Summary Report

Upper Mt. Emu Creek Flood Investigation

Glenelg Hopkins CMA

19 May 2020

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

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19 May 2020

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Dear Tatjana

Upper Mt. Emu Creek Flood Investigation

Please see attached Summary Report. This report summarises the outputs and findings for the Upper Mt. Emu Creek Flood Investigation and covers previous reporting stages.

This report is missing two outputs of the Upper Mt. Emu Creek Flood Investigation, recommendations regarding Flood Class Levels for Skipton and along Mt. Emu Creek and the development of Land Subject to Inundation Overlay and Flood Overlay. These will be discussed with the project reference group and finalised in the final version of this report.

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

Yours sincerely

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WATER TECHNOLOGY PTY LTD

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1 INTRODUCTION

This report is one of a series, documenting the outcomes of the Upper Mt. Emu Creek Flood Investigation. The study provided a detailed investigation of the Upper Mt. Emu Creek catchment, extending along Mt. Emu Creek from Trawalla to the township of Skipton, and Baillie Creek from Lake Burrumbeet to its confluence with Mt. Emu Creek. Reporting was broken up into a series of deliverables which are summarised in this report, these are 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.
- R07 – Flood Intelligence Report and Animations.
- R08 – **Final Summary Report (This report)**

1.1 Overview

Water Technology was commissioned by the Glenelg Hopkins Catchment Management Authority (GHCMA) 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 Trawalla to Skipton, and Baillie Creek. Both waterways have a well-known history of flooding and some of the most significant flood events are well recorded. These flood events caused substantial damages to the local infrastructure (e.g. roads and bridges) and agriculture (e.g. fencing) while also having severe impacts on the township of Skipton and the Lake Goldsmith Steam Preservation Society (LGSPS) facilities and historical artefacts.

A previous flood investigation at Skipton was undertaken by Water Technology in 2013. Since the completion of this study, flood mitigation works have been undertaken in Skipton. These works altered the inundation characteristics within Skipton and as a result, the flood intelligence elements in the study are no longer reliable. Additional updated modelling analysis was required to support the design and establishment of a formal flood warning service for Skipton.

The recent upgrade of the Western Highway is also likely to increase demand for land development west of Ballarat, and as a result of commute time reduction between Beaufort and Ballarat. This flood investigation provides a comprehensive flood analysis for several key areas of interest in the upper region of Mt. Emu Creek catchment and up-to-date flood intelligence information for the township of Skipton.

1.2 Project Objectives

The Upper Mt. Emu Creek Flood Investigation outputs are required to meet several floodplain management objectives, and these were highlighted in the project brief prepared by Glenelg Hopkins CMA as follows:

- Provision of a range of outputs to enable the implementation of a formal flood warning service for Skipton.
- Amended flood class levels for Skipton that account for changed flooding characteristics following completion of mitigation works.
- Heightened understanding of the hydrological drivers of flooding in the project area.

- Increased reliability of flood intelligence information and real time flood monitoring capability via production of (theoretical) stage/discharge ratings for three new gauging sites and improvement of ratings for three existing stations.
- Provision of flood mapping and intelligence products for the entire project area to inform and develop:
  - Emergency response planning; and
  - Heightened community resilience to floods.
- Establishment of flood related land use and development controls in the Pyrenees Shire Council planning scheme.
  - It is expected that the new mapping outputs for Skipton, Trawalla, Langi Kal Kal and the LGSPS will be of sufficient resolution to enable flood risk management planning at the building envelope scale (i.e. be of suitable resolution and rigour for a planning scheme amendment).
- Provision of reliable flood risk information for insurance purposes
- Assess options flood mitigation works and activities.

1.3 Study Area

Mt. Emu Creek is located approximately 30 km west of Ballarat at its closest point, flowing from Langi Kal Kal to the Hopkins River west of Cudgee. The Upper Mt. Emu Creek Flood Investigation focuses on the area extending from Trawalla to about 4 km downstream of Skipton whilst covering the entirety of Baillie Creek and its associated floodplain. This extends from Lake Burrumbeet to the confluence with Mt. Emu Creek. The total catchment area of the investigation is approximately 1,250 km^2, and spans three municipalities. However, the extent of the required project outputs is only relevant to the Pyrenees and Corangamite Shire areas.

The catchment within and upstream of the study area is largely agricultural, with several key agricultural weirs and other structures in the system. Key areas of interest within this study were identified as follows:

- Trawalla
  - Trawalla is a small township about 4 km south of Langi Kal Kal situated, adjacent to the Western Highway between Beaufort and Ballarat. Due to the reduction in commute time between Beaufort and Ballarat, a potential increase in housing demand, is expected. It is suggested that adoption of planning controls in Trawalla would be a high priority to minimise the potential flood risk for future development.
- Mena Park
  - The Mt. Emu Creek at Mena Park streamflow gauge has instantaneous records from October 1974 to present day. This gauge was a valuable source for both hydrology and hydraulic model calibration.
- Lake Goldsmith
  - The Lake Goldsmith Steam Preservation Society (LGSPS) facilities are located within the Mt. Emu Creek floodplain. The facilities house one of the most significant collections of historical machinery and artefacts in the southern hemisphere. Historical record shows that the site was severely impacted by the January 2011 flood, resulting in substantial losses of irreplaceable artefacts and significant flood recovery costs.
- Guthries Bridge
  - The Mt. Emu Creek at Skipton will be the flood level prediction gauge for township of Skipton while Guthries Bridge will be a key support location to forecast water level at Skipton.
- Skipton

- Skipton is the largest town in the investigation area which has a well-known and understood flood risk. The January 2011 flood was the largest event recorded on the Mt. Emu Creek at this location. Although floods in 2010 and 2011 had severe impacts on the town, relatively minor flooding occurred again in September 2016 and its impacts were largely mitigated by the completion of drainage works in Montgomery Street in mid-2016.

The study area of the Upper Mt. Emu Creek Flood investigation is displayed in Figure 1-1.

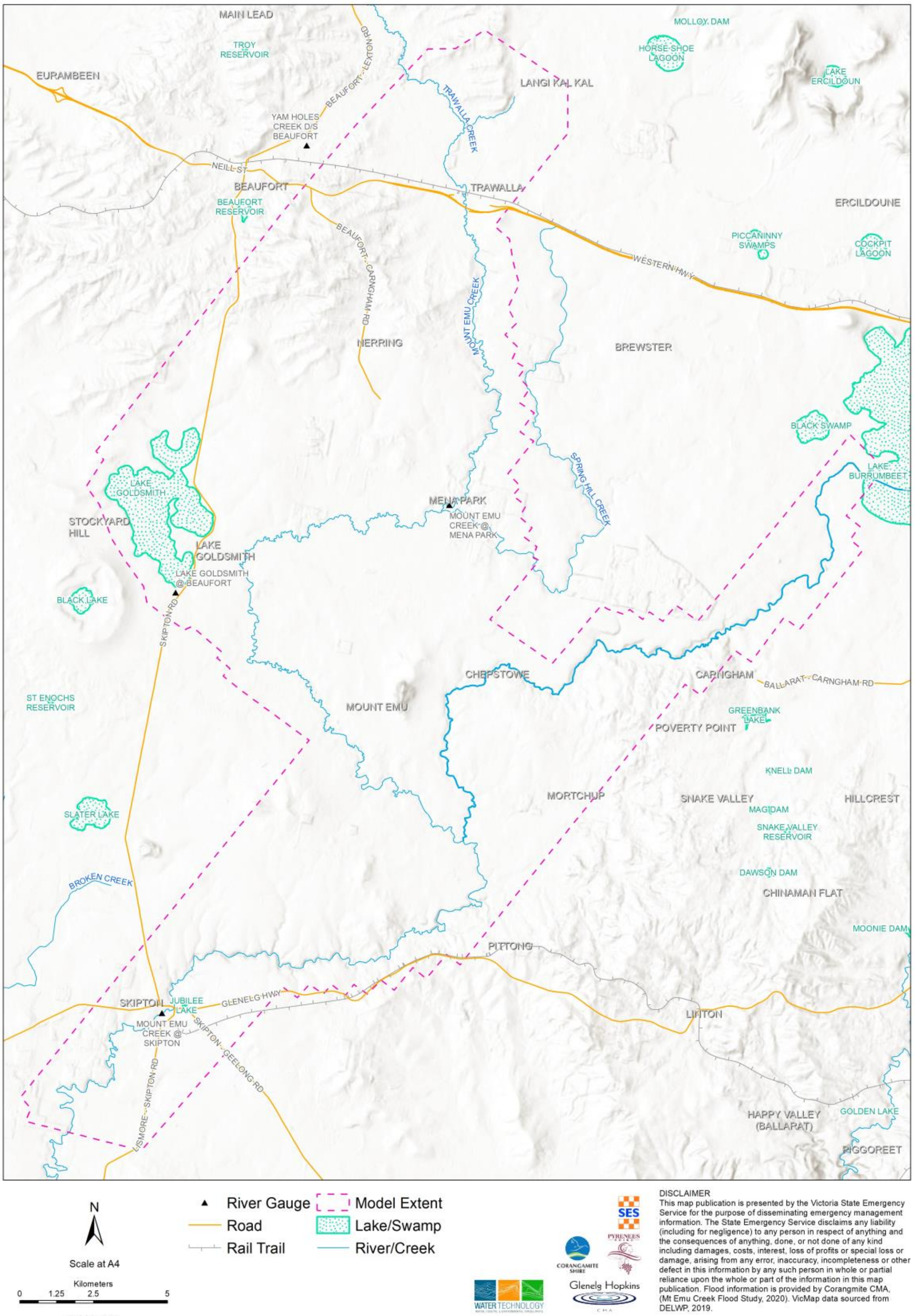

FIGURE 1-1 UPPER MT. EMU CREEK FLOOD INVESTIGATION – STUDY AREA

2 DATA REVIEW AND COLLATION

2.1 Overview

The Data Collation Report (R01) was complete in June 2019 and provided an overview of the available existing data and the modelling methodology used to complete this study. The data review detailed previous studies and historical floods. Rainfall and streamflow data were collected and evaluated. A review of available feature survey of key roads and drainage infrastructures, floor level data, and available topography data was completed. As a result of the data review, data gaps were identified in key structures, floor level survey and topography data.

2.2 Methodology

The hydrologic and hydraulic modelling methodology for this study was as follows:

- Review and update of hydrologic analysis (i.e. Flood Frequency Analysis).
- Review and modification of the existing hydrological model.
- Hydrological model calibration.
- Hydraulic model development.
- Hydraulic model calibration.
- Design event modelling via hydrological and hydraulic models.

2.3 Summary and Outcomes

The data review and collation detailed a thorough data review and identified gaps in the available data. The major data gaps included the feature survey in hydraulic infrastructures, floor level survey and the coverage of topography data (i.e. LiDAR data).

Feature survey for hydraulic structures was collected within the study area to aid the development of hydraulic model.

Floor level survey was undertaken, and was used in flood intelligence outputs.

The major outcome of this was the additional LiDAR data acquired of the study area vastly improved the dataset coverage, including additional floodplain areas and Lake Goldsmith and it also picked up the Western Highway Duplication where the old datasets did not. The new LiDAR data was verified through comparison to surveyed transects and existing topography data. This LiDAR data was then used as the base data for hydraulic model in this study.

3 CALIBRATION

The Calibration Report (R02) was completed in November 2019 and documented the development of hydrological and hydraulic models as well as the calibration process.

3.1 Methodology

The modelling methodology adopted is outlined as follows:

- Modification of the existing hydrological model (RORB).
  - The existing hydrological model – RORB produced in the Skipton Flood Investigation (2013) was modified to allow for the transition from a model schematised to produce inflows for the township of Skipton to a regional scale model producing inflows along Mt. Emu Creek and Baillie Creek.
- Hydrological modelling.
  - The January 2011 and September 2016 floods events were simulated in RORB.
  - The daily rainfall data (from several rainfall gauges) was used to generate spatial patterns for each event.
  - The sub-daily rainfall data at the Beaufort gauge was used to generate temporal patterns for each event.
- Hydraulic model development.
  - A 1D/2D hydraulic model – TUFLOW with 5 metre grid resolution was developed and this consists of:
    - Model inflow/outflow boundaries and extent.
    - Model topography.
    - Hydraulic roughness layer.
    - 1D/2D hydraulic structures; including bridges, pipes and culverts, and diversion channel at Lake Goldsmith.
- Model calibration.
  - The model calibration and validation focused on the January 2011 and September 2016 flood events.
  - A joint hydrologic and hydraulic calibration approach was adopted for this study. This enabled the RORB model parameters to be determined through a iterative process comparing hydraulic model outputs to observed timing and the flood peaks, while also adjusting the hydraulic model parameters and setup.

3.2 Summary and Outcomes

The calibration and validation process relied heavily on streamflow gauge flows and heights, surveyed flood marks, aerial flood photos and other anecdotal evidence. Missing gauge records during and gauge datums increased the difficulty of model calibration. The September 2016 flood had a relatively limited historic evidence compared to the January 2011 event.

Model calibration for the January 2011 event showed a strong match to the observed flood levels and extents while the timing of the September 2016 flood was slightly late, but matched closely flood extents well.

Results of the joint calibration validated the parameters adopted in both the RORB and TUFLOW models and were determined of sufficient accuracy to conduct the design modelling.

4 DESIGN MODELLING

The Design Modelling (R03) (issued in January 2020) detailed the revised and updated Flood Frequency Analysis (FFA) and together with the Final Hydraulic Modelling Report – R04 (issued in May 2020) provide all the outputs of the design modelling and the sensitivity tests on various assumptions made in the hydrologic and hydraulic modelling.

4.1 Methodology

The FFA completed in the Skipton Flood Investigation (2013) was revised and updated with the additional years of data using the recommended approach in AR&R 2019. This included analysis at the Mt. Emu Creek at Skipton streamflow gauge (236203), Mt. Emu Creek at Mena Park (236213) gauge and Burrumbeet Creek at Lake Burrumbeet gauge (236215). The design flows for a range of design Annual Exceedance Probability (AEP) events were produced for these gauges.

The RORB parameters - k_c and m determined in the hydrologic and hydraulic model calibration process were adopted whilst the RORB parameters of rainfall losses were adjusted in a reasonable range until the peak flows at Skipton gauge produced in TULFOW model matched to the design estimates from the FFA. Figure 4-1 below shows the process of design modelling in RORB and TUFLOW models.

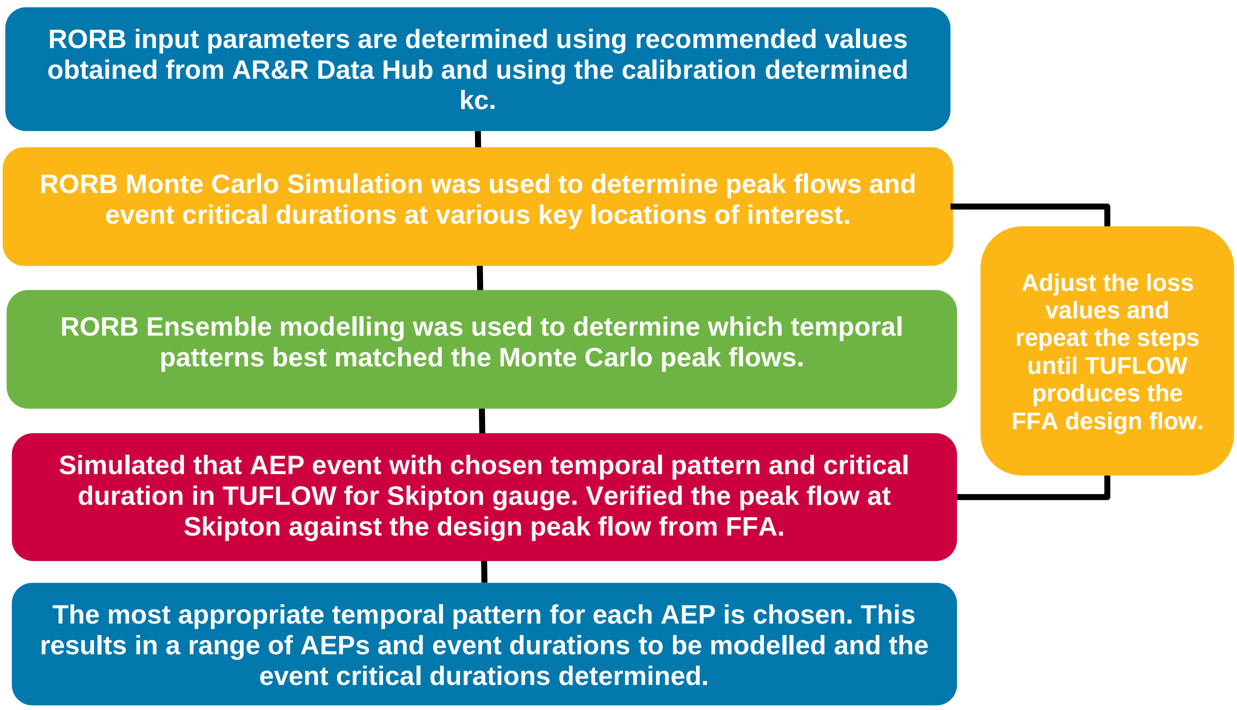

FIGURE 4-1 THE PROCESSES OF HYDROLOGIC AND HYDRAULIC DESIGN MODELLING

Once the design parameters of RORB model were determined, and the temporal patterns and critical durations were identified fat key locations, the design inflows were extracted and input into the TUFLOW model.

Design modelling included a range of AEP events, from 20% AEP up to 0.2% AEP and the Probable Maximum Flood (PMF) event, and a range of critical durations identified at key locations, including Langi Kal Kal, Trawalla, Mena park, Lake Goldsmith, Guthries Bridge and Skipton.

4.2 Results

Hydraulic modelling results for each AEP event were processed to produce the final maximum flood grids (i.e. depth, water level, velocity and hazard). Using the 1% AEP event as an example, there were four durations and five temporal patterns modelled and combined to form a maximum water level grid, calculated using the maximum water levels at each grid cell. Although they are all 1% AEP rainfall events, the water level and flood extents are affected by the event duration and temporal pattern of rainfall. Figure 4-2 and Figure 4-3 show an example of the range of flood extents for each AEP at Lake Goldsmith and the township of Skipton respectively.

Maps for each design event were produced mapping depth, water surface elevation, velocity and flood hazard. These were produced at a catchment wide scale as well as a closer perspective a key locations for easier viewing. An example of the flood depth map (i.e. 1% AEP) is shown in Figure 4-4.

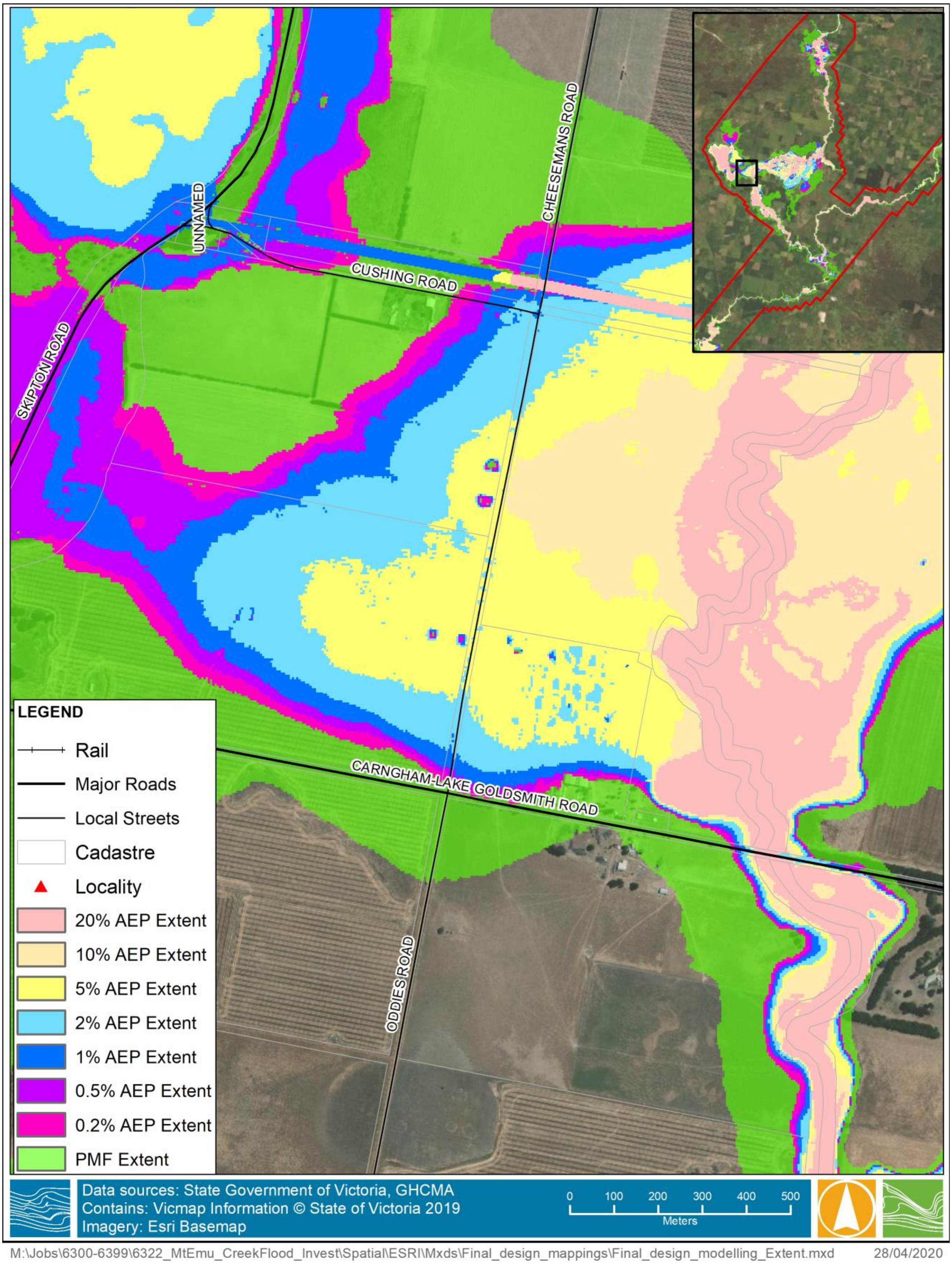

FIGURE 4-2 DESIGN FLOOD EXTENTS FOR ALL MODELLED AEP IN LGSPS

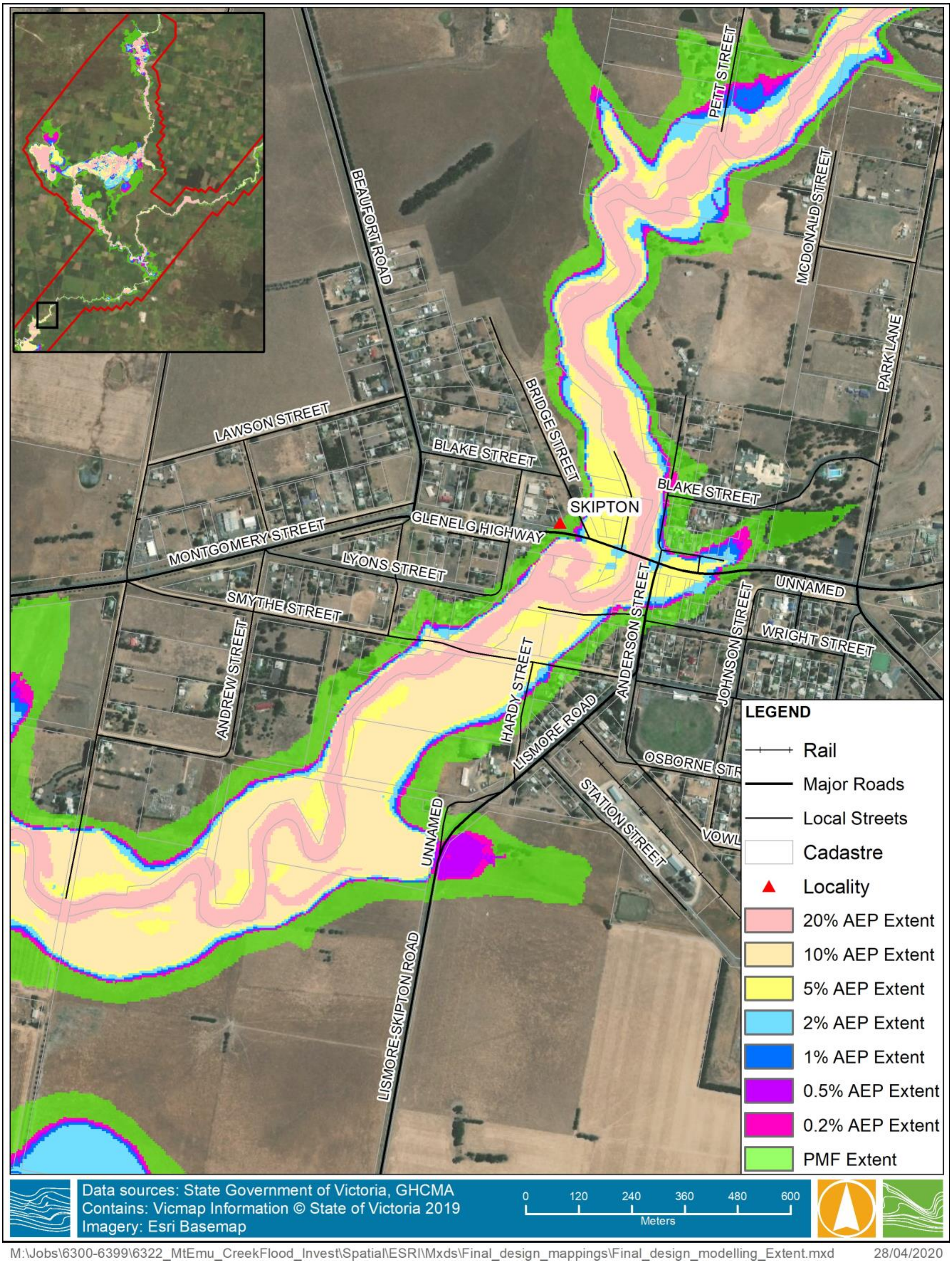

FIGURE 4-3 DESIGN FLOOD EXTENTS FOR ALL MODELLED AEP IN SKIPTON

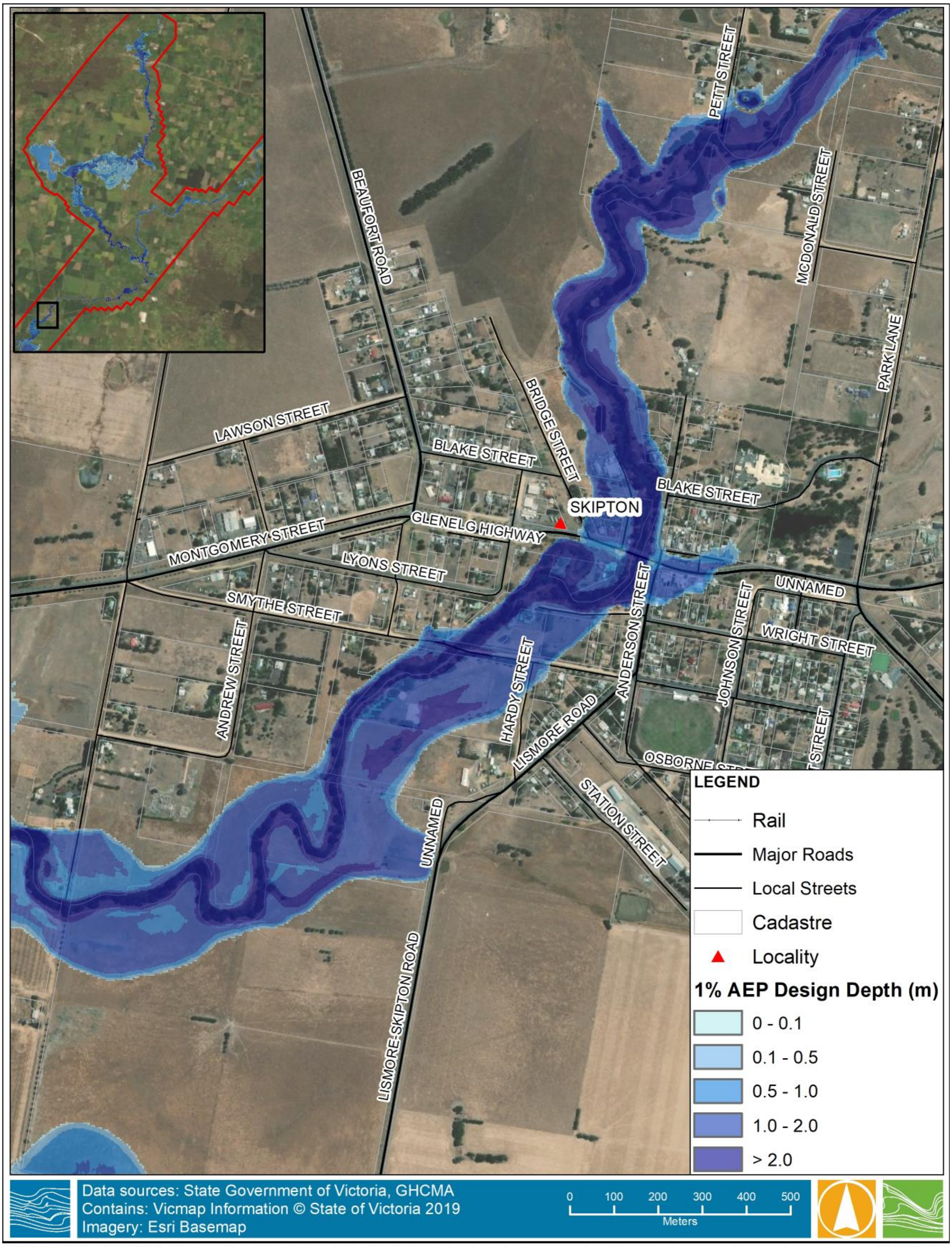

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FIGURE 4-4 1% AEP FLOOD DEPTH MAP IN SKIPTON

4.3 Sensitivity Analysis

The hydrologic and hydraulic modelling were based on various assumptions and it is good practice to understand the sensitivity of the model results to these assumptions. The model assumptions tested are listed below along with a summary of the sensitivity analysis undertaken:

- Spatial rainfall variation.
  - **Uniform and spatially varied rainfall depths were tested in RORB model and 1% AEP design flows compared.** A uniform spatial pattern uses the average rainfall depth within a catchment based on the catchment centroid, while a spatially varied pattern uses the average rainfall depths in each subarea within the catchment. Model results showed design flows at key locations were consistently greater when applying spatially varied rainfall depth. Increases in design flows were within 5% at key locations and within 3% in Skipton and Lake Goldsmith, which was equivalent to 2 cm and 5 cm increases in water level respectively.
- Temporal Variations of Rainfall
  - **All ten AR&R 2019 recommended temporal patterns were modelled in RORB for the 1% AEP event and design flows were compared across different temporal patterns.** During the design modelling stage, there was only one temporal pattern chosen for each key location in hydraulic model. Figure 4-5 shows the variation of the design flows at each key location using the potential range of possible temporal patterns of rainfall. Skipton was the most sensitive followed by Mena Park, whilst Langi Kal Kal and Guthries Bridge were the least sensitive to temporal rainfall variations. The cross markers highlight the selected temporal pattern used in the design flood modelling. Design flows produced at Skipton varied from 340 m³/s up to 520 m³/s. This was the equivalent of the adopted design flows ranging from 2% AEP to 0.5% AEP, which corresponds to a 0.5m increase in water level at the Skipton gauge. Overall, design flows at most key locations were relatively sensitive to temporal rainfall variation.

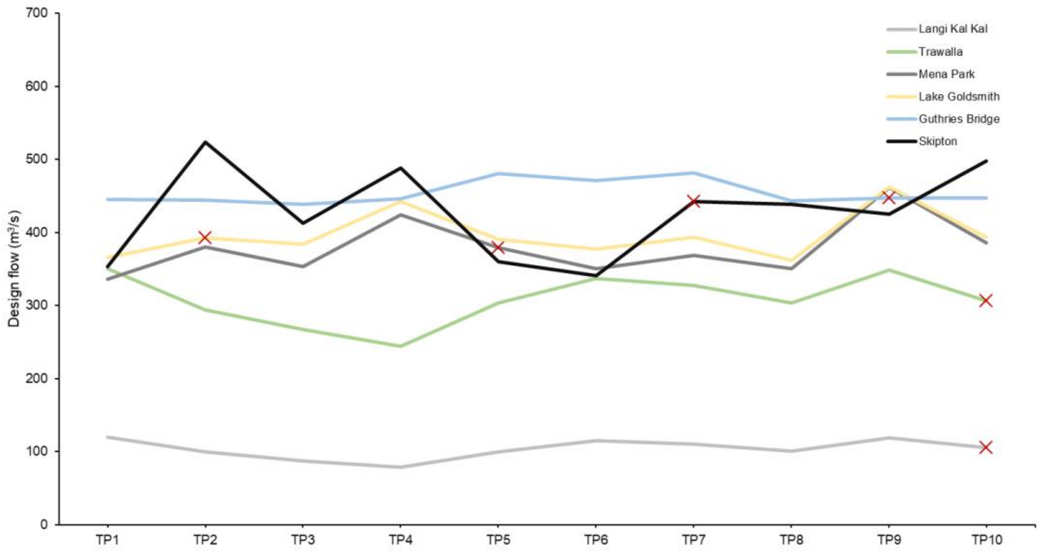

FIGURE 4-5 DESIGN FLOWS VARIATION AT KEY LOCATIONS USING DIFFERENT TEMPORAL PATTERNS

- Design Rainfall Losses.
  - **Initial and continuing losses were independently reduced by 50% and tested in RORB for the 1% AEP event.** The adopted design rainfall losses for each AEP event were applied using a Fraction Impervious for each subarea. The change to the adopted losses showed an increase in design flows

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and a larger impact by a reduction in continuing loss. Trawalla had the least increase while the Guthries Bridge and Skipton a more significant increase. The 1% AEP peak design flow at Skipton was increased by 11%, which is equivalent to a 12 cm increase in water level at the Skipton gauge.

- Lake Burrumbeet Storage.
  - **The 1% AEP event was modelled in RORB with the Lake Burrumbeet initial storage set as both empty and full.** When Lake Burrumbeet was empty, the outflow from Lake Burrumbeet was found to be negligible when compared to the broader Mt. Emu Creek flow at around 10 m^3/s. The peak also occurred 40 hours after Skipton reached its peak flow. When Lake Burrumbeet was assumed full, much larger flows spilled to Baillie Creek, causing an increase of 30 m^3/s in peak flow at Skipton in a 1% AEP event. This corresponds to a 10 cm increase in flood level.
- Lake Goldsmith Storage.
  - **The 1% AEP event was modelled in RORB with the initial storage in Lake Goldsmith set as empty and full.** The sensitivity test revealed there was a negligible impact on the peak flow at Skipton regardless the initial storage was empty or full. When the Lake Goldsmith was empty, it was not filled did not flow Mt. Emu Creek. Even if Lake Goldsmith was full before an event, the flow spilling to Mt. Emu Creek was trivial at around 0.5 m^3/s.
- Roughness Coefficients.
  - **The modelled hydraulic roughness was increased by 20% and modelled for the 1% AEP event in TUFLOW.** The increase in roughness resulted in an increase of 10 to 20 cm at Trawalla and a slight increase in extent the north of the railway. At the Lake Goldsmith steam rally site, there was a slight extension in flood extent, with flood water from Mt. Emu Creek entering Lake Goldsmith. There was a 16 cm increase in flood level at the steam rally site and a 20 cm increase at Camerons Bridge. There was a 20 cm increase in flood level in Skipton.
  - **The modelled hydraulic roughness was decreased by 20% and modelled for the 1% AEP event in TUFLOW.** The decrease in roughness resulted in a 10 to 15 cm reduction in water level at Trawalla and slight reduction in flood extent north of the railway. At the Lake Goldsmith Steam Preservation Society, there was a slight reduction in flood extent and a 17 cm reduction in flood level. A 20 cm reduction in flood level was observed at Camerons Bridge. Within the township of Skipton, there was a 20 cm reduction in water level and a minor reduction in flood extent.
- Bridge Blockage.
  - **A 50% blockage of bridges was modelled for the 1% AEP event in TUFLOW.** The Western Highway bridge was excluded from this sensitivity test as there is no likelihood that it will be blocked due to the large span and height of the bridge. Results showed a 10 to 20 cm increase in water level and an increase in flood extent immediately upstream of the old Western Highway bridge in Trawalla. There was also an increase in water level upstream of Camerons Bridge which resulted in an of less than 10 cm at the Stream Preservation Society. Similarly, blockage of the Glenelg Highway Bridge at Skipton increased water levels by less than 10 cm immediately upstream of the bridge.
- Climate Change.
  - **Modelling of Climate Change Representative Concentration Pathways (RCP) 4.5 and 8.5 for year 2090, was undertaken for the 1% AEP 36-hour and 96-hour events.** Results from the RORB model showed the maximum increase in peak design flows varied from 10% to 25% in the RCP4.5 scenario, and 20% to 50% in the RCP8.5 scenario. Results from the hydraulic model showed that the average increases in flood level ranged from 120mm in the RCP4.5 scenario and an increase of 250mm in the RCP8.5 scenario. It should be also noted that although the increase in rainfall intensity was modelled, the initial and continuing loss values were maintained. While predictions suggest

rainfall intensity is likely to increase as result of climate change, it is also expected that the average temperature will increase and catchment conditions would be drier.

5 FLOOD RISK AND DAMAGE

The Flood Damages and Mitigation Assessment Report (R06) documented the level of flood risk and damage within the study area the hydraulic modelling results. The model results were used to demonstrate which properties and roads would be inundated in each AEP.

5.1 Flood Risk

Flood mapping showed several roads became impacted by flood water during small and large events (i.e. 20% to 0.2% AEP). Table 5-1 summarises the major roads overtopped during the range of modelled design events

TABLE 5-1 MAJOR ROADS OVERTOPPED

Location	Road	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%
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 (Camerons 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	Guthreis Rd (Guthries Bridge)	2%

Flood level survey of 151 residential and commercial buildings was captured within the study area, including 78 in the Lake Goldsmith steam rally site. The flood results showed that in a 1% AEP event, there are 35 properties in Skipton, 74 properties at the Lake Goldsmith Steam Preservation Society site and three rural properties within the catchment identified to have above floor flooding. Figure 5-1 displays the properties inundated above floor flooding during the range of modelled AEP events at Skipton.

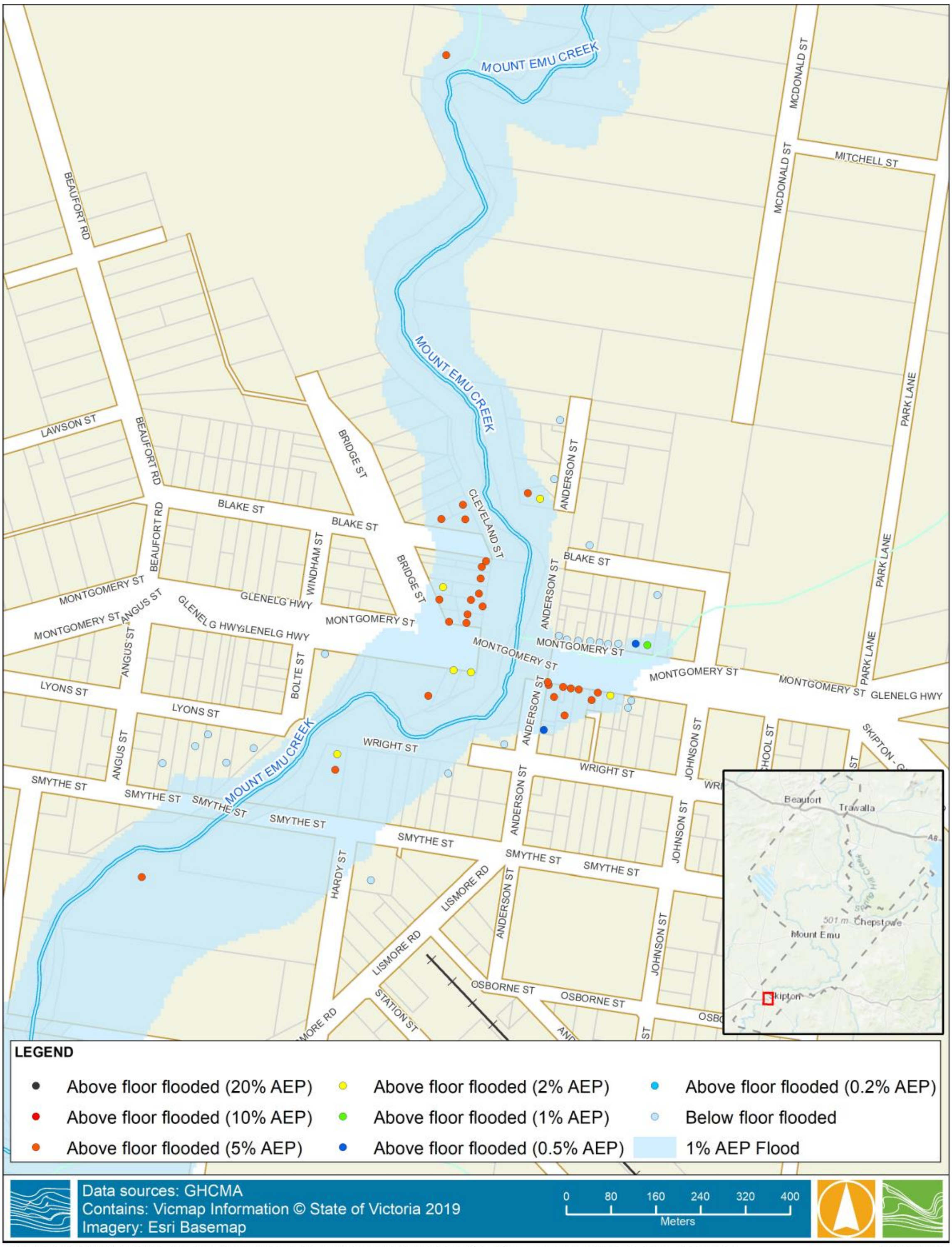

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FIGURE 5-1 PROPERTIES FLOODED ABOVE FLOOR DURING A RANGE OF AEP EVENTS

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5.2 Damages Assessment

The flood damage assessment determined the monetary flood damage for the range of modelled design events. 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 and below floor, properties did not have buildings impacted but the surrounding property was, and the length of flood affected roads.

A summary of flood damage assessment is shown in Table 5-2. Above floor flooding occurs during events as low as a 5% AEP (20 year ARI) event and the number of properties flooded is doubled above 2% AEP (50 year ARI) event. An Average Annual Damage (AAD) cost of $247,000 was determined.

TABLE 5-2 RIVERINE EXISTING CONDITIONS FLOOD DAMAGES

EXISTING CONDITIONS							
ARI (years)	500yr	200yr	100yr	50yr	20yr	10yr	5yr
AEP	0.002	0.005	0.01	0.02	0.05	0.1	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	32	32	30	27	20	0	0
Total Properties Flooded	**146**	**146**	**141**	**130**	**62**	**0**	**0**
Direct Potential External Damage Cost	$448,063	$437,773	$410,853	$356,854	$194,837	$0	$0
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	**$9,968,350**	**$9,015,234**	**$7,794,618**	**$5,349,070**	**$1,285,229**	**$0**	**$0**
Total Actual Damage Cost *(0.8*Potential)*	**$7,974,680**	**$7,212,187**	**$6,235,694**	**$4,279,256**	**$1,028,183**	**$0**	**$0**
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	**$8,568,724**	**$7,719,908**	**$6,627,522**	**$4,565,837**	**$1,221,672**	**$124,653**	**$85,897**

Average Annual Damage (AAD)	$247,267

6 FLOOD MITIGATION

The Flood Damages and Mitigation Assessment Report ()R06 documented the flood mitigation measures tested in hydraulic model.

6.1 Overview

Several mitigation options were assessed during this study, focusing on the Lake Goldsmith Steam Preservation Society and Skipton. The modelled mitigation options were either a requirement of the project and detailed in the tender brief or discussed with GHCMA and the project reference group. 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 Carngham – Lake Goldsmith bridge capacity - 1% AEP flood event.
  - Option 3 - Opening the Lake Goldsmith Diversion Channel at Cheesemans Road - 2016 and 1% AEP flood event.
- Skipton.
  - Option 4 - Doubling the size of the Glenelg Highway bridge - 1% AEP flood event.

6.2 Option 1 - Lake Goldsmith Steam Preservation Society levee

A levee was added around the Lake Goldsmith Steam Preservation Society site to prevent inundation. The levee blocked inundation from Mt. Emu Creek and increased water levels north and west of the site by slightly above 0.5 cm. The impact of the levee also resulted in a slight increase in water level in the diversion channel at Lake Goldsmith by about 2 cm. Water levels surrounding the steam rally site were slightly above 347 m AHD (i.e. approximately 1.5 m deep). If a levee were to be constructed it would also most likely require a 300-600 mm freeboard to meet the Victorian Levee Management Guidelines.

Overall, the construction of levee at the Lake Goldsmith Steam Preservation Society site is unlikely to have significant negative impacts on neighbouring properties, there are only minor increases in water level as a result of the levees restriction to floodplain flow.

6.3 Option 2 - Enlarging the Carngham – Lake Goldsmith bridge capacity

Enlarging the Carngham – Lake Goldsmith Rd bridge and removing constraints in the waterway channel was proposed to allow additional flow through the bridge and alleviate a backwater through the Lake Goldsmith Steam Preservation Society.

Results showed water levels within the floodplain immediately upstream of the bridge were reduced by more than 10 cm, including across the Lake Goldsmith Steam Preservation Society site. The flood extent was slightly reduced, with no flood water spilling into the diversion channel. There was also an increase in flood levels downstream of the Carngham – Streatham Rd bridge to Skipton, these increases relatively small with no enlargemnt of the flood extent.

Overall, the reduction in water level at the Lake Goldsmith Steam Preservation Society site does not effectively alleviate the flood risk a limited decrease to flood damages is expected.

6.4 Option 3 - Opening the Lake Goldsmith Diversion Channel at Cheesemans Road

Modelling of the Lake Goldsmith Diversion Channel both open and closed was completed for both the 2016 and 1% AEP event. The mitigation option aimed to evaluate whether opening the channel could reduce inundation of the Lake Goldsmith Steam Preservation Society. The channel was closed during the 2011 flood event but open during 2016. Modelling demonstrated a minor reduction in water levels could be achieved upstream of the channel. The diversion channel has a limited capacity and it cannot divert enough water to significantly reduce flood levels in Mt. Emu Creek. If this option was to be seriously considered, a large increase in the capacity of the channel would be necessary. However, this would be a costly exercise and be unlikely to significantly change the overall results given the relative comparison between the channel and the Mt. Emu Creek waterway and floodplain.

6.5 Option 4 – Increasing the size of the Glenelg Highway bridge at Skipton

Modelling of an increase to the Glenelg Highway bridge capacity (around double) showed flood level decreases of 10-15cm. There were no significant decreases in flood extent and flood risk within Skipton was not considered significantly reduced.

7 FLOOD WARNING

The Flood Warning Report (R05) detailed the flood warning deliverables and discussed the uncertainty in rating curve estimates and travel times.

7.1 Overview

The tender document sets out several specific flood improvements required to facilitate the implementation of a formal flood warning service for Skipton. The Bureau of Meteorology has highlighted the following locations as potentially useful gauging stations for Mt. Emu Creek:

- Mount Emu Creek at Guthrie's Bridge (has been used for PALS deployments).
- Mount Emu Creek at Mena Park (historic gauging station).
- Mount Emu Creek at Camerons Bridge (new gauging station).
- Mount Emu Creek at Skipton (historic gauging station).
- Mount Emu Creek at Trawalla (potential future gauging station).
- Baillie Creek at Carngham – Streatham Road (proposed PALS site).

The hydraulic model was used to produce raining curves at each of the above locations and the travel time estimates between each of them. The theoretical rating curves were compared to the available existing curves (where available) and historic observations. Travel time estimates are presented in a table showing a range of travel times dependent on the magnitude of events.

7.2 Summary and Outcomes

- Gauge Rating Curve Estimates
  - Comparisons between the existing and modelled rating curve was made. Information on low flows was missing in the modelled rating curves given only relatively high flow events were modelled. The modelled rating curved are expected to perform much more accurately high flow when the total flow is dominated by floodplain flow. An example rating curve comparison at Skipton is shown in Figure 7-1.

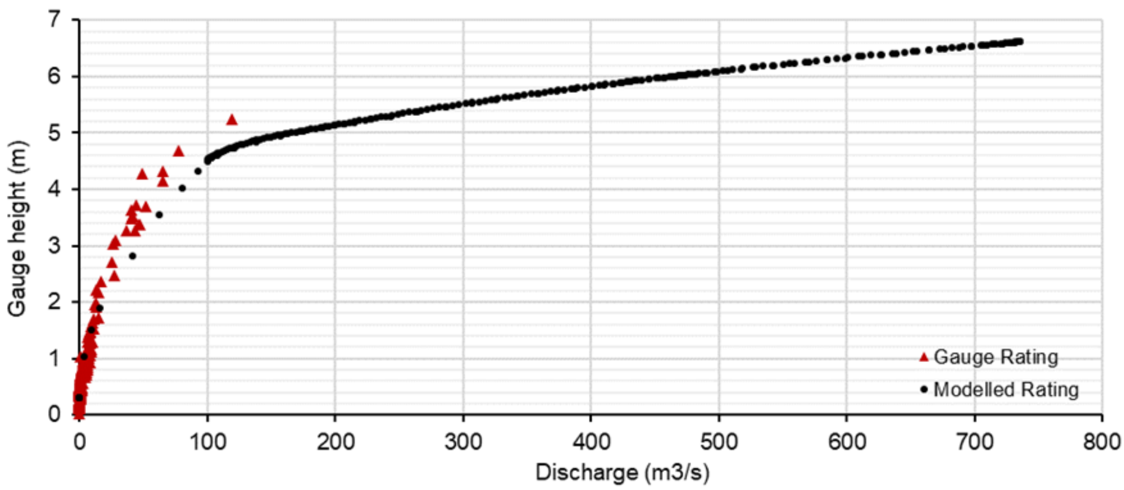

FIGURE 7-1 RATING CURVE COMPARISON AT SKIPTON GAUGE

- Travel Time Estimates
  - The effective warning time along the Mt. Emu Creek and Baillie Creek varies between flood events, depending on the storm durations, the magnitude of the event and catchment antecedent conditions. The travel time from the Mena Park gauge to Camerons Bridge is generally between 5 to 9 hours. The travel time from upstream gauges along Mt. Emu Creek and Baillie Creek to the Skipton gauge and Guthries Bridge gauge varied depending on which waterway dominated flow. From a flood warning perspective, Guthries Bridge can confirm the expected forecast at Skipton and should be used as a key site supporting flood forecasting. The travel time from Guthries Bridge gauge to Skipton gauge was between 2 to 4 hours. An example of travel time for the January 2011 flood is shown below.

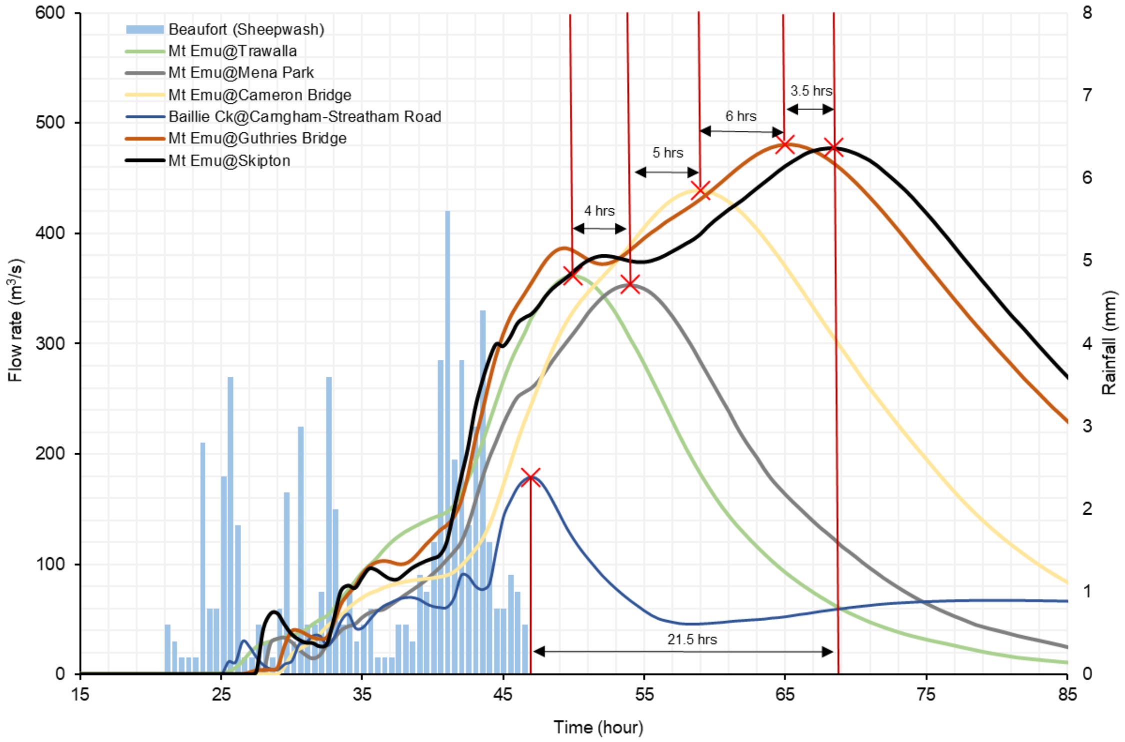

FIGURE 7-2 TRAVEL TIME ESTIMATES FOR JANUARY 2011 FLOOD

8 FLOOD INTELLIGENCE

The flood intelligence outputs were produced in two separate reports, each prepared for the Municipality Flood Emergency Plan (MFEP) for Corangamite and Pyrenees Shire Councils (i.e. MFEP Report – R07).

8.1 Flood Intelligence Deliverables

The typical flood peak travel times between key locations along Mt. Emu Creek and Baillie Creek were calculated. Table 8-1 below shows the Typical Flood Peak Travel Times Table prepared for Corangamite Shire Council.

TABLE 8-1 TYICAL FLOOD PEAK TRAVEL TIMES

Location From	Location To	Typical Travel Time	Comments
Riverine flooding – Mt. Emu Creek			
Start of rainfall	Trawalla	4 to 11 hours	To start of rise, the bigger the flood the closer time will be to 4 hours
Start of rainfall	Mena Park	7 to 14.5 hours	To start of rise, the bigger the flood the closer time will be to 7 hours
Start of rainfall	Camerons Bridge	8.5 to 20.5 hours	To start of rise, the bigger the flood the closer time will be to 8.5 hours
		38 to 49.5 hours	To peak
Start of rainfall	Guthrie's Bridge	5.5 to 18 hours	To start of rise, the bigger the flood the closer time will be to 5.5 hours
Start of rainfall	Skipton	6.5 to 16 hours	To start of rise, the bigger the flood the closer time will be to 7 hours
		47.5 to 63 hours	To peak
Trawalla	Skipton	18.5 to 27 hours	The bigger the flood the closer time will be to 18.5 hours
Mena Park	Skipton	14.5 to 20.5 hours	The bigger the flood the closer time will be to 14.5 hours
Camerons Bridge	Skipton	9.5 hours to 13.5 hours	The bigger the flood the closer time will be to 9.5 hours
Guthrie's Bridge	Skipton	0.5 to 3.5 hours	The bigger the flood the closer time will be to 0.5 hours
Riverine flooding – Baillie Creek			
Start of rainfall	Carngham – Streatham Road	4.5 to 10.5 hours	To start of rise, the bigger the flood the closer time will be to 4.5 hours
Carngham – Streatham Road	Skipton	20 to 34.5 hours	Peak at Skipton driven by Mt. Emu Creek
		3.5 to 5 hours	Peak at Skipton driven by Baillie Creek

A flood intelligence card was created to inform decision making during a flood event. It described the water level at each gauge station and the corresponding magnitude of the event (i.e. AEP event), the consequence of inundation and actions required to reduce it. An example of this deliverable is shown below.

TABLE 8-2 EXAMPLE OF FLOOD INTELLIGENCE CARD (20% AND 10% AEP)

Water level at Mt. Emu Creek, Skipton Gauge (m) (m AHD)	Annual Exceedance Probability (%AEP)	Consequence/ Impact	Action Actions may include: Evacuation, closure of road, sandbagging, issue warning and who is responsible etc.
It is important that the decision to mobilise to remove furniture, etc from buildings is made early and that, in general, sandbagging is reserved for non weatherboard buildings.			
USING THIS INTELLIGENCE CARD. Consider the appropriate flood inundation map. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Note that that some actions may need to be initiated in an order that is different from their relative placement in this table.			
If response has been initiated locally, the first action should be a call to VICSES.			
4.18 m **274.66 m AHD**	Minor Flood Level 20% AEP (5 year ARI)	▪ Stewart Park fills early ▪ No overbank flows ▪ No properties flooded ▪ Bridge overtopping at Smythe St	▪ Monitor rainfall and water level ▪ Place “Water over road” signs at Smythe St and consider closing this road ▪ If creek flooding likely to increase consider how to maintain function of aged care facility.
4.89 m **275.37 m AHD**	Minor Flood Level 10% AEP (10 year ARI)	▪ Breakout of flood water from eastern bank of Mt. Emu Creek ▪ Overtopping at Wright St and Smythe St ▪ Flood water flowing southward and inundating lands ▪ Property at 1 Pett St flooded below floor	▪ Continue to monitor rainfall and water level ▪ Place “Water over road” signs and consider closing inundated roads ▪ If creek flooding likely to increase, consider how to maintain function of aged care facility. ▪ Warn/sandbag property at 1 Pett St

Inundation tables were created to summarise the potential number of properties and roads inundated, their locations and the potential duration of isolation during a flood event. Examples are shown below.

TABLE 8-3 EXAMPLE PROPERTY INUNDATION SUMMARY

Summary of number of flood affected properties in Skipton							
	Design Flood AEP (%)						
	20%	10%	5%	2%	1%	0.5%	0.2%
Level at Skipton gauge, Mt Emu Creek (m)	**4.18**	**4.89**	**5.23**	**5.76**	**6.08**	**6.29**	**6.63**
Equivalent level in m AHD	274.66	275.37	275.71	276.24	276.56	276.77	277.11
Number of properties flooded above floor	0	0	28	33	35	37	37
Number of properties flooded below floor only	0	1	4	1	2	0	2
Total number of flooded properties	0	1	32	34	37	37	39

TABLE 8-4 EXAMPLE OF INUNDATION TABLE (5% AEP)

USING THE INUNDATION TABLES: the % AEP Flood (Annual Exceedance Probability) depends on a variety of factors such as catchment saturation, antecedent stream levels and rainfall intensity/duration. The "flood/no flood" calculator can provide a rough estimate of the flood magnitude. The CMA or a competent flood analyst should be consulted to assist in estimating the likely event magnitude

AEP	Properties Impacted by Over floor Flooding [note 1, 2, 7]	Depth over floor (m)	Type of Building	Sandbag? (yes/no) [note 3]	Roads Impacted by Flooding and approximate location [note 6]	Duration of impassable inundation (hour)	Maximum Depth over road (m)	Action [note 8]
5%								
5%	38 Bridge Rd	1.0	Residential		Smythe St	85	3.36	Road closed signs
5%	1 Cleveland St	0.29	Old common school - Bluestone		Wright St	45	0.59	Road closed signs
5%	3 Cleveland St	0.28	Residential		Hardy St		0.27	Water over road signs
5%	3 Cleveland St	0.26	Residential - Brickhouse		Montgomery St East	13	0.42	Road closed signs
5%	5 Cleveland St	0.16	Residential		Montgomery St West		0.26	Water over road signs
5%	Lot 2 Hardy St	0.40	Commercial - Tin Shed 'Castlebar'		Cleveland St	34	0.57	Road closed signs
5%	23 Montgomery St	0.41	Bluestone (Skipton Hotel Bar)		Anderson St South		0.23	Water over road signs
5%	23 Montgomery St	0.43	Render over brick (Hotel Dining Lounge)		Montgomery St North	53	0.44	Road closed signs
5%	23 Montgomery St	0.64	Bluestone Shed (No apparent floor level)					
5%	25 Montgomery St	0.40	Weatherboard					
5%	27 Montgomery St	0.06	Commercial					
5%	1 Pett St	0.48	Shed on stumps					
5%	Historical Society Museum	0.49	Commercial					

USING THE INUNDATION TABLES: the % AEP Flood (Annual Exceedance Probability) depends on a variety of factors such as catchment saturation, antecedent stream levels and rainfall intensity/duration. The “flood/no flood” calculator can provide a rough estimate of the flood magnitude. The CMA or a competent flood analyst should be consulted to assist in estimating the likely event magnitude

AEP	Properties Impacted by Over floor Flooding [note 1, 2, 7]	Depth over floor (m)	Type of Building	Sandbag? (yes/no) [note 3]	Roads Impacted by Flooding and approximate location [note 6]	Duration of impassable inundation (hour)	Maximum Depth over road (m)	Action [note 8]
5%	Art Gallery	0.662	Commercial					
5%	Eel Factory	0.321	Commercial					
5%	FoodWorks (existing)	0.280	Commercial					
5%	Healthcare Pharmacy	0.354	Commercial					
5%	Garage (workshop)	0.571	Commercial					
5%	Skipton Pottery	0.088	Commercial					

9 RECOMMENDATIONS

Recommendations made during the Upper Mt. Emu Flood Investigation have been separated into the agencies responsible for their fulfilment, these are as follows:

- **Corangamite and Pyrenees Shire Councils**
  - Endorse the flood study before putting it out for public comment with the aim of implementing a planning scheme amendment to update the flood related planning overlays – LSIO and FO.
  - Review of existing water level boards along road networks impacted.
  - Review the information within this document to undertake an update of the MFEP and discuss with VicSES the changes proposed by Water Technology prior to adopting the revised document.
  - Actively promote the use of the VicEmergency website and App to the community to improve flood preparedness and awareness.
  - Undertake a review of the current response, maintenance and operations documentation with Council staff.
  - Update Local Flood Guide.
  - The potential for a levee around the Lake Goldsmith Steam Preservation Society be considered in more depth.
- **Glenelg Hopkins Catchment Management Authority**
  - Endorse the flood study and use the flood mapping data to inform floodplain risk management decisions.
  - Upload the Victoria Flood Database mapping data and the excel spreadsheet of property inundation to FloodZoom.

  Victoria State Emergency Service with assistance from Corangamite CMA and City of Greater Geelong:

  - Continue to engage the community through regular flood awareness programs such as the VICSES FloodSafe program.
  - Update Local Flood Guide.
  - Provide assistance to Corangamite and Pyrenees Shire Councils in updating the MFEP.
  - Review the updated MFEP (when available) and discuss with Council the changes proposed by Water Technology prior to adopting the revised document.

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