and streamflow data available for calibration of the hydraulic model.

To achieve these aims, the hydrological assessment was separated into three components (Figure 3-1):

- Flood Frequency Analysis (FFA) – Which included analysis of the Barwon River at both the Pollocksford and Geelong gauges and the Moorabool River at Batesford.
- Waurn Ponds Creek hydrological (RORB) model.
- Rain-on-grid modelling of the small local tributaries.

The rainfall on grid modelling of the local tributaries has provided mapping of the smaller tributaries right to the top of each catchment. This adds significant benefit to the outcomes of the project with indicative flood mapping available across all of the local tributaries being investigated.

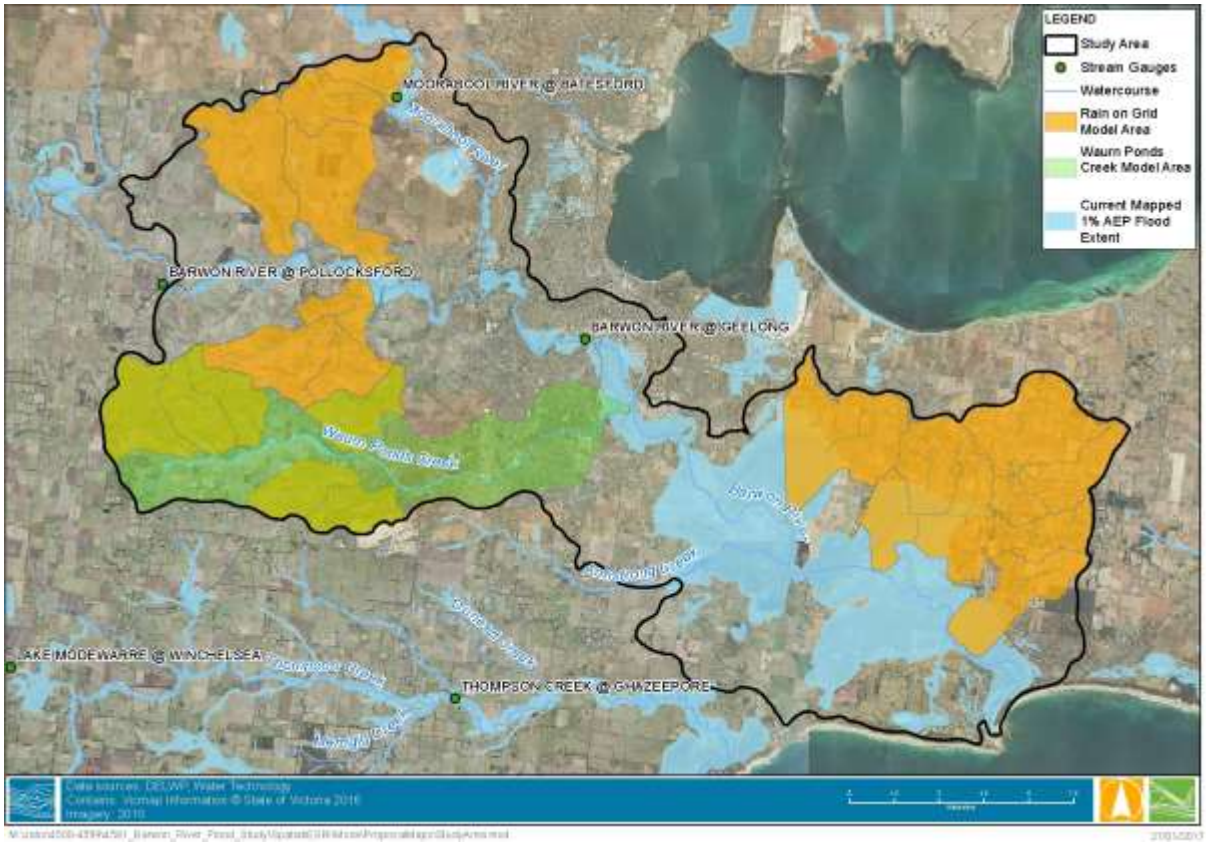

FIGURE 3-1 STUDY AREA AND HYDROLOGICAL MODEL AREAS

3.1.2 Summary of Design Flows

The design flows calculated during the hydrological analysis, through the FFA and RORB modelling, are summarized in Table 3-1. For reference the location of the streamflow gauges is presented in Figure 3-1.

TABLE 3-1 DESIGN FLOWS SUMMARY

	Barwon River at Pollocksford		Moorabool River at Batesford		Barwon River in Geelong (McIntyre's)		Waurn Ponds Creek at Barwon Heads Road bridge	
Design AEP (%)	**Peak Flow (ML/d)**	**m^3/s**	**Peak Flow (ML/d)**	**m^3/s**	**Peak Flow (ML/d)**	**m^3/s**	**Peak Flow (ML/d)**	**m^3/s**
50%	9,180	**106**	3,221	**37**	9,999	**116**	916	**11**
20%	24,063	**279**	8,771	**102**	25,983	**301**	1,643	**19**
10%	38,004	**440**	14,012	**162**	41,559	**481**	2,312	**27**
5%	54,149	**627**	20,071	**232**	60,343	**698**	3,168	**37**
2%	78,702	**911**	29,222	**338**	90,367	**1,046**	4,640	**54**
1%	99,568	**1,152**	36,926	**427**	117,198	**1,356**	5,897	**68**
0.50%	122,294	**1,415**	45,236	**524**	147,736	**1,710**	7,273	**84**
0.20%	155,267	**1,797**	57,048	**660**	194,022	**2,246**	10,014	**116**
PMF	1,453,594	**16,824**	827,971	**9,583**	395,615	**4,579**	64,714	**749**

3.2 Hydraulics Summary

3.2.1 Overview

This section discusses the application of the hydraulic model to simulate flood behaviour (extents, depth, velocities) for a range of historic and design floods.

The hydrologic analysis provided flood inflow hydrographs for the hydraulic model. These inflow hydrographs were routed through the calibrated hydraulic model. This enabled the modelling of flood depths, extents and velocities over a range of design flood magnitudes. It also provided a tool to assist the understanding flood behaviour across the study area.

3.2.2 Model Schematisation

A detailed description of the hydraulic model setup, calibration and validation is provided in the Hydraulics Report (Water Technology 2018). This section summarises the general model development and key outcomes from the hydraulic modelling investigation.

The approach adopted for the hydraulic model is a 1D/2D MIKE FLOOD coupled model, using flexible mesh and GPU technology.

The hydraulic model covers the Lower Barwon River, Lower Moorabool River and Waurn Ponds Creek as well as the surrounding floodplains. Topography and bathymetry data sets were used to develop the model in either 1D or 2D numerical schemes. Survey of all hydraulic structures impacting flood levels and extents, were included in the model.

The final hydraulic model had the following set-up:

- Moorabool River from the Batesford streamflow gauge to the confluence with the Barwon River is represented a detailed 2D model;
- Waurn Ponds Creek is represented by a 1D branch laterally linked to the 2D floodplain from the upstream boundary of the model to the confluence with the Barwon River
- Barwon River from Pollocksford streamflow gauge to Shannon Ave bridge is represented by a detailed 2D model;
- From Shannon Ave to the northern part of Connewarre Lake, the Barwon River is represented by a 1D model laterally linked to the the2D floodplain,
- Several hydraulic structures in the floodplain we're included in the model via linked 1D branches;
- The mesh was developed iteratively, starting with a coarse mesh for more efficient modelling (faster runs), with iterative refinements to provide improved connectivity through the various floodplains, accurate flood extents and achieve a better calibration. The compromise between run-time and model resolution was key to the model development. The 2D mesh was also supplemented with detailed linear features called dike lines, representing roads, channel banks and levees.

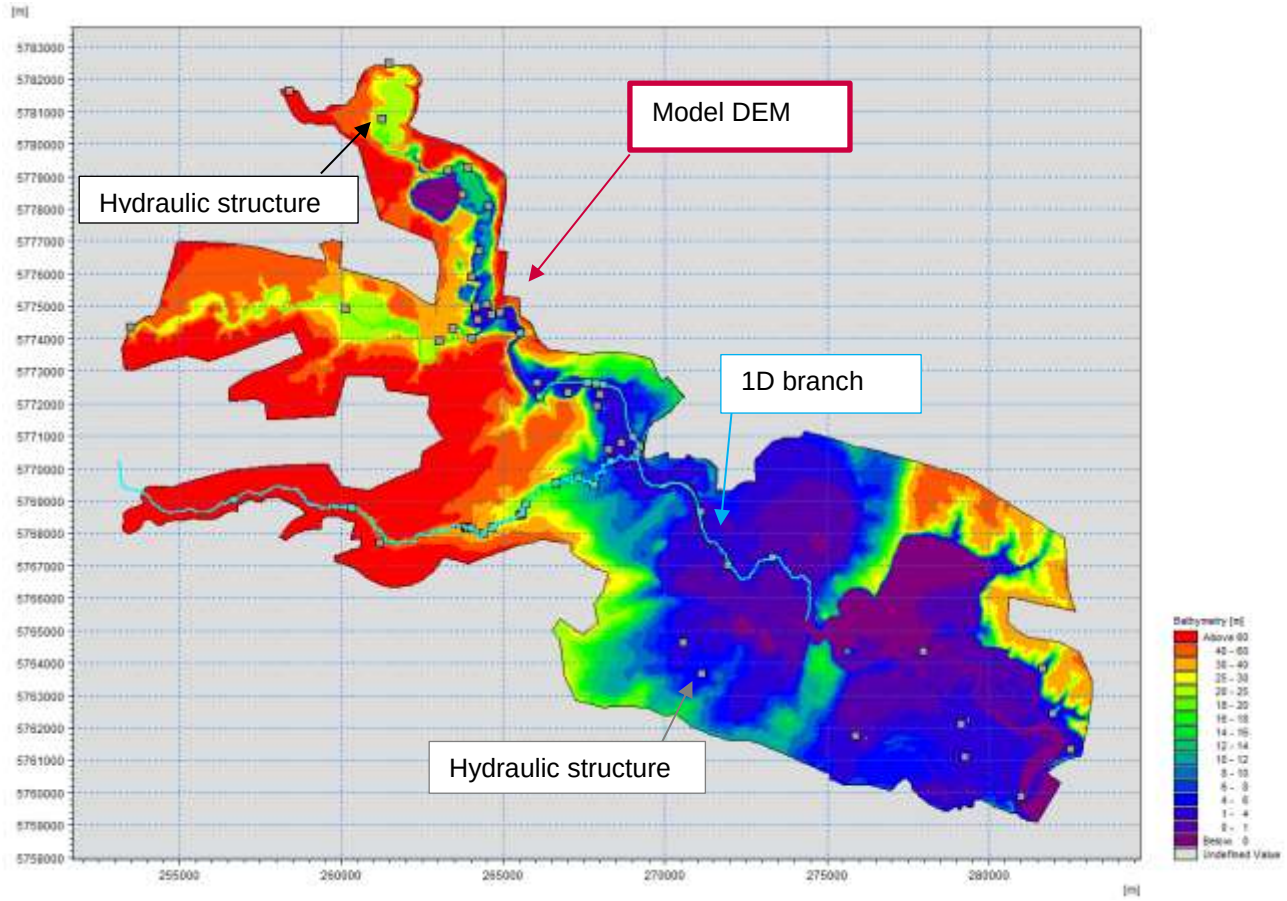

FIGURE 3-2 HYDRAULIC MODEL SCHEMATISATION

3.2.3 Calibration and Design Modelling

The modelling process involved the following stages:

- Model development and calibration
  - The historical events of November 1995, January 2011, April 2001 and September 2016 were used for calibration and validation process;
  - A review of the current rating curve at Geelong, including comparison to historic and hydraulic model rating curves, which has concluded that the current rating curve is appropriate and suitable for continued adoption across the range of flow rates up to the 1% AEP.
- Sensitivity tests; and
- Design flood simulations.
  - 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2%, and PMF

The calibration, validation and sensitivity assessments were completed during an iterative investigative process and all outcomes from these stages informed the final design flood simulations.

3.2.4 Local Tributary Modelling

A number of small, local tributaries have also been flood mapped within this study and are shown in Figure 3-3. Many of the local tributaries have very small upstream catchment areas which meant using a traditional methodology based on a rainfall runoff model has some limitations. Rainfall runoff models require a certain number of subareas to route through before being able to generate a hydrograph with appropriate routing characteristics. For this reason, a direct rainfall approach was adopted whereby rainfall was applied directly to the hydraulic model across the entire catchment area of each local tributary. Direct rainfall on grid models allow the simulation of overland flow generated from rainfall applied directly onto a two-dimensional grid, representative of the site topography. Rainfall, minus some interception and infiltration losses, are applied directly to each grid cell within the model. Overland flow then moves across the grid based on the topography of the site and the runoff characteristics. Further detail regarding the hydrology and hydraulic model development for the direct rainfall modelling can be found in the hydrology report.

FIGURE 3-3 LOCAL TRIBUTARIES WHICH HAVE BEEN FLOOD MAPPED

A range of outputs have been produced from the direct rainfall modelling including flood depths, velocities, hazard and water levels. The outputs are described further in Section 4.5.

4 FLOOD BEHAVIOUR AND INTELLIGENCE OUTPUTS

4.1 Overview

The flood behaviour and intelligence outputs developed as part of the Lower Moorabool and Barwon Flood Risk Management Study are described in this section. To take into account the contributions of the waterways for various flood events, the design flows of the Barwon and Moorabool Rivers were combined in different scenarios in order to obtain the design peak flow, for each AEP, downstream of the confluence of the two rivers at the McIntyre bridge in Geelong. Hence, as shown in **Error! Reference source not found.**, the modelled scenarios are based on the concomitance of flood events on the Moorabool River, Barwon River, Waurn Ponds Creek and storm-tide levels in the Barwon Heads Estuary. For each design event three scenarios were run:

- A Barwon-dominant flood which produces the desired design flood conditions for the Barwon River upstream of the Barwon-Moorabool River confluence through to the upstream boundary at Pollocksford;
- A Moorabool-dominant flood which produces the desired design flood conditions for the Moorabool River upstream of the Barwon-Moorabool River confluence through to the upstream boundary at Batesford and
- A “concurrent” scenario which produces the desired design flood conditions for the Barwon River downstream of the Barwon-Moorabool River confluence through central Geelong to the downstream boundary at Barwon Heads.

TABLE 4-1 DESIGN SCENARIOS - SUMMARY

Scenarios	Barwon at Pollocksford AEP	Peak flow m3/s	Moorabool at Batesford AEP	Peak flow m3/s	Barwon, McIntyre bridge - AEP	Peak flow m3/s	Waurn Ponds Creek AEP	Storm Tide AEP	Storm Tide Level (m) ADH)
50% - Concurrent	50%	106	57%	27	50%	116	50%-6h		
50% - Barwon Dominant	*50%*	*106*	*Low Flow*				*50% - 12h*		
50% - Moorabool Dominant	*Low flow*		*50%*	*37*			*50% - 1h*		
20% Concurrent	20%	279	33%	67	20%	312	20% - 6h		
20% Barwon Dominant	*20%*	*279*	*50%*	*37*			*20% - 12h*		
20% Moorabool Dominant	*50%*	*106*	*20%*	*102*			*20% - 1h*		
10% Concurrent	10%	440	20%	102	10%	493	10% - 6h		
10% Barwon Dominant	*10%*	*440*	*50%*	*37*			*10% - 12h*		
10% Moorabool Dominant	*50%*	*106*	*10%*	*162*			*10% - 1h*		
5% Concurrent	5%	627	15%	125	5%	694	5% - 12h		
5% Barwon Dominant	*5%*	*627*	*50%*	*37*			*5% - 6h*		
5% Moorabool Dominant	*50%*	*106*	*5%*	*232*			*5% - 1h*	10%	1.56
2% Concurrent	2%	911	~5%	218	2%	1045	2% - 12h		
2% Barwon Dominant	*2%*	*911*	*10%*	*162*			*2% - 6h*		
2% Moorabool Dominant	*10%*	*440*	*2%*	*338*			*2% - 1h*		
1% Concurrent	1%	1152	~2%	325	1%	1367	1% - 12h		
1% Barwon Dominant	*1%*	*1152*	*10%*	*162*			*1% - 1h*		
1% Moorabool Dominant	*10%*	*440*	*1%*	*427*			*1% - 6h*		
0.5% Concurrent	0.5%	1415	~1%	445	0.5%	1700	0.5% - 12h		
0.5% Barwon Dominant	*0.5%*	*1415*	*10%*	*162*			*0.5% - 6h*		
0.5% Moorabool Dominant	*10%*	*440*	*0.5%*	*524*			*0.5% - 1h*		
0.2% Concurrent	0.2%	1797	0.2%	660	0.2%	2265	0.2% - 12h		
0.2% Barwon Dominant	*0.2%*	*1797*	*10%*	*162*			*0.2% - 6h*		

0.2% Moorabool Dominant	*10%*	*440*	*0.2%*	*660*			*0.2% - 1h*		
PMF	**PMF**	**16824**	**PMF**	**9495**			**PMF - 3h**		
Sensitivity – Storm Tide	1%	1152	~2%	325	**1%**	**1367**	1% - 12h	1%	1.82
	10%	440	20%	102	**10%**	**493**	10% - 6h	1%	1.82
Climate Change – Sea level Rise only	1% Concurrent				**1%**	**1367**		1% + 0.2m	2.02
	10% Concurrent				**10%**	**493**		1% + 0.2m	2.02
	1% Concurrent				**1%**	**1367**		1% + 0.5m	2.32
	10% Concurrent				**10%**	**493**		1% + 0.5m	2.32
	1% Concurrent				**1%**	**1367**		1% + 0.8m	2.62
	10% Concurrent				**10%**	**493**		1% + 0.8m	2.62

4.2 Gauge height relationships

The major inflows of the hydraulic model are located upstream of Batesford on the Moorabool River and at the Pollocksford gauge on the Barwon River. For each design flood event the model results were interpreted to provide information on the relationship between the flood level at three key gauges (Moorabool River at Batesford, Barwon River at Pollocksford and McIntyre bridge in Geelong) and the equivalent design flood magnitude (in % AEP). Table 4-2 shows the results of the assessment.

TABLE 4-2 GAUGE HEIGHTS AND FLOWS FOR DESIGN FLOOD EVENTS

	Moorabool at Batesford				Barwon at Pollocksford				Barwon at Geelong (McIntyre's)				
Design Event	Peak Flow (m^3/s)	AEP	Peak Level (mAHD)	Gauge height (m)	Peak Flow (m^3/s)	AEP	Peak Level * (mAHD)	Gauge height * (m)	Peak Flow (m^3/s)	AEP	Peak Level (mAHD)	Gauge height (m)	Travel time from Pollocksford (h)
50% AEP	37	50%	20.30	3.19	106	50%	27.164	3.09	123	50%	2.51	2.51	6.7
20% AEP	101	20%	20.91	3.80	279	20%	29.634	5.56	312	20%	3.52	3.52	6.3
10% AEP	161	10%	21.21	4.10	440	10%	30.914	6.84	493	10%	4.03	4.03	7.5
5% AEP	228	5%	21.46	4.35	627	5%	31.984	7.91	694	5%	4.52	4.52	6.6
2% AEP	321	2%	21.72	4.61	911	2%	-	-	1045	2%	5.32	5.32	5.3
1% AEP	427	1%	21.86	4.75	1152	1%	-	-	1367	1%	5.94	5.94	4.8
0.5% AEP	440	0.5%	22.21	5.10	1415	0.5%	-	-	1700	0.5%	6.61	6.61	4.3
0.2% AEP	466	20%	22.75	5.64	1797	0.2%	-	-	2265	0.2%	7.48	7.48	4.0

** Station located at model boundary, levels were determined from the rating curve*

4.3 Flood Class Level Review

For reference, the three streamflow gauges described above are utilised by the Bureau of Meteorology for flood warning purposes. The gauge levels are displayed in near real time on the Bureau of Meteorology website on the Rainfall and River Condition page. Flood Class levels have been defined by the Bureau of Meteorology for these sites and are displayed below in Table 4-3.

TABLE 4-3 FLOOD CLASS LEVELS WITHIN THE STUDY AREA

Location	Minor Flood Class Level	Moderate Flood Class Level	Major Flood Class Level
Barwon River @ Pollocksford	3.50	4.50	6.50
Moorabool River @ Batesford	2.70	4.00	4.90
Barwon River @ Geelong	2.30	3.10	4.30

At the Barwon River at Pollocksford gauge, based on the rating curve data, the Minor Flood Class Level (FCL) at 3.5 m corresponds to a design event 0.41m above the 50% AEP event (3.09m). At this level, flooding occurs in low-lying areas along the Barwon River, impacting agricultural land and wetlands. The moderate FCL of 4.5 m corresponds to a level between the 50% and 20% AEP, the 20% AEP flood level is however 1m higher at 5.56m. The 10% AEP flood level is 0.34m higher than the Major FCL of 6.5m. Based on the definition of FCL provided by the Bureau of Meteorology, it is recommended that the levels for Moderate and Major FCL be revised.

For the Moderate FCL at Pollocksford, the 10% AEP level at Pollocksford would be appropriate with larger flood extents impacting rural areas upstream of Queens Park. Flood depths in urban areas in Geelong are still relatively shallow at this level. The definition by the Bureau of Meteorology of Major flooding corresponds to flooding caused by the 5% AEP flood event, with more extensive flooding of urban areas and a number of roads impacted. Hence it appears that levels of 6.8 m and 7.9m respectively for the Moderate and Major FCL would be more suitable with regard to the definitions of flood classes.

At the Moorabool River at Batesford gauge, the Minor FCL (2.7m) corresponds to an event 0.59m below the 50% AEP flood level. Flooding would be very limited at this level and minimal impacts are expected. It appears a level corresponding the 20% AEP flood level, 3.8m, would be more consistent with the definition of the FCL. The 10% AEP flood level of 4.10m is 0.1m higher than the Moderate flood class level of 4.0m. For the 10% flood event, there is extensive rural inundation including inundation of local roads, however the overall flood impacts are limited. Based on the definition of flood class levels provided by the Bureau of Meteorology, the Moderate class would be appropriate for the 10% AEP event.

The Major FCL of 4.90m at Batesford is 0.15m higher the 1% AEP flood level. Extensive flooding of the Batesford township occurs at this level in the Moorabool River and the FCL appears appropriate.

For the Barwon River at Geelong gauge (233217), similar to Pollocksford, it is recommended that a review of the Bureau of Meteorology flood class levels be undertaken based on the outcomes of this study. The FCLs defined appear to be too low, given the impacts at those levels, and more suitable levels for the Minor, Moderate and Major FCLs would be those calculated for the 50-20%, 10% and 5% AEP flood levels respectively.

4.4 Summary of Flood Behaviour

The following tables describe the key flood characteristics across the study area for each design flood event. The study area was broken up into geographical areas. Each table was developed to be read from top to bottom, with each subsequent larger magnitude event reporting on the incremental changes in consequences. For example, if the reader is wishing to understand the consequences of a 2% AEP event, then the flood characteristics should be read for the 20%, 10%, 5% and 2% AEP events in succession. It is also recommended that the reader refer to the corresponding PDF maps provided with the study. There is a separate map for each modelled design event which provides peak flood depths, extents and water surface elevations for each flood event.

It should be noted that the above floor flooding impacts described below do not take into account individual flood protection measures such as local flood walls or levees which protect individual homes. The condition of such works are generally unknown and they often require additional preparation such as sandbagging to be effective. For this reason, such measures cannot be assumed to be in place and operating effectively under design conditions.

It should also be noted that floor level survey is currently being gathered and additional detail regarding properties flooded above and below floor level will be added once the survey is available.

Moorabool Floodplain : Batesford

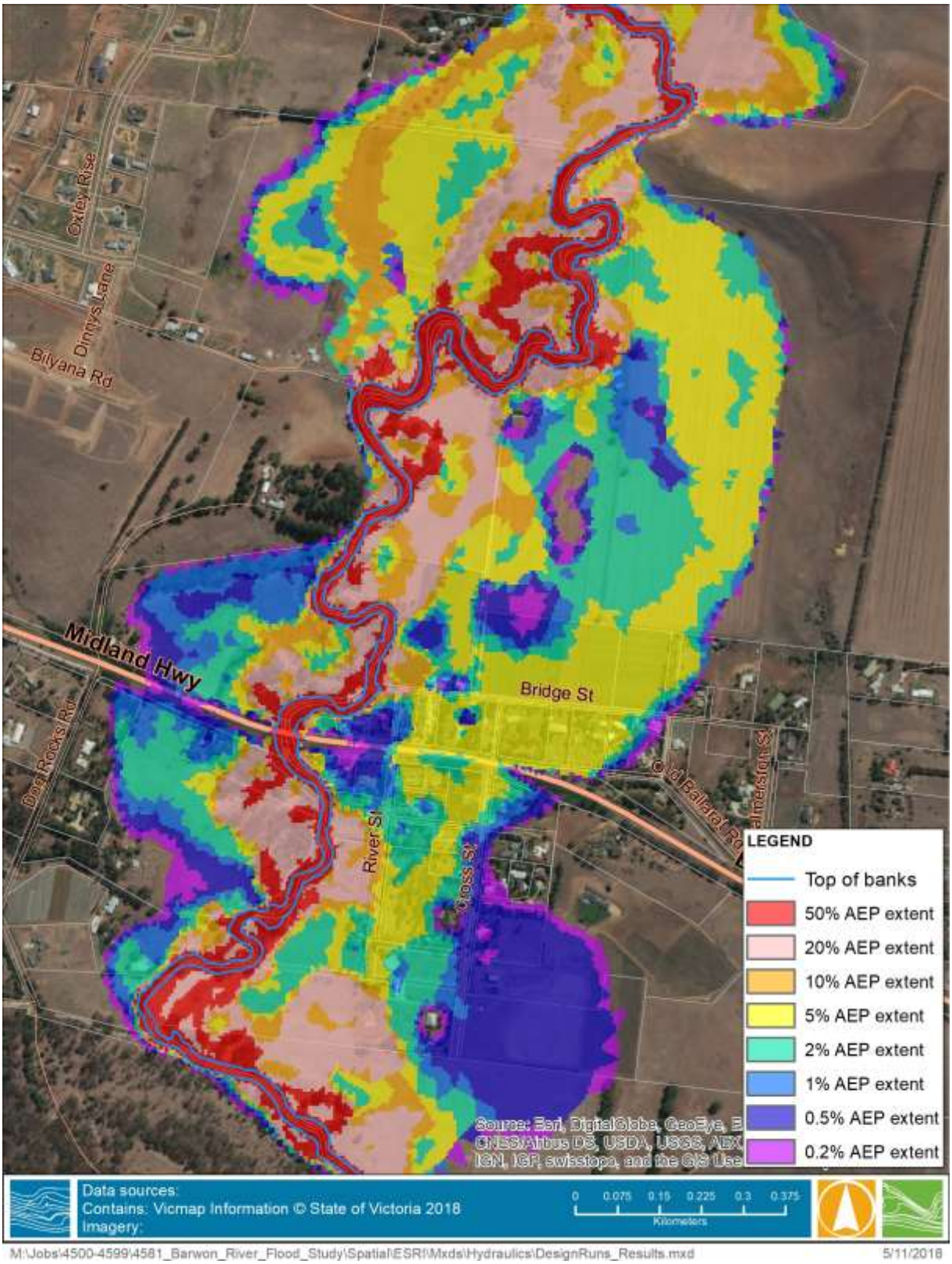

FIGURE 4-1 FLOOD EXTENTS OVERLAYED FOR THE FULL RANGE OF DESIGN EVENTS: MOORABOOL FLOODPLAIN BATESFORD

TABLE 4-4 SUMMARY OF FLOOD BEHAVIOUR ALONG THE MOORABOOL FLOODPLAIN, BATESFORD

Event	Flood Characteristics – Moorabool River floodplain, Batesford	Key roadways inundated
50% AEP Event **Moorabool River at Batesford Gauge:** ■ Gauge height: 3.19 m (20.30 mAHD) ■ 37 m^3/s peak flow **20% AEP Event** **Moorabool River at Batesford Gauge:** ■ Gauge height: 3.80 m (20.91 mAHD) ■ 102 m^3/s peak flow **10% AEP Event** **Moorabool River at Batesford Gauge:** ■ Gauge height: 4.10 m (21.21 mAHD) ■ 162 m^3/s peak flow	• 50% AEP Residential Above Floor Flooding – None • 50% AEP Residential Below Floor Flooding – None • 50% AEP Commercial Above Floor Flooding – None • 50% AEP Commercial Below Floor Flooding – None • 20% AEP Residential Above Floor Flooding – None • 20% AEP Residential Below Floor Flooding – None • 20% AEP Commercial Above Floor Flooding – None • 20% AEP Commercial Below Floor Flooding – None • 10% AEP Residential Above Floor Flooding – None • 10% AEP Residential Below Floor Flooding – None • 10% AEP Commercial Above Floor Flooding – None • 10% AEP Commercial Below Floor Flooding – None • Flood extents generally limited to the low-lying floodplain areas adjacent to the waterway. • Minor breakouts occur for the 20% AEP event, the flood extents a maximum of 125m from the river banks. • Larger breakouts occur under the 10% event north of Batesford. The flood extents a maximum of 250m from the river banks. • Water reaches River St under the 10% AEP event, without overtopping it. • Primarily crown and agricultural land impacted in these smaller events	

Event	Flood Characteristics – Moorabool River floodplain, Batesford	Key roadways inundated
5% AEP Event **Moorabool River at Batesford Gauge:** ■ Gauge height: 4.35m (21.46 mAHD) ■ 232 m3/s peak flow	• 5% AEP Residential Above Floor Flooding – 4 (between Bridge Street and Old Ballarat Road • 5% AEP Residential Below Floor Flooding –4 • 5% AEP Commercial Above Floor Flooding – None • 5% AEP Commercial Below Floor Flooding – None • Large breakouts north of Midland Highway • Floodwaters engage an overland flow path to the east of the Moorabool River. • Dwellings on the north side of Midland Hwy, between Bridge St and Old Ballarat St are impacted. Flood depths range from 0.1 to 1.1m. • Midland Highway is locally flooded on a width of approximately 50m, very shallow depths on road (0.01m) • Floodwaters impact Dwelling at 670 Ballarat Rd, Batesford. Water flows south, depths do not exceed 0.4m. • Floodwaters impact land at 1 River St, Batesford. • River St is flooded with 0.1m on road between properties15 and 30 River St.	■ Bridge St, Batesford ■ Midland Highway, Batesford ■ River St, Batesford

Event	Flood Characteristics – Moorabool River floodplain, Batesford	Key roadways inundated
2% AEP Event **Moorabool River at Batesford Gauge:** ■ Gauge height: 4.61 m ■ 21.72 mAHD ■ 338 m^3/s peak flow	• 2% AEP Residential Above Floor Flooding – 4 (between Bridge Street and Old Ballarat Road) • 2% AEP Residential Below Floor Flooding – 5 • 2% AEP Commercial Above Floor Flooding – None • 2% AEP Commercial Below Floor Flooding – None • Widespread flooding north of Batesford. Most of the floodplain is inundated, floodwaters spread over a width of 900m. • Dwellings on the eastern bank of the river, along the unnamed road north of Batesford are impacted by flood waters. • Water levels are increased by approximately 0.2 m on the north side of Midland Hwy. • Dwelling at 20 River St is impacted.	■ Cross St, Batesford ■ Bridge St, Batesford ■ Midland Highway, Batesford ■ River St, Batesford
1% AEP Event **Moorabool River at Batesford Gauge:** ■ Gauge height: 4.75 m ■ 21.86 mAHD ■ 427 m^3/s peak flow	• 1% AEP Residential Above Floor Flooding – 18 (distributed mostly eastern ride of river) • 1% AEP Residential Below Floor Flooding – 13 • 1% AEP Commercial Above Floor Flooding – None • 1% AEP Commercial Below Floor Flooding – None • Water levels are increased by 0.4m compared to the 2% scenario. • Midland Highway is flooded with a width of approximately 200m inundated. • All dwellings located between Cross St and River St are inundated, except 50 & 60 Cross St, Batesford. Above and below floor flooding numbers to be confirmed. • Flood waters impacting on dwelling and access to 23 Cross St, Batesford. Depths up to 0.36m. • Batesford Hotel and 750 Midland Highway are partly impacted by floodwaters up to 0.2m deep.	■ Cross St, Batesford ■ Bridge St, Batesford ■ Midland Highway, Batesford ■ River St, Batesford

Event	Flood Characteristics – Moorabool River floodplain, Batesford	Key roadways inundated
0.5% AEP Event **Moorabool River at Batesford Gauge:** ■ Gauge height: 5.1 m ■ 22.21 mAHD ■ 440 m^3/s peak flow	• 0.5% AEP Residential Above Floor Flooding –25 (distributed mostly eastern side of river) • 0.5% AEP Residential Below Floor Flooding – 20 • 0.5% AEP Commercial Above Floor Flooding – None • 0.5% AEP Commercial Below Floor Flooding – None • Flood levels increased by 0.14m compared to the 1% AEP. • Floodwaters progress further east and dwelling at 51 Cross St is inundated. Depths up to 0.25m.	■ Cross St, Batesford ■ Bridge St, Batesford ■ Midland Highway, Batesford ■ River St, Batesford
0.2% AEP Event **Moorabool River at Batesford Gauge:** ■ Gauge height: 5.62 m ■ 22.72 mAHD ■ 466 m^3/s peak flow	• 0.2% AEP Residential Above Floor Flooding – 35 (distributed, mostly eastern side of river) • 0.2% AEP Residential Below Floor Flooding – 19 • 0.2% AEP Commercial Above Floor Flooding – None • 0.2% AEP Commercial Below Floor Flooding – None • Marginal increase in flood extent compared to 0.5% AEP event. • Properties at 12 Regent St and 75 Old Ballarat Rod are impacted by floodwaters • Depths on Midland Hwy increased by 0.4m compared to the 0.5% AEP event. • Dwellings at 33,35 and 49 Cross St are impacted by floodwaters	■ Cross St, Batesford ■ Bridge St, Batesford ■ Midland Highway, Batesford ■ River St, Batesford

Moorabool Floodplain: Downstream of Batesford to Confluence

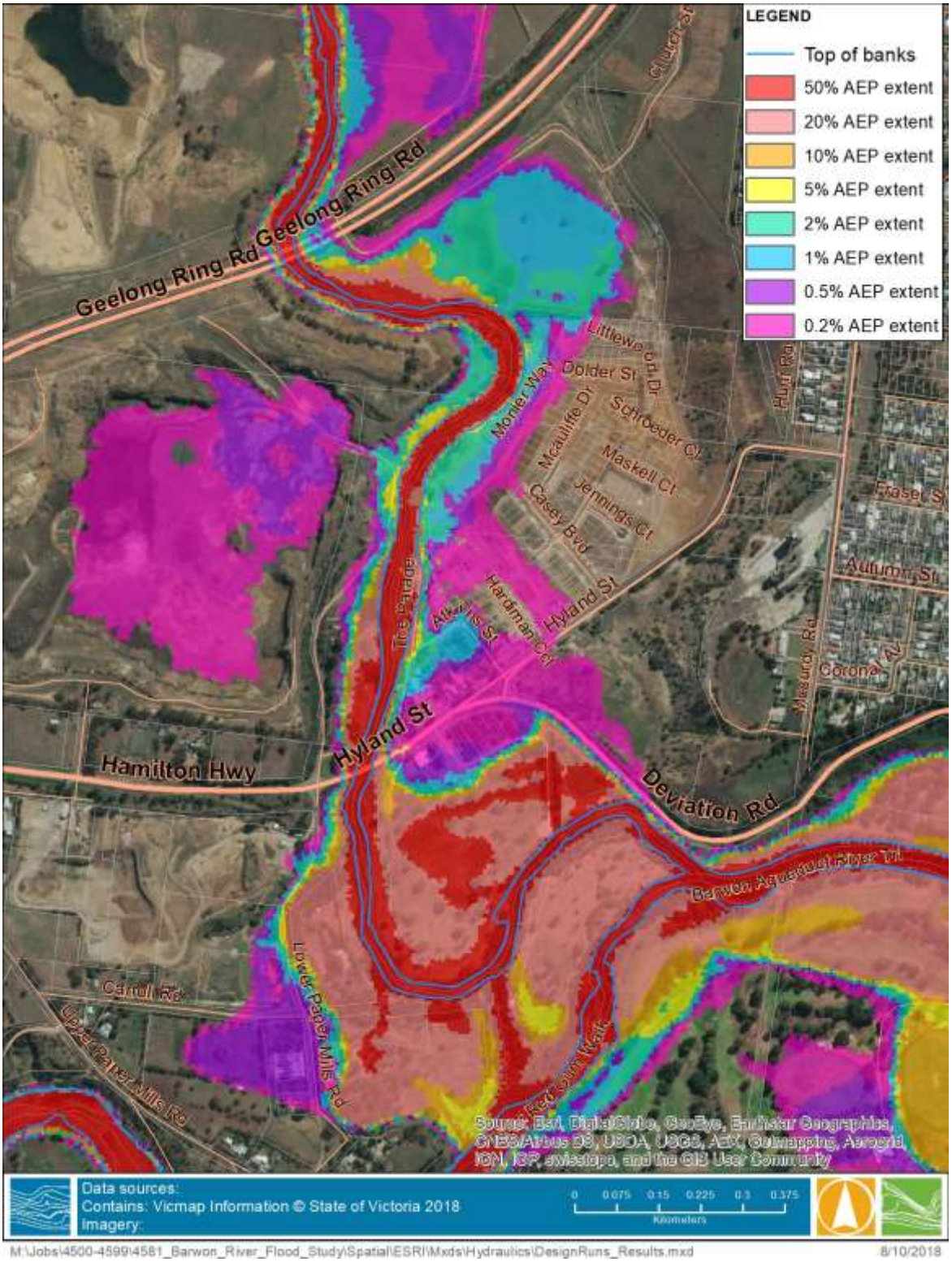

FIGURE 4-2 FLOOD EXTENTS OVERLAYED FOR THE FULL RANGE OF DESIGN EVENTS: MOORABOOL FLOODPLAIN NEAR FYANSFORD

TABLE 4-5 SUMMARY OF FLOOD BEHAVIOUR ALONG THE MOORABOOL FLOODPLAIN, TO CONFLUENCE AT FYANSFORD

Event	Flood Characteristics – Barwon River floodplain, Upstream of the confluence	Key roadways inundated
50% to 2% AEP events	• 50% AEP Residential Above Floor Flooding – None • 50% AEP Residential Below Floor Flooding – None • 50% AEP Commercial Above Floor Flooding – None • 50% AEP Commercial Below Floor Flooding – None • 20% AEP Residential Above Floor Flooding – None • 20% AEP Residential Below Floor Flooding – None • 20% AEP Commercial Above Floor Flooding – None • 20% AEP Commercial Below Floor Flooding – None • 10% AEP Residential Above Floor Flooding – None • 10% AEP Residential Below Floor Flooding – None • 10% AEP Commercial Above Floor Flooding – None • 10% AEP Commercial Below Floor Flooding – None • 5% AEP Residential Above Floor Flooding – None • 5% AEP Residential Below Floor Flooding – None • 5% AEP Commercial Above Floor Flooding – None • 5% AEP Commercial Below Floor Flooding – None • 2% AEP Residential Above Floor Flooding – None • 2% AEP Residential Below Floor Flooding – None • 2% AEP Commercial Above Floor Flooding – None • 2% AEP Commercial Below Floor Flooding – None • Floodplain is very confined from Batesford to the crossing under Geelong Ring Road. • Downstream of Hamilton Highway, Fyansford common is inundated under the 20% AEP event. Flooding occurs from the Barwon River. Flood extent is bound by Deviation Rd and Lower Paper Mills Rd south of Hamilton Highway.	▪ Gully Road, Ceres.

Event	Flood Characteristics – Barwon River floodplain, Upstream of the confluence	Key roadways inundated
1% AEP event **Moorabool River at Batesford Gauge:** ■ 427 m^3/s peak flow **Barwon River at Pollocksford Gauge:** 1,152 m^3/s peak flow	• 1% AEP Residential Above Floor Flooding – 3 • 1% AEP Residential Below Floor Flooding – None • 1% AEP Commercial Above Floor Flooding – 1 • 1% AEP Commercial Below Floor Flooding – None • Levels in the floodplain under the Moorabool Dominant scenario, with larger contribution of the Moorabool River, are higher than in the concurrent scenario up to 1.4 km upstream of Geelong Ring Road bridge. Past this area, the higher levels in the Barwon River downstream under the concurrent scenarios, impact the levels in the Moorabool River and yield larger flood extents along the latter down to the confluence. • Dwellings at 2 & 4 Atkins St, Fyansford are impacted by floodwaters • Parking lot of Fyansford Hotel are inundated	■ Gully Road, Ceres. ■ Atkins St, Fyansford
0.5% AEP event **Moorabool River at Batesford Gauge:** ■ 440 m^3/s peak flow **Barwon River at Pollocksford Gauge:** 1,415 m^3/s peak flow	• 0.5% AEP Residential Above Floor Flooding – 15 • 0.5% AEP Residential Below Floor Flooding – 1 • 0.5% AEP Commercial Above Floor Flooding – 1 • 0.5% AEP Commercial Below Floor Flooding – None • Quarry in Fyansford are inundated but depths and volume in the quarry are low. • Lower Paper Mills Rd is overtopped, following dwellings are impacted: • 30, 55, 42, 44, 48, 50, 52 and 70 Lower Paper Mills Rd, Fyansford •	■ Lower Paper Mills Rd, Fyansford ■ Gully Road, Ceres. ■ Atkins St, Fyansford

Event	Flood Characteristics – Barwon River floodplain, Upstream of the confluence	Key roadways inundated
0.2% AEP event **Moorabool River at Batesford Gauge:** ■ 466 m^3/s peak flow **Barwon River at Pollocksford Gauge:** 1,797 m^3/s peak flow	• 0.2% AEP Residential Above Floor Flooding – 16 • 0.2% AEP Residential Below Floor Flooding – 1 • 0.2% AEP Commercial Above Floor Flooding – 5 • 0.2% AEP Commercial Below Floor Flooding – None • • Hyland St is flooded on the left bank of the Moorabool River. Depths up to 0.5m on road • Fyansford Hotel and all buildings boarded by Atkins St are inundated • Larger volume of water inundates the Quarry in Fyansford	■ Hyland St (C118), Fyansford ■ Lower Paper Mills Rd, Fyansford ■ Gully Road, Ceres. ■ Atkins St, Fyansford

Barwon Floodplain: Upstream of Queens Park

TABLE 4-6 SUMMARY OF FLOOD BEHAVIOUR ALONG THE BARWON RIVER, UPSTREAM OF QUEENS PARK

Event	Flood Characteristics – Barwon River floodplain, Upstream of the confluence	Key roadways inundated
50% AEP event **Barwon River at Pollocksford Gauge:** ■ 106 m^3/s peak flow **20% AEP event** **Barwon River at Pollocksford Gauge:** ■ 279 m^3/s peak flow **10% AEP event** **Barwon River at Pollocksford Gauge:** ■ 440 m^3/s peak flow	• Downstream of Merrawarp Road, Barrabool, the floodplain is inundated under the 50% AEP event, impacting crown, agricultural land and access tracks to the River. • Gully Road, Barrabool is partly flooded under the 10% AEP event. Land at 285 Gully Road, Ceres is inundated. • 10% AEP Residential Above Floor Flooding – None • 10% AEP Residential Below Floor Flooding – None • 10% AEP Commercial Above Floor Flooding – 1 • 10% AEP Commercial Below Floor Flooding – 1	■ Gully Road, Ceres.
5% AEP event **Barwon River at Pollocksford Gauge:** ■ 627 m^3/s peak flow	• 5% AEP Residential Above Floor Flooding – None • 5% AEP Residential Below Floor Flooding – None • 5% AEP Commercial Above Floor Flooding – 3 • 5% AEP Commercial Below Floor Flooding – 1 • Merrawarp Road is flooded on the right bank of the Barwon River. Depths on the road reach 0.1 – 0.2 m. • The length of inundated road is approximately 100m.	■ Merrawarp Rd, Barrabool ■ Gully Road, Ceres.

Event	Flood Characteristics – Barwon River floodplain, Upstream of the confluence	Key roadways inundated
2% AEP event **Barwon River at Pollocksford Gauge:** ■ 911 m3/s peak flow	• 2% AEP Residential Above Floor Flooding – None • 2% AEP Residential Below Floor Flooding –None • 2% AEP Commercial Above Floor Flooding – 3 • 2% AEP Commercial Below Floor Flooding – 1 • Merrawarp Road is flooded up to the intersection with Crooks Road. Levels are 1.1m higher than under the 5% AEP event. • Land at 245 Merrawarp Road is impacted, flood water depths are below 0.25m	■ Merrawarp Rd, Barrabool ■ Gully Road, Ceres.
1% AEP event **Barwon River at Pollocksford Gauge:** 1,152 m^3/s peak flow	• 1% AEP Residential Above Floor Flooding – 1 • 1% AEP Residential Below Floor Flooding – None • 1% AEP Commercial Above Floor Flooding – 4 • 1% AEP Commercial Below Floor Flooding – None • Levels are 0.7m higher than the 2% AEP event in the area around the Merrawarp Road bridge.	■ Merrawarp Rd, Barrabool ■ Gully Road, Ceres.
0.5% AEP event **Barwon River at Pollocksford Gauge:** 1,415 m^3/s peak flow	• 0.5% AEP Residential Above Floor Flooding – 1 • 0.5% AEP Residential Below Floor Flooding – None • 0.5% AEP Commercial Above Floor Flooding – 5 • 0.5% AEP Commercial Below Floor Flooding – None • Merrawarp Road is flooded on the left bank (north) of the river. Depths reach 0.5m on the road. • Levels are 0.7m higher than the 1% AEP event in the area	■ Merrawarp Rd, Barrabool ■ Gully Road, Ceres.

Event	Flood Characteristics – Barwon River floodplain, Upstream of the confluence	Key roadways inundated
0.2% AEP event **Barwon River at Pollocksford Gauge:** 1,797 m^3/s peak flow	• 0.2% AEP Residential Above Floor Flooding – 1 • 0.2% AEP Residential Below Floor Flooding – 1 • 0.2% AEP Commercial Above Floor Flooding – 8 • 0.2% AEP Commercial Below Floor Flooding – None • Very limited increase in flood extent along the Barwon River compared to the 0.5% AEP event. No additional roads or properties are impacted.	▪ Merrawarp Rd, Barrabool ▪ Gully Road, Ceres.

Barwon Floodplain: Queens Park to Breakwater Road

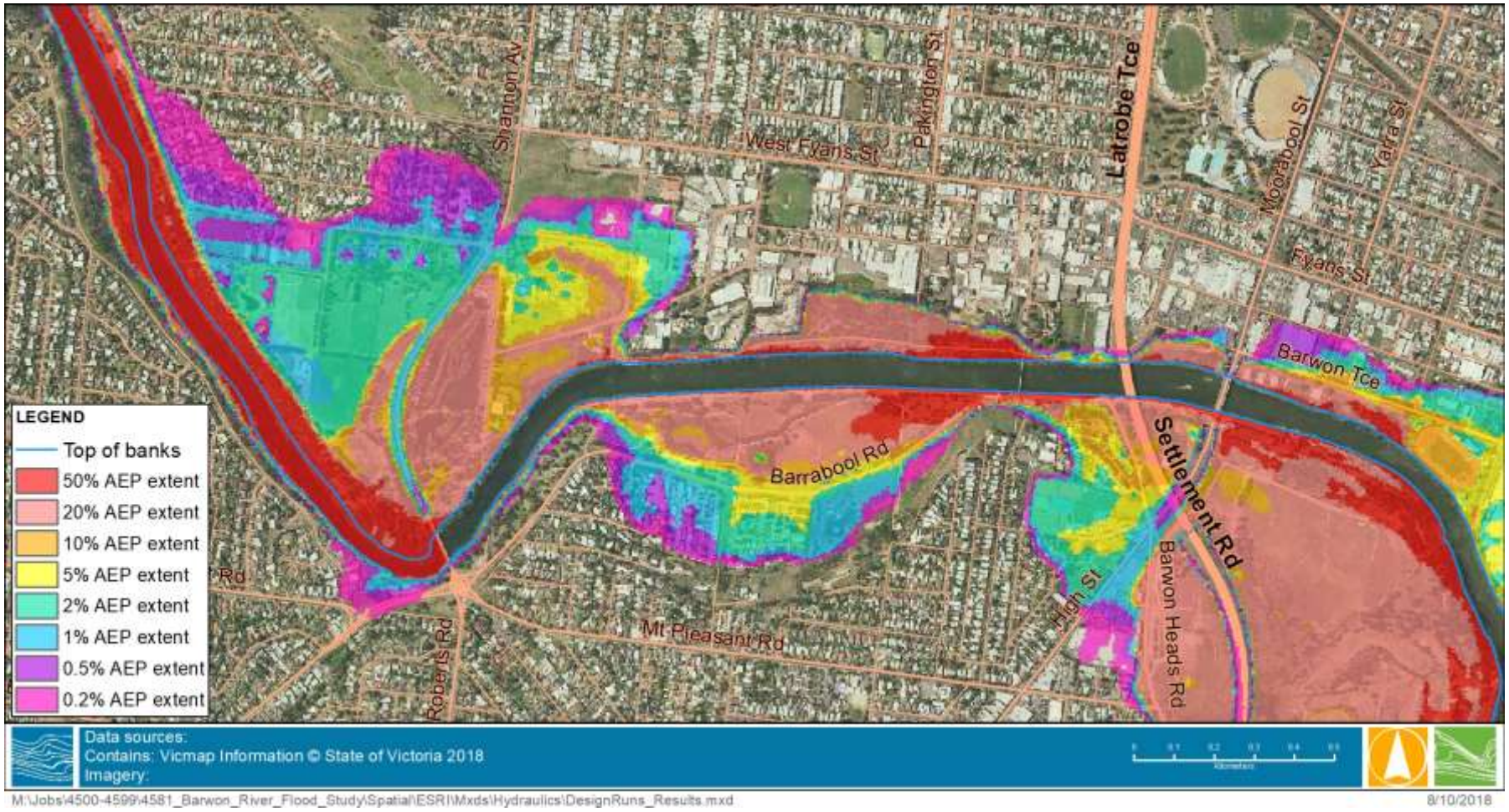

FIGURE 4-3 FLOOD EXTENTS OVERLAYED FOR THE FULL RANGE OF DESIGN EVENTS: BARWON FLOODPLAIN FROM SHANNON AVE TO SETTLEMENT RD

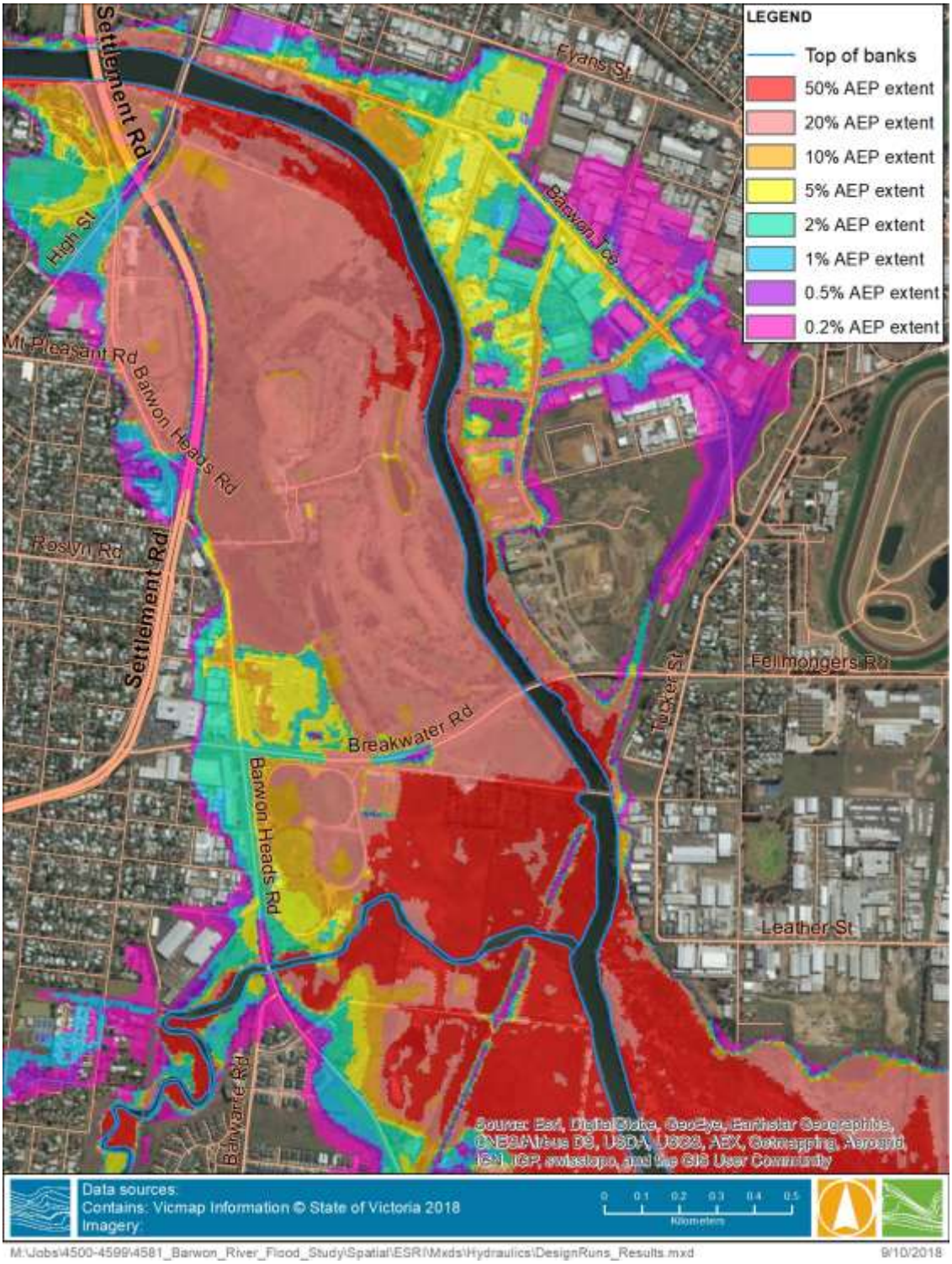

FIGURE 4-4 FLOOD EXTENTS OVERLAYED FOR THE FULL RANGE OF DESIGN EVENTS: BARWON FLOODPLAIN FROM SETTLEMENT RD TO WILSONS RD

TABLE 4-7 SUMMARY OF FLOOD BEHAVIOUR IN BARWON RIVER FLOODPLAIN FORM QUEENS PARK TO BREAKWATER ROAD

Event	Flood Characteristics – Barwon River floodplain, Queens Park to Waurn Ponds Creek	Key roadways inundated
50% AEP event **Barwon River at McIntyre Gauge:** ■ Gauge height: 2.51 mAHD ■ 123 m^3/s peak flow	• Only very localised out of bank flooding.	

Event	Flood Characteristics – Barwon River floodplain, Queens Park to Waurn Ponds Creek	Key roadways inundated
20% AEP event **Barwon River at McIntyre Gauge:** ■ Gauge height: 3.52 mAHD ■ 312 m^3/s peak flow	• 20% AEP Residential Above Floor Flooding – None • 20% AEP Residential Below Floor Flooding – None • 20% AEP Commercial Above Floor Flooding –10 • 20% AEP Commercial Below Floor Flooding – 2 • Low areas along the river in Queens Park area are flooded, impacting prairies. • Flooding occurs on the left bank along Shannon Ave, on both sides of the latter. Marnock Road and Riversdale Road are overtopped, Balyang Sanctuary is flooded and inundation to the north impacts the Balyang Golf course. • Barwon River bursts its banks and low areas along the river are flooded between Shannon Ave and Moorabool St bridge. The Promenade, Belmont is under water on the right bank and the Barwon Valley Fun Park is partially flooded. • On the left bank, properties south of Barwon Terrace part of the Rowing Club, between Moorabool Street and Bellarine St, are impacted by floodwaters. • Floodplain on the right bank downstream of Moorabool St bridge is largely inundated, Belmont Common, Barwon Valley Golf Club, Wildlife Reserve and Wetlands and Target Rifle Geelong in Belmont are inundated with depths mostly between 0.5 and 1.5m. Flood extent is bound to the west by Barwon Heads Road. • Barwon Valley Activity Centre (1 Barwon Heads Rd, Belmont) is impacted by floodwaters up to 0.75m deep. • Lower sections of Barabool Road beinging inundated adjacent to Barwon Lodge, Riverglen and Barwon River Caravan Parks. • On the left bank of the river, floodwaters reach Wood St through Steel Street and Gravel Pits Road. Depths don't exceed 0.5m. • Dwellings from 28 to 44 Gravel Pits Road are impacted	■ Riversdale Road, Newtown ■ Marnock Road, Newtown ■ Promenade, Belmont ■ Wood St, South Geelong ■ Gravel Pits Road, South Geelong ■ Steel St, South Geelong ■ Barrabool Road

Event	Flood Characteristics – Barwon River floodplain, Queens Park to Waurn Ponds Creek	Key roadways inundated
10% AEP event **Barwon River at McIntyre Gauge:** ■ Gauge height: 4.03 mAHD ■ 493 m^3/s peak flow	• 10% AEP Residential Above Floor Flooding – 1 • 10% AEP Residential Below Floor Flooding – 1 • 10% AEP Commercial Above Floor Flooding –17 • 10% AEP Commercial Below Floor Flooding – 3 • Oval at Queens Park is inundated (depths above 1m) • Geelong Canoe club at 1 Marnock Drive, Newtown is flooded • Barrabool Rd, Belmont is overtopped through entrance to Barwon Caravan and Tourist park. Depths reach 0.5m in low lying areas. • John Landy Athletics Field on the left bank of the Barwon River is flooded, depths reach a maximum of 0.55m. • Shallow floodwaters impact Barwon Tce between Moorabool St and Bellarine St. • Further south, flooding reaches Barwon Tce through Wood St. • Warehouse at 34 Gravel Pits Road is inundated. • Floodwaters impact buildings at 135 Barwon Heads Road, depths don't exceed 0.2m.	■ Barwon Terrace, Geelong ■ Barwon Heads Road, Geelong ■ Riversdale Road, Newtown ■ Marnock Road, Newtown ■ Promenade, Belmont ■ Wood St, South Geelong ■ Gravel Pits Road, South Geelong ■ Steel St, South Geelong ■ Barrabool Road, Belmont

Event	Flood Characteristics – Barwon River floodplain, Queens Park to Waurn Ponds Creek	Key roadways inundated

5% AEP event
Barwon River at McIntyre Gauge:
■ Gauge height: 4.52 mAHD
■ 694 m^3/s peak flow
	• 5% AEP Residential Above Floor Flooding – 2
	• 5% AEP Residential Below Floor Flooding – 2
	• 5% AEP Commercial Above Floor Flooding – 33
	• 5% AEP Commercial Below Floor Flooding – 10
	
	• Net ball courts and facilities are inundated in Queens Park.
	• Flood extent increased north of Riversdale Road, Bridge St is overtopped in Newtown.
	• South of Barwon Valley Park in Belmont, Barrabool Street is overtopped : Riverglen Holiday Park and City Southside Caravan Park are partially inundated.
	• Barwon Caravan & Tourist Park and Geelong Lawn Tennis Club in Belmont are flooded
	• On the left bank of the river, flooding occurs along Swanston St and Factories Road, as well as through Barwon Tce to Wood St. Impacted properties include:
	  • Little Creatures Brewery at 221 Swanston St, Geelong
	  • Commercial buildings on both sides of Factories Rd are flooded.
	  • 76-78 Barwon Tce, Geelong
	  • 12 & 26 Gravel Pits Rd, Geelong
	• Commercial area at 135 Barwon Heads Road, Belmont is entirely flooded. Depths increased to 0.6m.
	• All 5 ovals are flooded at the South Barwon Cricket Club
		■ Bridge St, Newtown
		■ Swanston St, Geelong
		■ Factories Rd, Geelong
		■ Barwon Terrace, Geelong
		■ Barwon Heads Road, Geelong
		■ Riversdale Road, Newtown
		■ Marnock Road, Newtown
		■ Promenade, Belmont
		■ Wood St, South Geelong
		■ Gravel Pits Road, South Geelong
		■ Steel St, South Geelong
		■ Barrabool Road, Belmont

2% AEP event
Barwon River at McIntyre Gauge:
■ Gauge height: 5.32 mAHD
■ 1045 m^3/s peak flow
	• 2% AEP Residential Above Floor Flooding – 2
	• 2% AEP Residential Below Floor Flooding – 2
	• 2% AEP Commercial Above Floor Flooding – 34
	• 2% AEP Commercial Below Floor Flooding – 9
	
	• In Newtown, the car Park of the Boat House on Anco Park Dr is flooded.
	• Land at 1A to 7 Belcombe Rd, Newtown is inundated
	• 13 bridge St, Newtown is impacted by floodwaters. Depths vary from 0.5 to 1.3m
	• In Belmont, Riverglen Holiday Park and City Southside Park are entirely inundated. Depths vary from 0.25m to 1.3m (estimated in Excess of 200 relocatable homes, vans and sites)
	• Geelong Lawn Tennis club flooded, depths vary from 0.25 to 1.2m.
	• Following properties are impacted:
	  • 1 Frank St, Belmont
	  • 7,9,15 Summers St, Belmont
	  • 2 High St, Geelong
	  • Cameron Park is inundated
	• On the left bank of the Barwon river, additional dwellings are impacted by floodwaters:
	  • 31 Barwon Tce, 42 Little Fyans St and 313 Bellarine St, Geelong
		■ Anco Pk Dr, Newtown
		■ Belcombe Rd, Newtown
		■ Bellarine St, Geelong
		■ Frank St, Belmont
		■ Summers St, Belmont
		■ Little Fyans St, Geelong
		■ Curtis Rd, Belmont
		■ Breakwater Rd, Belmont
		■ Bridge St, Newtown
		■ Swanston St, Geelong
		■ Factories Rd, Geelong
		■ Barwon Terrace, Geelong
		■ Barwon Heads Road, Geelong

Event	Flood Characteristics – Barwon River floodplain, Queens Park to Waurn Ponds Creek	Key roadways inundated
	• 1, 2, 5, 7, 9 Gravel Pits Rd, Geelong • 80 and 82 Barwon Tce, Geelong • Barwon Heads Road is overtopped near Breakwater Rd, the following locations are flooded in Belmont: • 1, 2, 3, 4 Curtis Rd • 4 to 10 breakwater Rd, • 84, 86, 88, 138, 140, 150 and 154 to 180 Barwon Heads Rd	■ Riversdale Road, Newtown ■ Marnock Road, Newtown ■ Promenade, Belmont ■ Wood St, South Geelong ■ Gravel Pits Road, South Geelong ■ Steel St, South Geelong ■ Barrabool Road, Belmont

Event	Flood Characteristics – Barwon River floodplain, Queens Park to Waurn Ponds Creek	Key roadways inundated

1% AEP event
Barwon River at McIntyre Gauge:
■ Gauge height: 5.94 mAHD
■ 1,367 m^3/s Peak flow
	• 1% AEP Residential Above Floor Flooding – 33
	• 1% AEP Residential Below Floor Flooding – 28
	• 1% AEP Commercial Above Floor Flooding – 105
	• 1% AEP Commercial Below Floor Flooding – 10
	
	• Shannon Ave is flooded in Newtown, depths reach 0.2m on the road.
	• North side of Anco Park Dr is flooded
	• Dwellings at 1 to 7 Belcombe Rd are inundated, as 12, 20, 26 and 28 on the other side of Belcombe Rd
	• 18, 19 and 20 Braemar Court are impacted by floodwaters, depths are below 0.5m
	• On the right bank of the Barwon river: Barwon Valley Lodge in Belmont is flooded. Discovery parks is partly inundated. The following dwellings are impacted:
	  • 49, 51 and 53 Barrabool Road
	  • 1, 2, 3 Riverglen Ct
	  • Parking lot at 50 Barwon Heads Rd is flooded (depths between 0.25-0.5m)
	  • Salvation Army at 2A Settlement Road
	  • 2 to 8 Tegwen St
	• The flood extent is slightly increased on the left bank, impacting 92-96 Barwon Tce, Geelong
		■ Shannon Ave, Newtown
		■ Braemar Ct, Newtown
		■ Riverglen St, Belmont
		■ Tegwen St, Belmont
		■ Anco Pk Dr, Newtown
		■ Belcombe Rd, Newtown
		■ BellerineBellarine St, Geelong
		■ Frank St, Belmont
		■ Summers St, Belmont
		■ Little Fyans St, Geelong
		■ Curtis Rd, Belmont
		■ Breakwater Rd, Belmont
		■ Bridge St, Newtown
		■ Swanston St, Geelong
		■ Factories Rd, Geelong
		■ Barwon Terrace, Geelong
		■ Barwon Heads Road, Geelong
		■ Riversdale Road, Newtown
		■ Marnock Road, Newtown
		■ Promenade, Belmont
		■ Wood St, South Geelong
		■ Gravel Pits Road, South Geelong
		■ Steel St, South Geelong
		■ Barrabool Road, Belmont

0.5% AEP event
Barwon River at McIntyre Gauge:
■ Gauge height: 6.61 mAHD
■ 1,700 m^3/s peak flow
	▪ 0.5% AEP Residential Above Floor Flooding – 113
	▪ 0.5% AEP Residential Below Floor Flooding – 40
	▪ 0.5% AEP Commercial Above Floor Flooding – 124
	▪ 0.5% AEP Commercial Below Floor Flooding – 14
	
	• Flood extent is increased to the north of Belcombe St in Newtown. Flooding occurs at:
	  • 33 to 41 Gairloch Grove
	  • 68 to 82, 15, 17, 19 Belcombe Rd
	  • 13, 14, 15, 16, 17 Glamis St
	  • Most of properties on Braemar Ct except at the northern end (6 to 10 Braemar Ct not flooded)
	  • 26 to 34 and 27 to 33 Sandringham Parade
	• Discovery Park in Belmont is entirely impacted by floodwaters
	• BUPA aged care in Barrabool is inundated, levels are 0.7m higher than in the 1% event
	• In Geelong the flood extent is marginally increased, impacting dwellings at 1 to 13 Barwon Tce and 62 Barwon Tce.
	• In South Geelong, flooding is increased along Wood St, the overland flowpath reaches Dalton St. The following properties are impacted:
	  • 57 Wood St, 14 Dalton St and the parking lot at 24 Wood St
		■ Gairloch Grove, Newtown
		■ Glamis St, Newtown
		■ Sandringham Parade, Newtown
		■ Dalton St, Geelong
		■ Shannon Ave, Newtown
		■ Braemar Ct, Newtown
		■ Riverglen St, Belmont
		■ Tegwen St, Belmont
		■ Anco Pk Dr, Newtown
		■ Belcombe Rd, Newtown
		■ BellerineBellarine St, Geelong
		■ Frank St, Belmont
		■ Summers St, Belmont
		■ Little Fyans St, Geelong
		■ Curtis Rd, Belmont
		■ Breakwater Rd, Belmont
		■ Bridge St, Newtown
		■ Swanston St, Geelong
		■ Factories Rd, Geelong

Event	Flood Characteristics – Barwon River floodplain, Queens Park to Waurn Ponds Creek	Key roadways inundated
	• In Belmont near Breakwater Road the flood extent is only marginally increased to the west compared to the 1% event. • 54, 56 and 58 Barwon Heads Road, Belmont are impacted by floodwaters	■ Barwon Terrace, Geelong ■ Barwon Heads Road, Geelong ■ Riversdale Road, Newtown ■ Marnock Road, Newtown ■ Promenade, Belmont ■ Wood St, South Geelong ■ Gravel Pits Road, South Geelong ■ Steel St, South Geelong ■ Barrabool Road, Belmont

0.2% AEP event
Barwon River at McIntyre Gauge:
■ Gauge height: 7.48 mAHD
■ 2,265 m^3/s peak flow
	• 0.2% AEP Residential Above Floor Flooding – 187
	• 0.2% AEP Residential Below Floor Flooding – 15
	• 0.2% AEP Commercial Above Floor Flooding – 160
	• 0.2% AEP Commercial Below Floor Flooding – 5
	
	• Queens Park bridge is overtopped
	• Flood extent is increased to the north of Belcombe St in Newtown. Flooding occurs at:
	  • 11 Belcombe Rd
	  • 10 Braemar Ct
	  • 36, 38, 40, 37, 39 Sandringham Parade
	  • All properties along Glamis St
	  • 11 to 31 Gairloch Grove,
	  • 90, 92 and 94 Buckingham Rd
	• On the right bank of the Barwon River, upstream of Shannon Ave, properties 1 to 13 Barwon Blvd (north side) are impacted.
	• In Geelong, several additional properties are inundated north of Barwon Tce, on both sides of Crown St, floodwaters reach the intersection with Dowsett St.
	• Flood extents are only marginally increased along Barwon Heads Road inn Belmont.
		■ South end of Barwon Blvd, Highton
		■ Crown St, South Geelong
		■ Gairloch Grove, Newtown
		■ Glamis St, Newtown
		■ Sandringham Parade, Newtown
		■ Dalton St, Geelong
		■ Shannon Ave, Newtown
		■ Braemar Ct, Newtown
		■ Riverglen St, Belmont
		■ Tegwen St, Belmont
		■ Anco Pk Dr, Newtown
		■ Belcombe Rd, Newtown
		■ BellerineBellarine St, Geelong
		■ Frank St, Belmont
		■ Summers St, Belmont
		■ Little Fyans St, Geelong
		■ Curtis Rd, Belmont
		■ Breakwater Rd, Belmont
		■ Bridge St, Newtown
		■ Swanston St, Geelong

Event	Flood Characteristics – Barwon River floodplain, Queens Park to Waurn Ponds Creek	Key roadways inundated
		■ Factories Rd, Geelong ■ Barwon Terrace, Geelong ■ Barwon Heads Road, Geelong ■ Riversdale Road, Newtown ■ Marnock Road, Newtown ■ Promenade, Belmont ■ Wood St, South Geelong ■ Gravel Pits Road, South Geelong ■ Steel St, South Geelong ■ Barrabool Road, Belmont ■

Waurn Ponds Creek

TABLE 4-8 SUMMARY OF FLOOD BEHAVIOUR ALONG WAURN PONDS CREEK

Event	Flood Characteristics – Waurn Ponds Creek	Key roadways inundated
50% AEP event 12 m^3/s peak flow at Torquay Road **20% AEP event** 19 m^3/s peak flow at Torquay Road **10% AEP event** 27 m^3/s peak flow at Torquay Road	• Flooding is confined to a narrow floodplain along the Creek on most of the study area. • Larger extents of flooded areas occur downstream of Torquay Rd and close to the confluence with the Barwon River. Impacting prairies and natural land. • 50% AEP Residential Above Floor Flooding – None • 50% AEP Residential Below Floor Flooding – None • 50% AEP Commercial Above Floor Flooding – None • 50% AEP Commercial Below Floor Flooding – None • 20% AEP Residential Above Floor Flooding – None • 20% AEP Residential Below Floor Flooding – None • 20% AEP Commercial Above Floor Flooding – None • 20% AEP Commercial Below Floor Flooding – None • 10% AEP Residential Above Floor Flooding – None • 10% AEP Residential Below Floor Flooding – None • 10% AEP Commercial Above Floor Flooding – None • 10% AEP Commercial Below Floor Flooding – None	

Event	Flood Characteristics – Waurn Ponds Creek	Key roadways inundated
5% AEP event 37 m^3/s peak flow at Torquay Road	• 5% AEP Residential Above Floor Flooding – None • 5% AEP Residential Below Floor Flooding – 1 • 5% AEP Commercial Above Floor Flooding – None • 5% AEP Commercial Below Floor Flooding – None • Rossack Dr is overtopped on the left bank. Depth on road is 0.1m	▪ Rossack Dr, Grovedale
2% AEP event 57 m^3/s peak flow at Torquay Road	• 2% AEP Residential Above Floor Flooding – None • 2% AEP Residential Below Floor Flooding – 1 • 2% AEP Commercial Above Floor Flooding – None • 2% AEP Commercial Below Floor Flooding – None • Rossack Dr is flooded on both sides of the waterway, maximum depth around 0.98m • Torquay Rd is overtopped, depths on the road reach 0.17m	▪ Torquay Rd, Belmont ▪ Rossack Dr, Grovedale

Event	Flood Characteristics – Waurn Ponds Creek	Key roadways inundated

1% AEP event
77 m^3/s peak flow at Torquay Road
	• 1% AEP Residential Above Floor Flooding – 1
	• 1% AEP Residential Below Floor Flooding – 12
	• 1% AEP Commercial Above Floor Flooding – None
	• 1% AEP Commercial Below Floor Flooding – None
	• Depths on Rossack Dr reach 1.03m
	• Torquay Rd is overtopped, depths on the road reach 0.25m. Breakout to the north along Torquay Road. Floodwaters then flow north east to Bailey St, depths are mostly below 0.25m. The following properties are impacted:
	  • 15, 16 Glenbrae Court,
	  • 2, 3, 12, 13, 14 Eldridge Pl
	  • 204, 206, 208, 175, 177 and 179 Francis St
	  • Sherwood Village Caravan Park
		▪ Glenbrae Court, Belmont
		▪ Eldridge Pl, Belmont
		▪ Francis St, Belmont
		▪ Bailey St, Belmont
		▪ Torquay Rd, Belmont
		▪ Rossack Dr, Grovedale

0.5% AEP Event
84 m^3/s peak flow at Torquay Road
	• 0.5% AEP Residential Above Floor Flooding – 1
	• 0.5% AEP Residential Below Floor Flooding – 24
	• 0.5% AEP Commercial Above Floor Flooding – None
	• 0.5% AEP Commercial Below Floor Flooding – None
	  • Depths on Rossack Dr reach 1.15m
	  • Overland flowpath from Torquay Rd goes through 9,10 and 13,18 Jacaranda Pl to inundate Sherwood Village Caravan Park
		▪ Jacaranda Pl, Belmont
		▪ Glenbrae Court, Belmont
		▪ Eldridge Pl, Belmont
		▪ Francis St, Belmont
		▪ Bailey St, Belmont
		▪ Torquay Rd, Belmont
		▪ Rossack Dr, Grovedale

Event	Flood Characteristics – Waurn Ponds Creek	Key roadways inundated
0.2% AEP Event 133 m^3/s peak flow at Torquay Road	• 0.2% AEP Residential Above Floor Flooding – 3 • 0.2% AEP Residential Below Floor Flooding – 40 • 0.2% AEP Commercial Above Floor Flooding – None • 0.2% AEP Commercial Below Floor Flooding – None • Properties on Bailey St, opposite the Caravan Park in Belmont are impacted	▪ Jacaranda Pl, Belmont ▪ Glenbrae Court, Belmont ▪ Eldridge Pl, Belmont ▪ Francis St, Belmont ▪ Bailey St, Belmont ▪ Torquay Rd, Belmont ▪ Rossack Dr, Grovedale

Barwon Floodplain: Breakwater Road to Lake Connewarre

TABLE 4-9 SUMMARY OF FLOOD BEHAVIOUR ALONG THE BARWON FLOODPLAIN, BREAKWATER ROAD TO LAKE CONNEWARRE

Event	Flood Characteristics – Barwon Floodplain, from Breakwater Rd to Wilsons Rd	Key Roadways inundated
50% AEP event 123 m^3/s peak flow at McIntyre Bridge **20% AEP event** 312 m^3/s peak flow at McIntyre Bridge **10% AEP event** 493 m^3/s peak flow at McIntyre Bridge	• Floodplain around Goat Island is inundated for all events. Flood extents do not vary much with increasing AEPs. Natural wetlands and agricultural subject to inundation • 50% AEP Residential Above Floor Flooding – None • 50% AEP Residential Below Floor Flooding – None • 50% AEP Commercial Above Floor Flooding – None • 50% AEP Commercial Below Floor Flooding – None	

Event	Flood Characteristics – Barwon Floodplain, from Breakwater Rd to Wilsons Rd	Key Roadways inundated
5% AEP event 694 m^3/s peak flow at McIntyre Bridge	• 20% AEP Residential Above Floor Flooding – None • 20% AEP Residential Below Floor Flooding – None • 20% AEP Commercial Above Floor Flooding – 1 • 20% AEP Commercial Below Floor Flooding – 1 • 10% AEP Residential Above Floor Flooding – 1 • 10% AEP Residential Below Floor Flooding – None • 10% AEP Commercial Above Floor Flooding –4 • 10% AEP Commercial Below Floor Flooding – 2 • 5% AEP Residential Above Floor Flooding – 1 • 5% AEP Residential Below Floor Flooding – None • 5% AEP Commercial Above Floor Flooding – 6 • 5% AEP Commercial Below Floor Flooding – 2 • Floodplain on the right bank of the Barwon River, East of Charlemont, is engaged under the 5% AEP flow. Mainly impacting agricultural land. • Lake Rd and Breamlea Rd in Connewarre are flooded.	■ Breamlea Rd, Connewarre

Event	Flood Characteristics – Barwon Floodplain, from Breakwater Rd to Wilsons Rd	Key Roadways inundated
2% AEP Event 1045 m^3/s peak flow at McIntyre Bridge	• 2% AEP Residential Above Floor Flooding – 2 • 2% AEP Residential Below Floor Flooding – 2 • 2% AEP Commercial Above Floor Flooding – 6 • 2% AEP Commercial Below Floor Flooding – 2 • 275 Barwon Heads Road, Belmont is flooded. • Floodplain east of Charlemont is fully inundated. Groves Rd, Armstrong Creek is flooded with depths above 0.75m, isolating properties to the east along the road. • Lake Rd, Connewarre is flooded. Connewarre Lake Centre is potentially impacted	■ Groves Rd, Armstrong Creek ■ Lake Rd, Connewarre
1% AEP Event 1367 m^3/s peak flow at McIntyre Bridge	○ 1% AEP Residential Above Floor Flooding – 9 ○ 1% AEP Residential Below Floor Flooding – 6 ○ 1% AEP Commercial Above Floor Flooding –18 ○ 1% AEP Commercial Below Floor Flooding – 1 ○ 41 Norcott Rd, Charlemont is impacted by floodwaters	■ Groves Rd, Armstrong Creek ■ Lake Rd, Connewarre
0.5% AEP Event 1700 m^3/s peak flow at McIntyre Bridge	• 0.5% AEP Residential Above Floor Flooding – 16 • 0.5% AEP Residential Below Floor Flooding – 12 • 0.5% AEP Commercial Above Floor Flooding – 24 • 0.5% AEP Commercial Below Floor Flooding – 1 • Wilsons Rd is overtopped. Properties at 341 to 355 Wilsons Rd, St Albans Park. Note that 355 Wilsons Rd is an Aged Care Home • Flooding on the northern shores of Reedy Lake, Farmland east of Scotts Rd, Moolap is inundated	■ Wilsons Rd, St Albans Park ■ Groves Rd, Armstrong Creek ■ Lake Rd, Connewarre

Event	Flood Characteristics – Barwon Floodplain, from Breakwater Rd to Wilsons Rd	Key Roadways inundated

0.2% AEP Event
2265 m^3/s peak flow at McIntyre Bridge
	• 0.2% AEP Residential Above Floor Flooding – 41
	• 0.2% AEP Residential Below Floor Flooding – 3
	• 0.2% AEP Commercial Above Floor Flooding – 28
	• 0.2% AEP Commercial Below Floor Flooding – 2
	
	• On the right bank of Waurn Ponds Creek, near Barwon Heads Rd bridge, properties along Ardeche Lane, Marshall are inundated
	• The parking lot of the Jehovah's Witness Kingdom hall is flooded, depths reach 0.5m.
	• Higher water levels inundate properties near the railway line in Marshall, along the following streets :
	  • Carlina Ct,
	  • Speranza Ct,
	  • Alegro Ct and
	  • MacFarlane St
	• Building at 72 Leather St, Breakwater is flooded
	• Flood extents increase to the east of Wilsons Rd, St Albans Park. Additional properties along Wilsons Rd, Riseborough Ct and Freeman Ct are flooded
	• Flood waters inundate low areas of agricultural land boarded by Townsend Rd and Wellington St in Moolap. Buildings at 312 Townsend Rd are impacted.
	• Flooding extends to the south of the Connewarre Wetland Centre and reaches Barwon Heads Road while flooding Breamlea Rd, Connewarre. Agricultural land is impacted.
		■ MacFarlane St, Marshall
		■ Riseborough Ct, St Albans Park
		■ Freeman Ct, St Albans Park
		■ Moolap Station Rd, Moolap
		■ Wilsons Rd, St Albans Park
		■ Groves Rd, Armstrong Creek
		■ Lake Rd, Connewarre

Barwon Floodplain: Barwon River Estuary

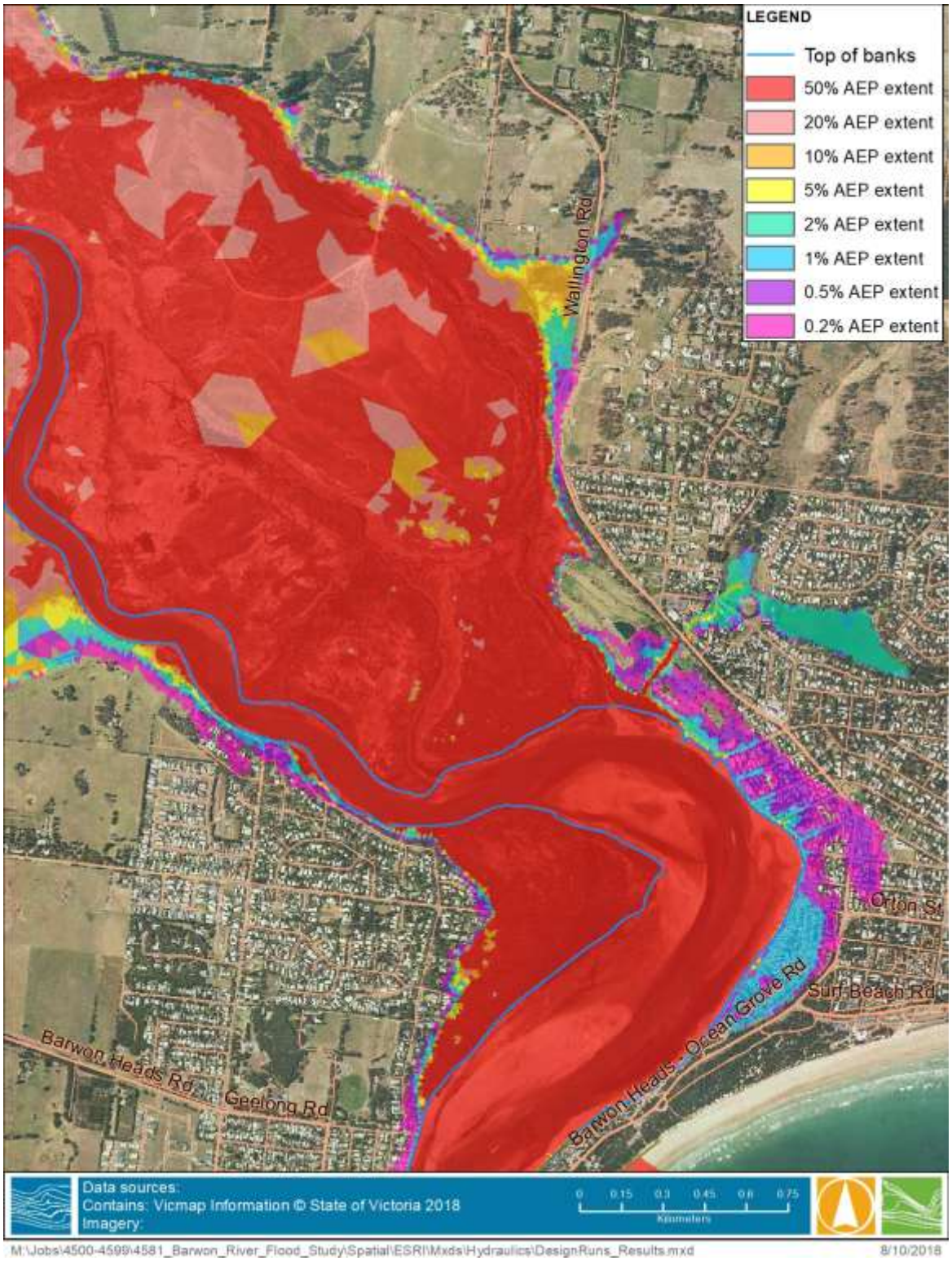

FIGURE 4-5 FLOOD EXTENTS OVERLAYED FOR THE FULL RANGE OF DESIGN EVENTS : OCEAN GROVE

Barwon Floodplain: Barwon River Estuary

TABLE 4-10 SUMMARY OF FLOOD BEHAVIOUR AT BARWON HEADS ESTUARY

Event	Flood Characteristics – Barwon Floodplain, from Breakwater Rd to Wilsons Rd	Key Roadways inundated
50% AEP event **20% AEP event** **10% AEP event** **5% AEP event** **2% AEP event**	Floodwaters remain within the estuary for design events below 1% AEP. • 2% AEP Residential Above Floor Flooding – None • 2% AEP Residential Below Floor Flooding – None • 2% AEP Commercial Above Floor Flooding – None • 2% AEP Commercial Below Floor Flooding – None	
1% AEP event	• 1% AEP Residential Above Floor Flooding – None • 1% AEP Residential Below Floor Flooding – 11 • 1% AEP Commercial Above Floor Flooding – 2 • 1% AEP Commercial Below Floor Flooding – None Inundation on left bank, floodwaters overtop Riverside Ave and flood the Riverview Caravan Park, extents are bound by Barwon Heads – Ocean Grove Road	▪ Riverside Avenue, Ocean Grove

Event	Flood Characteristics – Barwon Floodplain, from Breakwater Rd to Wilsons Rd	Key Roadways inundated
0.5% AEP event	• 0.5% AEP Residential Above Floor Flooding – 11 • 0.5% AEP Residential Below Floor Flooding – 92 • 0.5% AEP Commercial Above Floor Flooding – 6 • 0.5% AEP Commercial Below Floor Flooding – 3 Inundation on the left bank impacts the following roadways: Whitton St, Hurst St, Beaver St, Parker St and Guthridge St Western end of Lelean St and Dave St are flooded	■ Whitton St, Ocean Grove ■ Hurst St, Ocean Grove ■ Beaver St, Ocean Grove ■ Parker St, Ocean Grove ■ Guthridge St, Ocean Grove ■ Western end of Lelean St and Dave St, Ocean Grove ■ Wallington Road ■ Riverside Ave, Ocean Grove
0.2% AEP event	• 0.2% AEP Residential Above Floor Flooding – 79 • 0.2% AEP Residential Below Floor Flooding – 90 • 0.2% AEP Commercial Above Floor Flooding – 9 • 0.2% AEP Commercial Below Floor Flooding – 1 • Water level is 0.37m higher than in the 0.5% AEP scenario. Flood extents in Ocean Grove are marginally increased and impact several new properties listed under the 0.5% AEP event. • Flooding occurs at the north-end of Sheepwash Road and River Parade in Barwon Heads. Properties between River Parade (25 to 34) and Barwon Tce (22, 20 and 26) are impacted. Dwellings at 19 to 29 Midden Tce are also potentially impacted.	■ River Parade, Barwon Heads ■ Midden Tce, Barwon Heads ■ Sheepwash Rd, Barwon Heads ■ Whitton St, Ocean Grove ■ Hurst St, Ocean Grove ■ Beaver St, Ocean Grove ■ Parker St, Ocean Grove ■ Guthridge St, Ocean Grove ■ Western end of Lelean St and Dave St, Ocean Grove ■ Wallington Road ■ Riverside Ave, Ocean Grove

** It should be noted that for this part of the floodplain, flood levels and impacts will depend on storm tide conditions. A 10% AEP tide level has been applied for the design events, the resulting levels can be higher or lower depending on the ocean levels occurring during a flood event.*

4.5 Scenario modelling

In addition to the modelling of the range of design events under existing conditions, two scenarios, or sensitivity tests, were investigated :

- the impact of sea level rise, between 0.2 and 0.8m added to the current 1% AEP storm tide level, due to climate change under the 1% and 10% AEP flood events;
- and the opening of the gate under Plumbers Bank for the 1% AEP flood event.

4.5.1 Climate change scenarios (sea level rise)

The climate change scenarios consist of the 1% storm tide level increased by 0.2m, 0.5m and 0.8m.

Results for the 0.2m sea level rise scenario indicate the impact on maximum water levels (under the 1% AEP flood event in the Barwon River) gradually decreases going upstream along the Barwon River and in the floodplain. Water levels are increased by less than 5cm at Charlemont and St Alban Park. Upstream of the bridge on Breakwater Road the impact is negligible. Levels in Lake Connewarre approximately 20cm higher than with the current 1% AEP storm tide level. The only area where the flood extents are increased, however only marginally, is along Wallington Road in Ocean Grove. Elsewhere the flood extent fringe is slightly increased where the topography allows for it.

With the 0.5m sea level rise, the impact reaches Breakwater Road on the Barwon but not further upstream. Lake Connewarre levels are increased by 28cm. The flood extents are similar to those obtained with the 0.2m sea level rise.

The 0.8m sea level rise impacts levels up to Breakwater Road also. Levels in Lake Connewarre are increased by 38cm. Flood extents are similar to those obtained under the 0.2m sea level rise.

4.5.2 Gate opening under Plumbers bank

The opening of the gate under Plumbers Bank under the 1% AEP flood event allows flood water south of Plumbers Bank, flowing through the structure under Barwon Heads Road and reaches the Murtnaghurt Lagoon. Flow through the culvert under Plumbers reaches a peak of 0.34 m³/s. Since the levee isn't overtopped, the limited flow capacity of the structure prevents widespread flooding. The figure below presents the maximum water depths under the 1% AEP flood event (model was run for 3 days after flood peak) with the gate under Plumber bank open.

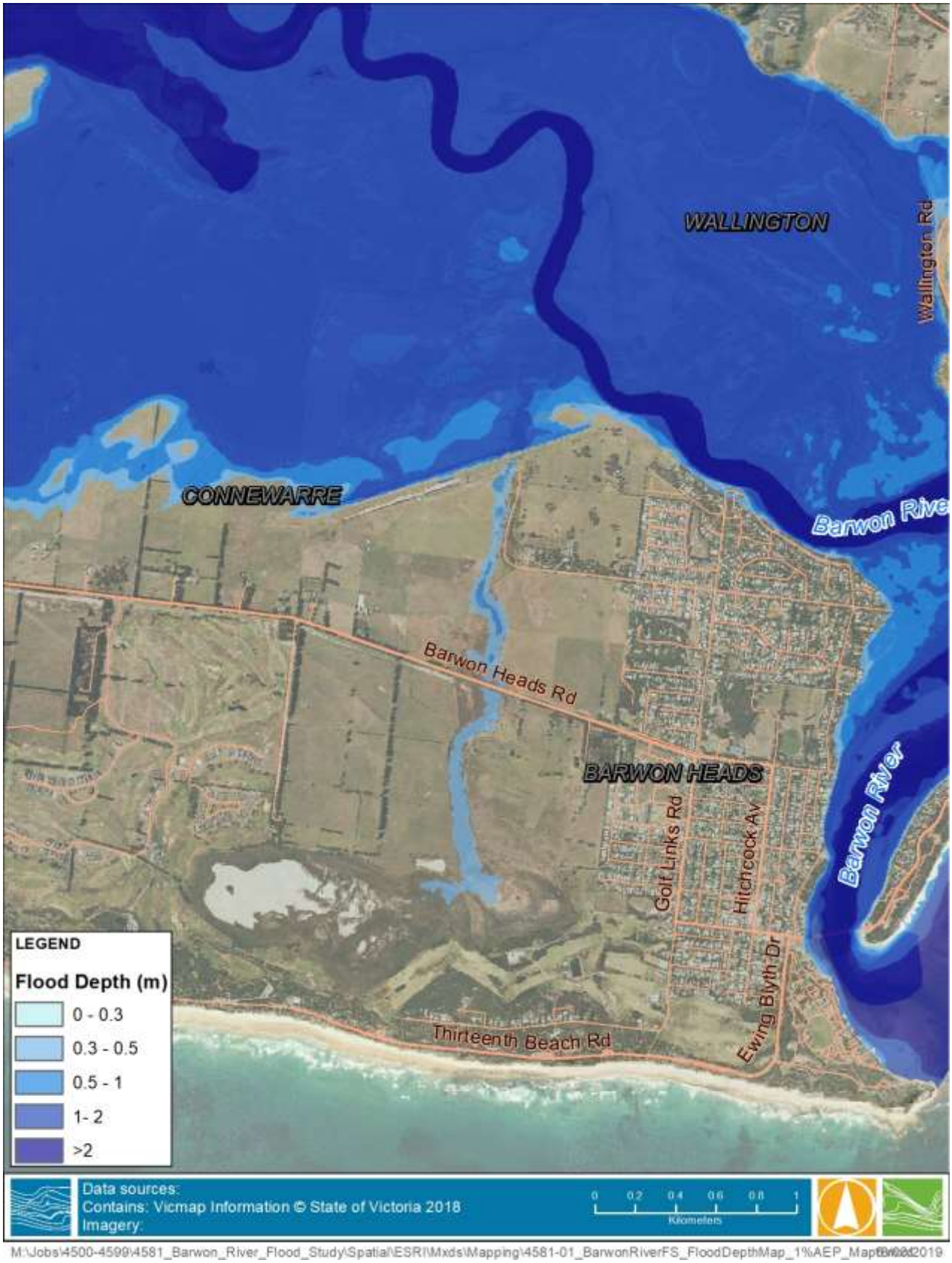

FIGURE 4-6 FLOOD DEPTHS : OPEN GATE UNDER PLUMBERS BANK (1% AEP EVENT)

4.6 Model result outputs

The model result data, including grids and extents, have been provided in specified Victoria Flood Database (VFD2) format for each flood event. The following result components were generated:

- Flood level, flood depth, flood velocity and flood hazard grids
- Flood elevation contours
- Flood extent data
- Hydrographs at key locations
- Long-section of river water levels

Grids and shapefiles (ESRI/VFD format), and Data tables (Excel csv/xlsx format) were provided on a Study USB upon completion of the study.

4.6.1 Data Sets

The following datasets were provided as final deliverables to the City of Greater Geelong and Corangamite CMA.

Grids

Gridded datasets of model results were provided for the following:

- Design events (50%, 20% 10%, 5%, 2%, 1%, 0.5%, 0.2% and 0.1%) – maximum depth, velocity, velocity x depth, Flood Hazard using AR&R Safety criteria for **vehicles**, Flood Hazard using AR&R Safety criteria for **people** and water surface elevation.
- Calibration events (1973, 1978, 1995, 2011 and 2016 events) – maximum depth velocity, velocity x depth, and water surface elevation.
- Model Topography

The hydraulic analysis provides regular grids of flood elevations across the hydraulic model study area. The flood extent was defined by converting the 2.5 m grid flood elevations to an extent polygon. The extent was smoothed to remove the sharp edges of the grid cells for cartographic / presentation purposes.

Flood depths were classified for mapping using the following classifications:

- 0 m to 0.25 m
- 0.25 m to 0.50 m
- 0.50 m to 1.00 m
- 1.00 m to 2.00 m
- Greater than 2.00 m

Vector Data

ERSI shapefiles in VFD2 format were provided for the following:

- Peak flood extents
- Peak flood elevation contours
- Mapping limits
- Recommended Flood Overlay & Land Subject to Inundation Overlay

- Flood Affected Properties
- Surveyed Floor Levels
- Study Area Extent

Maps

The flood response inundation maps have been produced for the following design flood events for both Barwon River and Leigh River dominant scenarios:

- 0.2% AEP event
- 0.5% AEP event
- 1% AEP event
- 2% AEP event
- 5% AEP event
- 10% AEP event
- 20% AEP event

Each map includes:

- Flood extent,
- Flood level contour at 1m intervals,
- Depth of inundation,
- Identification of essential services,
- Major Road/street names
- Cadastral base
- Gauge height indication for the Moorabool River at Batesford, Barwon River at Pollocksford and Barwon River at Geelong streamflow gauges.

Copies of the maps were provided in PDF format.

5 PLANNING LAYERS AND DOCUMENTATION

5.1 Overview

A separate planning report is currently being prepared by planner, Edwin Irvine. This will be provided with the final project deliverables and include recommended Land Subject to Inundation (LSIO) and Floodway Overlay (FO) extents. Draft planning extents and key findings from the planning report will be presented in the draft final flood study report.

5.2 Flood Related Zones and Overlays

5.2.1 Land Subject to Inundation (LSIO)

The LSIO identifies land liable to inundation by overland flow, in flood storage or in flood fringe areas affected by the 1% AEP flood. Draft LSIO layers have been prepared for the study area based on the 1% AEP flood extent.

The permit requirements of LSIO are intended:

- to ensure that development maintains the free passage and temporary storage of floodwaters,
- to minimise flood damage,
- to be compatible with the flood hazard and local drainage conditions,
- not to cause any significant rise in flood level or flow velocity,
- to protect water quality in accordance with relevant State Environment Protection Policies (SEPPs).

In general, emergency facilities (hospitals, schools and police stations etc.) must be excluded from this area (refer Clause 15.02). Similarly, developments or land uses which involve the storage or disposal of environmentally hazardous chemicals or wastes, and other dangerous goods should not be located within LSIO. Permit requirements as well as performance-based controls can be specified.

An LSIO is recommended for all of the key waterways assessed in this study.

5.2.2 Floodway Overlay (FO)

The FO identifies waterways, main flood paths, drainage depressions and high hazard areas. The identification of FO can be based on numerous methods, these are outlined below:

- Advisory Notes for Delineating Floodways (Edwards, 1998). This is the previous method used in VIC which uses an envelope of the following:
  - 1% AEP depths >= 0.5 m
  - 10% extent
  - 1% AEP high hazard area (velocity >= 1.5 m/s)
- CMA Method 01 (same as Edwards,1998 but drops 10% AEP and reduces depth threshold):
  - 1% AEP depths >= 0.3 m
  - 1% AEP high hazard area (velocity >= 1.5 m/s)
- CMA Method 02 - Method adopted by City of Ballarat for the Burrumbeet Catchment (C178). This is based on Cox et al (2010) as part of ARR Project 10 update. This uses the below criteria:
  - 1% AEP depths >= 0.5 m

- 1% AEP VxD >= 0.4 m²/s

The draft extent of the floodway overlay recommended for study area is based on CMA Method 2. This is the most recently developed method and has been utilised in other locations in the region including the City of Ballarat.

An FO is recommended for all of the key waterways assessed in this study.

6 FLOOD DAMAGES ASSESSMENT

1.1 Overview

A flood damages assessment has been undertaken for the study area under existing conditions. To inform the damages assessment floor level survey has been gathered for 850 buildings across the study area.

The flood damage assessment has determined the monetary flood damages across the range of design floods (50%. 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP flood events).

Water Technology has developed an industry best practice damage assessment methodology that has been utilised for a number of studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD and other relevant flood damage literature. A review by economists Aither on behalf of DELWP has led to the conclusion that ANUFLOOD stage damage curves underestimate flood damages, particularly for shallow above floor depths and for below floor flooding. The stage-damage curves developed by the New South Wales Office of Water have been recommended by Aither and were used for this study. The model results for all mapped flood events will be processed to calculate the number and location of properties affected. This included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were inundated. In addition to the flood affected properties, lengths of flood affected roads for each event will also be calculated.

1.2 Existing conditions

The 1% AEP flood damage estimate for existing conditions was calculated to be just over $6 million. A total of 307 properties are predicted to be flood affected in a 1% AEP flood event, with 55 of those properties flooded above floor level. The Average Annual Damages (AAD) was determined as part of the flood damage assessment. The AAD is a measure of the average flood damage per year. The AAD for existing conditions for the study area is estimated to be **$964,060**.

The AAD is effectively a measure of the amount of money that must be put aside each year to compensate for the physical impacts of flooding over time. This figure is quite high in comparison to other recent flood studies across Victoria but is also a result of the large study area being investigated. It is of note that the commercial damages are considerably larger than the residential damages, particularly in the rarer flood events.

Table 6-1 Flood damage assessment for existing conditions

Parameter	Annual Exceedance Probability					
	0.5%	1%	2%	5%	10%	20%
Residential Buildings Flooded Above Floor	182	65	9	8	2	1
Commercial Buildings Flooded Above Floor	153	123	39	38	22	11
Properties Flooded Below Floor	283	173	106	90	58	8
Total Properties Flooded	**618**	**361**	**154**	**136**	**82**	**20**
Direct Potential External Damage Cost	$1,291,052	$715,249	$439,987	$373,517	$244,445	$19,296
Direct Potential Residential Damage Cost	$13,436,877	$4,724,037	$738,714	$662,976	$152,268	$74,094
Direct Potential Commercial Damage Cost	$47,569,371	$28,775,915	$1,619,870	$1,607,986	$554,637	$128,841

Total Direct Potential Damage Cost	$62,297,300	$34,215,201	$2,798,571	$2,644,479	$951,350	$222,231
Total Actual Damage Cost *(0.8*Potential)*	$49,837,840	$27,372,161	$2,238,857	$2,115,583	$761,080	$177,785
Infrastructure Damage Cost	$1,510,363	$1,208,927	$697,918	$666,566	$500,523	$384,196
Total Cost	**$51,348,203**	**$28,581,088**	**$2,936,775**	**$2,782,149**	**$1,261,603**	**$561,981**
Average Annual Damage	**$964,060**					

* Figures do not include rural parcels where dwellings are not impacted by above or below flood flooding. These have been costed as rural damages but property numbers are not reported in this table.

** The NSW Office of Water stage damage curves incorporate indirect costs into direct potential costs so they are not listed separately.

7 SUMMARY AND RECOMMENDATIONS

7.1 Overview

The Lower Barwon and Lower Moorabool Flood Investigation has provided a much improved understanding of flood behaviour through the study area. This will ensure future flood-related planning decisions are soundly based and key agencies and residents have a much better understanding of flood risk through the study area. The investigation has provided a comprehensive analysis and review of existing and future potential flood risk in the township and surrounding areas. The study involved:

- Collection and review of a range of data relevant to the definition of flooding within the study area.
- A rigorous hydrologic analysis to develop robust design flood estimates for the study area including in the Moorabool and Barwon Rivers and Waurn Ponds Creek.
- Development of a detailed hydraulic model that is capable of predicting flood impacts in the complex floodplains of the Lower Barwon and Moorabool Rivers as well as Waurn Ponds Creek.
- Assessment of flooding along a number of local tributaries within the study area
- Quantification of flood risk in terms of flood damages – to be presented in final study report.
- A planning assessment presented in a separate report
- Review of flood warning and emergency management for the catchment including recommendations for improvement of the current total flood warning system (presented in a separate flood warning report).

7.2 Key Outcomes

The key findings and outcomes of the Wangaratta Flood Investigation are:

Study Area Hydrology & Hydraulic Characteristics - The study area covers the floodplains of the Barwon and Moorabool Rivers downstream of Pollocksford and Batesford. This includes the Barwon River floodplain through central Geelong and extending downstream to Barwon Heads and Ocean Grove. Waurn Ponds Creek was also included within the analysis. A comprehensive hydrological and hydraulics analysis has been undertaken of the study area.

Flood Damages – A flood damages assessment has been undertaken. The 1% AEP flood damage estimate for existing conditions was calculated to be just over $26.6 million. A total of 361 properties are predicted to be flooded affected in a 1% AEP flood event, with 65 residential and 123 commercial properties flooded above floor level. The Average Annual Damages (AAD) was determined as part of the flood damage assessment and estimated to be $512,662.

Future Development and Planning - The results of the investigation can be used to guide future development through the study area. A review of the existing planning scheme was undertaken and draft Land Subject to Inundation (LSIO) and Floodway Overlay (FO) planning maps were produced. A separate planning report has been provided.

Scenario Modelling – As well as the design event modelling a number of scenarios were modelled which included:

- A range of sea level rise scenarios were modelled included rises of 0.3, 0.5 and 0.8 metres.
- A scenario was modelled whereby the levee bank to the west of Barwon Heads (Plumbers Bank) was removed.

Flood warning – A comprehensive assessment of the current flood warning system has been made and a number of recommendations made. These are detailed in a separate flood warning report.

- A review of the existing planning scheme was undertaken and draft Land Subject to Inundation (LSIO) and Floodway Overlay (FO) planning maps were produced.
- Municipal Flood Emergency Plan (MFEP) – the MFEP will be updated with flood intelligence from this study. This should be utilised during future floods.

7.3 Recommendations

Following the investigations undertaken for this study it is recommended that:

- Corangamite CMA and the City of Greater Geelong adopt the determined design flood levels for future planning purposes.
- In conjunction with VICSES, the City of Greater Geelong and Corangamite CMA continue to engage the community in the treatment of flood risks through regular flood awareness programs such as the VICSES FloodSafe program, starting with the development of a local flood guide.
- In consultation with VICSES, the City of Greater Geelong and Corangamite CMA explore further the recommendations for enhanced flood response through co-operation with VICSES and Victoria Police, utilising the flood inundation maps and flood intelligence findings detailed in this report.
- The City of Greater Geelong and Corangamite CMA further consider the findings regarding flood warning and responses outlined in the flood warning report.

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

APPENDIX A
DESIGN FLOOD MAPS

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