Flood Damages and Mitigation Options Assessment Report

Upper Mt. Emu Creek Flood Investigation

Glenelg Hopkins CMA

17 June 2020

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Cover Image: Mt. Emu Creek at Trawalla, Jan 2011

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Dear Tatjana

Upper Mt. Emu Creek Flood Investigation

Please see attached flood mitigation report. This report details the mitigation options that were assessed as part of the Upper Mt. Emu Creek Flood Investigation. The report details the impact of each option has on flood behaviour both locally and regionally as well as preliminary costs of the modelled options specifically relating to inundation of the Lake Goldsmith Steam Preservation Society site. It also details the impact of completed flood mitigation work downstream of Jubilee Park Lake.

The project team would like to thank the Lake Goldsmith Steam Preservation Society for their considerable input during the study, with particular thanks to Brian Smith who provided an invaluable contribution to the project.

If you have any questions regarding this report, please do not hesitate to contact me.

Yours sincerely

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1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by the Glenelg Hopkins Catchment Management Authority (Glenelg Hopkins CMA) to undertake the Upper Mt. Emu Creek Flood Investigation. The investigation area covered the upper Mt. Emu Creek catchment, extending along Mt. Emu Creek from upstream of Trawalla to Skipton, and the length of Baillie Creek from Lake Burrumbeet to the confluence with Mt. Emu Creek. Both waterways have a well-known history of flooding and some of the most significant flood events are recent and well recorded (e.g. events in 2010, 2011 and 2016). These flood events caused substantial damage to local infrastructure and agricultural assets (e.g. roads, bridges and fencing, as well as fodder, crop and stock losses). Severe impacts have also occurred within the township of Skipton and at the Lake Goldsmith Steam Preservation Society (LGSPS), damaging facilities and historical artefacts.

A previous flood investigation at Skipton was undertaken by Water Technology in 2013[1]. Since the completion of the study several physical and academic changes have occurred which impact inundation along Mt. Emu Creek and within Skipton, these include:

- Flood mitigation works have been undertaken in Skipton, altering the inundation characteristics within the township.
- Upgrade of the Western Highway, adding a significant floodplain feature at Trawalla. This is likely to increase demand for land development west of Ballarat because of the reduction in commute time between Beaufort and Ballarat.
- Australian Rainfall and Runoff 2019[2] was released outlining revised recommendations for hydrologic and hydraulic analysis (updated from Australian Rainfall and Runoff 1987[3]).

The updated analysis of flooding along Mt. Emu Creek and Baillie Creek was required to support the design and establishment of a formal flood warning service for Skipton.

This flood investigation provides a comprehensive flood analysis for several key areas of interest in the upper region of Mt. Emu Creek and has assessed a series of flood mitigation options specifically relating to the Lake Goldsmith Steam Preservation Society and the Skipton township.

This report is one of a series, documenting the outcomes of the Upper Mt. Emu Creek Flood Investigation. The reporting stages of this project were as follows:

- R01 - Data Review and Validation.
- R02 – Draft Hydrology and Hydraulics Calibration Report.
- R03 – Draft Hydrology and Hydraulics Design Report.
- R04 – Final Hydraulic Report and Mapping Deliverables.
- R05 – Summary Report and Flood Warning Deliverables.
- R06 – **Flood Damages and Mitigation Assessment Report (this report).**

[1] Water Technology (2013), Skipton Flood Investigation.
[2] Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019), Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia
[3] Institution of Engineers, Australia (1987), Australian Rainfall and Runoff: A Guide to Flood Estimation , Vol. 1, Editor-in-chief D.H. Pilgrim, Revised Edition 1987 (Reprinted edition 1998), Barton, ACT

- R07 – Flood Intelligence Report and Animations.
- R08 – Project Summary Report.

This report (R06) describes the flood mitigation and damages assessment completed as part of the study, detailing the impact of the modelled mitigation options, indicative costs of mitigation and the potential financial cost/benefit ratio of the preferable option. This report is closely linked to the Design Modelling Report – R03.

1.2 Previous reporting

There were several previous reporting milestones and memos provided prior to the production of this report. These documents included:

- Data collation report – R01 (V01 – Issued 11/06/2019, V02 – Issued 05/07/2019).
  - This report detailed the data collated and gaps in the data required to be filled. The major outcome of this report was the requirement for additional LiDAR data, which was acquired of the study area vastly improving the dataset coverage. Additional areas included floodplain areas between Lake Goldsmith and Mena Park and Lake Goldsmith.
- Survey requirements memo – M01 (V01 – Issued 05/02/2019, V02 – Issued – 21/03/2019).
  - This memo was produced as a base guideline to assist in sourcing feature survey to verify the additional LiDAR data and accurately define structures within the hydraulic model.
- Calibration update memo report – M02 (V01 – Issued 04/09/2019).
  - This report was produced to update Glenelg Hopkins CMA on the progress of the hydraulic model calibration and to enable a clean handover between changing Project Managers.
- Calibration Report – R02 (V01 – Issued 13/11/2019, V02 – Issued 31/01/2020).
  - This report detailed development of the hydrologic and hydraulic models, as well as the hydraulic model calibration process.
- Design Modelling Report – R03 (V01 – Issued 28/01/2020).
  - This report outlined the design modelling process, design flows and design draft 1% Average Exceedance Probability (AEP) mapping.

2 FLOOD BEHAVIOUR

2.1 Overview

Flooding in the upper Mt. Emu Creek catchment is predominantly riverine. Skipton, the largest township within the catchment, has a well-documented history of significant flood events with numerous properties known to be flood prone. The Lake Goldsmith Steam Preservation Society (LGSPS), located immediately upstream of Cameron Bridge on Carngham – Lake Goldsmith Road, houses one of the most significant collections of historical machinery and artefacts in the southern hemisphere. During the 2011 flood event the LGSPS was severely impacted resulting in substantial losses of irreplaceable artefacts and flood recovery costs.

To classify the impact of flooding and risk to the communities within the upper Mt. Emu Creek catchment, hydraulic flood model results were used to determine the properties and assets likely to be inundated during a range of design events (20% AEP to 0.2% AEP). Given the size of the project area the event durations which generate the maximum flood levels and depths vary considerably, ranging from 18 hours in the upper reaches around Trawalla to 96 hours at Skipton.

2.2 Roads

During major flood events the regional road network often becomes inundated. There is risk associated with travelling through floodwaters of any depth. Flood water can often unknowingly exceed safe vehicle fording depths and velocities. This presents a risk to community, who may become isolated and seek to evacuate and to operational staff and emergency services.

Flood mapping shows several roads within the mapped area can become impacted by flood water during relatively frequent flood events (i.e. 20% AEP). Table 2-1 shows the major roads which become overtopped during the range of modelled design events. The flood extent for each AEP event was overlayed on the road network to identify the extent of flooding on the roads within the catchment. This is represented in Figure 2-1 to Figure 2-5. Consideration should be given of the below table in planning for suitable evacuation routes.

TABLE 2-1 MAJOR ROADS OVERTOPPED

Location	Road Name	Design event overtopped
Skipton	Smythe St	20%
Skipton	Wright St	10%
Skipton	Hardy St	5%
Skipton	Montgomery St East	5%
Skipton	Montgomery St West	5%
Skipton	Cleveland St	5%
Skipton	Anderson St South	5%
Skipton	Anderson St North	2%
Skipton	Montgomery St North	5%
Skipton	Montgomery St North2	2%
Skipton	Daly Rd	2%
Skipton	Pett St	1%
Trawalla	Trawalla-Waterloo Rd	20%
Trawalla	Langi Kal Kal Rd (railway north)	20%

Location	Road Name	Design event overtopped
Trawalla	Langi Kal Kal Rd (railway south)	10%
Trawalla	Langi Kal Kal Rd (old Western Hwy south)	2%
Trawalla	Langi Kal Kal Rd (further north)	1%
Langi Kal Kal	Racecourse Rd (Mt Emu Creek)	10%
Mena Park	Beaufort – Carngham Rd (Mena Park gauge)	5%
Lake Goldsmith	Carngham - Lake Goldsmith Rd (Cameron Bridge)	2%
Lake Goldsmith	Cheesemans Rd (west of LGSPS)	5%
Lake Goldsmith	Skipton Rd (Lake Goldsmith)	1%
Lake Goldsmith	Cushing Rd	2%
Lake Goldsmith	Carngham - Streatham Rd (Mt. Emu Ck)	10%
Chepstowe	MortChup - Mt Emu Rd (Baillie Ck)	20%
Chepstowe	Chepstowe-Pittong Rd (intersection with Guthries Rd)	1%
Chepstowe	Guthrie Rd (Guthries Bridge)	2%

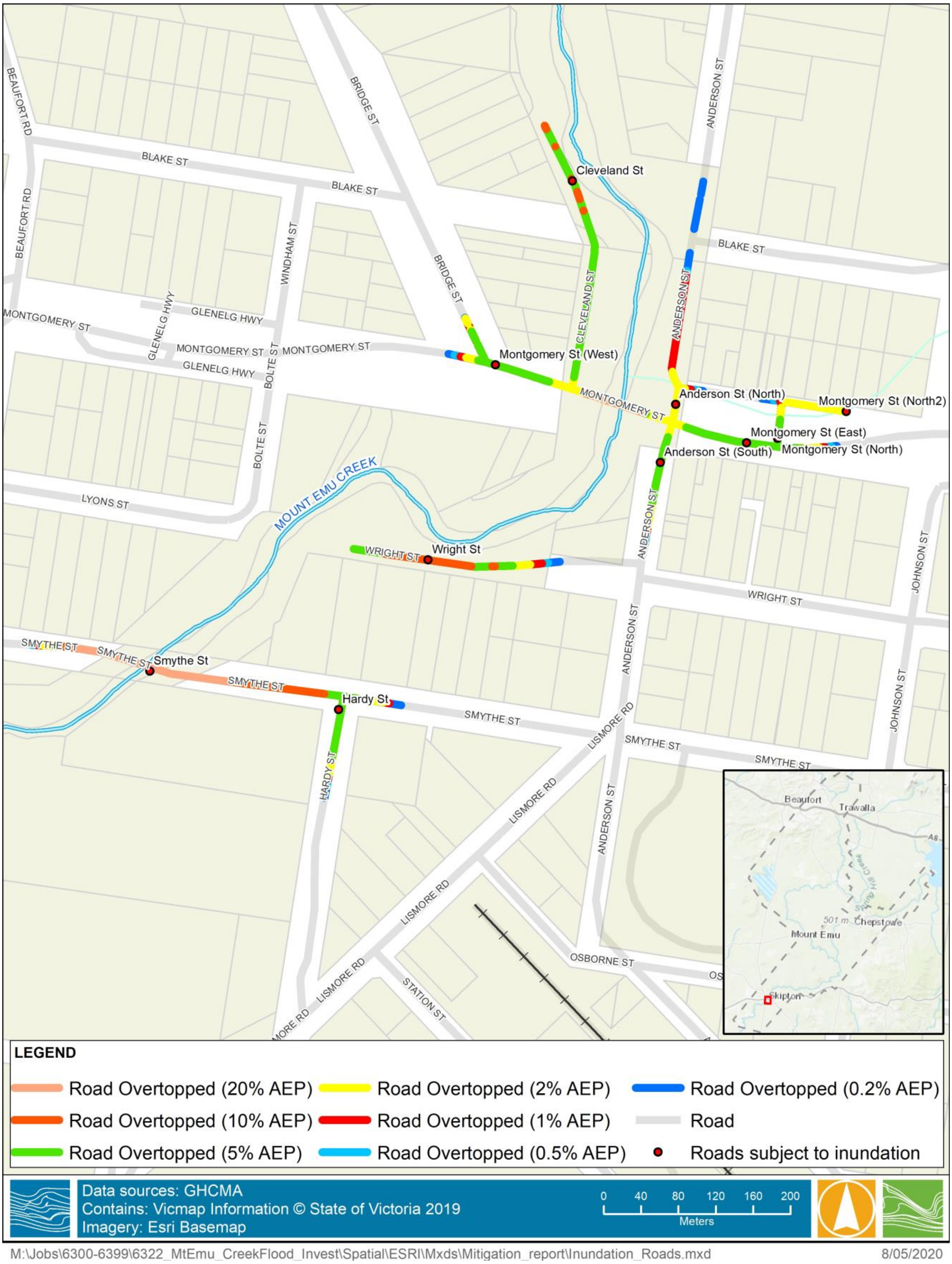

FIGURE 2-1 KEY ROADWAYS OVERTOPPED (SKIPTON)

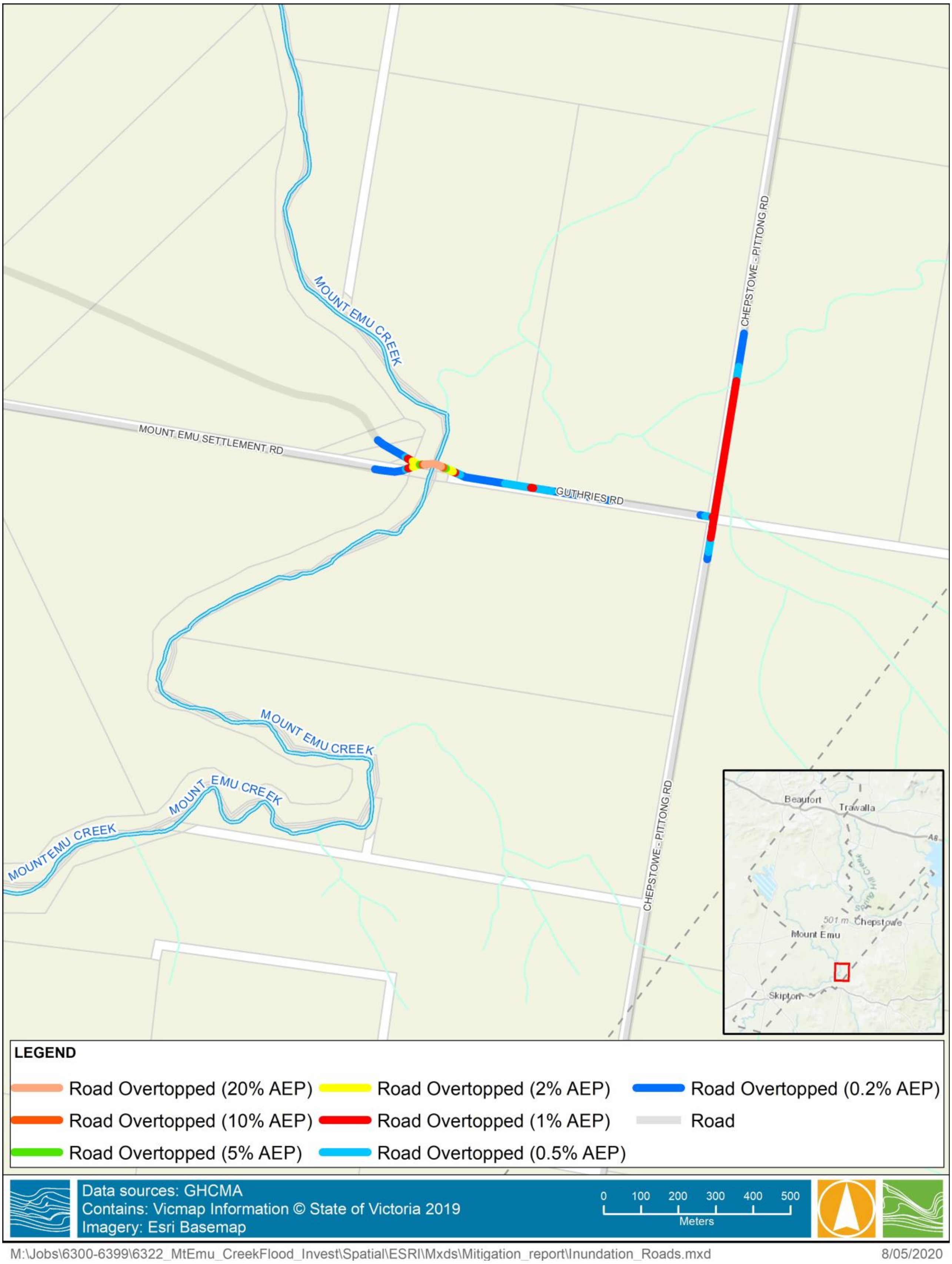

FIGURE 2-2 KEY ROADWAYS OVERTOPPED (GUTHRIES BRIDGE)

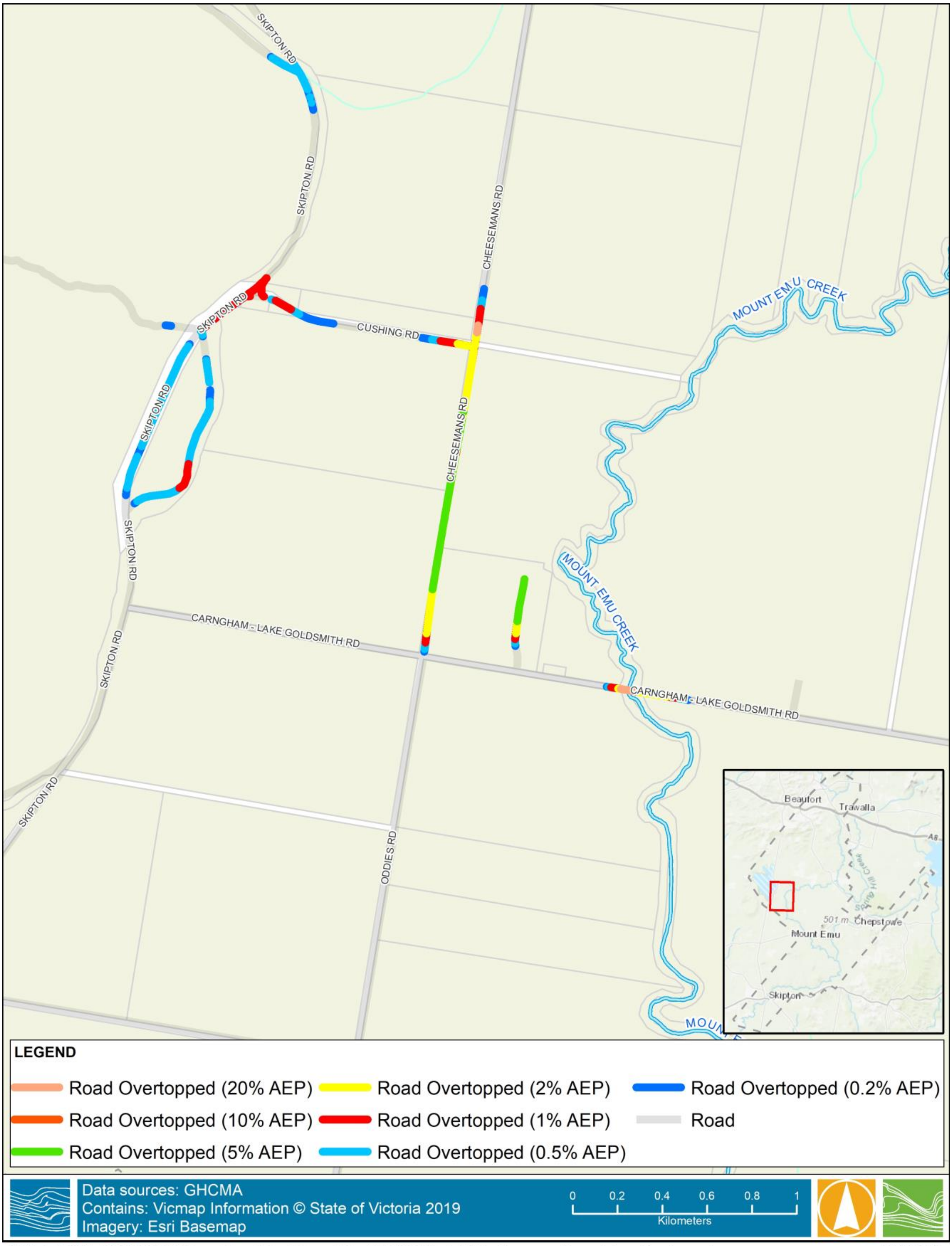

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FIGURE 2-3 KEY ROADWAYS OVERTOPPED (LAKE GOLDSMITH)

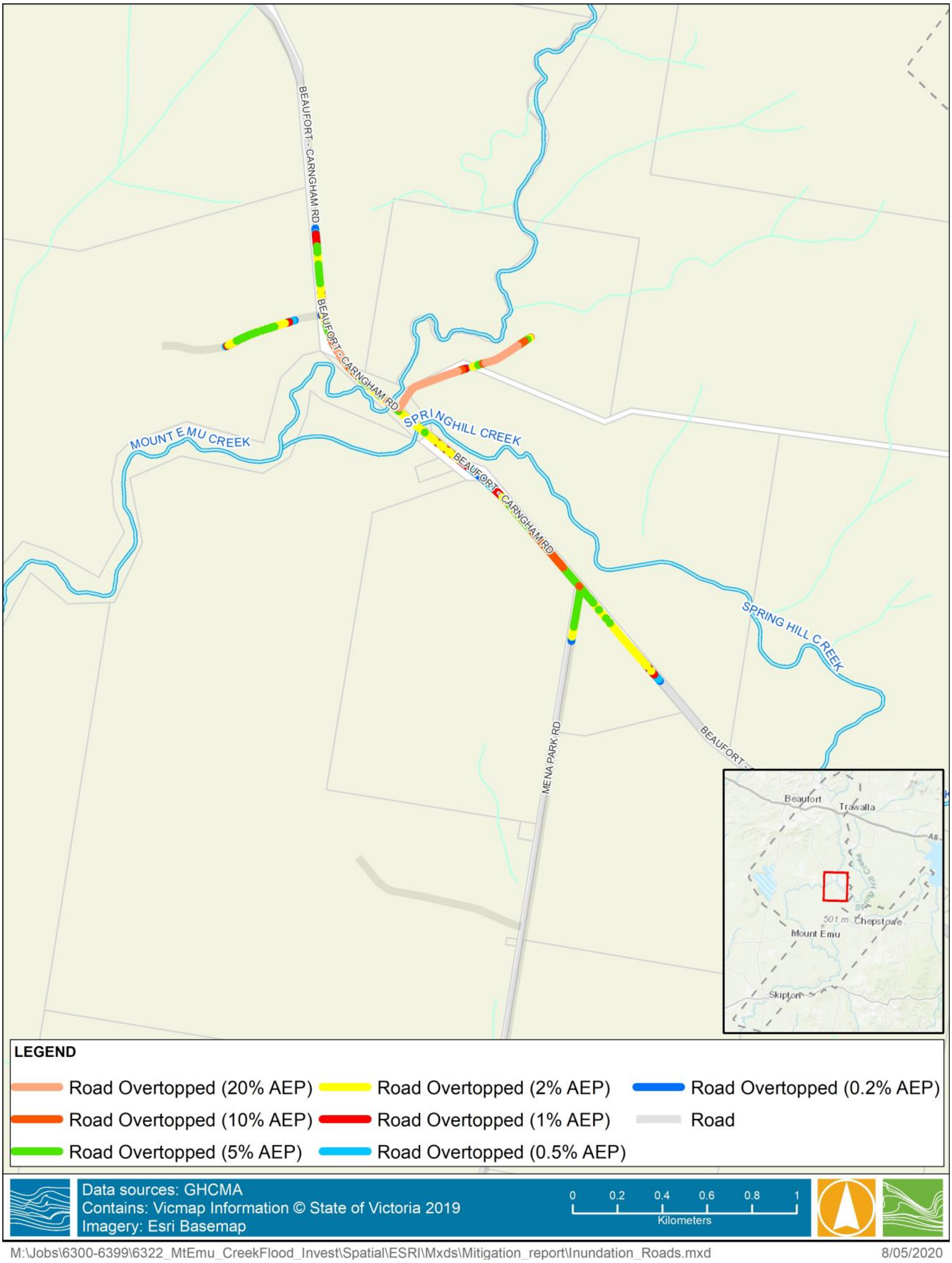

FIGURE 2-4 KEY ROADWAYS OVERTOPPED (MENA PARK)

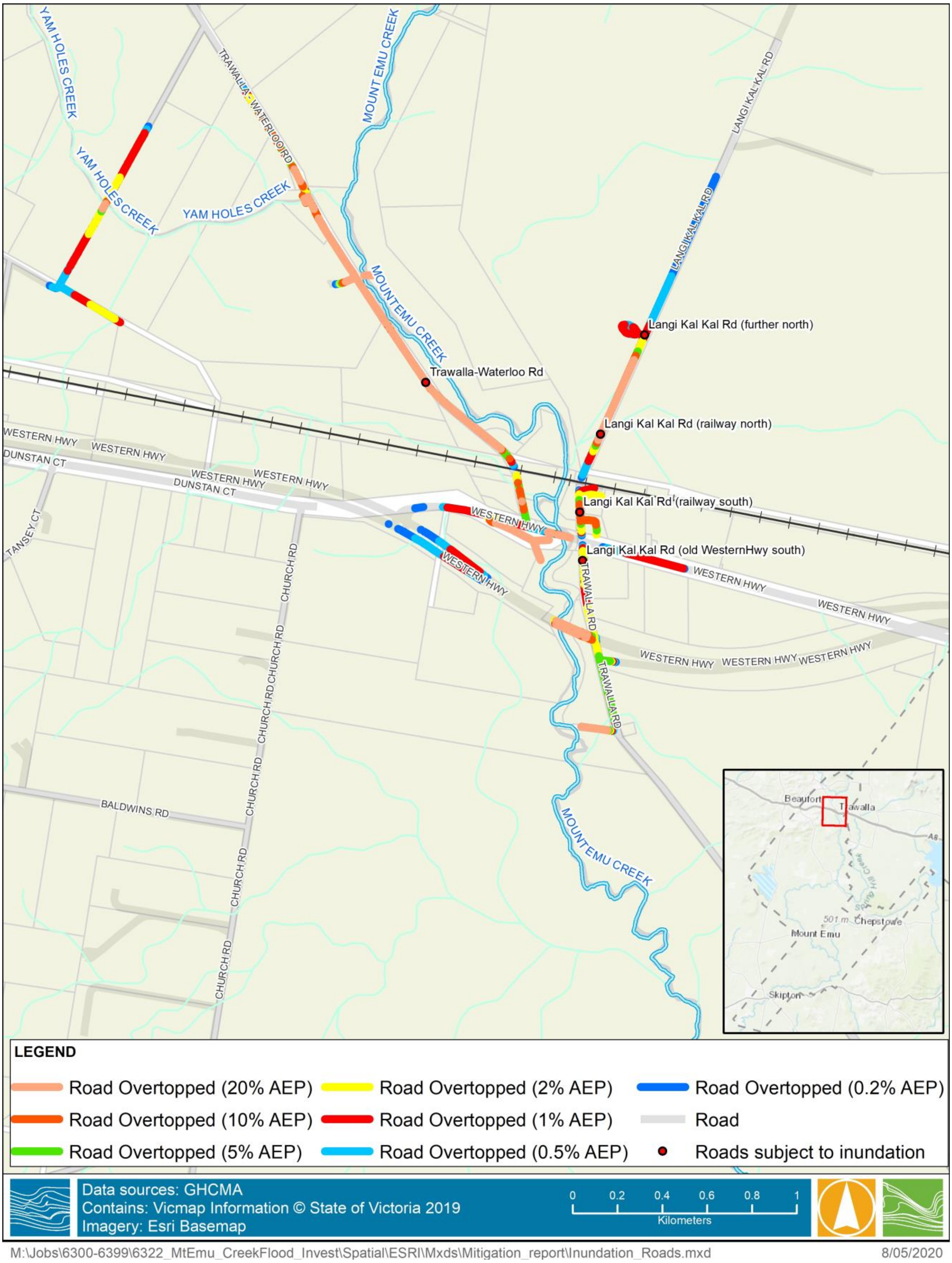

FIGURE 2-5 KEY ROADWAYS OVERTOPPED (TRAWALLA)

2.3 Properties

Flood level survey of 151 residential and commercial buildings was captured (56 in the previous Skipton Flood Study[1] and 95 in current study) within the study area, including 78 in the Lake Goldsmith Steam Preservation Society (LGSPS). These buildings were selected for survey based on the preliminary flood modelling undertaken at the beginning of this study (documented in the Survey Requirement Memo – M01). It should be noted that there were minor limitations within the floor level survey data captured, in that only the main residential dwelling or commercial building was captured for each property, outbuildings were not surveyed.

To classify the flood risk at a property scale, two categories were used, these were:

- Property flooded below floor.
  - This indicates the flood level is below the surveyed floor level
- Property flooded above floor.
  - This indicates the flood level is above the surveyed floor level

The number of properties flooded during the range of modelled design events is summarised in Table 2-2 to Table 2-4.

The existing conditions 1% AEP flood extent and the properties flooded above floor during the range of modelled design events are shown in Figure 2-6 to Figure 2-8.

TABLE 2-2 SUMMARY OF PROPERTIES FLOODED IN SKIPTON

Design event (AEP)	Properties flooded below floor	Properties flooded above floor
20%	0	0
10%	0	1
5%	28	4
2%	33	1
1%	35	2
0.5%	37	0
0.2%	37	2

TABLE 2-3 SUMMARY OF PROPERTIES FLOODED IN LGSPS

Design event (AEP)	Properties flooded below floor	Properties flooded above floor
20%	0	0
10%	0	0
5%	15	18
2%	69	4
1%	74	0
0.5%	75	0
0.2%	75	1

TABLE 2-4 SUMMARY OF PROPERTIES FLOODED IN BROADER CATCHMENT

Design event (AEP)	Properties flooded below floor	Properties flooded above floor
20%	0	0
10%	0	0
5%	0	1
2%	1	3
1%	3	1
0.5%	3	3
0.2%	3	5

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FIGURE 2-6 FLOODING ABOVE FLOOR (SKIPTON)

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FIGURE 2-7 FLOODING ABOVE FLOOR (LAKE GOLDSMITH)

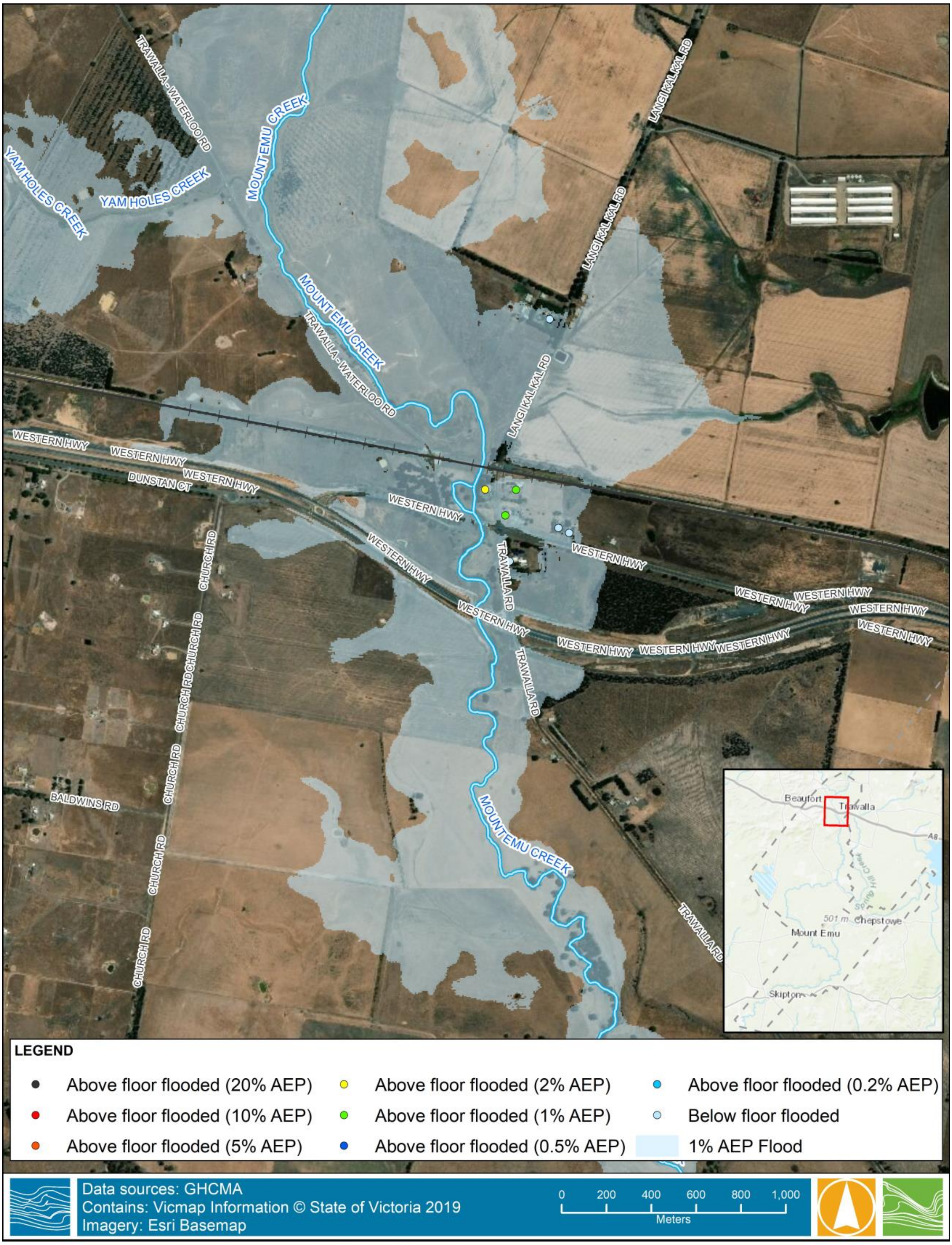

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FIGURE 2-8 FLOODING ABOVE FLOOR (TRAWALLA)

3 DAMAGES ASSESSMENT

A flood damage assessment was undertaken for the study area under existing conditions. The flood damage assessment determined the monetary flood damage for the range of modelled design events (i.e. 20%, 10%, 5%, 2% 1%, 0.5% and 0.2% AEP floods).

Model results for all mapped flood events were processed to calculate the number and the locations of properties and roads affected. This included properties inundated above floor, properties inundated below floor, properties which were not impacted but the grounds of the property were, and the lengths of flood affected roads. It should be noted that only sealed roads were assessed due to the availability of associated costs for flood damages.

Inundation damage of buildings within the Lake Goldsmith Steam Preservation Society site was assessed classifying each building as “commercial”. This applies a commercial use standardised damage curve[4]. During January 2011 the financial cost of damage to the tenants of the Lake Goldsmith Stream Preservation Society was estimated at $300,000[5]; however, this number is considered to be a significant underestimate as it only includes the replacement cost of damaged non fixed assets (e.g. electrical equipment, paperwork, oil, etc.) and does not include the cost of repairs to the stored machinery, labour required to repair damage (a significant cost), earth works to access tracks, irreplaceable machinery lost, machinery which was damaged and failed post inundation etc. The commercial damage curves were considered to give a more realistic representation of the financial cost of inundation at these buildings than using the replacement cost of assets calculated by the LGSPS during January 2011 but are likely to be an overestimate. A detailed site specific damage assessment and development of site specific damage curves would be required to gain a better understanding of the potential economic cost of inundation at the LGSPS.

A summary of the flood damage assessment for riverine flooding within the study area is shown in Table 3-1. It is noted that above floor flooding is likely to occur in a 5% AEP (20 year ARI) flood event with the number of properties flooded doubling for events above 2% AEP (50 year ARI). An Average Annual Damage (AAD) cost of $245,000 was determined.

[4] NSW Office of Environment and Heritage (2007) Floodplain Risk Management Guidelines, and Neil J. Ericksen, John W. Handmer, David I. Smith (1985), ANUFLOOD : Evaluation of a computerised urban flood-loss assessment policy for New Zealand
[5] Pers. Comm. Lake Goldsmith Steam Preservation Society (Brian Smith).

TABLE 3-1 RIVERINE EXISTING CONDITIONS FLOOD DAMAGES

EXISTING CONDITIONS

ARI (years) / AEP	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2
Residential Buildings Flooded Above Floor	15	15	14	11	5	0	0
Commercial Buildings Flooded Above Floor	99	99	97	92	37	0	0
Properties Flooded Below Floor	28	23	23	24	24	20	15
Total Properties Flooded	**142**	**137**	**134**	**127**	**66**	**20**	**15**
Direct Potential External Damage Cost	$170,224	$141,783	$132,296	$120,664	$114,553	$93,198	$37,230
Direct Potential Residential Damage Cost	$1,454,104	$1,325,926	$1,159,236	$870,691	$313,967	$0	$0
Direct Potential Commercial Damage Cost	$8,066,183	$7,251,535	$6,224,529	$4,121,525	$776,425	$0	$0
Total Direct Potential Damage Cost	**$9,690,511**	**$8,719,244**	**$7,516,061**	**$5,112,880**	**$1,204,945**	**$93,198**	**$37,230**
Total Actual Damage Cost *(0.8*Potential)*	**$7,752,409**	**$6,975,395**	**$6,012,849**	**$4,090,304**	**$963,956**	**$74,558**	**$29,784**
Infrastructure Damage Cost	**$594,044**	**$507,721**	**$391,828**	**$286,581**	**$193,488**	**$124,653**	**$85,897**
Indirect Clean Up Cost							
Indirect Residential Relocation Cost							
Indirect Emergency Response Cost							
Total Indirect Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$8,346,453**	**$7,483,116**	**$6,404,676**	**$4,376,885**	**$1,157,444**	**$199,211**	**$115,681**

Average Annual Damage (AAD)	$245,048

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4 IMPLEMENTED MITIGATION WORKS

An upgrade to culverts in Skipton downstream of Jubilee Lake increasing the conveyance of spills from the lake to Mt. Emu Creek was recommended in the Skipton Flood Investigation[1], and constructed by Corangamite Shire in mid-2016. The impact of the 2016 flood was considered to have been largely mitigated by these culverts. The culverts direct overflows from Jubilee Park Lake through the Skipton town centre into Mt. Emu Creek. THe culverts were upgraded from two reinforced concrete pipes to six box culverts. These mitigation culverts and their location are shown in Figure 4-1and Figure 4-2.

FIGURE 4-1 LOCATION OF MITIGATION CULVERTS IN SKIPTON

FIGURE 4-2 UPGRADED MITIGATION CULVERTS IN MONTGOMERY STREET, SKIPTON

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A review of the impact the mitigation culverts has had flood risk was undertaken by using a RORB model of the Jubilee Park Lake catchment developed during the Skipton Flood Study[1] and a newly established local TUFLOW model. The TUFLOW model had a single inflow at the upstream of Jubilee Park Lake. The RORB parameter, k_c was adjusted based on the ratio of the calibrated k_c and the average reach distance in the upper Mt. Emu Creek catchment RORB model, while the same rainfall losses adopted in the design modelling were used[6]. The updated parameters for the Jubilee Park Lake RORB model are summarised and compared to the previously adopted parameters in Table 4-1.

TABLE 4-1 UPDATED PARAMETERS FOR TRIBUTARY RORB MODEL AT SKIPTON

AEP	Updated model parameters			Model parameters used in 2013 Skipton study		
	k_c	IL (mm)	CL (mm/h)	k_c	IL (mm)	CL (mm/h)
20%	12.3	16	2.1	8.5	16	1.45
10%		16	1.6			
5%		16	1.4			
2%		16	0.8			
1%		16	0.5			
0.50%		14	0.5			
0.20%		12	0.3			

* IL = Initial loss, CL = Continuing loss

In accordance with the AR&R 2019[2] guidelines, a Monte Carlo Simulation was modelled in RORB to determine the critical durations for each AEP event, followed by a series of Ensemble runs to determine the representative temporal patterns for each AEP event. These results were then used to determine which peak flows best matched with the Monte Carlo Simulation results. The updated design flows using the AR&R 2019[2] recommended approaches has indicated around 30% reduction in peak design flows at the upstream of the Jubilee Park Lake compared to those produced as part of the Skipton Flood Study[1], as shown in **TABLE** 4-2.

TABLE 4-2 DESIGN FLOWS AT THE UPSTREAM OF JUBILEE PARK LAKE

AEP	Critical duration	Temporal pattern	New design flows (m^3/s)	Old design flows (m^3/s)	Change in % design flow
20%	1 hour	6	3.8	5.9	-36%
10%	45 min	16	4.6	6.0	-23%
5%	45 min	16	5.9	7.8	-24%
2%	45 min	21	7.7	10.0	-23%
1%	1 hour	23	8.7	14.1	-38%
0.50%	30 min	28	10.4	15.3	-32%
0.20%	30 min	26	13.3	-	-

The flood flow conveyance of the upgraded culverts was compared with the decommissioned Reinforced Concrete Pipes (RCP). The mitigation culverts were able to convey outflows from Jubilee Park Lake for up to 2% AEP event. In contrast, the old RCP pipes were unable to convey 20% AEP, as shown in Table 4-3.

[6] See R03 – Design Modelling Report for further detail.

TABLE 4-3 MITIGATION CULVERTS CAPACITY UNDER FULL RANGE OF DESIGN FLOWS

AEP	Jubilee Park Lake outflows (m^3/s)	Mitigation culverts flow (m^3/s)	Pipe flow (2x550mm RCP) (m^3/s)
20%	1.65	1.65	1.26
10%	2.10	2.10	1.27
5%	3.11	3.11	1.28
2%	5.22	5.09	1.30
1%	7.00	6.97	1.31
0.5%	7.51	7.46	1.31
0.2%	10.40	8.94	1.33

Figure 4-3 to Figure 4-9 show change in flood level as a result of the of the Jubilee Park Lake outflow upgrade. Plots have been provided for each modelled AEP ranging from the 20% AEP to the 0.2% AEP flood event. Under pre-mitigation conditions, Montgomery St was overtopped, and properties were flooded during a 20% AEP event. Under post-mitigation conditions, Montgomery St was not overtopped in events smaller than the 1% AEP event and properties were not flooded until the 0.2% AEP event. It should be noted that the Jubilee Park Lake outflow is the dominant flooding mechanism up to the 10% AEP event. For the 5% AEP and above, overbank flooding from the Mt. Emu Creek is the dominant flood mechanism, inundating properties above floor. This shows the mitigation measures have significantly reduced the impact of flooding via flow from Jubilee Park Lake, but have not changed the impact of inundation from Mt. Emu Creek.

Overall, the mitigation works completed in mid-2016 can significantly reduce flood risk from Jubilee Park Lake outflows up to 1% AEP event but inundation via Mt. Emu Creek will still occur in events as low as a 5% AEP.

FIGURE 4-3 20% AEP JUBILEE PARK LAKE OUTFLOW FLOODING – CHANGE IN FLOOD LEVELS

FIGURE 4-4 10% AEP JUBILEE PARK LAKE OUTFLOW FLOODING – CHANGE IN FLOOD LEVELS

FIGURE 4-5 5% AEP JUBILEE PARK LAKE OUTFLOW FLOODING – CHANGE IN FLOOD LEVELS

FIGURE 4-6 2% AEP JUBILEE PARK LAKE OUTFLOW FLOODING – CHANGE IN FLOOD LEVELS

FIGURE 4-7 1% AEP JUBILEE PARK LAKE OUTFLOW FLOODING – CHANGE IN FLOOD LEVELS

FIGURE 4-8 0.5% AEP JUBILEE PARK LAKE OUTFLOW FLOODING – CHANGE IN FLOOD LEVELS

FIGURE 4-9 0.2% AEP JUBILEE PARK LAKE OUTFLOW FLOODING – CHANGE IN FLOOD LEVELS

5 MITIGATION MODELLING

5.1 Overview

Flood risk and flood damages within the study area can be reduced with structural and non-structural mitigation options. Structural mitigation options are engineering solutions which focus on reducing flood extent, depth and damages. Non-structural mitigation options focus on ensuring that new development does not occur in high flood risk areas and they aim to raise community awareness of the risk and support improvement to emergency response during a flood event.

5.1.1 Structural Mitigation Options

Several structural mitigation options were assessed during this study, focusing on the Lake Goldsmith Steam Preservation Society (LGSPS) and Skipton. The modelled mitigation options were either a requirement of the project and detailed in the tender brief, or discussed with Glenelg Hopkins CMA and the Project Reference Group (PRG). The mitigation options were hydraulically assessed using the modelled 2016 flood event and/or the 1% AEP design flood event.

The mitigation options assessed in this study are summarised as follows:

- LGSPS.
  - Option 1 - A levee around the LGSPS site - 1% AEP flood event.
  - Option 2 - Enlarging the capacity of Cameron Bridge - 1% AEP flood event.
  - Option 3 – Enlarging capacity of Cameron Bridge and excavating additional floodplain storage to increase conveyance – 1% AEP flood event.
  - Option 4 - Opening the Lake Goldsmith Diversion Channel at Cheesemans Road - 2016 and all modelled AEP events.
- Skipton.
  - Option 5 - Doubling the size of the Glenelg Highway bridge - 1% AEP flood event.

The modelled water levels produced during each modelled mitigation option were compared to those produced in existing conditions. The change in modelled water levels for each option was thematically mapped to show a graphical representation of the increases and decreases to understand the impact of each respective mitigation option.

5.1.2 Non-Structural Mitigation Options

There are a range of non-structural mitigation options that can be implemented including land use planning, flood warning, flood response and flood awareness.

- The Victoria Planning Provisions (VPPs) contain several controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).
- Flood warning systems provide a means of gathering information about impeding floods, communicating information to those at risk and facilitating an effective and timely response. Flood warning systems aim to enable and persuade people and organisation to take action to increase potential safety and reduce the damage caused by flooding.

5.2 Lake Goldsmith Steam Preservation Society

5.2.1 Overview

The LGSPS site is located 1 km east of Lake Goldsmith and adjacent to Mt. Emu Creek. LGSPS has occupied its existing site since the late 1960's and brings significant economic benefit to Pyrenees Shire (estimated at $1.1m per annum)[7]. The facilities house one of the most significant collections of historical machinery and artefacts in Australia. Substantial loss of irreplaceable historic artefacts occurred as a consequence of inundation of the site during the January 2011 flood. Significant financial losses were also incurred due to the infrastructure and artefact repairs.

1% AEP design flood modelling as shown in Figure 5-1, demonstrates that the steam rally site is inundated to more than 1 metre due to riverine flooding from the Mt. Emu Creek.

FIGURE 5-1 1% AEP DESIGN FLOOD DEPTH AT LAKE GOLDSMITH STEAM RALLY SITE

5.2.2 Option 1 - Levee

5.2.2.1 Flood Mitigation Benefit

To prevent inundation of the LGSPS site, a levee was added to modelling of the 1% AEP event. Figure 5-2 shows the location of the modelled levee and mitigated flood depths across and around the steam rally site. Water levels surrounding the steam rally site are slightly above 347 m AHD (i.e. approximately 1.5 m deep). Should a levee to be constructed it would also require a 300-600 mm freeboard to meet the Victorian Levee Management Guidelines[8].

[7] Pyrenees Shire Council preliminary estimate.
[8] DELWP (2015), Victorian Levee Management Guidelines.

FIGURE 5-2 1% AEP FLOOD DEPTH WITH LEVEE AT STEAM RALLY SITE

The levee did not cause an increase in flood extent up or downstream of the steam rally site as shown in Figure 5-3. The levee around the site blocked inundation from Mt. Emu Creek increasing water levels north and west of the site by approximately 0.5 cm and approximately 2 cm in the Lake Goldsmith diversion channel.

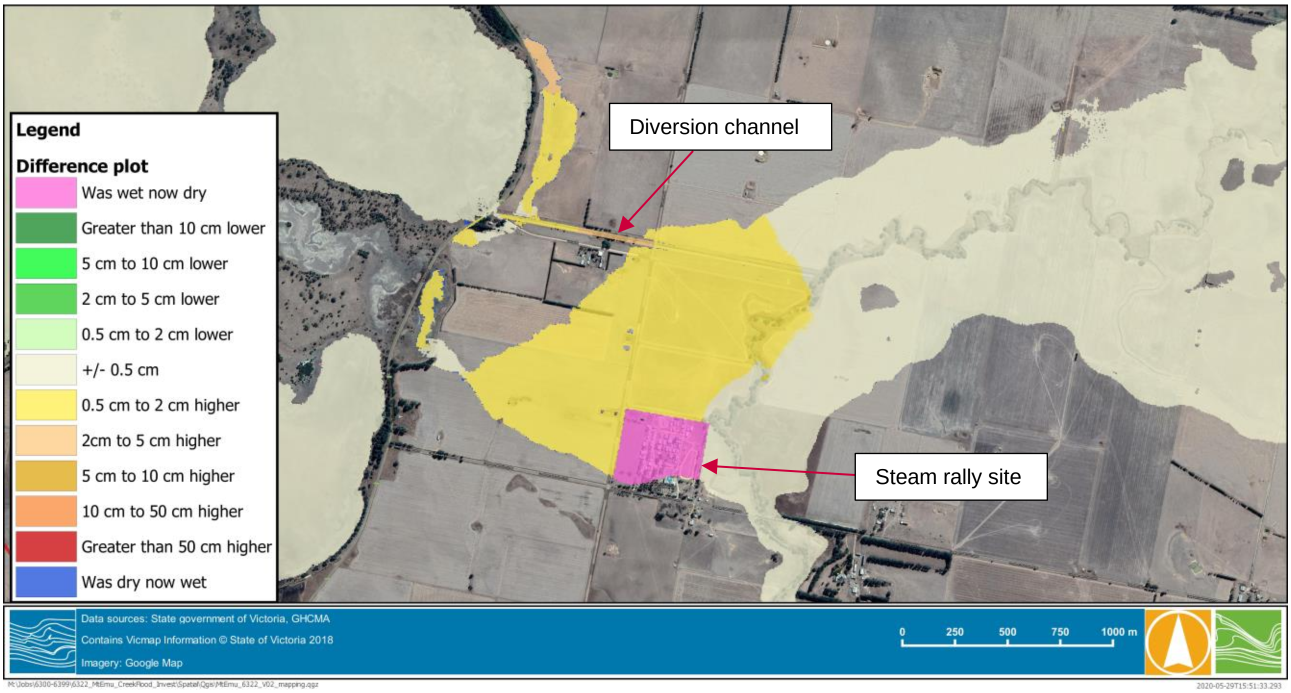

FIGURE 5-3 OPTION 1 - WATER LEVEL DIFFERENCES AT LAKE GOLDSMITH

Further downstream of the LGSPS site, water levels increases occurred at Guthries Road and immediately upstream of township of Skipton, as shown in Figure 5-4 and Figure 5-5. The increase in water levels at these two locations was less than 1 cm. No enlargement of the 1% AEP flood extent was observed.

Overall, construction of a levee at the LGSPS site is unlikely to have significant negative impacts on the flood behaviour. There are only minor increases in water levels observed as a result of the levee restricting floodplain flow.

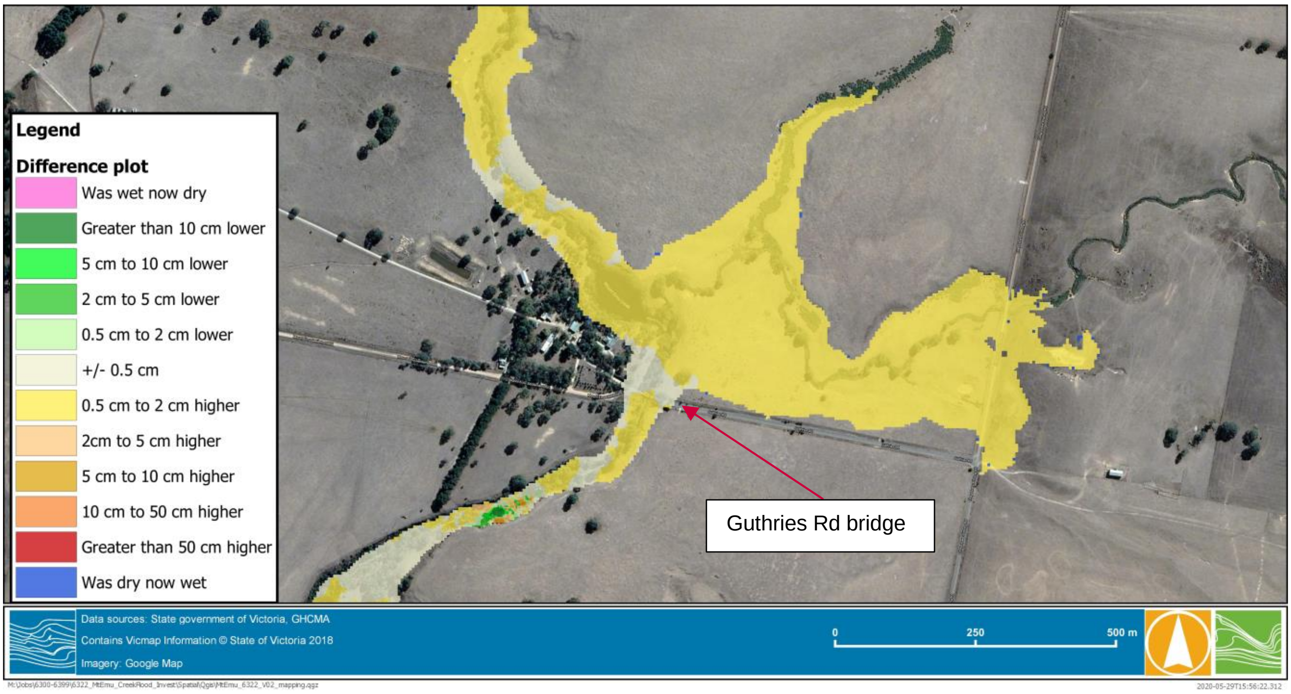

FIGURE 5-4 OPTION 1 - WATER LEVELS DIFFERENCES AT GUTHRIES ROAD BRIDGE

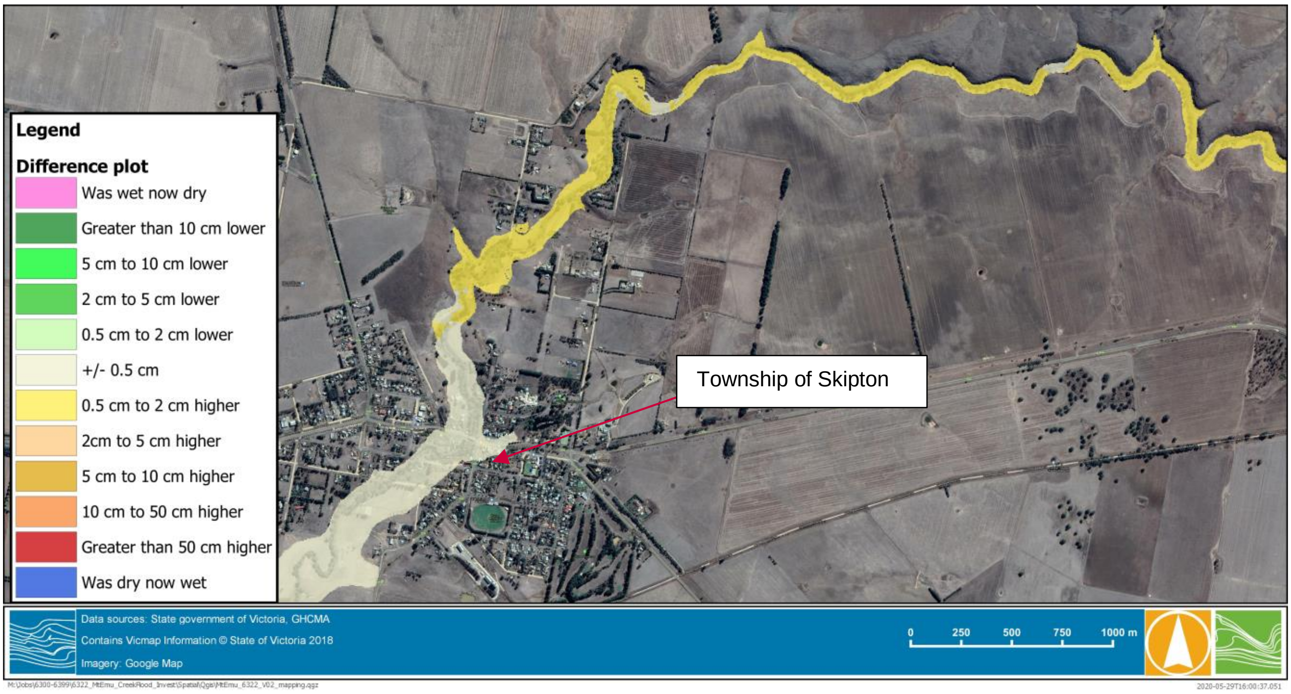

FIGURE 5-5 OPTION 1 - WATER LEVELS DIFFERENCES AT UPSTREAM OF SKIPTON

5.2.3 Option 2 – Cameron bridge capacity increase

Enlarging the Carngham – Lake Goldsmith Rd bridge (Cameron Bridge) and removing constrictions in the immediate waterway channel was proposed to allow larger flows underneath the bridge and alleviate a backwater through the LGSPS site.

To evaluate the maximum potential of this mitigation measure, the existing bridge was completely removed and constraints immediately downstream of the bridge were also removed, as shown in Figure 5-6.

The 1% AEP design event was modelled, and the results were compared to the existing conditions scenario.

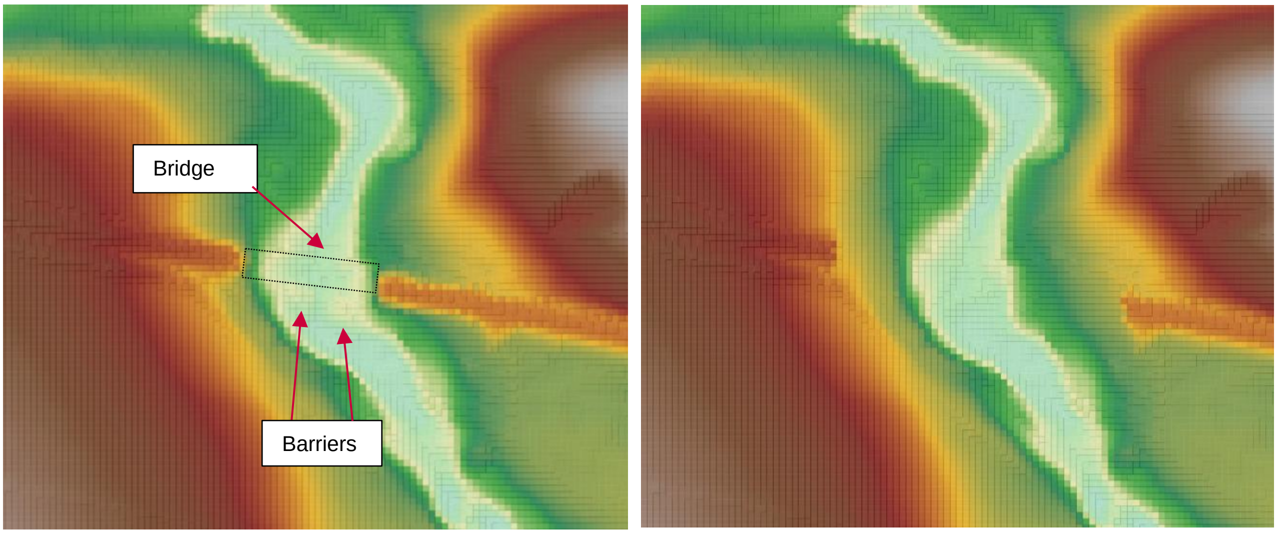

FIGURE 5-6 BRIDGE AND CONSTRAINTS IN THE TOPOGRAPHY, LEFT: EXISTING SCENARIO; RIGHT: MITIGATION SCENARIO

The change in flood levels as a result of increasing the bridge capacity are shown in Figure 5-7. Water levels within the floodplain immediately upstream of the bridge were reduced by more than 10 cm, including across the LGSPS site as shown in Figure 5-8. The flood extent was slightly reduced, with no flood water spilling out of the diversion channel.

There was also an increase in flood levels downstream of the bridge along Mt. Emu Creek from Carngham – Streatham Rd to the township of Skipton, as displayed in Figure 5-9. The average increase in water levels downstream of the bridge was approxinately 2 cm, with several sections of Mt. Emu Creek downstream of Guthries Rd reaching slightly above 2 cm.

The increase in water level at Skipton was around 1 cm and there was no enlargment of the flood extent within Skipton.

Overall, the increase in flood levels was not considered to be significant and no enlargement of the flood extent was shown.

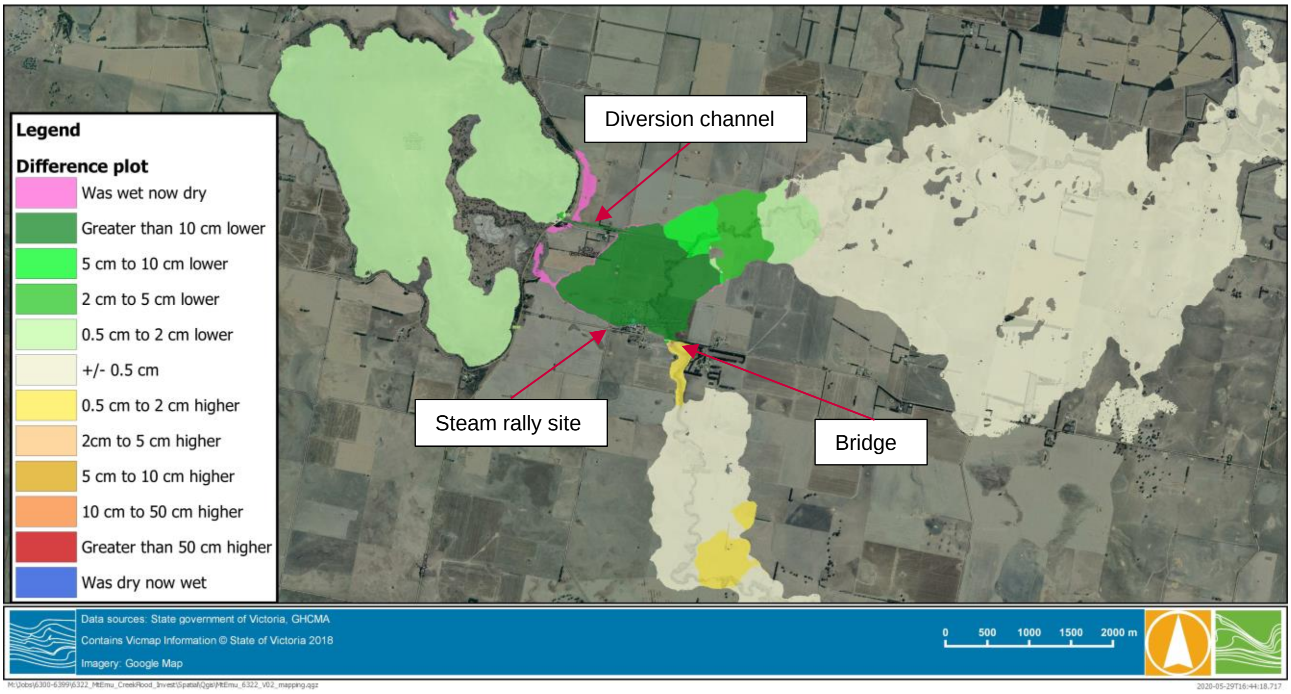

FIGURE 5-7 OPTION 2 - WATER LEVEL DIFFERENCES AT LAKE GOLDSMITH

FIGURE 5-8 OPTION 2 - WATER LEVEL DIFFERENCES AT LGSPS SITE

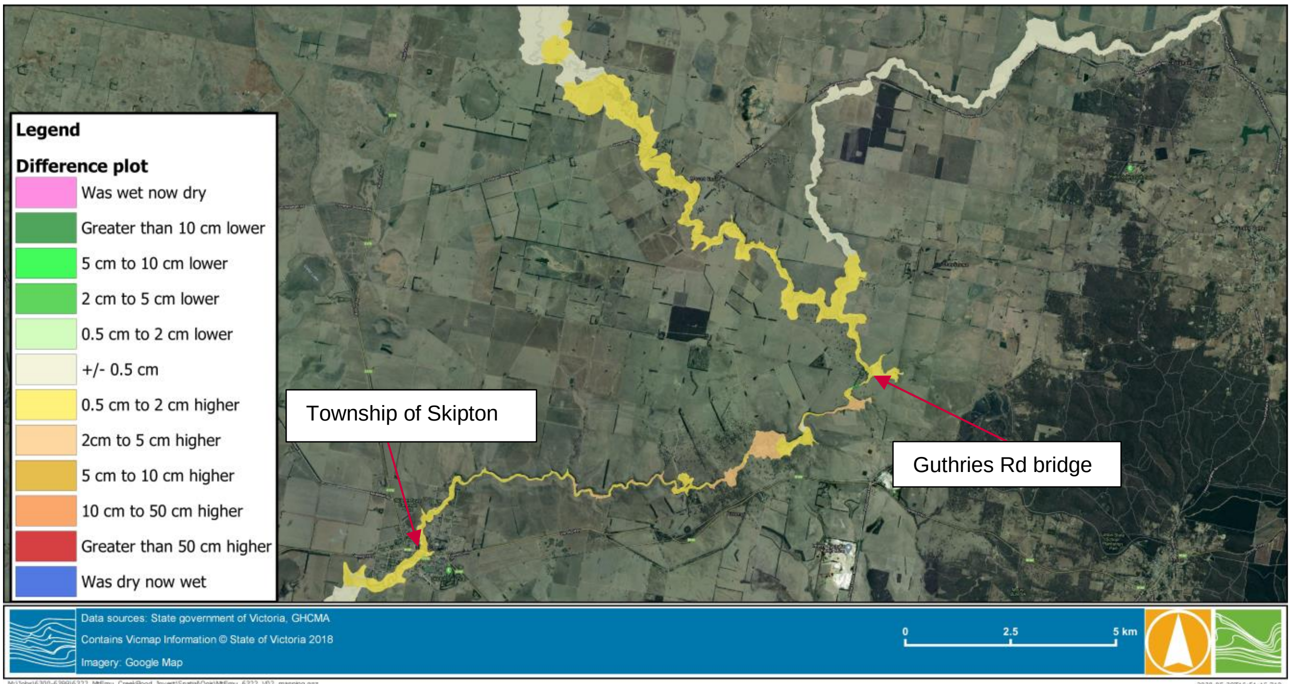

FIGURE 5-9 OPTION 2 - WATER LEVEL DIFFERENCES DOWNSTREAM OF CARNGHAM – LAKE GOLDSMITH RD BRIDGE

FIGURE 5-10 OPTION 2 - WATER LEVEL DIFFERENCES AT SKIPTON

5.2.4 Option 3 – Cameron Bridge capacity increase and enlargement of the waterway

An additional mitigation option proposed by the LGSPS was to increase the floodplain conveyance up and downstream of Cameron Bridge with a series of excavations as well as increasing the size of Cameron Bridge. This option lowered the floodplain to the same level as the existing creek invert to maximise the potential for mitigation measure to reduce flood levels. The existing bridge and excavated areas up and downstream of the bridge are shown in Figure 5-11 and Figure 5-12. The 1% AEP design event was modelled and the results were compared to the existing conditions scenario as shown in Figure 5-13.

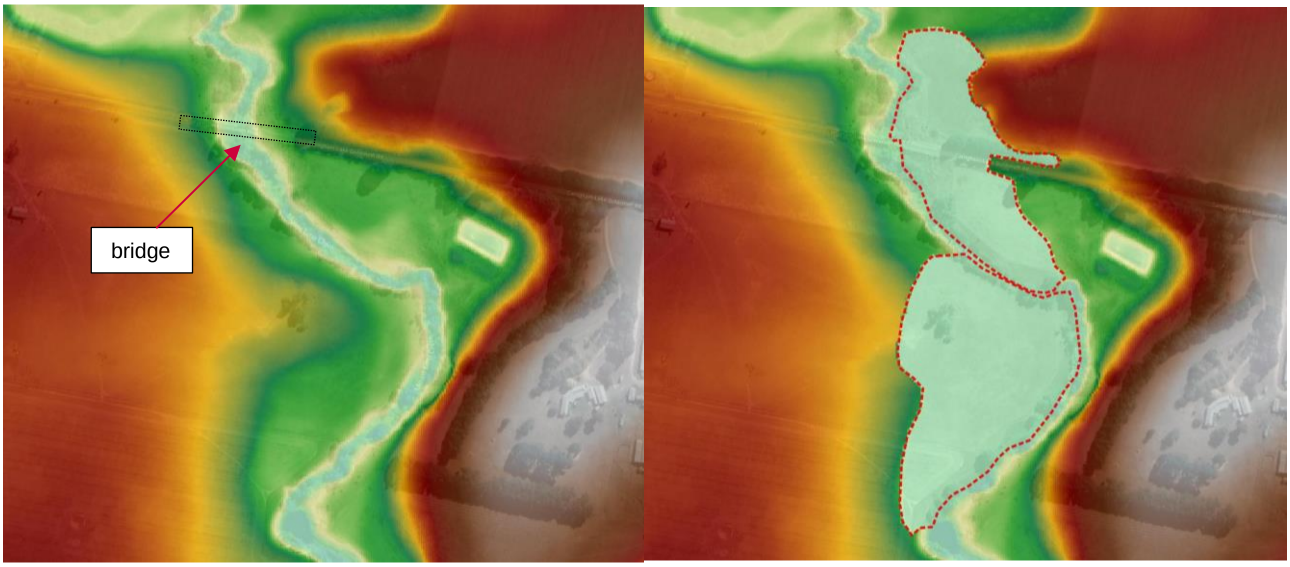

FIGURE 5-11 OPTION 2- BRIDGE AND FLOODPALIN AREA IN THE TOPOGRAPHY, LEFT: EXISTING SCENARIO; RIGHT: MITIGATION SCENARIO

FIGURE 5-12 OPTION 2 - LOCATIONS OF THE PROPOSED EARTHWORK

1% AEP water levels immediately upstream of the bridge and within LGSPS site were reduced by more than 60 cm and the flood extent was noticeably reduced as shown in Figure 5-14. However, the site was still inundated by up to 50 cm.

In contrast, increases in water levels downstream of Cameron Bridge were observed as shown in Figure 5-15. The increase in water levels immediately downstream of the bridge was around 1 cm, with several sections of Mt. Emu Creek downstream of Guthries Bridge reaching up to 6 cm.

The increase in water levels at Skipton was between 2 cm to 5 cm (see Figure 5-16). There was no observed enlargement of flood extent within Skipton due to the confined floodplain within the township.

Overall, enlargement of waterway to allow more flows can significantly reduce the floodwater levels and flood extent in LGSPS site. However, the economic feasibility of this mitigation option needs to be taken consideration while there is also potential increase in water level at Skipton.

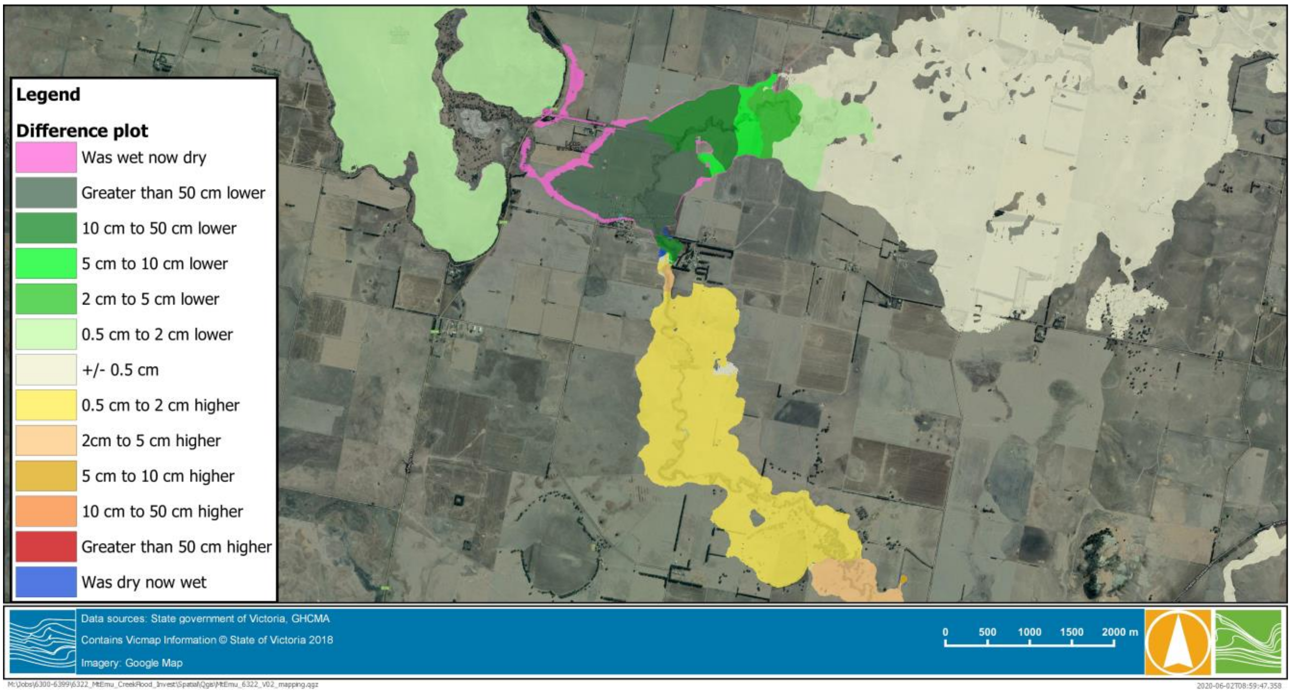

FIGURE 5-13 OPTION 3 – WATER LEVEL DIFFERENCES AT LAKE GOLDSMITH

FIGURE 5-14 OPTION 3 – WATER LEVEL DIFFERENCES AT LGSPS SITE

FIGURE 5-15 OPTION 3 – WATER LEVEL DIFFERENCES DOWNSTREAM OF CARNGHAM – LAKE GOLDSMITH RD BRIDGE

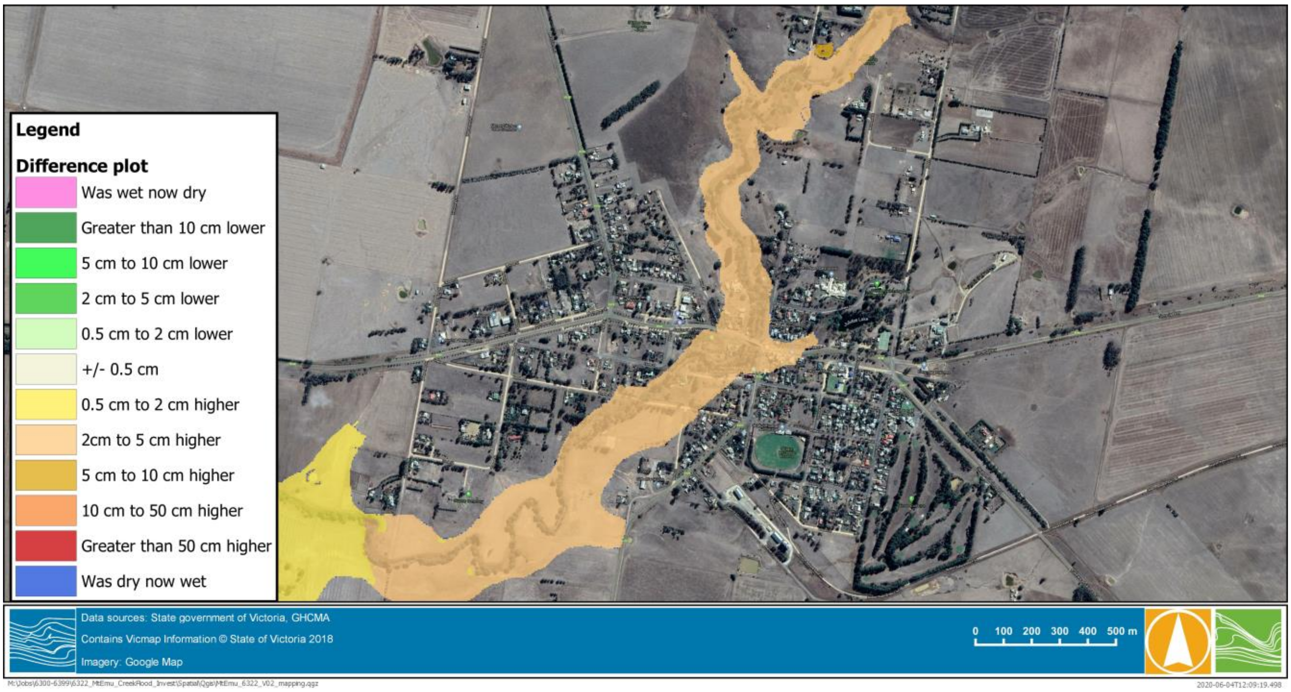

FIGURE 5-16 OPTION 3 – WATER LEVEL DIFFERENCES AT SKIPTON

5.2.5 Option 4 - Lake Goldsmith diversion channel

The Lake Goldsmith diversion channel was constructed as a means of diverting water from Mt. Emu Creek to Lake Goldsmith. The diversion channel has a stone arch bridge at Cheesemans Road where drop boards initially existed and were removed during the September 2016 flood event, as shown in Figure 5-17. The 2013 Skipton Flood Study[1] completed a detailed assessment of the Lake Goldsmith diversion channel and its ability to mitigate flood impacts downstream. The assessment concluded that the diversion channel is incapable of providing significant downstream flood mitigation benefit. However, there is a strong perception that opening the channel during the 2016 flood reduced the severity of flooding downstream exists. As a result, this study investigated the viability of using the diversion mitigate inundation along Mt. Emu Creek.

The diversion channel was modelled open and closed for the 2016 flood event and the 1% AEP design event. The modelling results of “channel open” and “channel closed” were compared for each scenario.

FIGURE 5-17 PICTURE OF THE BRIDGE AT LAKE GOLDSMITH DIVERSION CHANNEL

The change in flood levels as a result of opening the Lake Goldsmith diversion channel during the 2016 flood event are shown in Figure 5-18. There are decreases in water levels immediate downstream of the channel and further downstream to Carngham – Lake Goldsmith Road. Results indicate that water levels were reduced by approximately 3 cm.

Further downstream of Lake Goldsmith, the average water level reduction along Mt. Emu Creek was around 2 cm, as shown in Figure 5-19. Figure 5-20 shows the difference in water levels at Skipton, with the average decrease in water levels less than 2 cm with no significant reduction of flood extent.

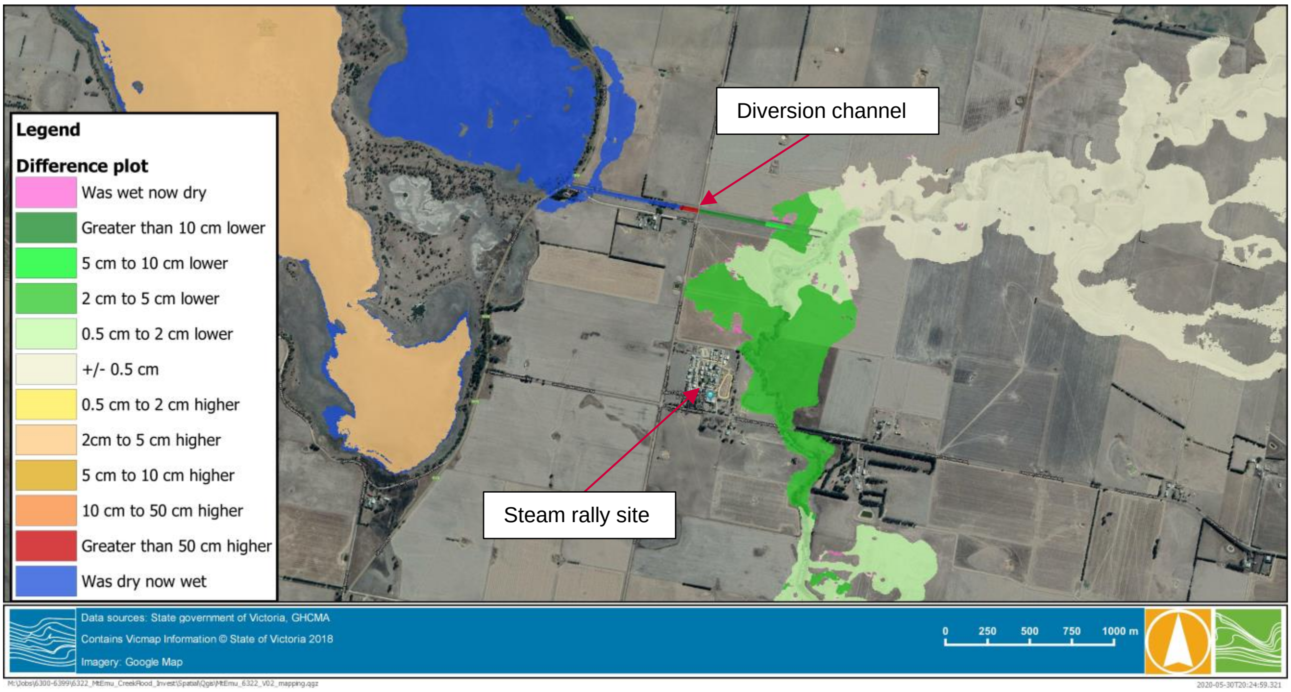

FIGURE 5-18 OPTION 4 - WATER LEVEL DIFFERENCES (2016 EVENT) – CHANNEL OPEN VERSUS CHANNEL CLOSED AT LAKE GOLDSMITH

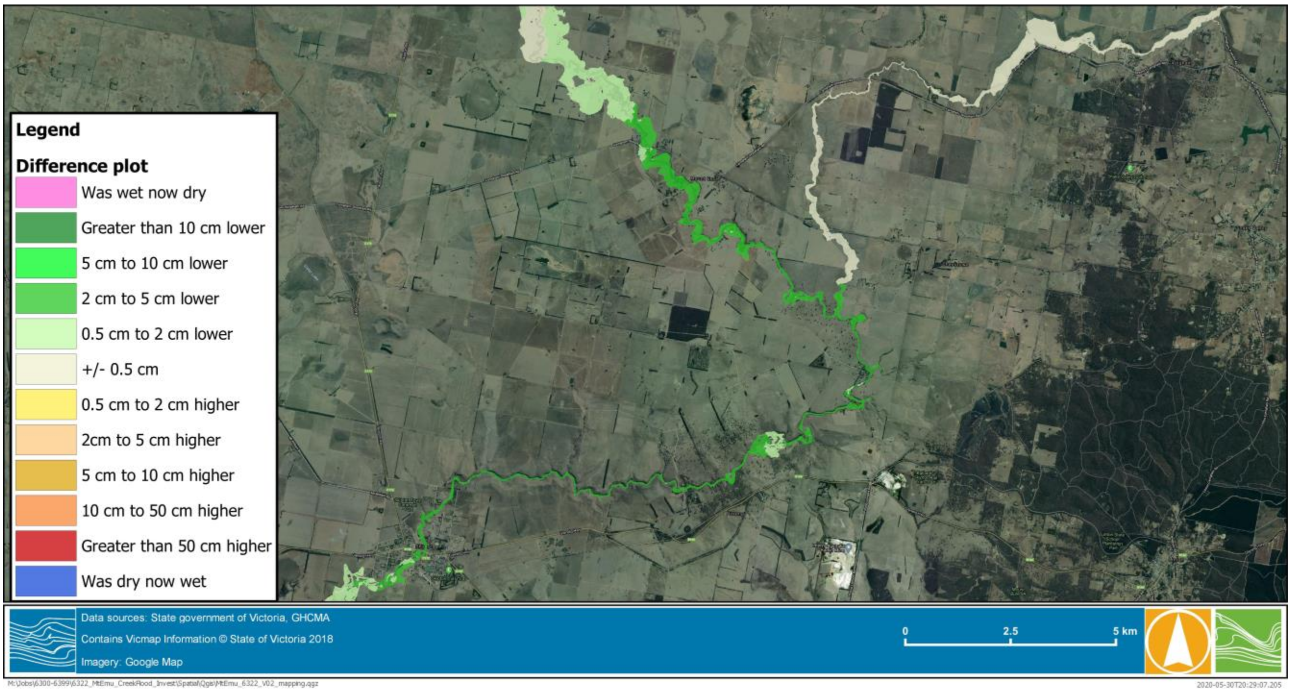

FIGURE 5-19 OPTION 4 - WATER LEVEL DIFFERENCES (2016 EVENT) – CHANNEL OPEN VERSUS CHANNEL CLOSED AT DOWNSTREAM OF LAKE GOLDSMITH

FIGURE 5-20 OPTION 4 - WATER LEVEL DIFFERENCES (2016 EVENT) – OPENED CHANNEL

Changes to flood levels due to opening the Lake Goldsmith diversion channel at Cheesemans Road in a 1% AEP event are shown from Figure 5-21 to Figure 5-23. The larger event (i.e. the 2016 event was smaller than a 1% AEP event) caused a greater reduction in flood levels. Water levels were reduced by approximately 2.6 cm within the LGSPS site. Downstream of Lake Goldsmith, water levels along Mt. Emu Creek were reduced by 2 cm to 4 cm. The maximum reduction in water levels within Skipton was just above 2 cm as shown in Figure 5-23.

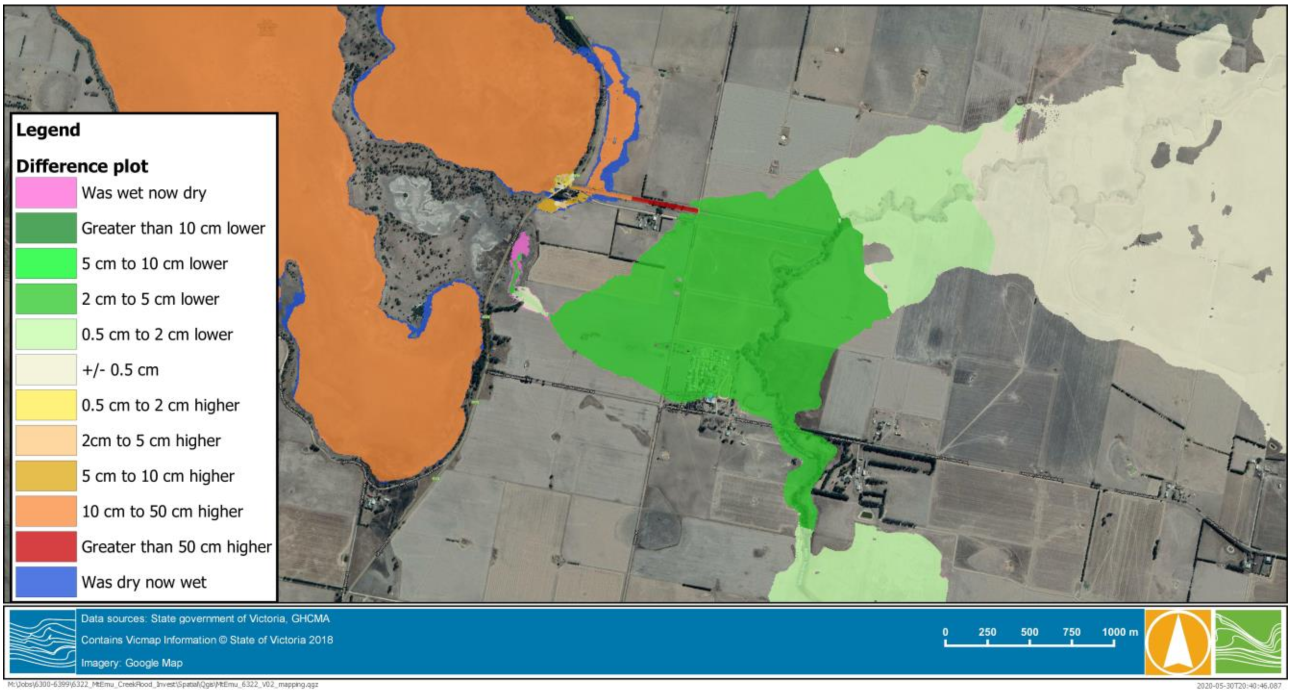

FIGURE 5-21 OPTION 4 - WATER LEVEL DIFFERENCES (1% AEP EVENT) – OPENED CHANNEL

FIGURE 5-22 OPTION 4 - WATER LEVEL DIFFERENCES (1% AEP EVENT) – OPENNED CHANNEL, DOWNSTREAM OF LAKE GOLDSMITH

FIGURE 5-23 OPTION 4 - WATER LEVEL DIFFERENCES (1% AEP EVENT) – OPENED CHANNEL, SKIPTON

A detailed review of the capacity of the existing diversion channel and its flood mitigation benefit at Skipton was undertaken using the critical duration for each AEP at Lake Goldsmith. The flows split between Mt. Emu Creek and the existing diversion channel in the range of the design AEP events was calculated and are shown in Table 5-1 and Figure 5-24.

The existing diversion channel only has the capacity to divert around 3% of Mt Emu Creek flows in events up to 1% AEP. The flood mitigation benefit at Skipton is summarised in Table 5-2, which demonstrates that only limited reduction in peak flows and water levels would have resulted at Skipton if the diversion channel was to remain open.

Like the conclusion made in the Skipton Flood Study[1], the diversion channel would need to be enlarged significantly to allow Lake Goldsmith to perform effectively as a flood storage reservoir. Overall, the hydraulic modelling affirms the conclusions made during the Skipton Flood Study[1] that opening of the diversion channel at Lake Goldsmith will not provide a perceivable reduction in flood levels and flood extent at the LGSPS site or Skipton.

TABLE 5-1 CAPACITY OF THE EXISTING DIVERSION CHANNEL UNDER A RANGE OF DESIGN FLOWS

AEP	Flows in Mt Emu Creek (m^3/s)	Flows in diversion channel (m^3/s)	Diversion of % Mt Emu Creek flows
20%	71	1.7	2.4%
10%	134	3.3	2.5%
5%	189	4.5	2.4%
2%	301	6.4	2.1%
1%	410	10.5	2.6%
0.50%	493	18.4	3.7%
0.20%	621	31.4	5.1%

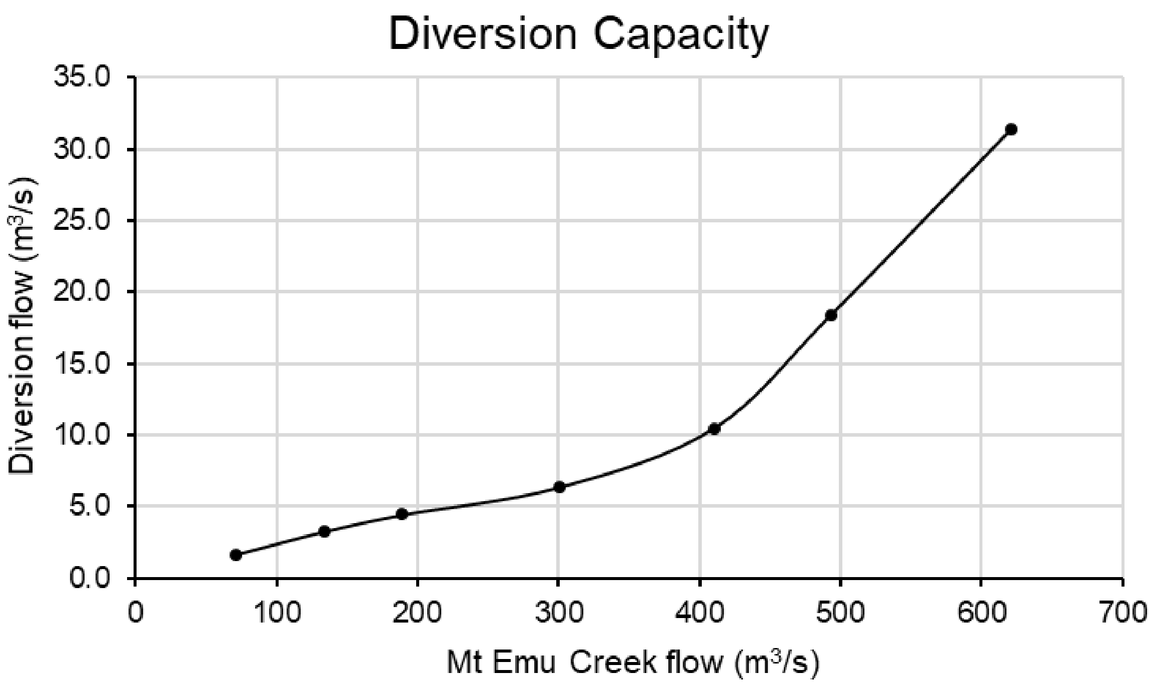

FIGURE 5-24 DIVERSION CAPACITY FOR A RANGE OF DESIGN FLOWS IN MT EMU CREEK

TABLE 5-2 FLOOD MITIGATION BENEFIT OF DIVERSION CHANNEL

AEP	Peak flows at Skipton gauge (m^3/s) with "channel closed"	Peak flows at Skipton gauge (m^3/s) with "channel open"	Change in peak flows at Skipton gauge	Change in water level at Skipton gauge (m)
20%	76	76	-0.02%	0.00
10%	140	137	-2.52%	-0.02
5%	223	219	-1.94%	-0.02
2%	361	355	-1.64%	-0.02
1%	472	465	-1.35%	-0.02
0.50%	582	577	-0.97%	-0.01
0.20%	739	735	-0.54%	-0.01

5.2.6 Discussion and summary

Of the modelled mitigation options the following summaries were determined:

- Option 1 (levee around the LGSPS) – viable option for decreasing flood risk at the LGSPS, can reduce inundation damage to the site buildings to zero. No perceivable increase to flood levels or extents external to the LGSPS site.
  - This option was determined as worth further consideration, cost and benefit analysis.
- Option 2 (Cameron Bridge capacity increase) – slight reduction in flood levels within the LGSPS site (around 10cm). Very minor increases to flood levels or extents external to the LGSPS site.
  - Worth determining the considering potential costs of the mitigation option.
- Option 3 (Cameron Bridge capacity increase and enlargement of the waterway) – reasonable reduction in flood levels within the LGSPS site (around 10cm). Moderate increases to flood levels or extents external to the LGSPS site.
  - Worth determining the considering potential costs of the mitigation option.
- Option 4 (Lake Goldsmith diversion channel) – no perceivable reduction in flood levels within the LGSPS site or external to the LGSPS site.
  - The reduction in water levels was shown to be too minor to warrant investigation of the measure. In a 1% AEP flood event properties are flooded by a significant margin, as shown in Figure 5-24, opening the diversion channel may reduce inundation depths at these properties by up to 2cm, making no perceivable difference to flood damage. An example of this is shown in Figure 5-26.

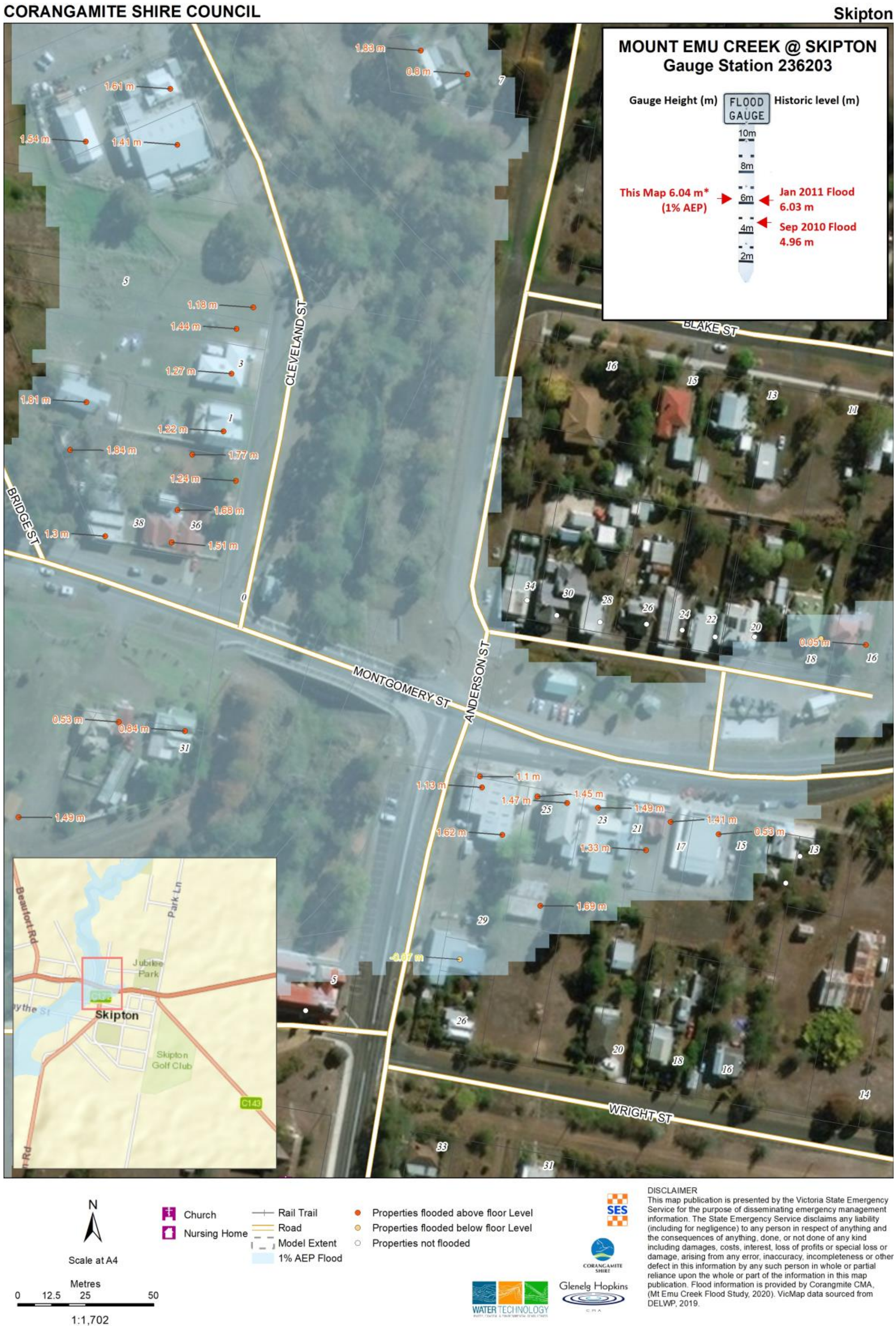

FIGURE 5-25 1% AEP ABOVE FLOOR INUNDATION IN SKIPTON

FIGURE 5-26 DEMONSTRACTION OF THE REDUCTION IN 1% AEP ABOVE FLOOR INUNDATION AT THE SKIPTON HOTEL

5.2.7 Cost Benefit Analysis

5.2.7.1 Option 1 – LGSPS Levee

5.2.7.1.1 COSTING

As shown in Figure 5-2 (Section 5.2.2), the assessed levee protecting the LGSPS site is in an inverted U shape connecting to the Carngham - Lake Goldsmith Road at the south western and south eastern corners. Characteristics of the levee are shown in Table 5-3.

TABLE 5-3 LAKE GOLDSMITH STEAM PRESERVATION SOCIETY LEVEE ASSUMPTIONS/DIMENTIONS

Assumption/Dimensions	Measurement
Water Face Batter Slope	1:4
Outside Face Batter Slope	1:4
Freeboard	0.3m
Crest Width	4m
Length	1,120 m
Average Depth	1.5m
Max. Depth	1.9m
Min. Depth	0.0m
Average Width	15.9m
Max Width	19.5m

Assumption/Dimensions	Measurement
Total Volume	16,294 m^2
Total Area	16,505 m^2

The determined levee dimensions were used to calculate a preliminary cost of the levee. The costing was based on standard industry rates used by Melbourne Water for earthworks and construction and comparison to cost estimates for similar works for other flood studies.

The estimated cost of the LGSPC levee is show in Table 5-4, outlining the determined construction costs on a unit rate basis, total cost and inclusion of engineering, administration and contingency costs.

TABLE 5-4 LGSPS LEVEE COSTING

Description	Qty	Unit	Rate	Estimated Cost	Estimated Cost including Engineering, Administration & Contingencies
			($/unit)	$	$
Construction and Compaction	16,294	m^3	$25	$407,350	$632,819
Top soiling (100mm)	1,650	m^3	$20	$33,010	$51,281
Grassing	16,505	m^2	$1	$16,505	$25,640
Subtotal				**$456,865**	**$709,740**

5.2.7.1.2 REDUCTION IN DAMAGES

As discussed in Section 3, the Average Annual Damage (AAD) of a flood event within the study area was estimated at $245,000. The AAD was recalculated with the inclusion of the levee protecting the LGSPS site from all events up to a 0.2% AEP event, as shown in Table 5-5. If a levee was to be constructed, a lower level of protection may be adopted to lower the cost of protection, which would increase the cost of flood damage. While the cost of damage during individual large floods is higher than more frequent events, smaller events generally contribute more cost to the AAD, given the occur more frequently. For example, the estimated damages incurred during a 5% AEP event totals around $1.16M, or $58,000 per year (e.g. $1.16M x 0.05), whereas damage during a 0.2% AEP event totals around $8.35M, or $16,700 per year. If a lower level of protection is preferable it may not significantly the impact the AAD for post mitigation works, depending on how far it is reduced.

TABLE 5-5 RIVERINE FLOOD DAMAGES WITH THE INCLUSION OF THE LGSPS LEVEE

EXISTING CONDITIONS							
ARI (years) AEP	500yr 0.002	200yr 0.005	100yr 0.01	50yr 0.02	20yr 0.05	10yr 0.1	5yr 0.2
Residential Buildings Flooded Above Floor	15	15	14	11	5	0	0
Commercial Buildings Flooded Above Floor	24	24	23	23	22	0	0
Properties Flooded Below Floor	28	23	23	24	24	20	15
Total Properties Flooded	**67**	**62**	**60**	**58**	**51**	**20**	**15**
Direct Potential External Damage Cost	$170,224	$141,783	$132,296	$120,664	$114,553	$93,198	$37,230
Direct Potential Residential Damage Cost	$1,454,104	$1,325,926	$1,159,236	$870,691	$313,967	$0	$0
Direct Potential Commercial Damage Cost	$1,892,766	$1,728,282	$1,592,721	$1,336,506	$672,516	$0	$0
Total Direct Potential Damage Cost	**$3,517,094**	**$3,195,991**	**$2,884,253**	**$2,327,861**	**$1,101,036**	**$93,198**	**$37,230**
Total Actual Damage Cost *(0.8*Potential)*	**$2,813,675**	**$2,556,793**	**$2,307,402**	**$1,862,289**	**$880,829**	**$74,558**	**$29,784**
Infrastructure Damage Cost	**$594,044**	**$507,721**	**$391,828**	**$286,581**	**$193,488**	**$124,653**	**$85,897**
Indirect Clean Up Cost							
Indirect Residential Relocation Cost							
Indirect Emergency Response Cost							
Total Indirect Cost	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Total Cost	**$3,407,720**	**$3,064,514**	**$2,699,230**	**$2,148,870**	**$1,074,317**	**$199,211**	**$115,681**
Average Annual Damage (AAD)	$144,289						

The revised damages assessment shows a reduction in AAD of around $100,000. LGSPS rally events are a significant economic contributor to Pyrenees Shire Council. Events are run twice a year and are estimated to bring in around $1.1M to the local economy annually[9]. During the study, factoring in the economic impact of this loss of revenue due to a flood event damaging the site was considered. However, recovery from the 2011 event at the LGSPS was reported as very rapid with no reduction in the capacity to run events[10] and it was not included as a factor in the damage assessment.

5.2.7.1.3 COST BENEFIT RATIO

A benefit-cost analysis was undertaken to demonstrate the financial viability of undertaking levee works protecting the LGSPS. Results are shown in Table 5-6. For this analysis, a net present value model was used, applying a 6% discount rate over a 30 year project life. A benefit cost ratio should ideally be equal to or greater than 1, meaning that the long term benefit of flood mitigation equals or exceeds the long term costs. Maintenance of the levee has been assumed to cost $2,000/year as an indicative sum, this maintenance will likely be undertaken by the LGSPS and the levee managed as a private asset. The LGSPS levee is clearly a cost effective solution with a benefit cost ratio of 2.0. As noted in Section 3, the estimated cost of flood damage within the LGSPS is likely to be an overestimate; however, without detailed damage data it is difficult to completely understand the cost of flood damage at the site, this is complicated but the potential loss of irreplaceable historical artefacts for which not financial value can be given. For the cost benefit ratio to equal 1 an annual saving of $50,000 is required, this would roughly equate inundation causing $500,000 to $600,000 of damage in a single flood event.

TABLE 5-6 COST BENEFIT RATIO FOR THE LGSPS LEVEE

Benefit cost ratio	
Material/ Construction Labour Cost	$ 456,865
Engineering, administration and contingency	$ 252,875

[9] Pyrenees Shire Council preliminary estimate.
[10] Pers. Comm. LGSPS – Brian Smith.

Benefit cost ratio	
Total Cost	**$ 709,740**
Annual Maintenance	$ 2,000
Existing Conditions AAD	$ 245,000
AAD	$ 144,000
Annual Saving	$ 99,000
NPV 6%	$ 1,392,178.25
Capital Cost	$ 709,740
B-C Ratio	2.0

5.2.7.1.4 RECOMMENDATION

The LGSPS levee is a viable option for protection of the site with a positive cost benefit ratio. It is recommended the LGSPS, Pyrenees Shire Council consider how this levee could operate with operation of the LGSPS site they specific requirements.

5.2.7.2 Options 2 and 3 – Cameron Bridge capacity increase and enlargement of waterway

5.2.7.2.1 COSTING

The LGSPS proposed a series of culverts under the Carngham Lake Goldsmith Road to reduce its hydraulic impact, as well as excavating a portion of the floodplain to increase the capacity of a confined section of Mt. Emu Creek. Modelling of this option didn't explicitly include the culverts but removed the bridge entirely and increased the available opening to a much greater area than the proposed culverts arrangement could to assess the maximum potential reduction in flood levels upstream of the structure. Excavation of the floodplain was also very extensive in order to demonstrate the maximum benefit that could be achieved.

The proposed culvert arrangement was adapted to the available culvert sizes available for direct purchase (rather than custom culverts). This involved twelve 3.6m x 2.1m culverts, connected with eleven 3.6m link slabs. The cost of this culvert arrangement was indicatively determined using standard industry rates used by Melbourne Water for earthworks and culvert installation.

The indicative cost of the culverts is outlined in Table 5-7 with the total cost including engineering, administration and contingency costs shown in Table 5-8

TABLE 5-7 OPTION 2 - INDICATIVE CULVERT SUPPLY COST

Item	Size	Length	Number	Unit	Unit Cost	Total Cost
Supply - Crown Units	3600 x 2100 mm	12	12	m	$ 3,767	$ 542,484
Supply - Base Slab	Item	12	12	m	$ 2,020	$ 290,938
Supply - Link Slab		11	12	m	$ 2,020	$ 266,693
Installation (Laying)		12	12	m	$ 7,808	$ 371,039
Headwalls & endwalls		24	12.91	m^3	$ 2,600	$ 805,584
Subtotal						**$2,276,737**

TABLE 5-8 OPTION 2 - INDICATIVE TOTAL CULVERT COST

Works Description	Estimated Basic Construction Cost	Provisions
Culverts	$2,276,737	$432,580
Sub-total 'A'	**$2,276,737**	**$432,580**
'A' x Site Establishment, Preparation & Reinstatement Costs @ 6%	$136,604	-
'A' x Site Environmental & Traffic Management Plans @ 2.5%	$56,918	-
Sub-total 'B'	**$2,470,260**	**$432,580**
'B' x Engineering Fee @ 15%	$370,539	$64,887
Sub-total 'C'	**$2,840,799**	**$497,467**
'C' x Administration Fee @ 9%	$255,672	$44,772
Sub-total 'D'	**$3,096,470**	**$542,239**
'B' x Contingencies @ 5%	$123,513	-
Cost	**$3,219,983**	**$542,239**
TOTAL COST	**$3,762,222**	

The excavation of floodplain storage was estimated to cover around 6.6 Ha and 267,000 m^3. The estimated cost of excavation and disposal of fill is estimated at $15/m^3. With the resulting cost of excavation around $4,000,000.

5.2.7.2.2 RECOMMENDATION

As discussed in Section 5.2.3, increasing the capacity of Cameron Bridge is expected to reduce inundation at the LGSPS site by less than 0.1m in a 1% AEP event, at an indicative cost of around $3.7M the cost of the works far outweighs the benefits and is not considered a viable option.

As discussed in Section 5.2.4, increasing the capacity of Cameron Bridge and increasing the capacity of the Mt. Emu Creek channel is expected to reduce inundation at the LGSPS site by 0.5-0.6m at most. With 1% AEP depths still reaching up to 0.5m, at an indicative cost of around $7.7M the cost of the works far outweighs the benefit and was not considered a viable option.

5.3 Skipton

5.3.1 Option 5 - Glenelg Highway bridge capacity increases

Expanding the current Glenelg Highway bridge capacity was modelled following a discussion with the project reference group. The capacity was increased by opening the perched bridge approach to the west of the existing structure to around double the current length of the bridge. The road west of the current bridge was removed to enable the conveyance of flows to the south of Stewart Park, as shown in Figure 5-27 and Figure 5-28. To maximise the effectiveness of the mitigation measure, the existing Glenelg Highway bridge was also removed from the hydraulic model to represent an assumed bridge replacement with increase span and deck level.

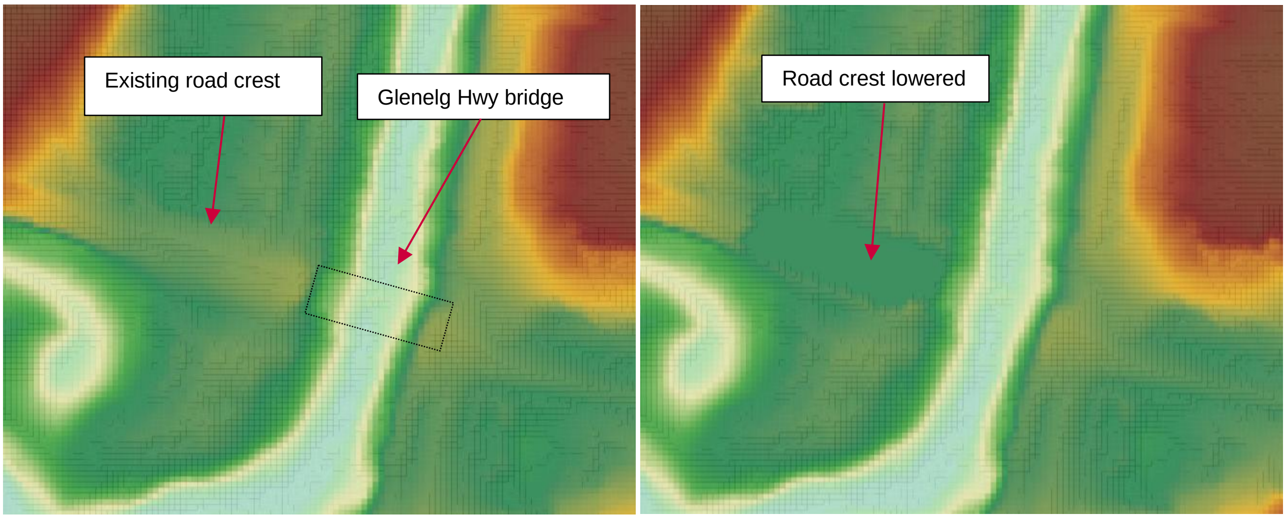

FIGURE 5-27 GLENELG HIGHWAY BRIDGE, LEFT: EXISTING; RIGHT: ROAD CREST WAS LOWERED

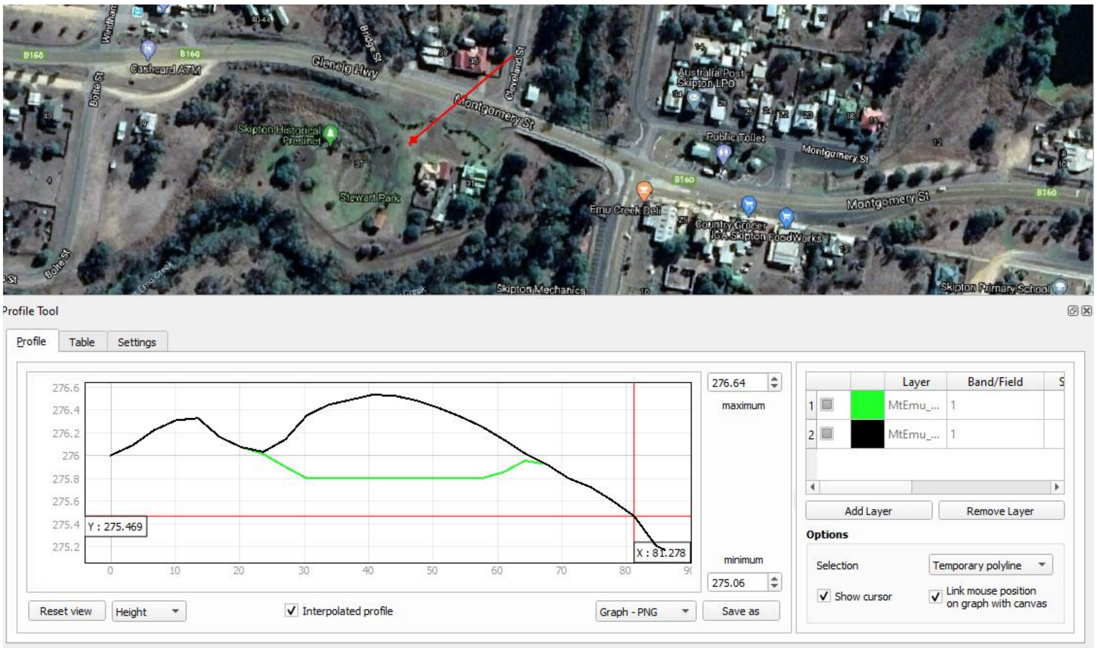

FIGURE 5-28 ROAD CREST MODIFICATION, BLACK: EXISTING; GREEN: MITIGATION

Figure 5-29 shows the change in water levels at Skipton as a result of opening of Glenelg Highway bridge. Water levels immediately upstream of the bridge were reduced by 10 to 15 cm, and water levels at Stewart Park were increased by less than 5 cm. There were some small decreases in flood extent at Anderson Street, Bridge Street and east of Montgomery Street.

FIGURE 5-29 OPTION 5 - WATER LEVEL DIFFERENCES AT SKIPTON - GLENELG HIGHWAY BRIDGE OPEN

Upstream of Skipton, the reduction of water levels was less than 10 cm (i.e. average about 5 cm) with no observed decrease in flood extent as shown in Figure 5-30.

FIGURE 5-30 OPTION 5 - WATER LEVEL DIFFERENCES UPSTREAM OF SKIPTON - GLENELG HWY BRIDGE OPEN

Opening the Glenelg Highway bridge reduced the flood levels on the properties north of the bridge (i.e. > 10 cm); however, flood risk on other surrounding properties within Skipton was not shown to be significantly reduced. In a 1% AEP event these properties are inundated to significant depths exceeding 0.5m and the works did not reduce their expected level of flood risk or damage.

5.4 Land use and planning control

5.4.1 Overview

The Victoria Planning Provisions (VPPs) contain several controls that can be employed to provide guidance for the use and development of land that is affected by inundation from floodwaters. These controls include the Floodway Overlay (FO), the Land Subject to Inundation Overlay (LSIO), the Special Building Overlay (SBO), the Urban Floodway Zone (UFZ) and the Environmental Significance Overlay (ESO).

Section 62(e) of the Planning and Environment Act 1987 enables planning schemes to 'regulate or prohibit any use or development in hazardous areas, or areas likely to become hazardous'. As a result, planning schemes contain State planning policy for floodplain management requiring, among other things, that flood risk be considered in the preparation of planning schemes and in land use decisions.

Guidance for applying flood controls to Planning Schemes is available from the Department of Environment, Land, Water and Planning's (DELWP) Planning Practice Note 12[11] on Applying the Flood Provisions in Planning Schemes, and The Victorian Floodplain Management Strategy (DELWP, 2016). The objectives of the state planning policy framework[12] for floodplain management is to assist in the protection of:

- Life, property and community infrastructure from flood hazard.
- The natural flood-carrying capacity of rivers, streams and floodways.
- The flood storage function of floodplains and waterways.
- Floodplain areas of environmental significance or of importance to river health.

Planning Schemes can be viewed online at https://www.planning.vic.gov.au/. It is recommended that the planning scheme for this project's study area is amended to reflect the flood risk identified by this project.

This study has produced the outputs for generation of LSIO and FO layers for inclusion in the Corangamite Shire Council and the Pyrenees Shire Council Planning Schemes. These layers were created in line with the Glenelg Hopkins CMA criteria, as shown below:

- LSIO – area inundated in a 1% AEP flood extent.
- FO – area inundated meeting the following criteria:
  - Land where the 1% AEP flood depth is likely to reach or exceed 0.5 metre, and/or
  - Land where the 1% AEP flood hazard factor (the produce of depth and velocity) is likely to reach or exceed 0.4 m^2/s, and/or
  - Land inundated in a 10% AEP event.

[11] DELWP Planning Practice Notes, accessed from https://www.planning.vic.gov.au/resource-library/planning-practice-notes
[12] Victorian Floodplain Management Strategy (2016), accessed from https://www.water.vic.gov.au/__data/assets/pdf_file/0017/53711/Victorian-Floodplain-Management-Strategy-Introduction-Section-1.pdf

5.4.2 Existing Planning Controls in Skipton

The existing planning overlays in Skipton include the Land Subject to Inundation Overlay (LSIO) and the Floodway Overlay (FO), based on the results of the Skipton Flood Study[1]. A comparison between the Skipton Flood Study[1] LSIO and the LSIO produced in current Upper Mt. Emu Creek Flood Investigation was made, as shown in Figure 5-31. The new LSIO produced shows a similar extent compared to the existing LSIO. The layers along the Mt. Emu Creek are identical, differences in the overlays are within the local tributaries connecting to Mt. Emu Creek which were not included in the revised modelling and subsequent LSIO delineation.

Overall, the planning overlays at Skipton produced in this study have shown a negligible difference to that existing. It is suggested there is no need to update the existing planning overlays in Skipton.

5.4.3 Planning Controls in Upper Mt Emu Creek Catchment

In assessing how flood controls should be applied within the Upper Mt. Emu Creek Catchment area, consideration must be given to both the extent of 1% AEP flood event as produced by the hydraulic modelling results and the nature of the flood risk. Figure 5-32 and Figure 5-33 show the draft planning overlays produced in this study for Pyrenees Shire Council and Corangamite Shire Council. Figure 5-34 to Figure 5-36 show the planning overlays in key townships within Pyrenees Shire and Figure 5-37 shows the township of Skipton within Corangamite Shire.

- **Land Subject to Inundation Overlay (LSIO)** – defines the floodplain fringe and lower hazard areas within the 1% AEP flood extent
  - Land Subject to Inundation Overlays are planning scheme controls that apply to land affected by flooding associated with waterways, natural flow paths and drains. Such areas are commonly known as floodplains. The LSIO is used to identify flood fringe areas of the floodplain where flooding depths and velocities are typically lower.

  The LSIO identifies lands in flood fringe areas with shallow or slow moving water.
- **Floodway Overlay (FO)** – defines the high hazard portion of the floodplain
  - Floodway Overlays apply to land that is identified as carrying active flood flows associated with waterways, natural flow paths and drains. The overlay is characterised by areas impacted by deep and or fast flowing floodwaters during the 1% AEP flood event.

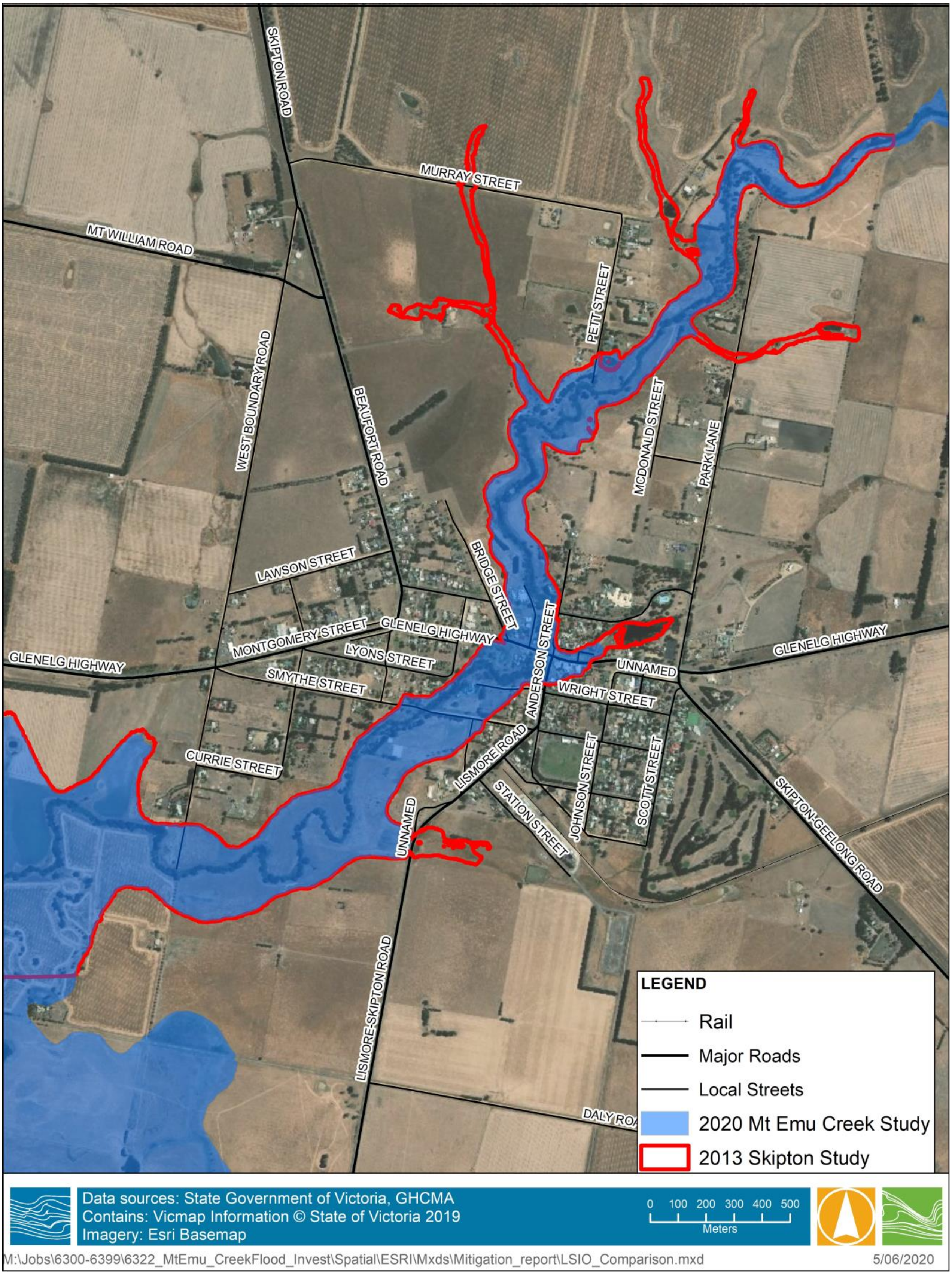

FIGURE 5-31 LAND SUBJECT TO INUNDATION OVERLAY COMPARISON

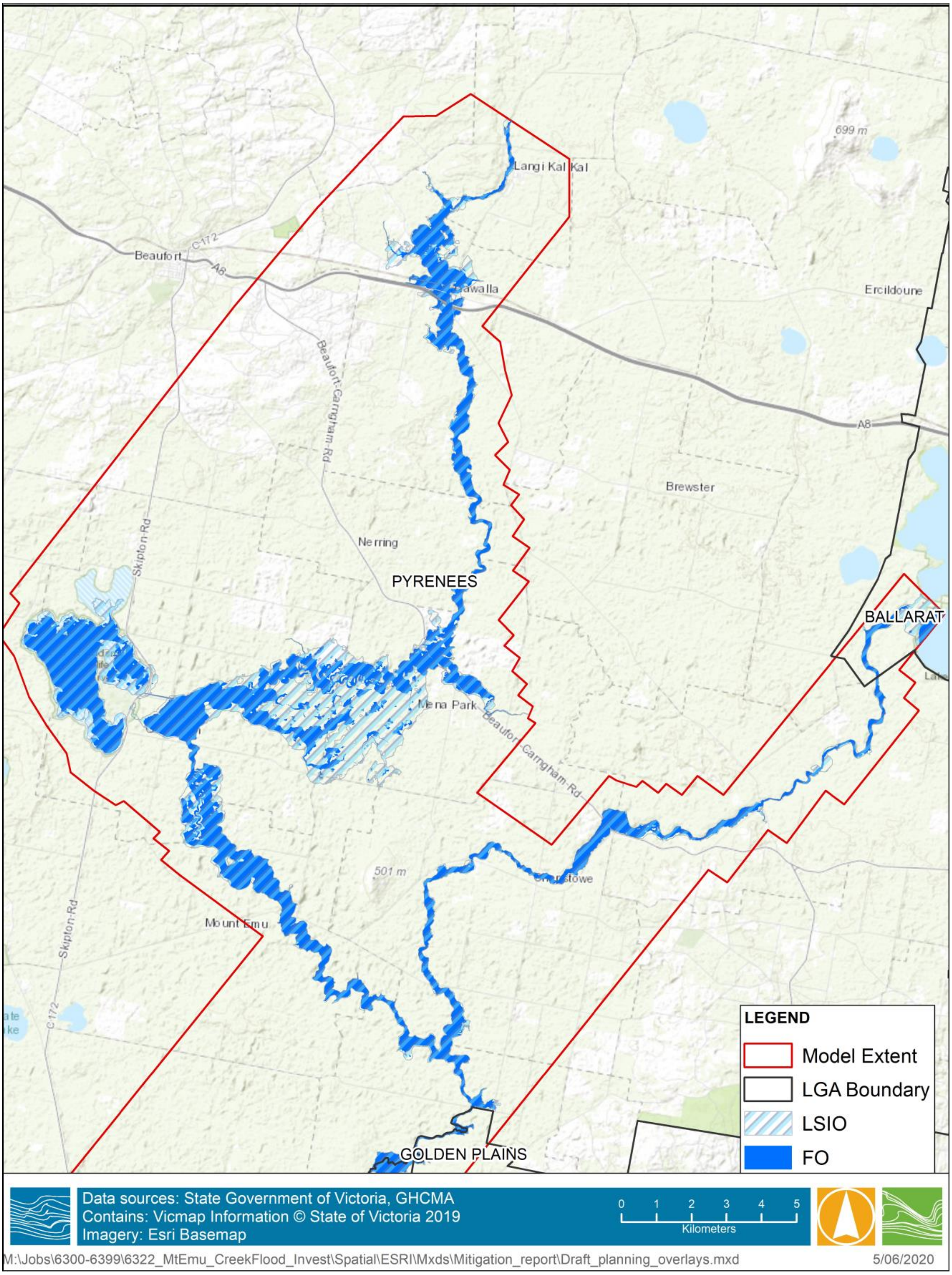

FIGURE 5-32 FLOOD RELATED PLANNING CONTROLS - PYRENEES SHIRE AREA

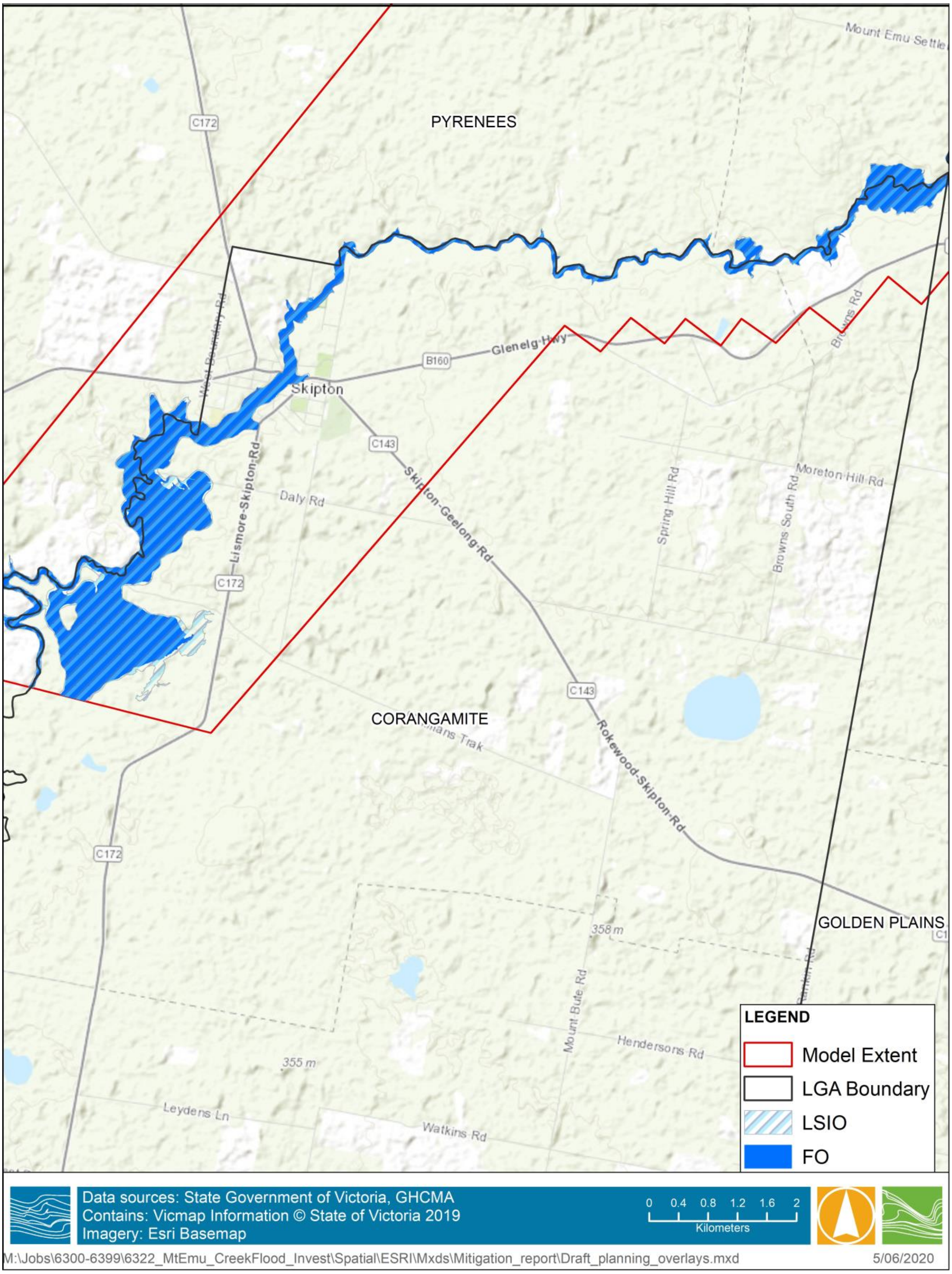

FIGURE 5-33 FLOOD RELATED PLANNING CONTROLS - CORANGAMITE SHIRE AREA

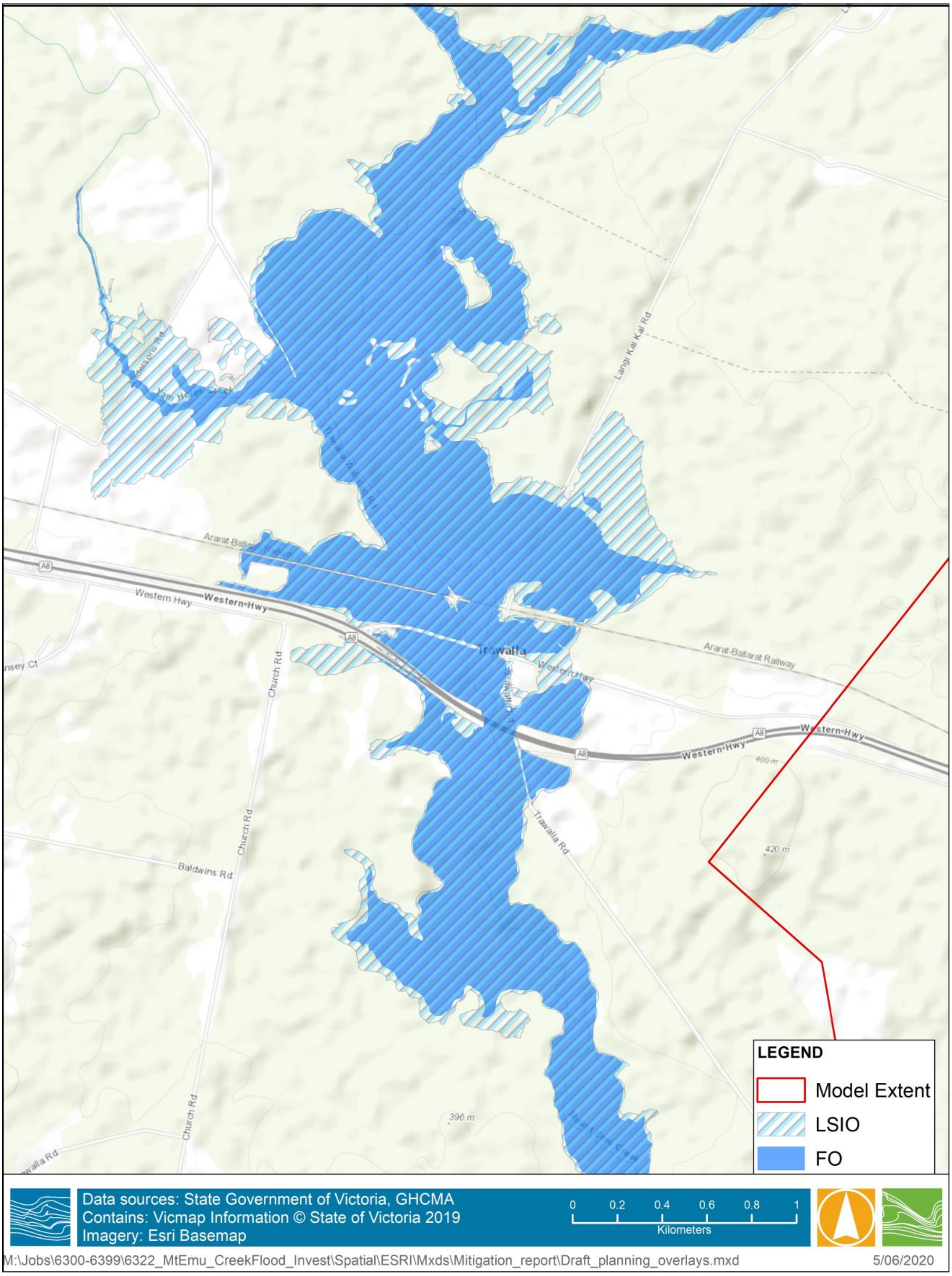

FIGURE 5-34 FLOOD RELATED PLANNING CONTROLS - TRAWALLA

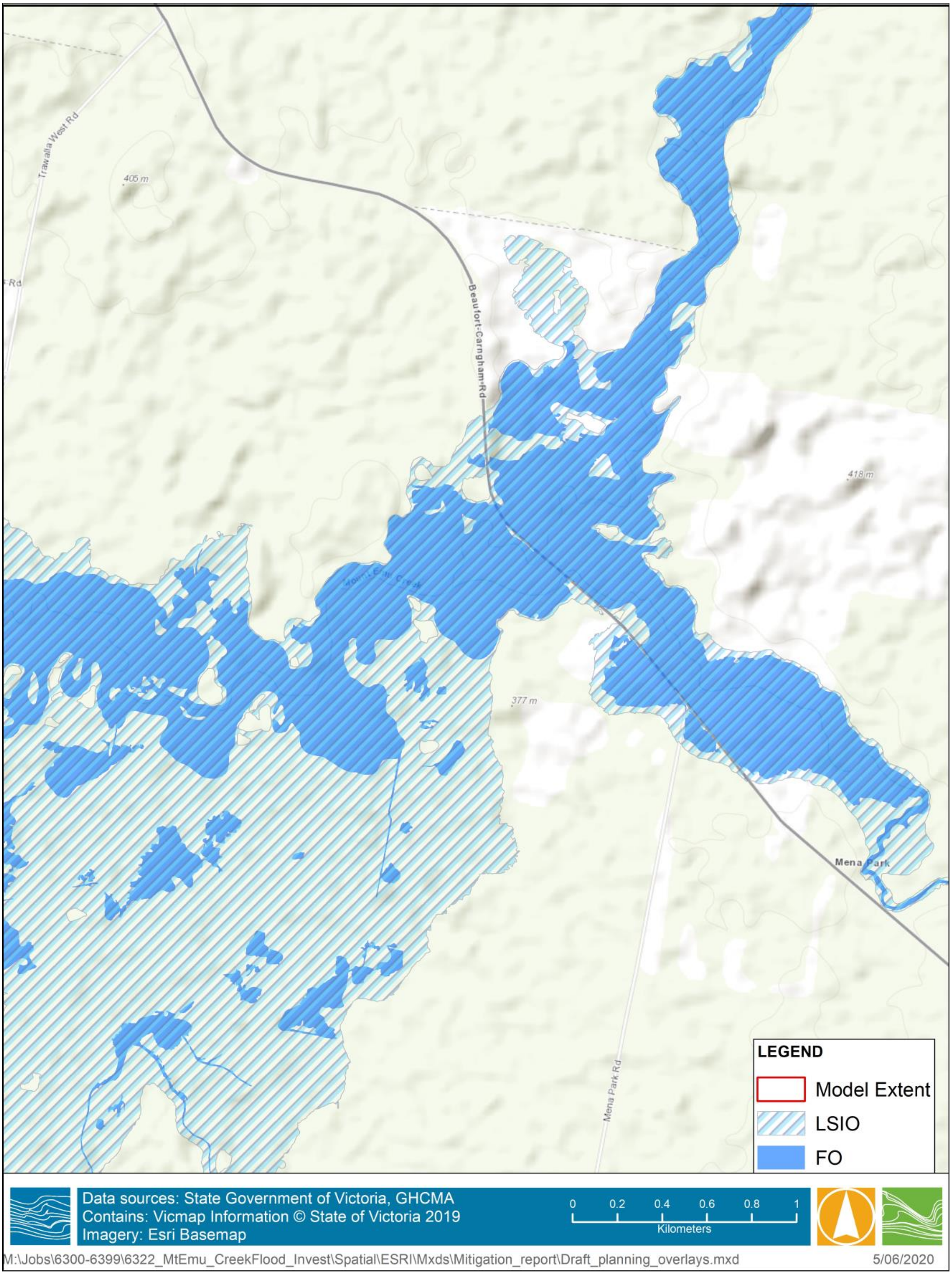

FIGURE 5-35 FLOOD RELATED PLANNING CONTROLS – MENA PARK

6322_R06V02d_Mt_Emu_Ck_FI_FloodDamages_MitigationAssessment.doc

FIGURE 5-36 FLOOD RELATED PLANNING CONTROLS – LAKE GOLDSMITH

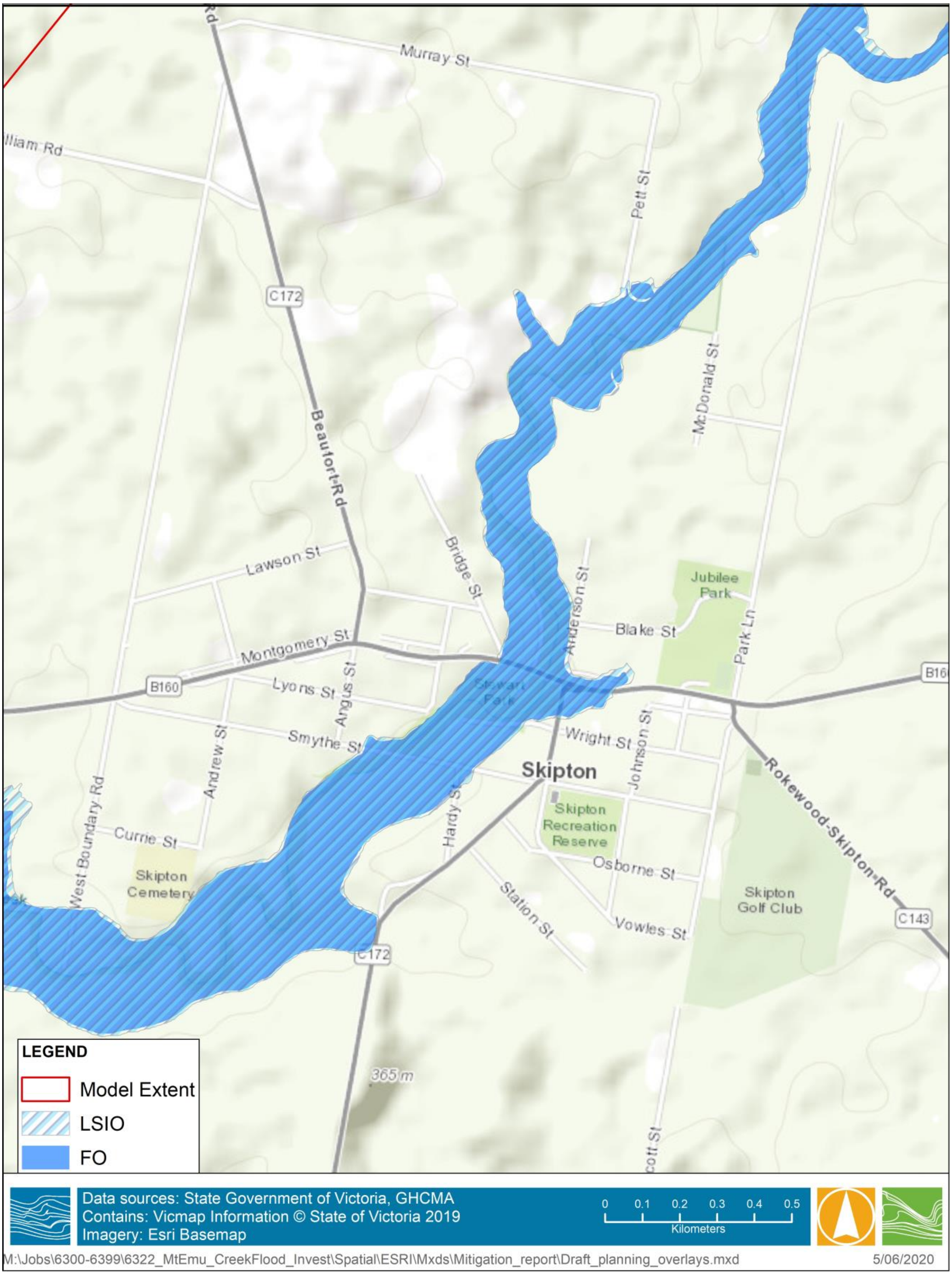

FIGURE 5-37 FLOOD RELATED PLANNING CONTROLS - SKIPTON

6322_R06V02d_Mt_Emu_Ck_FI_FloodDamages_MitigationAssessment.doc

6 SUMMARY AND DISCUSSION

Several mitigation measures were tested in the upper Mt. Emu Creek hydraulic model, focusing on alleviating flood risk at the Lake Goldsmith Steam Preservation Society and the township of Skipton. Impacts of each mitigation option were demonstrated and a summary of the impacts and discussion on feasibility of each mitigation measure is detailed below:

- Construction of levee at the LGSPS site
  - Modelling demonstrated that this option can prevent the steam rally site from becoming inundated, with negligible negative impacts up or downstream of the site. To completely prevent the flood water entering the site the levee may be up to 1.8-2.1m, including freeboard. The estimated cost and benefits of the levee indicate it is a financially viable option that should be considered further.
- Carngham – Lake Goldsmith Rd bridge
  - Opening the bridge and removing the barriers in the river channel caused a reduction in water levels at the steam rally site by more than 10 cm with extensive excavation improving the reduction to up to 0.6 m. However, the reductions did not effectively alleviate the flood risk or damage. Indicative costs for both increasing the bridge capacity with culverts and excavation the floodplain indicated the options were not financially viable.
- Lake Goldsmith diversion channel
  - Modelling of the diversion channel both open and closed was undertaken for both 2016 and the 1% AEP events. This mitigation option aimed to evaluate whether opening of the channel could alleviate flooding at the LGSPS and improve inundation in Skipton. Modelling demonstrated a very minor reduction in water levels in both locations. The diversion channel has a limited capacity and it cannot divert enough water to significantly reduce flood levels in Mt. Emu Creek. This finding is identical to that determined during the Skipton Flood Study (Water Technology, 2013).
- Glenelg Highway bridge capacity increase
  - Modelling of an increase to the Glenelg Highway bridge capacity (around double) showed flood level decreases by 10-15cm upstream of the existing bridge location. There were no significant decreases in flood extent. There were properties located within the area of maximum impact; however these properties were all flooded to significant depths exceeding 0.5m and the reduction in flood depth would not significantly reduce flood risk or damage.

7 RECOMMENDATIONS

The construction of a proposed levee around the LGSPS site is the most effective mitigation measure modelled with very limited negative impact. It can prevent the LGSPS site from flood inundation and subsequent future damage. The cost of the levee construction and reduction in financial damage also indicated a strong cost benefit ratio..

It is recommended Glenelg Hopkins CMA and Pyrenees Shire Council review this report prior to discussion with the LGSPS.

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