Skipton Flood Investigation

Summary Study Report

March 2013

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PROJECT DETAILS

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EXECUTIVE SUMMARY

This report details the input data, approach and outcomes for the Skipton Flood Investigation.

The study has been initiated by the Glenelg Hopkins Catchment Management Authority (GHCMA) in order to define the extent and characteristics of flooding in Skipton so that future planning decisions may be soundly based and measures may be put in place to minimise risk to the community.

The study provides information on flood levels and flood risk within the township of Skipton for both local catchment and Mt Emu Creek flooding. The study involved a rigorous technical analysis of the drivers for flooding, which provided confidence in the use of this information to guide floodplain management in and around Skipton.

Community consultation was undertaken during the early stages of the study, primarily in order to gather data and accounts of flooding. The flood information provided by residents was invaluable in the development of the study outcomes.

A hydrologic analysis of Mt Emu Creek was undertaken to determine design flood hydrographs for the 20%, 10%, 5%, 2%, 1% and 0.5% annual exceedance probability (AEP) flood events at Skipton as well as the probably maximum flood (PMF) and climate change scenarios. A rigorous approach has been applied to test and validate the design flows by utilising a number of hydrologic approaches including Flood Frequency Analysis, regional comparisons, and development of a detailed hydrologic (RORB) model. The adopted design flood inflows for the study, listed in Table 1, are considered appropriate for the definition of flood risk in Skipton.

Table 1 Design peak flows at Skipton

Location	Mt Emu Creek Catchment Design Peak Flow (m^3/s)					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP
Skipton	78	136	221	386	575	827

To place the design peak flows in a historical context, the approximate AEP (and Average Recurrence Interval, ARI) of significant historical flood events are provided in Table 2. The January 2011 event is the largest gauged event recorded at Skipton over 90 years of record. Historical information suggests an event of similar magnitude occurred in 1909 although no gauge data exists for the event. Prior to the January 2011 and September 2010 flood there had been no events of similar or greater magnitude at Skipton since 1933.

Table 2 Mt Emu Creek, Approximate AEP/ARIs for significant historical flood events

Historical event (year)	Approximate AEP/ARI (based at Skipton)
January 2011	1.5% / 70 years
September 2010	7% / 15 years
August 2010	20% / 5 years

A digital terrain model (DTM) was developed from field and LiDAR survey. Using the DTM, a hydraulic model was established to simulate flood behaviour within the study area. Flood behaviour was assessed for flooding originating from Mt Emu Creek and local catchment runoff. The hydraulic model was calibrated to three historic flood events (January 2011, September 2010 and August 2010). There was a good level of calibration data available for these recent events which enabled a high level of model calibration to be achieved. The outputs of the hydraulic modelling are considered appropriate for the definition of flood risk in Skipton.

A flood risk assessment was undertaken which involved the estimation of tangible flood damages for a range of design events. The average annual damage (AAD) was then calculated to be approximately $133,551 per year with current topography and flows. These results showed that up to and including the 10% AEP flood event relatively minor flood damages are predicted with only 6 properties flooded above floor from a total of 25 flood effected properties. From the 5% AEP flood, damages increase more rapidly. Table 3 below summarises the flood damage calculations. Flooding of property for those events up to and including the 10% flood are predominantly a result of local catchment flooding, whereas above the 10% AEP event flooding directly from Mt Emu Creek occurs.

Table 3 Flood Damage Assessment Costs for Existing Conditions

Parameter	**Annual Exceedance Probability**					
	0.5%	**1%**	**2%**	**5%**	**10%**	**20%**
Buildings Flooded Above Floor	37	36	30	25	6	6
Properties Flooded Below Floor	14	13	14	15	19	9
Total Properties Flooded	51	49	44	40	25	15
Direct Potential External Damage Cost	$53,606	$41,059	$46,340	$53,473	$56,096	$24,183
Direct Potential Residential Damage Cost	$518,035	$439,355	$266,231	$120,300	$22,037	$20,474
Direct Potential Commercial Damage Cost	$1,394,588	$1,217,992	$1,111,192	$473,337	$171,787	$159,304
Total Direct Potential Damage Cost*	**$1,966,229**	**$1,698,405**	**$1,423,762**	**$647,110**	**$249,920**	**$203,960**
Total Actual Damage Cost *(0.8*Potential)*	**$1,572,983**	**$1,358,724**	**$1,139,010**	**$517,688**	**$199,936**	**$163,168**
Infrastructure Damage Cost	**$91,193**	**$82,337**	**$73,519**	**$56,523**	**$33,470**	**$18,352**
Indirect Clean Up Cost	$156,281	$150,838	$120,143	$96,851	$22,852	$22,852
Indirect Residential Relocation Cost	$10,688	$9,924	$6,107	$3,817	$763	$763
Indirect Emergency Response Cost	$23,269	$23,269	$23,269	$13,961	$9,308	$4,654
Total Indirect Damage Cost	**$190,238**	**$184,031**	**$149,519**	**$114,629**	**$32,923**	**$28,269**
Total Damage Cost	**$1,854,414**	**$1,625,093**	**$1,362,047**	**$688,840**	**$266,329**	**$209,789**

A feasibility assessment was undertaken of 8 flood mitigation options. Based on the outcomes of the feasibility assessment 3 options were investigated in more detail including preliminary cost estimates. The three options assessed were:

- Installation of flap gates on local drainage pipes discharging into Mt Emu Creek,
- Upgrading of local drainage infrastructure receiving water from Skipton Reservoir, and
- Increased Mt Emu Creek channel capacity through the town through vegetation and debris removal.

Of the options tested, the installation of flap gates on local drainage pipes was the most cost effective, providing a modest benefit in the 10% AEP flood for limited cost. Upgrading the local drainage provided a major benefit to the Average Annual Damage Cost but was a high cost option.

Vegetation and debris clearing from Mt Emu Creek through the town could result in a moderate reduction in Average Annual Damage Cost for a moderate cost. However, this option would require regular maintenance which would significantly increase its long-term cost. It would also cause detrimental impacts to the character, amenity and biodiversity of the creek reserve through the town, which were not incorporated into the cost estimates. Overall, there was no mitigation option (or suite of options) identified that would significantly reduce the flood risk and flood damage costs at Skipton for larger flood events.

A draft flood related planning overlay map, Floodway Overlay (FO), has been prepared to reflect the study outcomes. The FO delineates land that is subject to high hazard flooding based on the depth and velocity of flood water and the frequency of flooding.

Flood response maps have also been produced that relate flood extents in Skipton to gauge heights on the Mt Emu Creek at Skipton gauge. These maps will assist VICSES and Council in planning for and responding to flood situations. This information has also been integrated into a proposed flood intelligence tool as part of the Corangamite Municipal Flood Emergency Plan (MFEP).

An assessment of flood warning issues and options has been undertaken, resulting in a detailed report on flood warning options as part of a total flood warning system for Skipton. The following staged approach to the development of a flood warning system has been proposed:

1. Work to ensure roles and responsibilities are agreed, understood and accepted across all relevant agencies and that there is a firm foundation for the development of an effective flood warning system.
2. Establishment of a robust framework for communicating and disseminating flood related information so that immediate and maximum use can be made of available information as the ability to detect and predict flooding at Skipton improves.
3. Secure the funding needed to buy, install and operate field equipment as well as other services needed to build elements of the total flood warning system.
4. The installation of data collection equipment then follows, with a two tiered approach in the event that funding is not available or is delayed.
5. Development of other technical elements and the build and delivery of on-going flood awareness activities then occur in the knowledge that required data is / will be available and that robust and sustainable arrangements are in place that will enable maximum benefit to be derived from any information or programs delivered to the community.

In light of the study outcomes it is recommended that:

- The GHCMA and Corangamite Shire Council adopt the determined design flood levels and proceed with the planning scheme amendment process.
- The Corangamite Shire Council and GHCMA continue to engage the community in the treatment of flood risks through regular flood awareness programs such as the VICSES FloodSafe program, starting with the development of a local flood guide.
- The Corangamite Shire Council and GHCMA explore further the recommendations for enhanced flood response through co-operation with VICSES and Police, utilising the flood inundation maps and flood intelligence tools included in the Municipal Flood Emergency Plan (MFEP). Consideration should be given to the use of the MFEP during an emergency.
- The Corangamite Shire Council and GHCMA explore further the recommendations for the development of the proposed total flood warning system for Skipton in conjunction with the Bureau of Meteorology and VICSES.

ACKNOWLEDGEMENTS

Numerous organisations and individuals have contributed both time and valuable information to the Skipton Flood Investigation. The study team acknowledges the contributions made by these groups and individuals, in particular:

- Graeme Jeffery (Glenelg Hopkins CMA & Project Manager)
- Lyall Bond (Corangamite Shire Council)
- Simone Wilkinson (Department of Sustainability and Environment)
- Nurullah Ozbey, Thiess Hydrographic Services.

The study team also wishes to thank all those stakeholders and members of the public who participated in the steering group and community information sessions and provided valuable records (including historic photos) and discussed their experiences and views on flooding in and around Skipton.

GLOSSARY OF TERMS

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be of extreme magnitude.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood damage	The tangible and intangible costs of flooding.
Flood frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity.
Flood mitigation	A series of works to prevent or reduce the impact of flooding. This includes structural options such as levees and non-structural options such as planning schemes and flood warning systems.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.

Freeboard	A factor of safety above design flood levels typically used in relation to the setting of floor levels or crest heights of flood levees. It is usually expressed as a height above the level of the design flood event.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Intensity frequency duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
LiDAR	Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping.
MIKE FLOOD	A hydraulic modelling tool used in this study to simulate the flow of flood water through the floodplain. The model uses numerical equations to describe the water movement.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Probable Maximum Flood	The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequence and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Topography	A surface which defines the ground level of a chosen area.

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1. INTRODUCTION

1.1 Overview

The Glenelg Hopkins Catchment Management Authority (GHCMA), in partnership with Corangamite Shire Council (CSC) commissioned Water Technology in association with Michael Cawood & Associates and Planning & Environmental Design to undertake the Skipton Flood Investigation. This study involved detailed hydrological and hydraulic modelling of Mount Emu Creek, flood mapping of relevant areas, flood warning assessment, provision of planning documentation and provision of recommendations for flood mitigation works.

The objective of the Skipton Flood Investigation was to define the extent and characteristics of flooding in Skipton so that future planning decisions may be soundly based and measures may be put in place to minimise risk to the community.

The study addressed the following aspects:

- Examine contributing factors to flood events within Skipton including variables within the Mount Emu Creek Catchment;
- Determine flood levels and extents for a range of flood modelling scenarios within the study area;
- Consider and assess capacity and efficiency of local stormwater system
- Provide draft documentation to be used to update the Corangamite Planning Scheme to reflect the findings of the investigation;
- Consider and provide recommendations for the provision of a flood warning system for the study area;
- Provide draft documentation for inclusion in the Corangamite Shire Municipal Flood Emergency Plan;
- Consider and provide recommendations about achievable flood mitigation options.

1.2 Study Catchment and Floodplain

Skipton is a small rural township located in the Western District of Victoria, approximately 50 km west of Ballarat. It is situated within the Mt Emu Creek catchment. The Mount Emu Creek headwaters begin north of Beaufort in an area between Beaufort and Lexton. From there it meanders southwest and through Skipton and continues southward to join the Hopkins River just upstream of Warrnambool near Cudgee.

There are five major sub-catchments comprising:

- Upper Mt Emu Creek with its headwaters just south of Lexton;
- Yam Holes Creek which rises to the north and west of the catchment and then passes through Beaufort;
- Trawalla Creek with its headwaters a little to the east and north of Chute;
- Spring Hill Creek which joins Mt Emu Creek a little downstream from Mena Park; and
- Burrumbeet Creek which rises to the northeast of Ballarat passes through Invermay and Miners Rest and discharging into Lake Burrumbeet. Lake Burrumbeet outflows to Baillie Creek which joins Mt Emu Creek well downstream from Mena Park.

Other tributary creeks include Broken Creek, Blacks Creek, Reedy Creek and numerous small, unnamed or locally named tributaries. Figure 1-1 provides an overview of the hydrologic catchment extent for Mt Emu Creek at Skipton. This includes the Lake Burrumbeet and Mena Park catchments.

Apart from the township areas of Skipton, Beaufort, Wendouree and Miners Rest, land use across the catchment is primarily agricultural.

Major storages in the catchment are Lake Burrumbeet and Lake Goldsmith. Lake Burrumbeet is located at the downstream end of Burrumbeet Creek, overflowing to Baillie Creek and then on into Mt Emu Creek. Lake Burrumbeet has a surface area of approximately 23 km^2 and a capacity at full level of approximately 38.4 GL. The lake has a large active storage capacity and a small capacity weir outlet, meaning that it has a strong retarding effect on flows from the Burrumbeet catchment. The Lake Goldsmith reservoir has a surface area of around 8.9 km^2 and a capacity at full level of approximately 7.5 GL. The lake has been previously connected to Mt Emu Creek via a channel and gated structure. The structure has never been in operation and the gates remain closed so that Lake Goldsmith is not directly connected to Mount Emu Creek.

Mount Emu Creek through Skipton is a partially confined channel with a bankfull width of approximately 50 m and a bankfull depth of approximately 5 m. Natural levees are present on one or both sides of the channel, particularly downstream of the town. The floodplain is well-defined, with steep-sided margins, and its width through the township is approximately 150-200 m. The floodplain is narrower upstream of the town and widens to a width of approximately 400 m just downstream of the study area. The creek banks are vegetated with a narrow strip of mature riparian vegetation.

The study area for the purposes of flood modelling, mapping and planning aspects of this project covers a 5 km reach of the Mount Emu Creek and floodplain through Skipton township. The study area is shown in Figure 1-2.

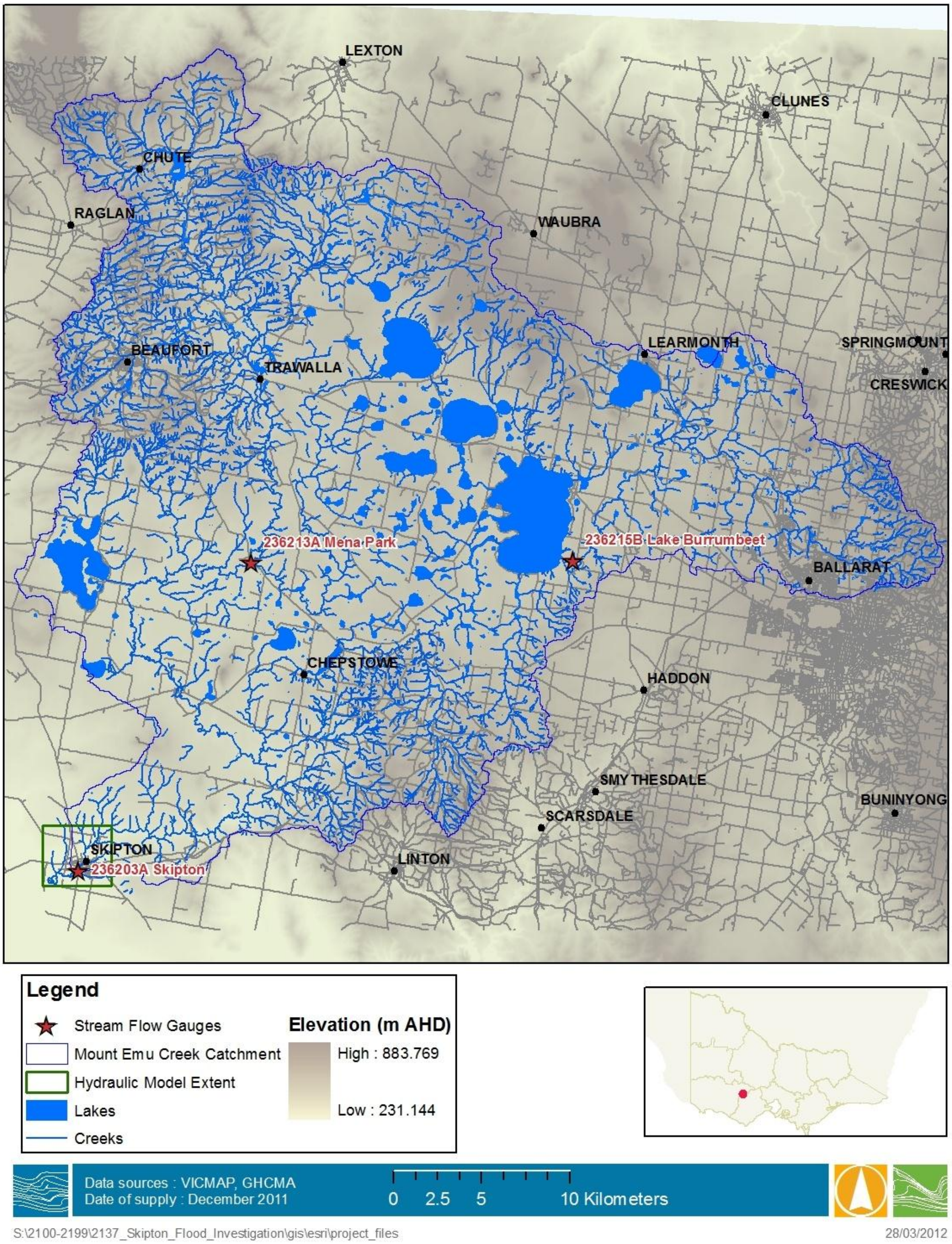

Figure 1-1 Mt Emu Creek catchment extent including waterways and storages

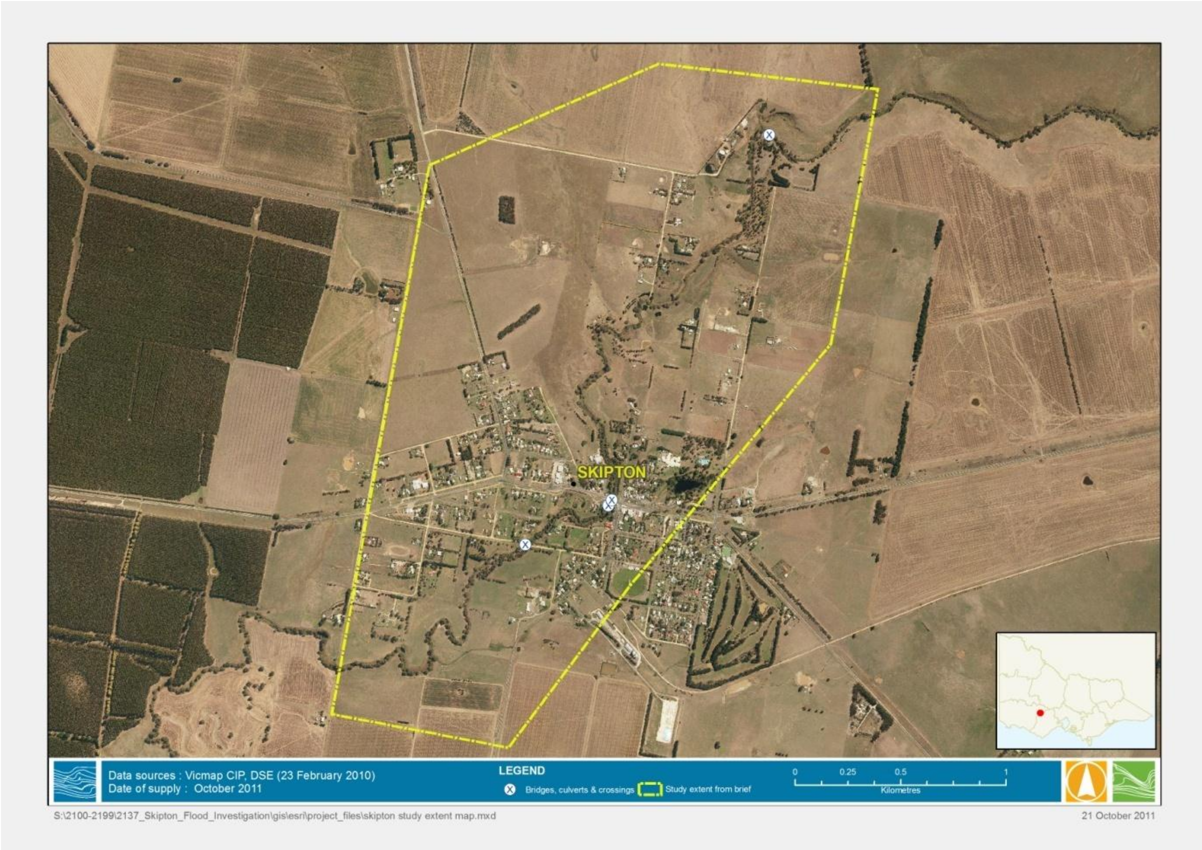

Figure 1-2 Study Area

1.3 Historical and Recent Flood Events

Skipton is located within a natural floodplain and has a long history of flooding. The following historical flood images have been provided by Corangamite Shire Council and show significant flood events in Skipton since 1870 and their impacts on Skipton.

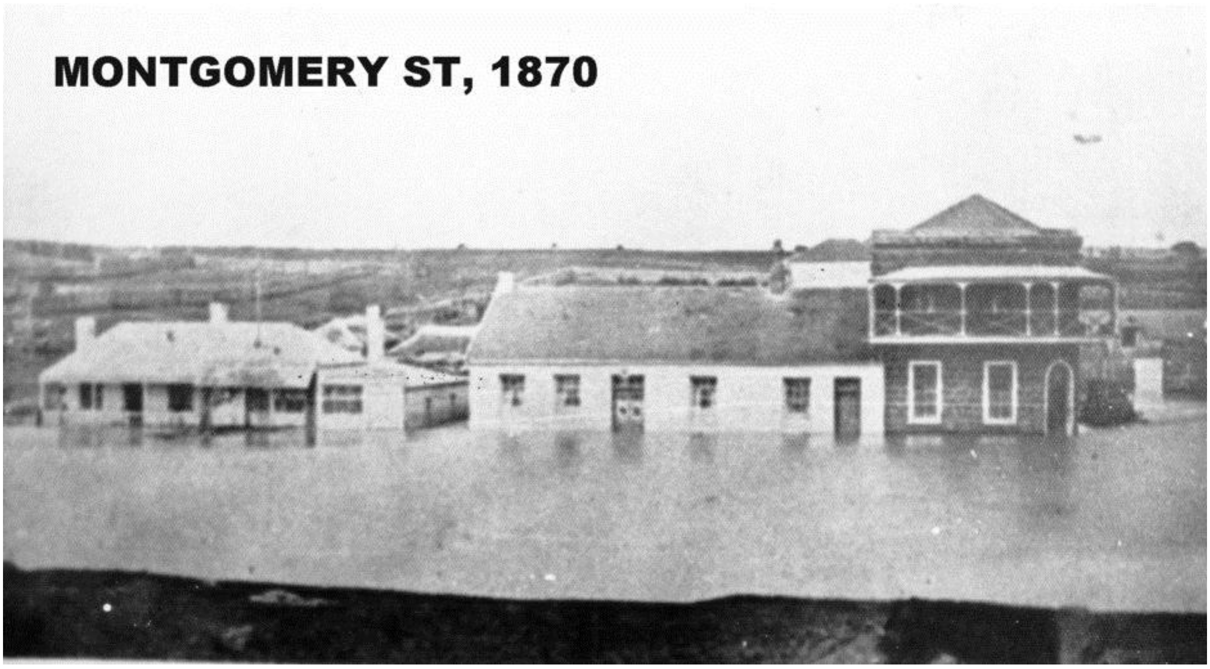

Figure 1-3 Skipton Flood Photos – 1870 (Corangamite Shire Council)

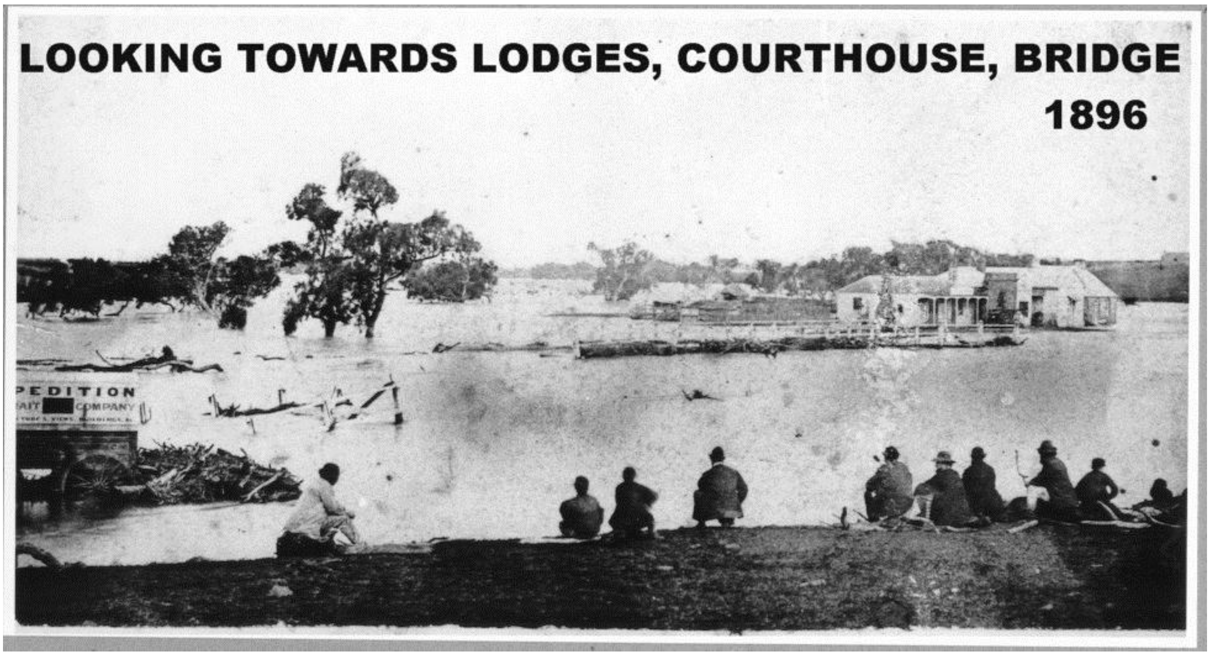

Figure 1-4 Skipton Flood Photos – 1896 (Corangamite Shire Council)

Figure 1-5 Skipton Flood Photos – 1909 (Corangamite Shire Council)

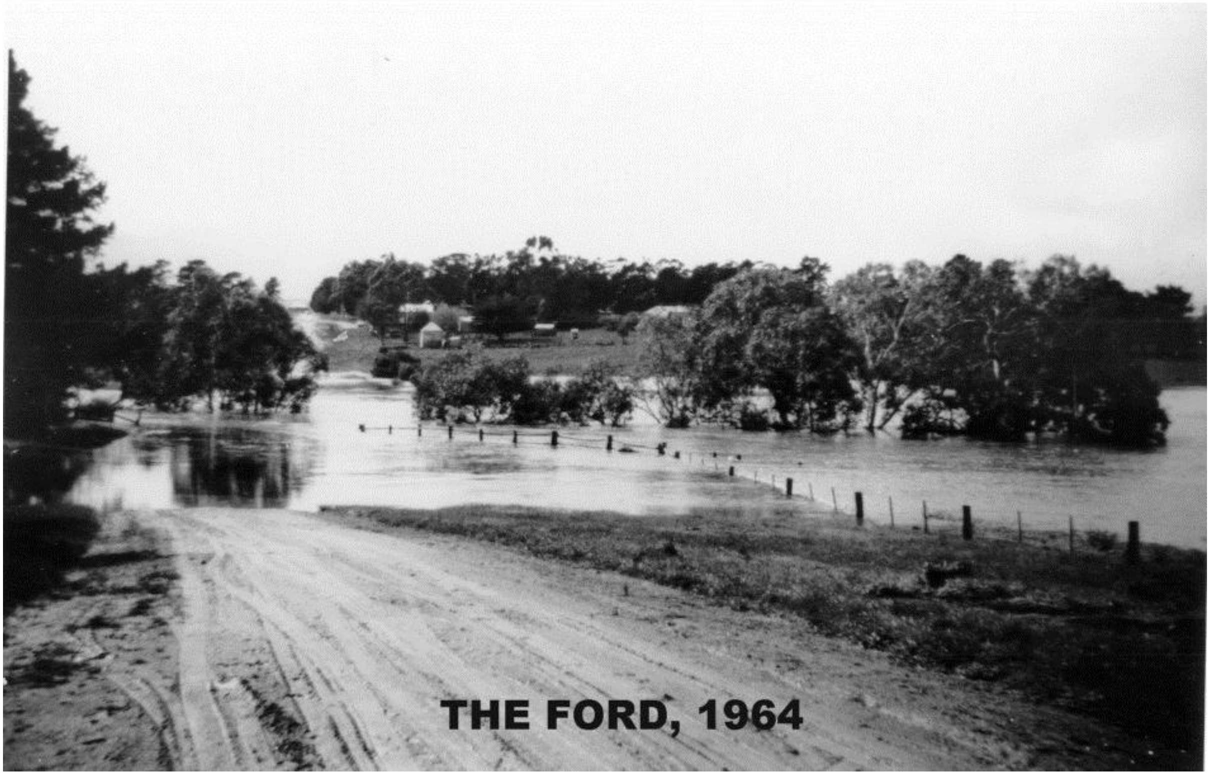

Figure 1-6 Skipton Flood Photos – 1964 (Corangamite Shire Council)

The annual flood series at the Skipton gauging station is shown in Figure 1-7, presenting the maximum peak instantaneous flow recorded in every year. This clearly shows the range of flood events that have historically been experienced in the township, with significant flood events occurring in the early 1920s, 1933 and the recent floods in 2010 and 2011.

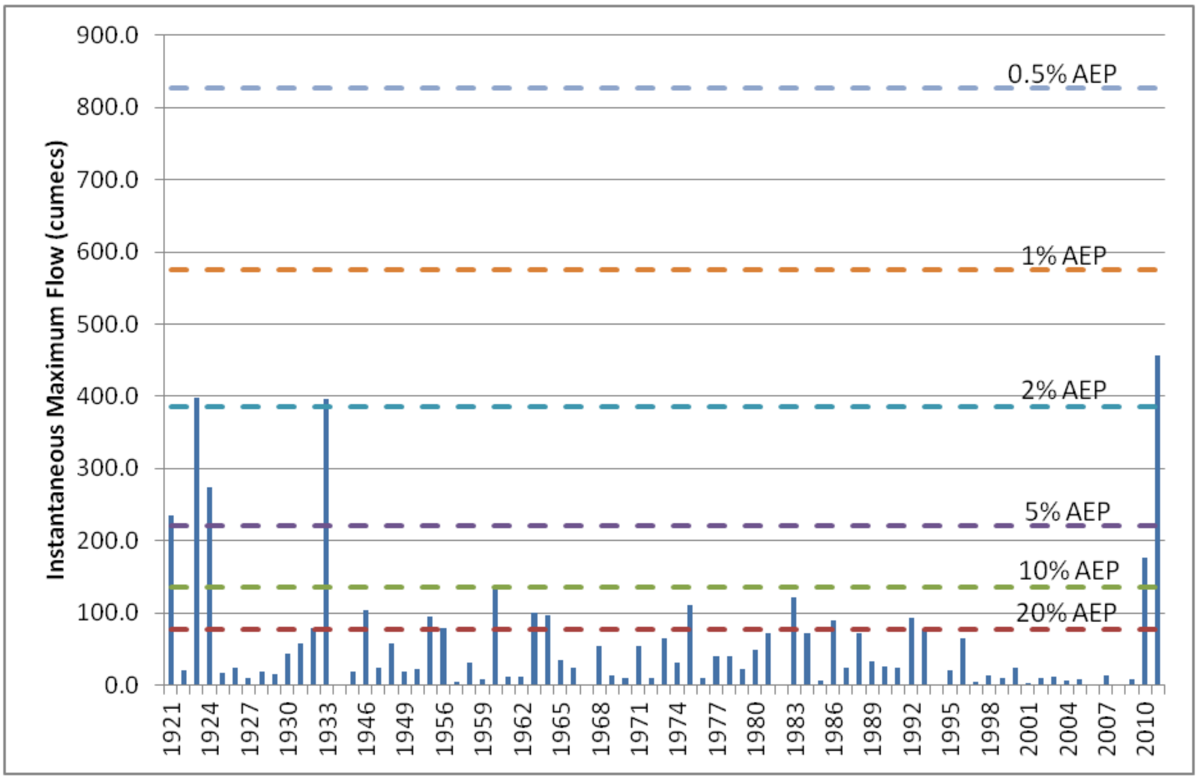

Figure 1-7 Annual Series for Mount Emu Creek at Skipton, also showing AEP design flows

Skipton was significantly affected by the flood events in Mount Emu Creek in August and September 2010 and January 2011.

The flood event in 1909 was ungauged but is thought to be the largest flood event to occur in Skipton until the recent January 2011 flood event although there are no flow or gauge records to confirm this. Records indicate that flooding historically occurs between the months of August and January.

August 2010

Conditions prior to August 2010 were relatively dry. From Tuesday 10th to Thursday 12th August a low pressure system which developed over the interior of the continent moved over the State and into Bass Strait. As the low moved into Bass Strait and deepened on Wednesday 11th, very heavy rainfall was recorded in most western Victoria catchments including the Mt Emu Creek and Burrumbeet Creek catchments. The highest daily rainfalls were recorded on the 12th (e.g. Skipton, 32.4 mm; Ballarat Aerodrome, 49.6 mm; Beaufort, 33.2 mm). Rainfalls over the month were generally between 100 mm and 200 mm. Beaufort received its highest ever August rainfall total in 128 years of record.

Mt Emu Creek through Skipton experienced relatively minor flooding (approx. 20% AEP) over the period 11th to 14th August with the peak near or just above the top of bank through the town and at Stewart Park. No roads or buildings were inundated.

September 2010

Heavy rain was recorded in the Mt Emu Creek and Burrumbeet Creek catchments from late Friday 3rd into Saturday 4th as a result of the deepening of a low pressure system over South Australia and its passage into Bass Strait. The highest daily rainfall totals for the month were generally recorded on the 4th (e.g. Ballarat Aerodrome, 46 mm; Beaufort, 29.2 mm). The highest daily rainfall at Skipton (10 mm) was recorded on the 13th.

The flooding in Skipton was more severe than in August. The unnamed creek flowing through Jubilee Park Lake flooded first. It inundated Anderson Street and Montgomery Street and flooded a number of properties. Later, over-bank flooding from Mt Emu Creek occurred on the west (right) bank upstream of the Glenelg Highway Bridge and flooded a number of properties and dwellings. Backflow through a stormwater drain into the main commercial centre (Montgomery Street) also flooded a number of business premises and cut the Glenelg Highway (Montgomery Street). The eastern (left) bank of Mt Emu Creek was not overtopped. The September flood event was approximately a 7% Annual Exceedence Probability (AEP) event.

January 2011

The extreme rainfall observed during the month was generated by the passing of complex and persistent low pressure systems. A broad slow moving trough centered over western Victoria and a ridge of high pressure to the south of Tasmania were the main drivers for the rainfall which commenced on Sunday 9th January. The two systems created exceptionally humid conditions and unstable easterly flow across Victoria. The trough strengthened on Wednesday 12th and developed into a low pressure system over eastern South Australia on Thursday 13th as a high pressure system moved into the Tasman Sea. The low pressure system cleared the State on Friday evening after adding an additional 50 mm to 100 mm of rain. The Mt Emu Creek and Burrumbeet Creek catchments received between 200 mm and 300 mm of rain for the month. The highest daily falls were recorded on the 14th (e.g. Skipton, 64.4 mm; Ballarat Aerodrome, 95 mm; Beaufort, 78.6 mm).

In Skipton, shops on the lower end of Montgomery Street (the main commercial centre) including the supermarket, chemist, hotel, garage, art gallery and pottery were flooded along with 30 residential properties. Flood depths exceeded 1.5 m in some properties. The Glenelg Highway

Bridge was overtopped and the Highway was closed for more than 2 days. The town was split in two.

The event of 13-18th January 2011 was the largest flood on record and was estimated to be approximately a 1.5% AEP event. An aerial image of flooding in Skipton on 15th January 2011, close to the peak of that event, is shown in Figure 1-8.

Figure 1-8 Flooding in Skipton on 15th January 2011

1.4 Supporting Documents

A number of reports were prepared at each stage of the study. These reports were produced separate standalone volumes, and a summary of each is provided in Table 1-1. In addition to these documents, flood maps and GIS layers have been provided for each of the design, climate change and probable maximum flood events.

Table 1-1 Supporting documents

Volume	Document Number	Title	Summary
1	R01	Data Review	Review of flood related information for the study area, a review of available topographic and structure data (bridges and culvert information), and verification of topographic data including the identification of a discrepancy between the supplied ISC LiDAR data and field survey. It was agreed in consultation with the GHCMA that a correction factor be applied to the LiDAR dataset to resolve this discrepancy
2	R02	Modelling Methodology	Outline of hydrologic analysis and hydraulic modelling

Volume	Document Number	Title	Summary
		Report	methodology
3	R03	Hydrology	Hydrologic modelling and analysis report, summarising results of flood frequency analysis, RORB modelling, estimation of design event, climate change and probable maximum flood hydrographs
4	R04	Hydraulics Report	Hydraulic modelling report providing details of hydraulic model construction and calibration, and results of design event, climate change and probable maximum flood simulations
5	R05	Mitigation Options Report	Summary and assessment of mitigation options
6	R06	Planning Scheme Amendment	Documentation to support an application for planning scheme amendment to update local flooding controls in light of the study outcomes.
7	R07	Flood Warning Assessment Report	Review of flood warning systems and assessment of flood warning options for Skipton
8	R08	Municipal Flood Emergency Plan Appendices	Appendices to the Corangamite Shire Municipal Flood Emergency Plan, including a community flood emergency management plan for Skipton and detailing flood threats, flood rise and recession rates, travel times, evacuation arrangements and flood warning systems.

2. DATA REVIEW

On inception of the project a detailed review was undertaken of all available flood related information as well as topographic data, structure information, and hydrological data. Details of this review are provided in Volume 1, while a short overview is provided herein.

2.1 Flood Related Information

No detailed flood study has been completed previously for Skipton, and there are no flood-related planning scheme overlays. However there have been a number of flood related studies completed in Skipton and nearby:

- Beaufort Flood Study (2009) – Water Technology completed a flood study on the township of Beaufort (2008), including RORB modelling of the catchment above the Mena Park gauge,
- Skipton Flood Frequency Analysis - The Glenelg Hopkins CMA has completed Flood Frequency Analysis of Mt Emu Creek at Skipton (2009). This superseded an earlier Flood Frequency Analysis in 2008 by Glenelg Hopkins CMA.
- Western Highway Duplication - The Western Highway duplication by VicRoads recently involved Water Technology updating the Flood Frequency Analysis at the Mena Park Gauge in light of the 2010 and 2011 flood events.
- Burrumbeet Flood Investigation - Water Technology is currently undertaking a flooding investigation of the Burrumbeet Creek Catchment, a tributary of the Skipton study area.
- Glenelg Highway Bridge Design - GHD (2006) undertook HEC RAS flood modelling to assess the impacts of the proposed replacement Glenelg Highway Bridge crossing of Mt Emu Creek.

Historical flood records were also collected, which included the following:

- A historical overview of flood and heavy rainfall events in Skipton between 1851 and 1992 compiled by Juli Davine,
- Historical photographs, as supplied by Corangamite Shire Council,
- Flood data from the 2010-2011 events, as summarised in Table 2-1.

Table 2-1 Flood data summary for 2010-2011 events

Event	Data Available
August 2010	31 Flood photos from GHCMA 8 Flood marks (surveyed) Observed flood level profile along creek
September 2010	63 Flood photos from GHCMA 21 Flood marks (surveyed) Observed flood level profile along creek
January 2011	Flood photos: - 82 aerial (non-ortho) flood photos from CSC, - 49 flood photos from CSC - 145 flood photos from GHCMA Aerial flood photos (14 Jan, 15 Jan) 27 Flood marks (surveyed) 23 Floor levels within flood extent

2.2 Site Visit

A site visit was undertaken by Water Technology staff on 15th December 2011 with Lyall Bond of Corangamite Shire Council. The site visit provided an opportunity to assess flooding issues in Skipton, identify key structures and investigate locations and options for potential mitigation works. Structures and flood-affected areas within the study area were visited, as well as Lake Goldsmith and its connection channel and the Lake Burrumbeet outflow structure in the catchment upstream.

The sites visited in Skipton are shown in Figure 2-1.

Figure 2-1 Locations visited during site visit 15th December 2011 (Skipton Area)

2.3 Topographic Data

2.3.1 Available Datasets

Available topographic data for this study included LiDAR, an existing digital elevation model (DEM), as well as field survey. Verification of topographic data from various sources provided guidance on the suitability of the data for use in the hydrologic and hydraulic modelling.

Three sources of topographic and field survey data were obtained for preparation of the hydrological and hydraulic models. These included:

- Existing Digital Elevation Model (DEM). This information was used in the schematisation and development of the RORB hydrologic model of the Mt Emu Creek catchment.

- Light detection and ranging (LiDAR) data. The LiDAR information was used to create a digital elevation model (DEM) of the study area as the basis of the hydraulic model;
- Field survey (captured in January 2012 by ThinkSpatial for this study).

Details of each of the topographic data sets are provided in Volume 1.

2.3.2 Data Verification

The accuracy of the hydraulic modelling relies to a large degree on the accuracy of the topographic datasets. Therefore a detailed verification process was undertaken for the LiDAR using the field survey information.

It was expected that the LiDAR and field survey would line up quite closely. The only expected area of significant discrepancy was below the water level within the river channel, as LiDAR cannot penetrate the water column. However, the Index of Stream Condition (ISC) LiDAR was found to be consistently around 0.3 m higher than the surveyed levels.

A range of additional checks were undertaken to determine the possible sources of the discrepancy and possible inconsistency was identified in the post-processing of the ISC LiDAR.

To progress with the hydraulic model development for this study, it was agreed with GHCMA that a suitable correction factor be applied to the ISC LiDAR dataset.

2.4 Structure Information

The available structure information includes structure drawings as well as a field survey. Review of the data from various sources provided guidance on the reliability of the data for use in the hydrologic and hydraulic modelling.

2.4.1 Culverts & Bridges

Information (dimensions, inverts) of the key hydraulic structures (bridges/culverts) along Mt Emu Creek at Skipton was required for input into the hydraulic model and to understand the impacts of local drainage in particular on flooding issues in the township.

Once all relevant structures (including local drainage) were identified, detailed field survey of each structure was undertaken by ThinkSpatial in January 2012. An overview of all surveyed structures is provided in Figure 2-2.

2.4.2 Local Drainage

Details of the underground drainage network are important for the establishment of the hydraulic model and identification of flood related drainage issues. It should be noted however that this study did not consider the entire town stormwater system, and only considered components of the stormwater system that are important for larger flood events.

A number of culverts and drains discharge directly into Mt Emu Creek in the vicinity of the Glenelg Highway Bridge. The community expressed concern that these structures contribute to flooding within the township. In order to ensure the correct inverts and dimensions of all relevant structures the field survey by ThinkSpatial in January 2011 & March 2011 collected inverts, pipe/culvert dimensions and locations for all relevant infrastructure.

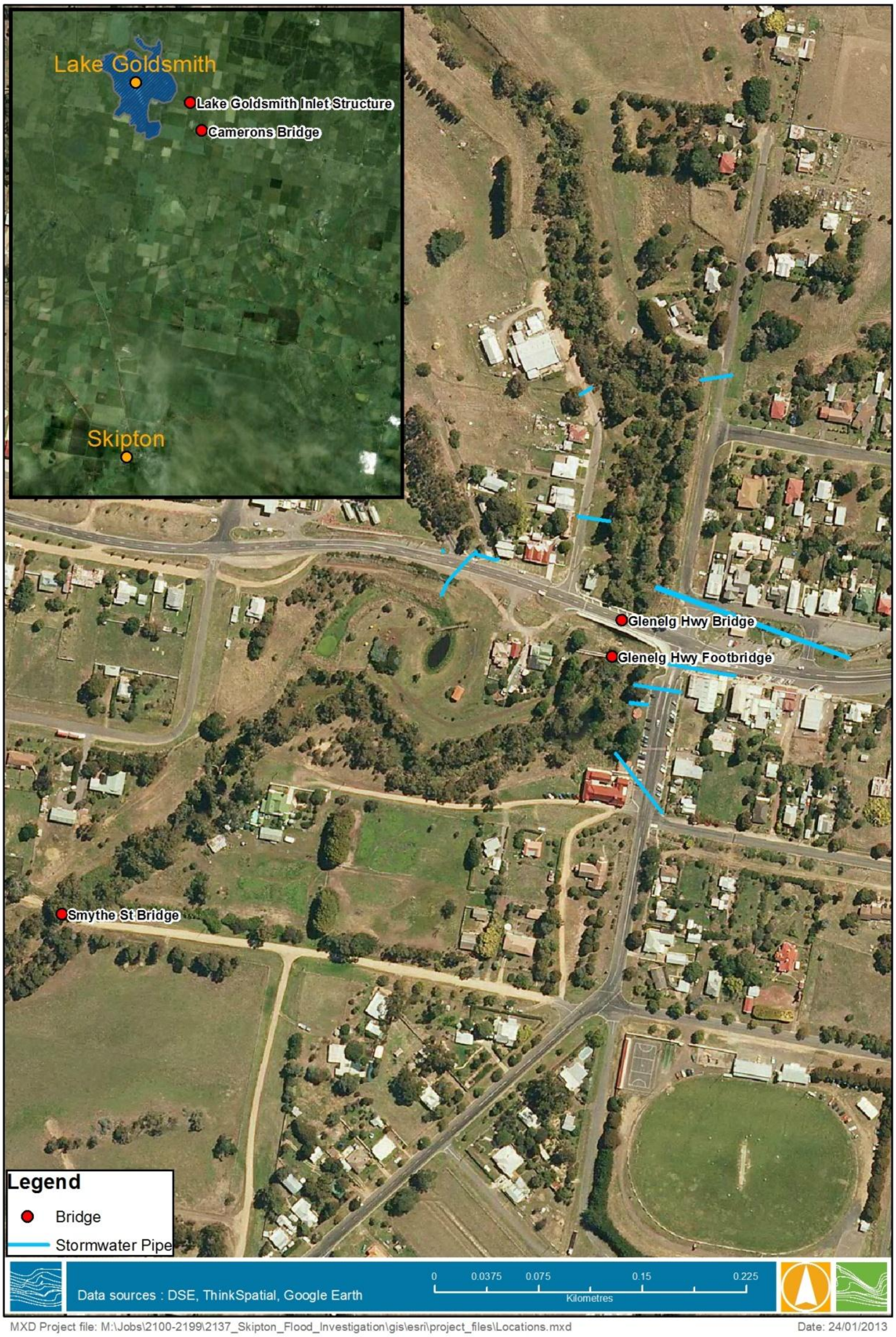

Figure 2-2 Location of bridges, culverts, drainage surveyed in Skipton study area

2.4.3 Floor Survey

The vertical and horizontal accuracy of the 2010 and 2011 flood marks and flood level survey is +/- 40 mm (GHCMA, pers. comm.). A summary of the floor level and flood marks surveyed from these events is provided in Table 2-1.

The additional floor level survey conducted by ThinkSpatial in January 2012 consisted of 16 properties, which had been identified as either within the 2011 flood extent and not previously surveyed or close enough to this flood extent such that they may be inundated during a 1% AEP flood event. The vertical and horizontal accuracy of the 2010 and 2011 flood marks and flood level survey is +/- 25 mm (ThinkSpatial, pers. comm.).

2.5 Hydrological Data

Hydrological data required for the study included streamflow, rainfall, and water storage information.

2.5.1 Streamflow Data

Stream flow data was required for the hydrological analysis. Table 2-2 shows the stream flow gauges relevant to Mt Emu Creek flows in Skipton. There is a stream flow gauge on Mt Emu Creek at Skipton, shown in Figure 2-3. There is also a gauge at Mena Park (46 km upstream of Skipton), and on Burrumbeet Creek upstream of Lake Burrumbeet. These gauges were critical to the hydrology and hydraulic modeling for this study. Details of the gauging station data and its analysis are discussed in Volume 3.

Table 2-2 Streamflow gauge details

Station Name	Station No.	Status	Data Type	Period of record
Mt Emu Creek @ Skipton	236203	Active	Instantaneous Flow	July 1975 – August 2011
Mt Emu Creek @ Mena Park	236213	Active	Instantaneous Flow	October 1974 - Present
Burrumbeet Creek @ Lake Burrumbeet	236215	Washed out Jan 2011	Instantaneous Flow	June 1977 – Jan 2011

Gauge data was also available from the Rural Water Commission (1990) for Mt Emu Creek at Skipton and Mena Park which is outside the gauge information available through the Victorian Water Data Warehouse. The data from Skipton contained maximum and minimum mean daily flows from 1920 through to 1981 (no data was available from 1951 to 1954 inclusive). Instantaneous maximum flow was also included. From 1920 through to 1963, data was only available on some selected months. From 1963 instantaneous daily flows were available for most months through to December 1981.

The Rural Water Commission (1990) source contains monthly instantaneous maximum flow from September 1967 through to December 1981 for the Mena Park gauge. Maximum and minimum mean daily flows as well as monthly and annual discharges were available for the same period at monthly intervals.

Figure 2-3 Gauging Station – Mt Emu Creek at Skipton

2.5.2 Rainfall Data

Both pluviograph and daily rainfall records were used for the hydrological analysis. Pluviograph rainfall data indicates the temporal distribution pattern while daily rainfall data provides the spatial variation. Figure 2-4 shows the locations of daily rainfall and pluviograph stations in the region.

Table 2-3 Daily rainfall station details

Name	Site	Start	End
Addington	89106	Jul-56	Sep-11
Beaufort	89005	Oct 1882	Oct-11
Burrumbeet	89007	May-49	Oct-01
Chepstowe	89046	Sep 1887	May-50
Mount Lonarch	79033	Dec-06	Aug-47
Skipton (Baangal)	89026	Jan-33	Aug-78
Skipton (Waverley)	89027	Oct-49	Oct-63
Trawalla	89030	Jan 1888	Sep-11
Trawalla State School	89091	Jan-27	Feb-40
Waubra	89090	Jun-70	Mar-05
Windermere	89073	Sep-03	Feb-38

Table 2-4 Pluviograph station details

Name	Site	Start	End
Ballarat Aerodrome	89002	Mar-08	Oct-11
Ballarat Hopetoun Rd	89111	May-04	Aug-11
Beaufort (Sheepwash)	89082	May-74	Oct-11
Skipton Post Office	89025	Sep 1897	Oct-11

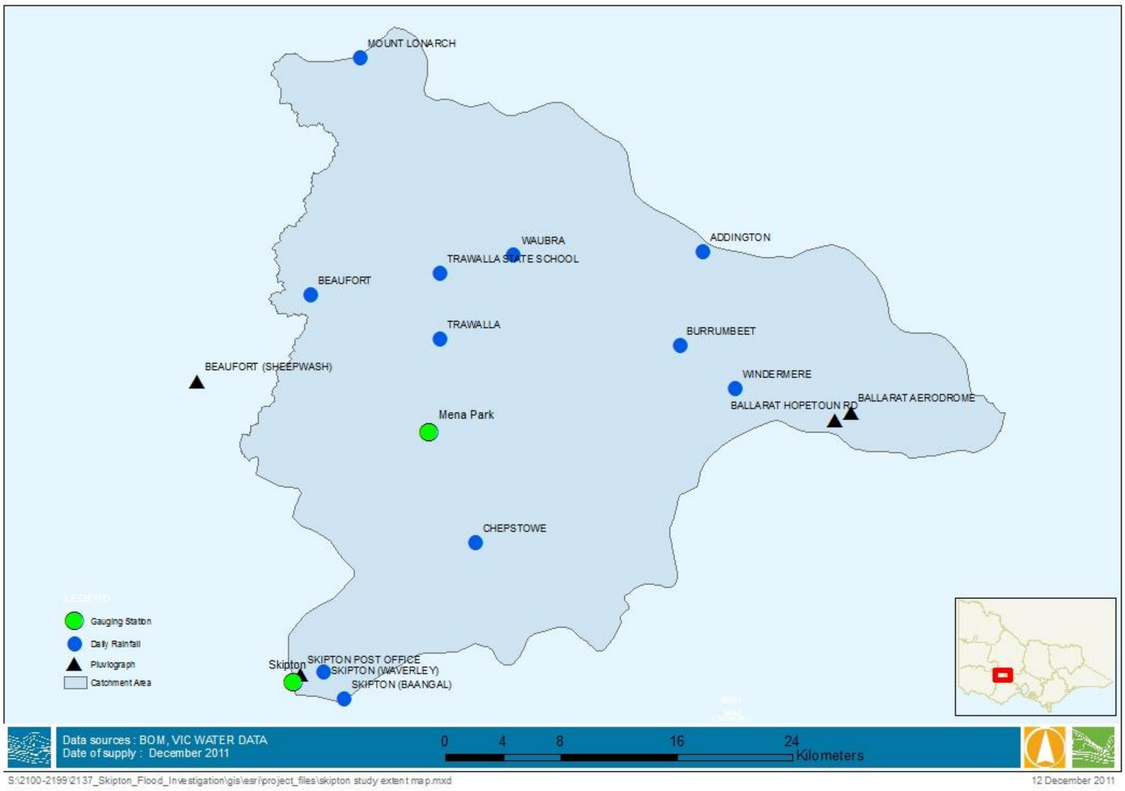

Figure 2-4 Daily rainfall, pluviograph and stream flow gauge locations

2.5.3 Storages

There are three important water storages that are likely to affect the hydrology of Mt Emu Creek at Skipton – Lake Burrumbeet, Lake Goldsmith and Jubilee Dam (also known as Skipton Dam). These are all located on tributaries to Mt Emu Creek. There is also an additional fourth storage (Beaufort Lake) located on the Cemetery Creek (a tributary of Mt Emu Creek) at Beaufort, however given its location in the upper catchment, this storage does not significantly affect the hydrology of Mt Emu Creek at Skipton and is not considered further in this study.

Lake Burrumbeet is located at the end of Burrumbeet Creek, overflowing to Baillie Creek. The Lake Burrumbeet outlet structure was described in Lawson and Treloar (2003). The structure is a 30.7 m wide weir with a crest level of 378.7 m AHD, and removable wooden planks to a height of 379.1 m AHD. Anecdotal evidence cited by Lawson and Treloar (2003) suggests that the boards have not been in operation since their implementation in 1996. The boards were thought to have been implemented to control outflows from Lake Burrumbeet under flood conditions, but there appear to be no operating rules in place for the weir. At the time of the site visit on 15th December 2011, the boards were in place and the lake was full to the top of the boards.

The Lake Goldsmith reservoir has a surface area of around 8.9 km^2 AHD. The Lake was historically connected to Mt Emu Creek via a channel and gated structure. The structure was never in operation and the gates remain closed so that Lake Goldsmith is no longer connected to Mt Emu Creek. It was proposed that the diversion of flows from Mount Emu Creek into Lake Goldsmith may be a possible flood mitigation option for Skipton, which is discussed further in Section 6.

Also of interest is Jubilee Dam (also known as Skipton Dam). This small dam sits on a tributary of Mt Emu Creek within Skipton. Skipton Dam is around 7,300 m^2 in surface area at a full supply level of 283.4 m AHD. While Skipton Dam is quite small, its close proximity to town means that overflows from the dam can result in flooding of areas within the township. The overflow from this reservoir flows into the town stormwater system and then into Mt Emu Creek.

3. PROJECT CONSULTATION

3.1 Overview

A key element in the development of this flood investigation was the active engagement of residents in the study area. This engagement was developed over the course of the study through community consultation sessions, public questionnaires and meetings with a Steering Committee containing several members of the community. The community consultation sessions were largely managed by the GHCMA and Corangamite Shire Council. The aims of the community consultation were as follows:

- To raise awareness of the study and to identify key community concerns; and
- To provide information to the community and seek their feedback/input regarding the study outcomes including the existing flood behaviour and proposed mitigation options for the township.

3.2 Steering Committee

The Flood Investigation was led by a Steering Committee consisting of representatives from Glenelg Hopkins Catchment Management Authority (GHCMA), Corangamite Shire Council (CSC), Department of Sustainability and Environment (DSE), Bureau of Meteorology (BoM), State Emergency Service (SES), VicRoads, Water Technology and the Skipton community.

The Steering Committee met on 3 occasions at key points throughout the study, to review and manage the development of the study.

3.3 Community Consultation

The main aim of the community engagement process was to provide information regarding the development of the study and to seek feedback, both verbally and through more formal feedback methods. All community meetings were supported by media releases to local papers and meeting notices.

The public consultation process was led by the Glenelg Hopkins CMA and Corangamite Shire Council. The following community meetings were held as part of the consultation process:

- Initial community meeting, 6th February 2012 – The first public meeting was held to outline the objectives of the study to the community and to distribute the community Questionnaire. A total of 19 people registered attendance at this meeting, however more than 20 were present for the meeting;
- Second community meeting, 17th September 2012 – This meeting presented the results of the flood modelling and also outlined a list of potential flood mitigation options identified to date. Community feedback was sought on the flood modelling results and their preference/suggestions for flood mitigation options. A total of 12 people registered attendance at this meeting; however more than 20 were present for the meeting.
- Third community meeting, 25th February 2013 – This meeting presented the result of the study; outlining the mitigation options assessed and presented the proposed approach for flood warning. VICSES provided information on actions they were taking regarding flood warning and response and GHCMA provided a brief overview of the planning scheme amendment process. A total of 20 people attended at this meeting.

3.4 Community Questionnaire

3.4.1 Questionnaire #1

A community questionnaire was distributed to local residents during the first community meeting. This questionnaire was used to seek feedback on flooding in Skipton. The following seven questions were listed on the questionnaire:

- How long have you been a Skipton resident?
- Have you been affected by floods in the past, and if so, when (month/year), and where?
- Please rate the following broad options for reducing the level of flood risk at Skipton on a scale of 1 = most important to 4 = least important.
    - Land use planning
    - Flood mitigation works
    - Flood warning
    - Other (provide details)
- Do you know of or have any recent or historical flood information for Skipton?
- How are you currently made aware of imminent flooding?
- What do you see as the main flooding issues in your area? E.g. flood warning, flood damage, levees, inappropriate development etc.
- The attached map shows an aerial photograph of the flood extent close to the peak in January 2011. If you think flood water extended further than this extent please mark where you think the flood water got to on the photograph.

Six feedback forms were filled in and returned to the GHCMA. Feedback from the questionnaires indicated what the community saw as potential flood mitigation options and provided data for model calibration.

3.4.2 Questionnaire #2

A community questionnaire was distributed to local residents during the second community meeting. This questionnaire was used to seek feedback on the accuracy of the flood mapping produced by the project, the completeness of the assessment of structural mitigation options, and the best ways to provide flood warnings to the Skipton community. The following five questions were listed on the questionnaire:

- What level of confidence do you have that the flood mapping produced by the project accurately reflects flood levels and extents in Skipton (High to Low)?
- Should any of the structural mitigation options listed above be pursued (a summary table was provided on the questionnaire)?
- Would you be prepared to make a financial contribution to the cost of implementing structural mitigation options?
- Are there any other structural flood mitigation options that should be assessed for Skipton?
- Please rate the following communication methods for effectiveness in warning Skipton residents to prepare for a flood:
    - Door knock
    - Text message
    - Radio
    - other

Four feedback forms were filled in and returned to the GHCMA, and a number of residents present at the meeting also provided verbal feedback to the GHCMA, CSC and Water Technology staff. Feedback from the questionnaires was used in particular to inform the flood mitigations options reporting. The community members who participated in the consultation session expressed high confidence in the flood mapping, both verbally and via the questionnaire.

3.5 Community Feedback on Study

The third and final community consultation provided the opportunity for the community to ask questions on all aspects of the study and provide comments or feedback where necessary.

VICSES presented information as to the next steps for the community with regard to flood preparedness and response. Examples of FloodSafe brochures and property flood risk information cards were shown to the community.

GHCMA provided a brief overview of the Planning Scheme Amendment process that Corangamite Shire Council will likely undertake as an outcome of the Skipton Flood Investigation.

4. FLOOD BEHAVIOUR

4.1 Overview

Flooding in Skipton township can occur from two major sources:

1. Flooding in Mt Emu Creek due to widespread and prolonged rainfall;
2. Overtopping of the Skipton Reservoir (otherwise known as Jubilee Park Lake) through intense local rainfall, causing flash flooding of Montgomery Street; termed local catchment flooding.

The flood behaviour associated with these different flooding mechanisms has been assessed using a range of industry standard approaches and tools:

- Hydrological analysis – this involves the analysis of the magnitude of previous flood events at Skipton, the development of a rainfall-runoff model for the entire Mt Emu Creek catchment, and the prediction of the likelihood of future flood events of a given magnitude,
- Hydraulic analysis – the physical understanding of what a given flood event may look like in Skipton was assessed through a hydraulic analysis. A hydraulic model was used to predict the extent of flooding, flood depths and flow velocities for a range of possible future flood events.

The different flood mechanism and the results of the hydrologic and hydraulic analysis for the study area are discussed in detail in the following sections. Detailed reports are also provided in Appendices 3 & 4.

4.1.1 Flooding from Mt Emu Creek

Flooding in Mt Emu Creek depends on long duration rainfall events occurring in the upper catchment. The catchment above Lake Goldsmith (situated on the western side of the catchment between Beaufort and Skipton) does not contribute to flooding in Mt Emu Creek. The catchment above Lake Burrumbeet, despite having a large catchment area (approximately 200 km^2), makes only a minor contribution to flooding in Mt Emu Creek at Skipton, due to the attenuating effect of Lake Burrumbeet. The Baillie Creek catchment (between Lake Burrumbeet and Mt Emu Creek) is significant and inflows to Mt Emu Creek can be substantial.

The nearest upstream gauge is located at Mena Park, upstream of the Baillie Creek inflow. The Mean Park gauge provides a good indication of the likely magnitude of floods in Skipton provided flows from the Baillie/Burrumbeet Creek catchment are relatively minor. Flood level observations at Mena Park bear no relationship to the likely impact of a flood in Skipton when the Baillie/Burrumbeet Creek catchment contributes major inflows to Mt Emu Creek downstream of the Mena Park gauge. This highlights a significant gap in the existing flow monitoring capability and the need for an additional water level gauge downstream of the confluence of Baillie Creek with Mt Emu Creek (see Section 7)

The lag time of the flood peak at Skipton after the start of rainfall is generally around 30-32 hours, and the peak travel time from Mena Park ranges from 16 to 20+ hours.

A period of rain is required to “wet up” the catchment and fill the natural floodplain storage (of which there is substantial volume) before significant runoff is generated. Water levels then rise quickly within Mt Emu Creek, with initial rises occurring at Skipton within about 4 hours or so of the start of heavy rain, and peak levels occurring within about 30 hours.

General rain of around 40 to 50 mm in 6 to 12 hours across a wet Mt Emu Creek catchment will causes significant rises at Skipton – to around 4.00 m on the Skipton gauge. More substantial rainfall (of order 75 mm to 100 mm or more in 24 hours or less), again on a wet catchment, will cause severe flooding and deep over-floor inundation of a number of buildings within the town.

Large severe floods generally occur as a result of either:

1. Very heavy rainfall, such as occurred in January 2011, as a result of warm moist air from north western or northern Australia moving down and across western Victoria; or
2. Moderate to heavy rainfall associated with a slow moving or complex low pressure system after a prolonged period of general rainfall such as can result from sequences of cold fronts during winter and spring. The August 2010 and September 2010 flood events followed weather of these characteristics.

The channel capacity of Mt Emu Creek at Skipton is approximately equal to the 20% AEP flood. At the 10% AEP flood, overbank flow commences downstream of Montgomery St and via backflow up some stormwater pipes. At and above the 5% AEP flood, widespread overbank flooding occurs, extending to the valley margins. Above this flow the depth and velocity of flooding increases but the extent is only marginally increased. At the 2% AEP and above the Glenelg Highway bridge is overtopped.

4.1.2 Local Catchment Flooding

Local catchment flooding is dependent on high intensity short duration rainfall in the local Skipton area. The catchment above the Skipton Reservoir is small (2.8 km^2) with an estimated time of concentration of approximately 1 hour. Skipton Reservoir has very little effective flood storage capacity and overflows over the two spillway weirs are common. Downstream of the spillways a channel carries overflows into two 550 mm stormwater pipes under the Montgomery street car park and then into Mt Emu Creek.

The pipes are currently undersized for the 20% AEP flood, and when the pipe capacity is overwhelmed, excess flow causes flooding in Montgomery Street. Flooding of properties in Montgomery Street occurs under even moderate local rainfall events due to this mechanism.

4.2 Hydrology

4.2.1 Streamflow Gauging and Rating Curve Revision

The streamflow gauge at Skipton was used for flood frequency analysis and calibration data for the hydrologic and hydraulic models. Initial calibration tests of the hydraulic model developed for this study using August and September 2010 and January 2011 gauged flows resulted in an under-prediction of water levels at Skipton by between 0.5 and 0.6 m. This under-prediction was also visible in the modelled flood extents which could not replicate the flooding experienced in the central business area of the township. All industry standard approaches to modifying model parameters to improve the accuracy of the model were explored but the discrepancy could not be improved using the gauged flow information.

It was therefore decided to revisit the flow-water level relationship (termed the 'rating curve') at the Skipton gauging site. This resulted in a revision of the rating curve, which is detailed in report R03 – Hydrology. The final revised rating curve replicated the original rating curve for low flows (<10% AEP), but for higher flows a revised flow-level relationship was adopted.

All subsequent hydrological analysis was undertaken using the revised rating curve.

4.2.2 Flood Frequency Analysis

A flood frequency analysis was used to estimate the magnitude of flood events at Skipton in terms of a probability of occurrence. This allows the quantification of previous flood events and also enables the estimation of the frequency of future flood events.

The flood frequency analysis was based on an annual series of maximum flows at Skipton with 77 years of data. It was found during the analysis that there were 7 “non-flood” years (i.e. years where the maximum flow was not a significant flood event) which were excluded. The Log-Pearson III, Log Normal and Generalised Extreme Value (GEV) distributions were fitted, with the Log-Pearson III distribution giving the best fit overall. The design flows resulting from the flood frequency analysis are given in Table 4-1. Given the 77 year length of record and the good fit of the Log Pearson III distribution, these peak design flows are considered to be a good predictor of flood probability (assuming no climate trend).

Table 4-1 Adopted Design Peak Flows for Mt Emu Creek at Skipton

AEP	Peak Design Flow (m^3/s)		
	Log Pearson III (7 low flows excluded)	5%-95% Confidence Limits	
20%	77	58	103
10%	136	95	195
5%	220	139	350
2%	388	207	729
1%	575	267	1,239
0.5%	830	332	2,072

4.2.3 Hydrologic Modelling

The catchment hydrologic model, RORB, was employed to estimate flood hydrographs. RORB (*Laurenson et al 2005*) is a nonlinear rainfall runoff and streamflow routing model for calculation of flow hydrographs in drainage and stream networks. The model requires catchments to be subdivided into subareas, connected by conceptual flow reaches. The structure of the RORB model is shown in Figure 4-1. Lake Burrumbeet and Lake Goldsmith were modelled as explicit storages to ensure that the attenuation through these storages was modelled appropriately.

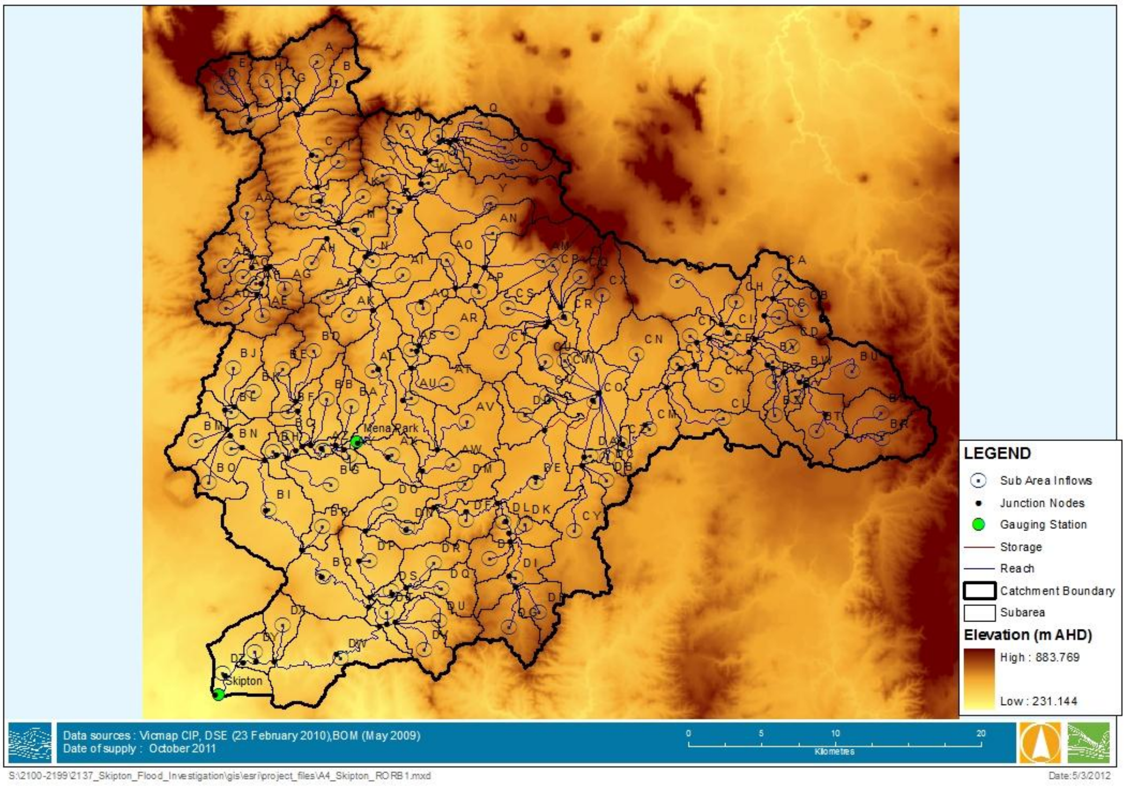

Figure 4-1 RORB Model Structure

The RORB model parameters were determined through calibration against observed flood hydrographs at the Mena Park and Skipton gauges. Four calibration events (1983, August 2010, September 2010 and January 2011) were selected to calibrate the RORB model over a range of flows.

Design flow hydrographs were developed using the calibrated routing parameters, and loss parameters adjusted to reconcile the flood peak to the flood frequency analysis. The critical storm duration for design events ranged from 36 hours to 72 hours. In addition to the design events, climate change hydrographs were developed for sensitivity testing. These were based on the design events with an increase in rainfall intensity of 20%, based on discussions with the GHCMA. The adopted peak design flows are provided in Table 4-2.

Table 4-2 Adopted Peak Flows for Mt Emu Creek at Skipton

Event Scenario	AEP	Peak Design Flow (m^3/s)	Source
Design	20%	78	Calibrated RORB model with losses reconciled to Flood Frequency Analysis
	10%	136	
	5%	221	
	2%	386	
	1%	575	
	0.5%	827	
Climate	10%	199	RORB model with rainfall intensity increased by 20%

Event Scenario	AEP	Peak Design Flow (m^3/s)	Source
Change	1%	787	
	0.5%	1,127	

A smaller-scale RORB model for the local tributaries to Skipton was developed separately and the peak flows were reconciled to rational method estimates. The 1% AEP flood peak for catchment B (the Skipton Reservoir catchment, which is critical to flooding in Montgomery Street) was 14 m^3/s for a 1 hour duration storm.

4.2.4 Probable Maximum Flood

The Probable Maximum Flood (PMF) was estimated for Mount Emu Creek and the tributaries using the Quick Method of Nathan et al. (1994). This method applies a set of empirical equations to compute a triangular PMF hydrograph. The resulting peak PMF for Mount Emu Creek was 8,277 m^3/s.

4.3 Hydraulics

4.3.1 Overview

This section discusses the application of the hydraulic models to simulate and map flood behaviour (extents, depth, velocities) for a range of flood magnitudes.

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

A detailed description of the hydraulic model setup, calibration and design event simulation is provided in Volume 4. This section summaries the key outcomes from the hydraulic model investigation.

The mapping outputs were applied for flood response planning, and land use planning purposes (Section 7 and 8 respectively).

4.3.2 Understanding Flood Behaviour

Table 4-3 describes the flood characteristics in Mt Emu Creek at Skipton for each design event. The key aspect to note is the difference in behaviour between local catchment flows and Mt Emu Creek flows with respect to flooding. For flows up to and including the 10% AEP event, flooding in Skipton is dominated by local catchment flows, predominately those flows from the Skipton Dam catchment. The capacity of the local drainage in the township is exceeded during all flood events modelled which means that these local flows then generate flooding of Montgomery Street and surrounding areas.

The critical duration in Table 4-3 refers to the duration of design storm that produces the highest peak flood discharges for that flooding source. The local catchments have a shorter critical storm duration than the Mt Emu Creek catchment, meaning that they are responsive to short, high intensity storms, whereas the Mt Emu Creek flows are more responsive to long, sustained rainfall.

For flood events exceeding the 10% AEP event, overbank flows from Mt Emu Creek start to influence flood behaviour in the township and these flows become the dominant flooding mechanism.

Table 4-3 Summary of Flood Behaviour for Various Flood Events

Event	Local Catchments	Mt Emu Creek Catchment
20% AEP	Critical Duration – 1.5-48 hrs • Local catchment flows from the Skipton Dam catchment enter the main street to the east of the highway bridge. The current drainage system downstream of the dam is under capacity and flows cannot pass through the culvert to the river. There is flooding around the shops and along the Lismore-Skipton Road. • Minor overbank flows to Mt Emu Creek along the Lismore-Skipton Road	Critical Duration – 72hrs • Stewart Park area fills early during the event. • No overbank flows.
10% AEP	Critical Duration – 1-48 hrs • Local catchment flows from the Skipton Dam catchment enter the main street to the east of the highway bridge. The current drainage system downstream of the dam is under capacity and flows cannot pass through the culvert to the river. There is significant flooding around the shops and along the Lismore-Skipton Road. • Minor overbank flows to Mt Emu Creek along the Lismore-Skipton Road	Critical duration – 48hrs • Backflow from Mt Emu Creek into the western floodplain via a drainage pipe upstream of the Eel factory. Results in overland flows southward towards the highway. • Later in the event there is a breakout from Mt Emu Creek on the western bank (upstream of the pipe) but the volumes are limited. • Minor backflow from Mt Emu Creek via drainage pipes on the eastern bank.
5% AEP	Critical Duration – 1.5-24 hrs • Local catchment flows from the Skipton Dam catchment enter the main street to the east of the highway bridge. The current drainage system downstream of the dam is under capacity and flows cannot pass through the culvert to the river. There is significant flooding around the shops and along the Lismore-Skipton Road. • Overbank flows to Mt Emu Creek along the Lismore-Skipton Road.	Critical Duration – 36hrs • Backflow from Mt Emu Creek into the western floodplain via a drainage pipe upstream of the Eel factory. Results in overland flows southward towards the highway. • Later in the event there is a breakout from Mt Emu Creek on the western bank (upstream of the pipe) which flow overland and join backflow, moving overland towards the highway. • Properties flooded on western floodplain and some limited flooding across the highway. • Backflow through drainage pipes into the eastern floodplain causing flooding in the main street. • Overbank flows into the eastern floodplain upstream of the highway

Event	Local Catchments	Mt Emu Creek Catchment
		bridge contributing to flooding in the main street. • Significant floodplain inundation south of the highway bridge. Properties on the floodplain to the south of the bridge are inundated. No houses flooded.
2% AEP	Critical Duration – 1-6 hrs • Significant flooding within the main street from local catchment inflows.	Critical Duration – 36hrs • Significant flooding on the western bank of the river and floodplain both upstream and downstream of the highway bridge. • Flooding in the main street on eastern floodplain through both backflow through the drainage system from Mt Emu Creek and overbank flows. • Glenelg Highway Bridge overtopped.
1% AEP	Critical Duration – 1-6 hrs • Significant flows into the main street from the Skipton Dam catchment. • Flows from the local catchment are sufficient to create overbank flow into Mt Emu Creek at the Lismore-Skipton Road and immediately to the north of the bridge.	Critical Duration – 72hrs • Significant flooding on the western bank of the river and floodplain both upstream and downstream of the highway bridge. • Significant flooding on the eastern bank of the river and floodplain. • Inundation of the Glenelg Highway and Glenelg Highway Bridge overtopped. • Inundation of a significant number of properties on both sides of the river.
0.5% AEP	Critical Duration – 1-6 hrs • Significant flow flows into the main street from the Skipton Dam catchment. • Flows from the local catchment are sufficient to create overbank flow into Mt Emu Creek at the Lismore-Skipton Road and immediately to the north of the bridge.	Critical Duration – 72hrs • Significant flooding on the western bank of the river and floodplain both upstream and downstream of the highway bridge. • Significant flooding on the eastern bank of the river and floodplain. • Inundation of the Glenelg Highway and Glenelg Highway Bridge overtopped. • Inundation of a significant number of properties on both sides of the river.
PMF	• Significant flow flows into the main street from the Skipton Dam catchment causing flood depths up to 3 m • Flows from the local catchment are sufficient to create significant	• Deep inundation filling the entire Mount Emu Creek valley and starting to spill out onto the flat terrace areas above the steep-sided valley • Flood depths of up to 11 metres on the floodplain • Inundation of a number of roads

Event	Local Catchments	Mt Emu Creek Catchment
	overbank flow into Mt Emu Creek at the Lismore-Skipton Road and immediately to the north of the bridge	including a 550m length of Glenelg Highway • Inundation of a significant number of properties on both sides of the river

4.3.3 Impacts on Infrastructure – Glenelg Highway and Bridge

The Glenelg Highway passes through Skipton and the Glenelg Highway Bridge is an important structure for the township of Skipton and the surrounding district as well as providing a significant regional transport link. The road would typically be closed when a depth of flooding greater than 300 mm is present.

Flood impacts include:

- Outflow from Skipton Dam inundates and renders the Glenelg Highway impassable east of the bridge and Anderson St for floods of a 20% AEP event magnitude or greater. However bypass via Anderson St is possible up to the 5% AEP event. Above the 5% AEP magnitude both Anderson St and Glenelg Highway are impassable.
- The highway on the western side of the Bridge is inundated and impassable in the 5% AEP event, meaning that the town access east-west becomes difficult at this flood level.
- The bridge itself becomes inundated and impassable in the 2% AEP event.

The bridge itself affects flood levels immediately upstream due to the blockage effect it creates across the creek. However, this increase in flood depths is in the order of 100-150 mm due to a hydraulic control further upstream. The hydraulic control is produced by an effective floodplain constriction at the transition from rural to developed areas, with increased vegetation and more building blockages. Flood levels upstream of that point are expected to be relatively insensitive to bridge conditions.

Overall, the Glenelg Highway and Bridge is extremely vulnerable to flooding. Access from one side of town to the other is cut off from around the 20% AEP flood event. Above this level it becomes difficult for emergency services to operate, and there is no access to the hospital from the west side of town.

4.3.4 Performance of Drainage Network

The current total capacity of the two 550 mm drainage pipes downstream of Skipton Dam is 1.5 m^3/s. This capacity is exceeded by the outflow from the reservoir in all design events from the 20% AEP up. The result is flooding of the township in and around Montgomery Street and inundation of the Glenelg Highway.

Another aspect of flood impacts on the local drainage is the potential for flood waters from Mt Emu Creek to back flow during high river conditions. This impact is noticeable for flooding up to around the 10% AEP event. In events greater than a 10% AEP overbank flows from the creek are the dominant flooding mechanism.

4.3.5 Climate Change Sensitivity Tests

The sensitivity of flood behaviour to projected Climate Change was tested using a scenario of 20% increase in rainfall intensity for the 10%, 1% and 0.5% AEP events. The increased rainfall intensity was simulated in the RORB model to give input hydrographs for the hydraulic modelling. The input hydrograph peak flows for Mt Emu Creek were increased by 36-46%, and for the tributaries were increased by 22-43%.

Table 4-4 describes the key changes to flooding characteristics in Mt Emu Creek at Skipton for each design event with climate change effects, compared to the base design event.

Table 4-4 Summary of Climate Change Effects on Flood Behaviour for Various Flood Events with an Increase in Rainfall Intensity of 20%

Event	Local Catchments	Mt Emu Creek Catchment
10% AEP	• Flood levels in the tributaries are relatively unaffected and are raised by less than 0.2 m, including in the Montgomery Street area • There is a small increase in flood extent in the main street from the Skipton Dam catchment and on the other tributaries	• Flood levels are raised by up to 0.9 m, particularly upstream of the town. • There is a significant increase in flood extent as the western bank upstream of the bridge and the eastern bank downstream are overtopped. • The number of properties inundated below and above floor is significantly increased
1% AEP	• Flood levels in the tributaries are relatively unaffected and are raised by less than 0.3 m. • Flood extents in the tributaries are relatively unchanged	• Flood levels are raised by up to 0.8 m upstream of Skipton, and by up to 0.6 m in the town itself • There is only a small increase in the flood extent as the flood extent is at the steep valley margin both with and without climate change effects • The inundation depth on a number of inundated properties is increased by up to 0.6 m, but the number of inundated properties is not significantly increased.
0.5% AEP	• Flood levels in the tributaries are relatively unaffected and are raised by less than 0.3 m. • Flood extents in the tributaries are relatively unchanged	• Flood levels are raised by up to 0.9 m upstream of Skipton, and by up to 0.7 m in the town itself • There is only a small increase in the flood extent as the flood extent is at the steep valley margin both with and without climate change effects • The inundation depth on a number of inundated properties is increased by up to 0.7 m, but the number of inundated properties is not significantly increased.

5. IMPACTS OF FLOODING

5.1 Overview

The impact of flooding is assessed by estimating the likely cost of damages associated with a range of flood events in Skipton. Flood damage estimates have been calculated for a range of flood events from a 20% AEP to the 0.5% AEP event.

Key datasets that were required for the assessment process included:

- Topographic data (as described in Section 2) including aerial imagery and LiDAR,
- Location and description of buildings with floor levels and details of other infrastructure
- Design flood levels (from Section 4)
- Flood damage cost from available literature.

The information presented in this Section is for the existing conditions at Skipton and its immediate surrounding floodplain. It has been used to undertake a preliminary cost-benefit analysis between different flood mitigation options, detailed in Section 6.

5.1.1 Topographic Data

The detailed terrain model developed for this study was used for the assessment, as detailed in Volume 1 and 4.

5.1.2 Property Survey Data

Floor survey of properties in Skipton was undertaken by the GHCMA following the flood events in 2010 and 2011. This comprised 23 properties.

A floor survey was undertaken for this project by ThinkSpatial, to pick up floor levels of any properties not previously surveyed that may potentially be impacted by flood events. A total of 16 additional properties were surveyed.

The remaining properties were taken into account during the damages assessment through manually locating buildings using high resolution aerial imagery. Where floor survey could not be obtained, a freeboard of 200 mm was assumed above the topographic elevation derived from LiDAR.

5.1.3 Design Flood Levels

Design flood levels predicted by the hydraulic modelling (Section 4) were used to assess the damage risk at each property.

Due to the nature of the study area the design flood level for each flood event depends on the property under consideration. Detailed hydraulic model outputs were used to assess the site specific flood level for each property in the damage assessment.

5.1.4 Flood Damage Cost Information

Six key sources were used for flood damage cost estimation methodology:

- ANUFLOOD cost curves, from CRES (1992)
- ‘Rapid Appraisal Method (RAM) For Floodplain Management’ (Read Sturgess & Associates, 2000);
- ‘Economic Costs of Natural Disasters in Australia’ (Bureau of Transport Economics, 2001); and,
- ‘Guidance on the Assessment of Tangible Flood Damages’ (Queensland Government Department of Natural Resources and Mines, 2002).

- Impact of velocity on flood damage assessments in a recent study by Geoscience Australia (Middelmann-Fernandes, 2010)
- 'www.abs.gov.au' (The Australian Bureau of Statistics).

5.2 Assessment of Flood Damages Cost

5.2.1 Existing Conditions

The flood damages assessment covers the study extent as detailed in Figure 1-2, with economic costs and benefits focussing on urban areas, although farm buildings were included.

5.2.2 Direct Damages to Buildings (commercial, residential, rural)

Floods can potentially cause a high level of damage to buildings, including structural damage (eg. walls, floors, doors, etc.), contents damage (eg. carpets, furniture, etc.) and external damage (eg. gardens, etc.).

For each building, a depth of above floor inundation was calculated under existing conditions for the design flood levels adopted from Section 4, using the floor levels from the property data described in Section 5.1.2. External damage was incorporated using the properties flooded below floor level for the same design events and property data.

Stage-damage curves estimate the relationship between the depth of above floor inundation of a building and the potential flood damage cost. This relationship is typically calculated by post-flood survey. ANUFLOOD stage-damage curves for residential and commercial buildings (NRM, 2002), were factored up by 60% to bring them up to a representative 1999 flood damage cost level, as recommended by Read Sturgess & Associates (2000). They were then factored up to a June 2011 flood damage cost level using Building Price Index (BPI) and Consumer Price Index (CPI) from the Australia Bureau of Statistics website (www.abs.gov.au). At the time of the study data for 2012 was not currently available.

The total potential flood damage cost for existing conditions was then calculated by applying the updated stage-damage curves to each building and summing the individual potential flood damage costs.

The total potential flood damage cost represents the flood damage cost if no remedial action is taken. In reality, communities at risk of flooding will usually have some warning and will be able to take steps toward reducing the cost of flood damage (i.e. evacuation, doorstep sandbagging or removing valuable items to a safe level above flood waters). Read, Sturgess & Associates (2000), estimated that for communities such as Skipton, having prior flood experience and some warning time (2-4 hours), the ratio of actual to potential flood damage cost could be around 0.8. With increased warning time this ratio can be reduced to around 0.4. In this study a ratio of 0.8 was applied to the total potential flood damage cost as a conservative estimate of the total actual flood damage cost.

The total actual flood damage cost along with the number of residential, commercial and agricultural buildings inundated for the adopted existing condition design flood levels are presented in Table 5-1.

As presented in Table 5-1 the estimated actual flood damage cost for buildings under existing conditions is approximately **$1,358,724** for the 1% AEP event. The estimated damages costs relate to the Skipton township only. It should be recognised that damage to farm infrastructure, especially fencing and creek crossings, also occurs during major flood events. Assessment of these coasts was however outside the scope of this project.

5.2.3 Direct Damages to Infrastructure

Floods can potentially cause significant damage to roads and other inundated infrastructure such as agricultural land. Roads can suffer initial damage from flooding as well as accelerated deterioration due to water intrusion under the pavement. While for agricultural land, the type of land use (e.g. crop type) is important for estimating likely damages.

The RAM method (Read Sturgess & Associates, 2000) includes costings for roads and bridges, and agricultural enterprises in addition to the direct building costs. The costs for roads, bridges from the RAM method were adopted and updated in the NRM (2002) report. These values were applied to the present study and factored up by CPI to June 2011 dollars. Agricultural land was not included in the damages assessment at Skipton as the study area is predominantly limited to commercial and residential property.

The length of inundated major, minor and unsealed roads was calculated for the adopted existing condition design flood levels, and used to estimate the total cost of flood damage to, Table 5-2.

5.2.4 Indirect Damages

Indirect flood damages are damages sustained as a consequence of a flood but are not due to the direct impact of a flood (eg. emergency services, clean-up costs, alternative accommodation, disruption to business, etc.). Indirect costs are much harder to quantify than direct costs, so only the more readily estimated costs are usually included.

Read, Sturgess & Associates (2000) recommend estimating indirect costs as 30% of total direct costs (depending on population density). This is a fairly coarse approximation and has not been adopted in this case. Instead a more detailed analysis has been undertaken, using methodology from BTE (2001).

Included in the estimate of indirect flood damage costs are residential and commercial clean-up, alternative accommodation and relocation of household goods, and emergency response costs, Table 5-3.

5.2.5 Total Existing Conditions Damages

The total flood damage cost for the Skipton study area under existing conditions is a sum of the actual flood damage cost of buildings, the road flood damage cost and the indirect flood damage cost, Table 5-4. The total existing conditions flood damage cost for the 1% AEP event is **$1,625,093.**

This gives an annual average damage (AAD) cost of **$133,551**. The AAD is a measure of the flood damage per year averaged over an extended period. It is calculated by the area under the flood frequency and total flood damage curve.

5.2.6 Comparison to Recent Flood Damages Costs

Flood damage cost values were provided by Corangamite Shire Council for the January 2011 flood event. This flood event has an estimated AEP around 1.5%.

Costs related to housing were $820,000, to businesses was $2,710,000, and Council clean up and repairs was $240,000.

No further detail was available as to how these costs were derived or the actual work they covered. It is therefore difficult to compare these values directly to the damages costs provided in the current assessment.

Table 5-1 Total Actual Flood Damage Cost to Buildings for Existing Conditions

Parameter	Annual Exceedence Probability					
	0.5%	1%	2%	5%	10%	20%
Buildings Flooded Above Floor	37	36	30	25	6	6
Properties Flooded Below Floor	14	13	14	15	19	9
Total Properties Flooded	51	49	44	40	25	15
Direct Potential External Damage Cost	$53,606	$41,059	$46,340	$53,473	$56,096	$24,183
Direct Potential Residential Damage Cost	$518,035	$439,355	$266,231	$120,300	$22,037	$20,474
Direct Potential Commercial Damage Cost	$1,394,588	$1,217,992	$1,111,192	$473,337	$171,787	$159,304
Total Direct Potential Damage Cost*	**$1,966,229**	**$1,698,405**	**$1,423,762**	**$647,110**	**$249,920**	**$203,960**
Total Actual Damage Cost *(0.8*Potential)*	**$1,572,983**	**$1,358,724**	**$1,139,010**	**$517,688**	**$199,936**	**$163,168**

*Note that these costs are for property damage only and do not include road repairs or indirect clean-up costs.

Table 5-2 Total Actual Flood Damage Cost to Infrastructure for Existing Conditions

Parameter	Annual Exceedence Probability					
	0.5%	1%	2%	5%	10%	20%
Infrastructure Damage Cost	**$91,193**	**$82,337**	**$73,519**	**$56,523**	**$33,470**	**$18,352**

Table 5-3 Total Indirect Damage Cost for Existing Conditions

Parameter	Annual Exceedence Probability					
	0.5%	1%	2%	5%	10%	20%
Indirect Clean Up Cost	$156,281	$150,838	$120,143	$96,851	$22,852	$22,852
Indirect Residential Relocation Cost	$10,688	$9,924	$6,107	$3,817	$763	$763
Indirect Emergency Response Cost	$23,269	$23,269	$23,269	$13,961	$9,308	$4,654
Total Indirect Damage Cost	**$190,238**	**$184,031**	**$149,519**	**$114,629**	**$32,923**	**$28,269**

Table 5-4 Total Flood Damage Cost for Existing Conditions

Parameter	Annual Exceedence Probability					
	0.5%	1%	2%	5%	10%	20%
Total Damage Cost	**$1,854,414**	**$1,625,093**	**$1,362,047**	**$688,840**	**$266,329**	**$209,789**

6. FLOOD RISK MITIGATION

6.1 Overview

Mitigation measures provide a means to reduce the existing flood risk. Mitigation measures can reduce existing flood risk by lowering the likelihood of flooding and/or lowering the flood damages (consequences) for a given flood depth. Mitigation measures can be broken into:

- Structural: Physical barriers or works designed to prevent flooding up to a specific design flood standard. Structural measures aim to reduce existing flood risk by reducing the likelihood of flooding at given locations. Structural works include levees, floodways, waterway works, improvements to hydraulic structures.
- Non-structural: Management and planning arrangements between relevant authorities designed to reduce flood related damages. Non-structural measures aim to reduce existing flood risk by lowering the potential for flood damage. Non-structural measures include land use planning, flood warning, flood response and flood awareness.

The following discussion outlines the preliminary assessment of structural mitigation measures for the study area. Non-structural mitigation measures are discussed in detail in Section 8.3.

6.2 Structural Mitigation Measures

6.2.1 Overview

Structural mitigation measures are physical works to reduce the likelihood of flooding in a given location. The full list of potential structural mitigation measures for Skipton and the source of the suggestion are shown in Table 6-1.

Table 6-1 Suggested mitigation options

Option No.	Detail	Source
1	Connecting Mt Emu Creek to Lake Goldsmith upstream to provide flood detention	Community Project brief
2	Create a new flood storage dam upstream of Skipton on Mt Emu Creek	Steering Committee members
3	Increased Mt Emu Creek channel capacity though the town through vegetation & debris clearing	Community
4	Increase capacity of the Glenelg Highway bridge	Community Steering Group Committee members
5	Reconnecting Stewart Park to Mt Emu Creek	Community Steering Group Committee members
6	Upgrading of local drainage infrastructure receiving water from Skipton Reservoir	Project team Community Questionnaire
7	Installation of flap gates on local drainage pipes discharging into Mt Emu Creek	Community Steering Group Committee members
8	Use of Lake Burrumbeet as a flood storage	Steering Committee members

Option No.	Detail	Source
	reservoir	
9	Levees along Mt Emu Creek through the township	Community
10	Manipulation of the Skipton Reservoir water level	Steering Committee members

Options 1, 3, 5, 6 and 8 have been investigated in detail, using hydrologic and/or hydraulic modelling. The others have been subject to a preliminary feasibility assessment only. Details of the assessment are provided in Volume 5.

An additional mitigation option of relocating flood prone commercial properties was raised at the final community consultation session. The relocation of flood-prone buildings would mitigate the majority of the cost of flooding to the Skipton community. However this option raises significant issues beyond the question of flood related impacts which are outside the scope of this flood investigation study. The feasibility and appropriateness of this option has therefore not been investigated further by this study.

6.2.2 Assessment Criteria

Each mitigation option was assessed against a number of criteria, potential reduction in flood damage, cost of construction, feasibility of construction and environmental impact. The score for each criterion was based on a ranking system of 1 to 5, with 1 being the worst score and 5 the best. Each criteria score was then weighted according to the weighting shown in Table 6-2 below. The reduction in flood damage was of course the most heavily weighted criteria as this is really the main objective for all flood mitigation.

Table 6-2 Prefeasibility assessment criteria

Score	Reduction in Flood Damages	Cost ($)	Feasibility/Constructability	Environmental Impact
Weighting	**2**	**1**	**0.5**	**0.5**
5	Major reduction in flood damage	Less than $50,000	Excellent (Ease of construction and/or highly feasible option)	None
4	Moderate reduction in flood damage	$50,000 – $100,000	Good	Minor
3	Minor reduction in flood damage	$100,000 – $500,000	Average	Some
2	No reduction in flood damage	$500,000 – $1,000,000	Below Average	Major
1	Increase in flood damage	Greater than $1,000,000	Poor (No access to site and/or highly unfeasible option)	Extreme

6.2.3 Assessment Outcome

Each of the suggested mitigation options was assessed using the outlined assessment criteria as shown in Table 6-2. In some instances additional modelling or review was undertaken to provide input to the assessment as detailed in Volume 5.

Using the feasibility assessment above, the 10 mitigation options were ranked by weighted score. The ranking of the top 3 options is shown below in Table 6-3. All other options were found to be unfeasible on the basis of low associated damage reduction, high costs and other constructability or environmental issues. A discussion for each of the top three options is provided in the following sections.

Table 6-3 Weighted feasibility mitigation Scores

Rank	Option No.	Mitigation Option	Weighted Score
1	7	Installation of flap gates on local drainage pipes discharging into Mt Emu Creek	13.5
2	6	Upgrading of local drainage infrastructure receiving water from Skipton Reservoir	11.5
3	3	Increased Mt Emu Creek channel capacity through the town through vegetation & debris clearing	10.0

6.2.4 Installation of flap gates on local drainage pipes discharging into Mt Emu Creek

This option was not modelled, but is considered an effective low cost option to prevent flooding of low lying properties under moderate (~10% AEP) Mt Emu Creek flood conditions. It is unlikely to have any effect on flooding at and above the 5% AEP event.

The pipe outlets that would provide a benefit if fitted with functioning backflow prevention devices have been identified in Figure 6-1. A total of 9 pipe outlets have been identified as candidates for backflow prevention.

As a specific benefit, providing backflow prevention on the 300 mm culvert between 7 and 5 Cleveland St could eliminate flooding of Cleveland St properties under the 10% AEP flood (see Figure 6-2).

A preliminary cost estimate indicates a total cost of $7,760 for this option. This does not include the cost of installation or the on-going maintenance requirements.

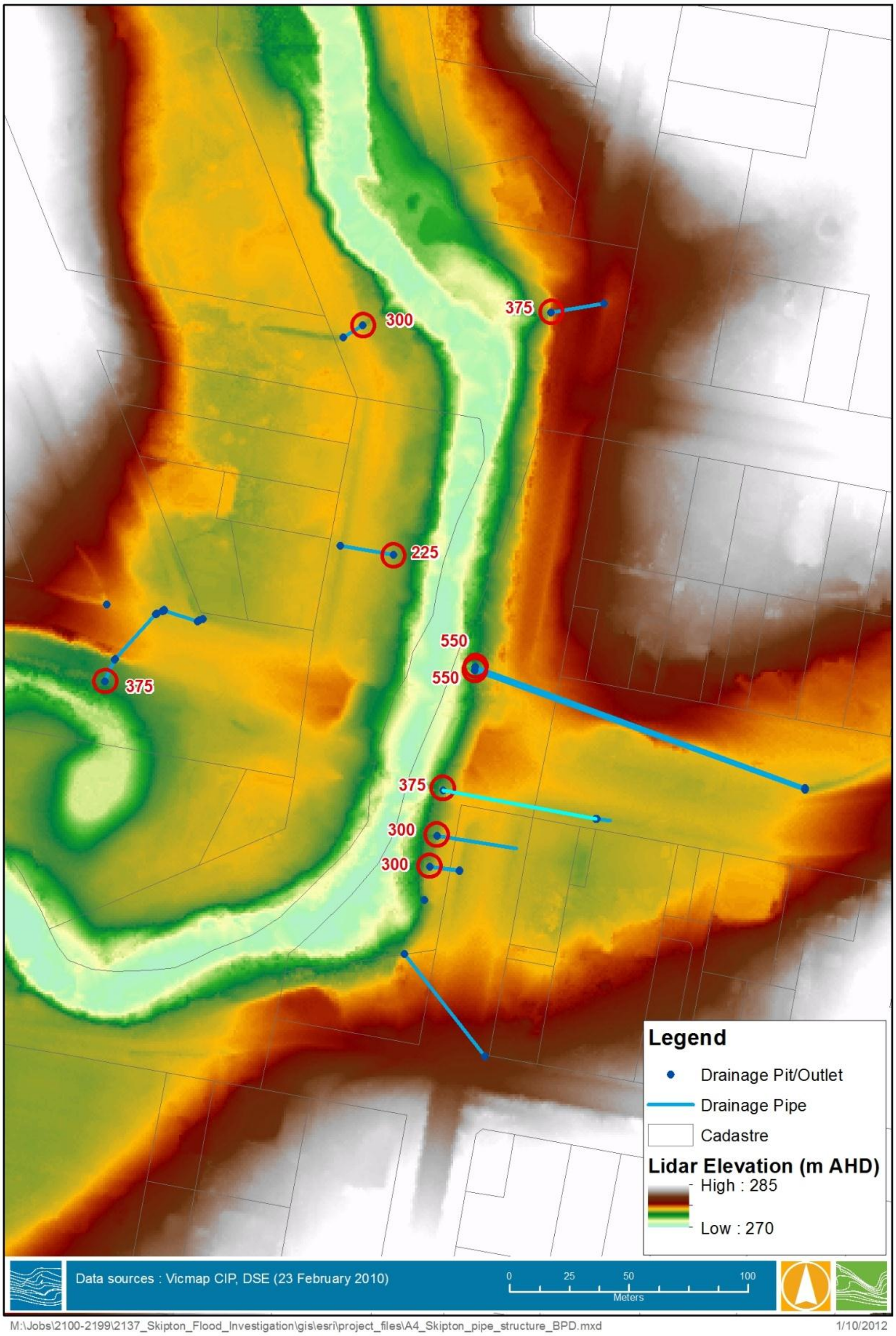

Figure 6-1 **Identification of pipe outlets (circled in red and showing pipe internal diameter) that should be considered as candidates for backflow prevention devices**

Figure 6-2 Difference in 10% AEP flood extent that could be achieved by installation of backflow prevention devices

6.2.5 Upgrading Drain Pipes from Skipton Reservoir

The current total capacity of the two 550 mm drainage pipes downstream of Skipton Reservoir is 1.5 m^3/s. This capacity is exceeded by the outflow from the reservoir in all design events from the 20% AEP up. The frequency and severity of flooding in Montgomery Street could be dramatically reduced by providing adequate drainage of the Skipton Reservoir outflows.

The Skipton Reservoir outflow is the dominant flooding mechanism up to the 10% AEP event. For the 5% AEP and above, flooding from Mount Emu Creek overtopping the bank is the dominant mechanism. It was therefore proposed to size the Skipton Reservoir Drainage Pipes to the 10% AEP flow.

This upgraded pipe array has the capacity to carry a flow between the 10% and 5% AEP local flow, and could therefore effectively eliminate flooding of Montgomery Street in the smaller events. The reduction in flood extent is estimated to be approximately 0.8 ha, and there will be 6 fewer properties flooded above floor level (see Figure 6-3 for comparison).

At and above the 5% AEP event, there is limited benefit to providing drainage of the reservoir overflow, as Montgomery Street flooding is dominated by Mt Emu Creek overflows. The culvert upgrade is expected to have no effect on flood levels caused by Mt Emu Creek flooding.

Table 6-4 Proposed pipe capacity under full range of design flows

AEP	Skipton Reservoir Overflow (m^3/s)	Pipe Flow (6 x 900 RCP) (m^3/s)	Remaining Flood Flow (m^3/s)
20%	6	6	0
10%	7	7	0
5%	9	8.8	0.2
2%	12	10.2	1.8
1%	14	10.9	3.1
0.5%	17	11.8	5.2

A preliminary cost estimate has been prepared using Melbourne Water's Costing and Risk Spreadsheet (Table 6-5). Unit costs in the spreadsheet vary depending on the region of Melbourne. The region with the highest unit costs (North East) was selected to provide a conservative cost estimate. A redevelopment factor of 1.4 was used to factor in the cost of installing pipes under the car park and Anderson Street.

Table 6-5 Cost Estimate for Skipton Reservoir Drainage Pipes

Pipeline Diameter	Length (m)	Factor	Factored Unit Cost ($/m)	Number of Pipes	Cost ($)	TOTAL Cost With Design & Contingency ($)
900	147	1.40	$ 550	7	$ 566,153	$ 880,522

An assessment of the provision of additional flood storage by increasing the size of Skipton Reservoir has not been undertaken due to issues surrounding the current condition of the existing dam structure and the likely flood impacts on private owned land upstream of the present lake area.

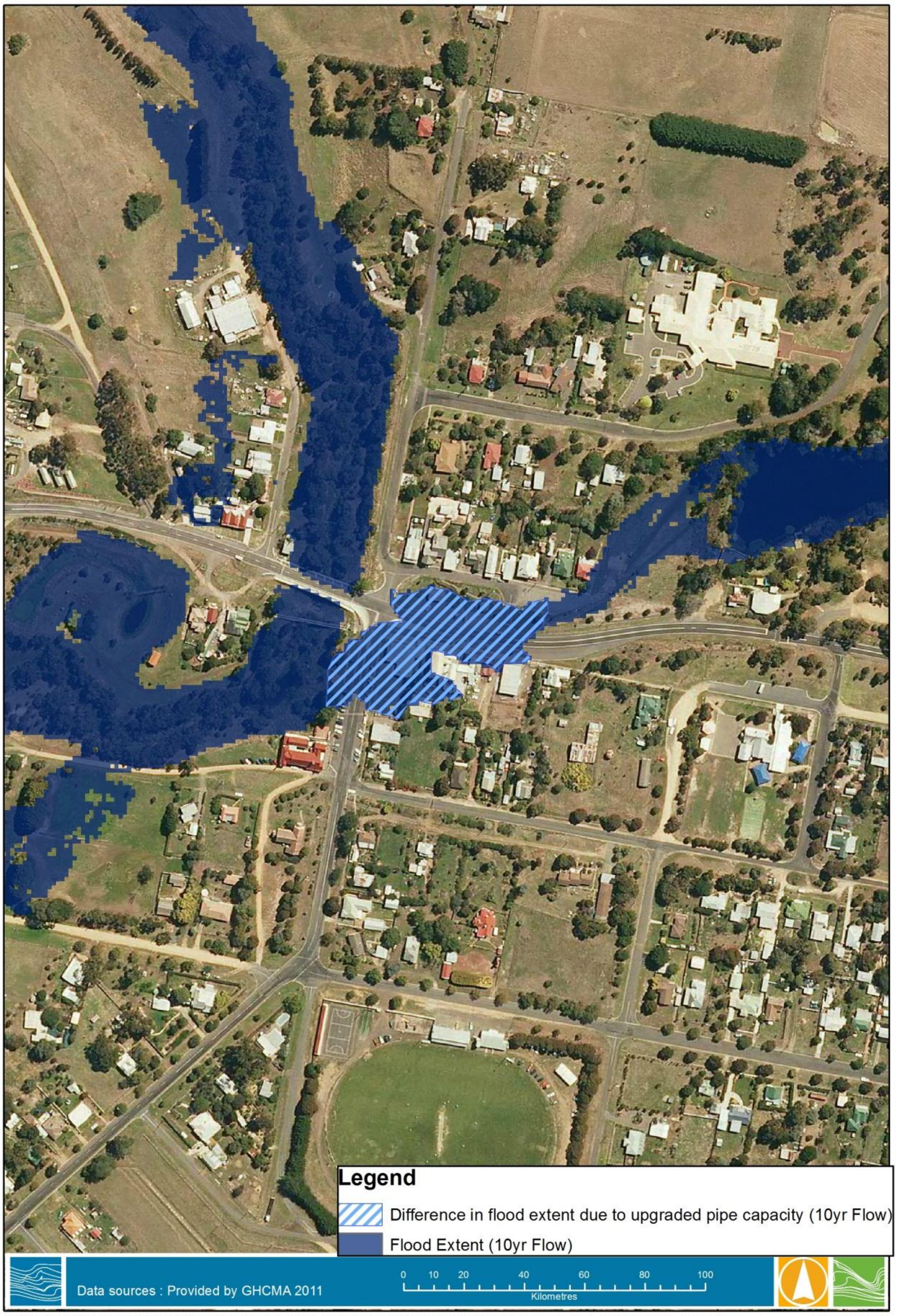

Figure 6-3 Difference in flood extent due to upgrade pipe capacity for outflow from Skipton reservoir (10% AEP Flow)

6.2.6 Removal of Vegetation and Debris from Mt Emu Creek

The effectiveness of removing vegetation and debris from the channel was assessed by lowering the channel roughness through the township area. The Manning's "n" value was reduced from 0.1 (the calibrated value) to 0.045, representing a moderately clean, regular channel section with some weeds and/or brush. Some vegetation and debris removal was undertaken by Corangamite Shire Council after the 2011 flood event.

The 1% AEP and 5% AEP flood flows were run with the lower Manning's "n" value. For the 1% AEP flow, clearing of the channel is expected to lower flood levels in the town by up to 0.2 m (Figure 6-7). In Montgomery Street, levels are expected to be decreased by approximately 0.08m. The flood extent is not expected to be greatly reduced, as the river valley is steep-sided. Most buildings within the flood extent are flooded well above floor level, and a reduction on the order of 8-20 cm is unlikely to materially reduce the flood damage. Examples of flood depth above floor level for selected properties are given in Table 6-6 below. For example, the Skipton Hotel Bar is subject to 1.73 m of flood depth above floor level in the 1% AEP flood under current conditions. With the creek cleared, the inundation depth would be approximately 1.65 m.

Vegetation removal has a larger effect for smaller flows, in which a greater proportion of the total flow is within the channel. For the 5% AEP flow, clearing of the channel is expected to reduce flood levels by up to 0.25 m (Figure 6-8). Flood levels in the Skipton Hotel Bar are expected to be reduced by approximately 0.14 m, from 0.42 m to 0.28 m above floor level. The approximate reduction in levels at the Skipton Hotel Bar due to vegetation clearing is shown in Figure 6-4.

Figure 6-4 Comparison of flood depths at Skipton Hotel with and without vegetation removal

Table 6-6 Change in flood depths as a result of vegetation removal

Property	Current 1% AEP flood depth above floor (m)	Mitigated 1% AEP flood depth above floor (m)	Current 5% AEP flood depth above floor (m)	Mitigated 5% AEP flood depth above floor (m)
Skipton Hotel Bar	1.73	1.65 (-0.08 m)	0.42	0.28 (-0.14 m)
Art Gallery	1.63	1.48 (-0.15 m)	0.72	0.52 (-0.20 m)
Eel Factory	1.73	1.57 (-0.16 m)	0.41	0.20 (-0.21 m)
Bolte House (44 Wright St)	0.91	0.78 (-0.13 m)	0	0

The channel topography was not altered in the model runs. Note that if the channel were cleared of vegetation and debris, the banks may become unstable leading to a change in channel geometry. The stability of the Skipton Mechanics Hall could be undermined if active erosion of the channel bank downstream of the bridge is initiated following vegetation removal. An example of active bank erosion is shown in Figure 6-5, which shows substantial erosion of a sparsely vegetated channel bank on Boyd Creek in the Maribyrnong River catchment.

Figure 6-5 Example of bank erosion related to vegetation removal (Photo by Sally Day, 2008)

The loss of any visual and recreational amenity or the loss of ecological value caused by clearing the channel has not been considered in the cost benefit analysis. The effect of vegetation removal post floods is shown in Figure 6-6 at Clunes, where flood recovery works included substantial vegetation removal from the creek.

Figure 6-6 Examples of post flood vegetation removal undertaken as part of the flood 2011 recovery program, Clunes

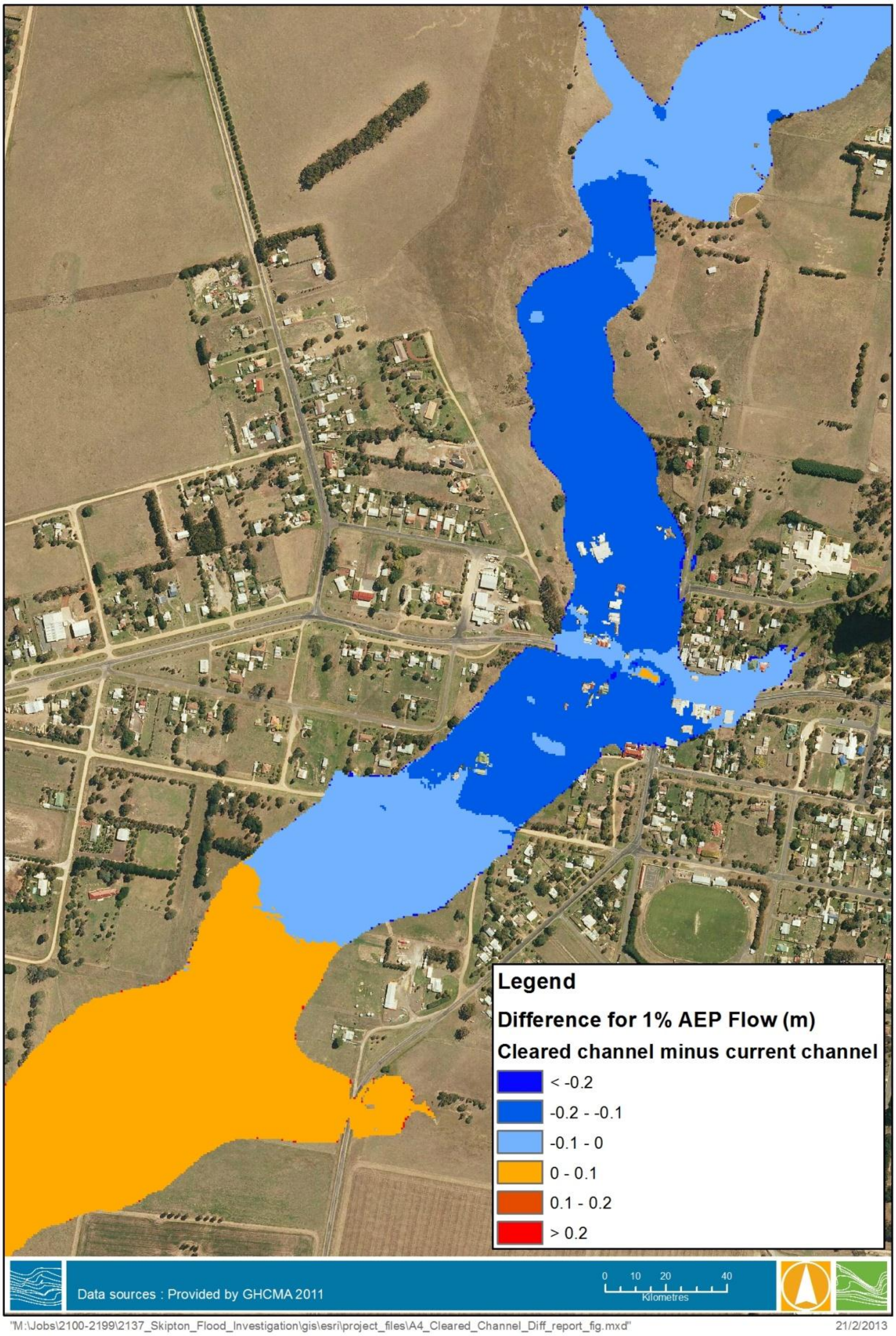

Figure 6-7 Difference between water surface elevation for the current channel state and the cleared channel state (1% AEP flow)

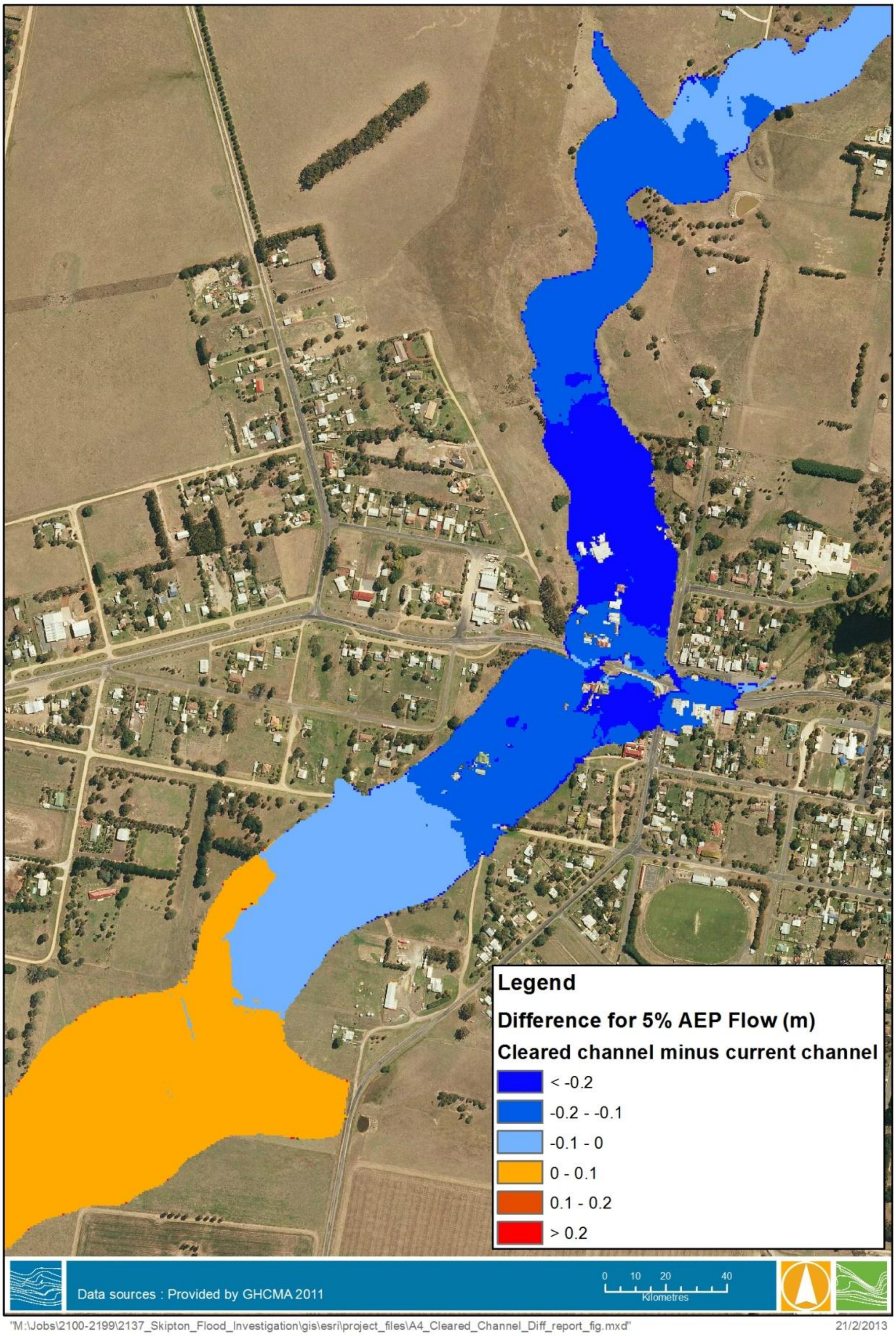

Figure 6-8 Difference between water surface elevation for the current channel state and the cleared channel state (5% AEP flow)

6.3 Damages Assessment for Structural Mitigation Options

An indicative cost benefit analysis has been undertaken for the three options identified as feasible through the mitigations options assessment process. The cost-benefit is defined as the cost of works for an option versus the reduction in flood damages associated with the various flood events.

Damage estimates are provided in Section 6.2. Only changes in the likely damages costs are reported here, Table 6-7.

Option 7 (Installation of flap gates on local drainage pipes discharging into Mt Emu Creek) provides a modest benefit in the 10% AEP flood for very little cost. It would be expected to reduce the Average Annual Damage Cost by approximately $1,000, and could pay itself off within 8 years.

Option 6 (Upgrading of local drainage receiving water from Skipton Reservoir) Provides a major benefit to the Average Annual Damage Cost, but is a high-cost option. It would be expected to have a pay-off period of approximately 15-17 years.

For Option 3 (Increased Mt Emu Creek channel capacity though the town through vegetation & debris clearing) there is expected to be a moderate reduction in Average Annual Damage Cost for a moderate cost. There would be three less properties flooded above floor under the 1% AEP flood, one less property flooded above floor under the 5% AEP flood, and 8 less properties flooded (all below floor) under the 10% AEP flood. A pay-off period of 4-12 years is expected, considering only the cost of initial works. This option would require regular maintenance which would significantly increase its long-term cost. It would also cause detrimental impacts to the character, amenity and biodiversity of the creek reserve through the town, which has not been costed here.

Table 6-7 Preliminary estimates of damages cost reductions associated with mitigation options

Option No.	Mitigation Option	Estimated Cost*	Estimated Reduction in Damage Cost for Various AEP Events						Estimated Reduction in Average Annual Damage
			0.5%	1%	2%	5%	10%	20%	
7	Installation of flap gates on local drainage pipes discharging into Mt Emu Creek	$7,760	0	0	0	0	$12,888	0	$996
6	Upgrading of local drainage receiving water from Skipton Reservoir	$880,000	0	0	0	up to $191,921**	$191,921	$180,070	$50,408-$58,085
3	Increased Mt Emu Creek channel capacity though the town through vegetation & debris clearing	$50,000 to $100,000	<$105,918***	$105,918	$105,918-$110,404***	$110,404	$14,611	<$14,611***	$8,424-$11,701

*Does not include on-going maintenance costs

**No flood modelling simulations undertaken for the 5% AEP event to accurately determine the likely damage reduction but costs due to overbank flows from Mt Emu Creek occurring for this event inundation of property is likely to occur.

***No flood modelling undertaken for these AEP events, values have been inferred from the results of other AEPs

6.4 Non-Structural Mitigation Measures

6.4.1 Overview

Non-structural measures are floodplain management activities aimed at reducing future flood damages. Non-structural measures aim to reduce existing flood risk by lowering flood damages (consequences) at a given location (as opposed to structural measures which tend to reduce frequency or likelihood of flooding). Non-structural measures include:

- Catchment management
- Flood awareness, preparedness, warning and response
- Land use planning

Catchment management activities in the upstream catchment can influence the existing catchment runoff characteristics (flood peaks and volumes). Flood volumes and peaks are a function of the vegetation cover and land use within a catchment (in addition to topography). Land clearing and drainage works have significantly altered flood response in the catchment. Further drainage works may increase flood peaks and flood volumes resulting from significant rainfall events. Increases in peak flows and flood volumes in turn result in a higher flooding likelihood and flood risk. Catchment revegetation, over the longer term may reduce flood volumes. However, in major floods reductions in peak flow would be expected to be minimal.

Flood awareness, preparedness, warning and response aims to reduce the growth in future flood damages by improving community awareness of flooding and emergency services response. Flood awareness within a community reflects the frequency of significant flooding i.e. infrequent insignificant flooding leads to lower community flood awareness. The most recent significant flooding events occurred in the 2010/2011 flood events. Given the recent occurrence of significant flooding with associated damages to property, the community awareness of flooding in Skipton is expected to be medium.

Further discussion of flood warning and response arrangements, and community flood awareness is provided in Section 7.

Land use planning aims to reduce flood damages by providing appropriate guidelines/controls for land use and development. The Victoria Planning Provisions (VPPs) allow for zoning of land and the application of controls on the type of land use and permitted activities in areas prone to flooding. The VPPs provide for the following flood related zone and overlays:

- Land Subject to Inundation Overlay (LSIO)
- Floodway Overlay (FO)
- Urban Floodway Zones (UFZ)

The VPPs provide guidelines for the appropriate uses and/or development of land in LSIO, UFZ and FO areas. Further discussion of proposed land use planning mapping developed by this study for Skipton is provided in Section 8.

7. EMERGENCY MANAGEMENT

7.1 Overview

The 2010-11 flood events confirmed that a formal flood forecasting and warning system does not exist for Mt Emu Creek or for any of the communities within the catchment. Further, the events highlighted critical deficiencies in existing arrangements and demonstrated that they failed to meet community and emergency agency expectations regarding the provision of accurate and timely information aimed at facilitating appropriate response actions. These issues were discussed in the Glenelg Hopkins CMA submission (Water Technology, 2011) to the Comrie Review (Comrie, 2011). While a range of matters were covered in that submission, it was noted in particular that:

- The "total" flood warning system is limited and that most of the deficiencies arise from the lack of data and related flood intelligence.
- The rain and river level data collection network is sparse and is inadequate for the need: it is not sufficiently dense or accessible:
  - There is a clear need for a more dense network of rain and stream[1] gauges;
  - Rain and stream gauges need to be automated and to report in real-time;
  - Resulting data needs to be uploaded to the Bureau of Meteorology website so that it is accessible to communities and response and related agencies and available to assist their maintenance of an up-to-date appreciation of event development.
- At-risk communities within the Mt Emu Creek catchment are not provided with any guidance on likely future flood conditions (i.e. a flood forecast or other information about the time to rise above predetermined critical levels, time to peak, likely peak level, etc.) with the result that appropriate damage reducing actions are not implemented with sufficient lead time:
  - There is need for an improved flood forecast capacity based on robust hydrologic (i.e. rainfall-runoff) models that use rainfall data to predict stream flows and levels at key locations;
  - Flood class levels need to be established for all at-risk / forecast locations.
- The intelligence that enables a predicted flood height to be interpreted in terms of flood inundation extents, depths and likely impacts is not available.
- Other elements of the total flood warning system need to be fully established and / or strengthened.

With the above comments in mind and the benefit of the flood intelligence (particularly the Corangamite Flood Emergency Plan Appendices for Skipton) and flood mapping delivered by the Skipton Flood Investigation, existing flood warning arrangements have been examined in the context of the Total Flood Warning System (TFWS) model (EMA, 2009). Following consideration of available remedies and local flooding characteristics, actions aimed at addressing deficiencies in each of the eight TFWS building blocks have been recommended, refer Volume 7. Ball park cost estimates have also been provided, refer Volume 7.

The detailed flood warning/emergency response report is provided in Volume 7 while a summary of the recommendations is provided in the following section.

[1] Also referred to as river gauging stations. Both terms are used throughout this report.

7.2 Suggested Actions

A staged approach to the development of a flood warning system for Skipton is proposed. The stages have been ordered and the tasks within each stage grouped to facilitate growth of all elements of the TFWS in a balanced manner and with full regard for matters discussed in Volume 7. While it may be tempting to immediately move to install additional rain and river gauges and to develop a forecast model, there are other more fundamental matters that experience tells us need to be addressed first. Thus early attention is directed at ensuring roles and responsibilities are agreed, understood and accepted and that there is a firm foundation for the development of an effective flood warning system: one that does not fail when it is needed most. Attention is then directed to establishing a robust framework for communicating and disseminating flood related information so that immediate and maximum use can be made of available information as the ability to detect and predict flooding at Skipton improves.

Next, attention is focussed on securing the funding needed to buy, install and operate field equipment as well as other services needed to build elements of the TFWS. The installation of data collection equipment follows, with a two tiered approach in the event that funding is not available or is delayed. Development of other technical elements and the build and delivery of on-going flood awareness activities can then occur in the knowledge that required data is / will be available and that robust and sustainable arrangements are in place that will enable maximum benefit to be derived from any information or programs delivered to the community.

The potential for flash flooding and inundation of parts of the main street by overflows from the Jubilee Park Lake via the Skipton Dam suggests that the flood action group or warden system proposed herein as part of the staged development, coupled with use of the indicative quick look ‘flood / no flood’ tool, should endure after implementation of a formal flood forecasting service by the Bureau of Meteorology.

Table 7-1 Suggested Flood Warning/Emergency Management Actions for Skipton

Stage	Suggested Actions
Stage 1	Council, GHCMA, VICSES and other entities to determine the responsible entity in relation to “ownership” of each element of the flood warning system for Skipton. Note that ownership is considered to denote overall responsibility for funding as well as the functioning of the system element and, in the event of failure, responsibility for either fault-fix or the organisation of appropriate fault-fix actions along with any associated payments. This includes resolving responsibility for funding the continued operation of equipment upgraded by the GHCMA at the Mena Park and Skipton gauging stations. VFWCC (2001) provides guidance on data collection network aspects although Recommendation 1 from the Comrie Review Report (Comrie, 2011) suggests that some clarifications may be required.
Stage 2	1. Council champion and in conjunction with VICSES oversee the establishment of a flood action or flood warden group for Skipton. Clearly establish the role for this group along with its authority and structure with due regard for liability issues. Essentially the group would: a. Collect and collate rain and water level / flow data and also monitor rain and river information via the Bureau’s website. b. Make initial assessments of the likelihood and scale of flooding at Skipton based on available rainfall data, water levels and trends at Mena Park and Skipton, and the indicative quick look ‘flood / no-flood’ tool developed for Skipton and included in the Corangamite Municipal Flood Emergency Plan (MFEP).

Stage	Suggested Actions
	c. In the event of likely flooding, call VICSES to advise of likely flooding and, subject to discussion with the Regional Duty Officer (RDO) or Incident Controller (IC), call the Corangamite Shire Municipal Emergency Resource Officer (MERO) and initiate flood response actions within Skipton consistent with the MFEP. This may include door knocking and through the MFEP, identification of roads and properties likely to be impacted and the coordination of removal of items susceptible to damage from floodwater from buildings likely to be flooded over-floor when conditions indicated it is warranted or necessary and thereafter work closely with VICSES, CFA and Council. d. Maintain a watching brief on flood response arrangements within Skipton and provide feedback to Council on the adequacy and efficacy of arrangements in place at the time. 2. Council with the support of VICSES, GHCMA and the Skipton community to submit an application for funding under the Australian Government Natural Disaster Resilience Grants Scheme (or similar) for all outstanding elements of a TFWS for Mt Emu Creek to Skipton. 3. Council to share the MFEP with the Skipton community. 4. Council to establish arrangements for the timely supply of sandbags and sand within Skipton. 5. Council to load and maintain flood related material (including the MFEP) to its website. 6. Council and VICSES to encourage and assist residents and businesses to develop individual flood response plans.
Stage 3	1. Install a set of staff gauges (up to 5 x gauge plates) immediately upstream of Guthries Bridge on the Mt Emu Settlement Road and another set immediately upstream of the Streatham-Carngham Road (or the Beaufort-Carngham Road) on Bailie Creek. Set to either AHD (Australian Height Datum) or local datum and survey to AHD. Establish on-going gauge reading and maintenance arrangements, the latter ideally through the Surface Water Monitoring Partnership. 2. Update the MFEP with staff gauge datums and other relevant details. 3. Council in conjunction with VICSES to establish and document in the MFEP arrangements for the timely: ➢ Pick-up and removal of items susceptible to damage from floodwater from buildings likely to be flooded; ➢ Supply of sandbags and sand within Skipton with sufficient lead time to enable buildings at risk of minimal over-floor flooding to be sandbagged / protected. 4. VICSES to initiate a community engagement program at Skipton in order to communicate how the flood warning system will work. This will need to be repeated as the system matures

Stage	Suggested Actions
	5. VICSES to develop and distribute a FloodSafe brochure for Skipton. 6. Council to oversee the development, printing and distribution of property-specific flood depth charts for properties within Skipton.
Stage 4A	**To be actioned only if funding to undertake Stage 4B is either not available or is delayed** 1. Either directly with the reader or possibly through Bureau of Meteorology, arrange for access to as-required rainfall data from the BOM daily-read rain gauge at Skipton. Ideally this will involve the reader in providing data directly to the flood action or flood warden group at frequent intervals during heavy rain events. 2. Determine the location of private rain gauges in close vicinity to Lake Burrumbeet within the Bailie Creek catchment and at Skipton (if the outcome from 1 above was negative) and establish arrangements for the provision of rainfall data to the flood action or flood warden group at frequent intervals during heavy rain events. Alternatively, source two rain gauges and distribute to local residents willing to provide rainfall data at frequent intervals during heavy rain events in the general vicinity of: ➢ Skipton (priority 1). ➢ Bailie Creek between Lake Burrumbeet and Mt Emu Creek (priority 2).
Stage 4B	1. Using equipment similar to (or the same as) that already installed and operational at the Mena Park gauging station: • Establish a telemetered rain and stream gauge at Guthries Bridge; • Establish a telemetered rain and stream gauge at the staff gauge site on Bailie Creek; • Add a rain gauge to the Skipton gauging station. 2. Establish on-going maintenance arrangements for all installed equipment, ideally through the Surface Water Monitoring Partnership. 3. Approach Bureau of Meteorology (BOM) to add all telemetered sites to appropriate rainfall and river level bulletins accessible via the BOM website. Requires telemetry systems used to be fully compatible with BOM systems. 4. Council to begin building a relationship between levels at the stream monitoring site on Bailie Creek, at Guthries Bridge and at Skipton in order to assist flood assessment and response at Skipton and in order to inform the development and / or firming up of flood class levels at each site 5. If appropriate and following achievement of full operational status of each telemetered site providing additional rain and river data, retire the manual readers in the general vicinity who have previously provided that data for the Skipton flood warning system.
Stage 5	1. In conjunction with VICSES, GHCMA and the Skipton-based flood action or flood warden group, Council to determine appropriate rain and river trigger levels for the initiation of SMS alerts and / or email alerts from telemetry sites. 2. BOM to establish a rainfall-runoff based flood forecast model for Mt Emu Creek to

Stage	Suggested Actions
	Skipton.
Stage 6	Install flood depth indicator boards at key locations in and around Skipton (e.g. on the approaches to the Smythe Street and Montgomery Street bridges and at strategic locations on Anderson Street as indicated by the flood inundation maps delivered by the Skipton Flood Investigation) and further afield.

8. DATASETS AND MAPPING

8.1 Overview

The flood mapping and datasets developed as part of the Skipton Flood Investigation are described in this section. Details are provided regarding the input data, methodology and outputs for the emergency response inundation and land use planning mapping.

8.2 Flood Response Inundation Mapping

8.2.1 Overview

For each design flood, the peak flood elevation at the Skipton gauge was determined from the maximum modelled flood level at the location of the gauge. Table 8-1 displays the gauge heights at the Skipton gauge for which flood emergency response maps have been prepared.

Table 8-1 Flood inundation Emergency Response Maps: Skipton Gauge Heights for Design Flood Events

Skipton Gauge Height[2] (m)	Flood level at Skipton Gauge (m AHD)	Design Flood Event AEP (%)	Design Flood Event ARI (years)
4.09	274.57	20	5
4.70	275.18	10	10
5.10	275.58	5	20
5.81	276.29	2	50
6.07	276.55	1	100
6.54	277.02	0.5	200

The flood response inundation maps have been provided in pdf format for each flood event at 1:5,000 and 1:15,000 scales. The map base is cadastre as supplied in 2011 and is subject to change.

The following map components were generated:

- Flood extent and flood depth
- Flood elevation contours
- Flood affected properties
- Emergency service locations

8.2.2 Flood Extent and Flood Depth Zones

The hydraulic analysis provides regular grid of flood elevations across the hydraulic model study area. The flood extent was defined by intersecting the modelled flood elevations with a 3 m grid of the LiDAR. Following the intersection, all grid cells with a depth > 0.05 are selected and this is then converted to an extent polygon. The extent is smoothed to remove the sharp edges of the grid cells for cartographic / presentation purposes.

[2] The Skipton Gauge is located immediately downstream of the Smythe Street Bridge. Gauge zero is 270.48 m AHD

Flood depths were classified for mapping using the following classifications:

- 0 m to 0.25 m
- 0.25 m to 0.5 m
- 0.5 m to 1.0 m
- Greater than 1.0 m

8.2.3 Flood Elevation Contours

The flood elevations were contoured at 0.2 m intervals. The automatic contouring procedures can create erroneous flood elevation contours, therefore manual refinement of the flood contours was undertaken to improve their interpretability.

8.2.4 Flood Affected Properties

As detailed in Section 2.4.3 a survey was carried out of building floor heights identified within the study area that were within the likely 1% AEP flood extent.

The location of the property footprint polygons indicates the building location. The building footprint polygons were coloured as follows to indicate the flooding status:

- Below floor flooding:- light grey shading
- Above floor flooding:- red shading

Light grey shading denotes the location of a building not inundated above floor height. It should be noted other areas within the property allotment may however be flooded and access issues should be considered

8.2.5 Emergency Service Locations

The location of the following emergency services were included on the flood response maps:

- Fire Station
- Police Station

8.3 Flood Mapping for Land Use Planning

8.3.1 Overview

Land use planning controls and building regulations provide mechanisms for ensuring appropriate use of land and building construction, given the flooding risks to a particular area. Land use planning controls are aimed at reducing the growth in flood damages over time. The controls balance the likelihood of flooding with the consequences (flood risk).

As part of ongoing municipal reform, the State Government introduced a consistent planning scheme format for application across the State. The Victorian Planning Provisions (VPPs) are employed by all Victorian municipalities.

Victorian Building Regulations specify that floor levels should be at least 300 mm above a nominated flood level. If land is subject to flooding, the municipal council may set conditions that require particular types of construction or particular types of construction materials.

This section details the input data, methodology and outputs for the land use planning flood mapping. The following are discussed:

- Victorian Planning Provisions – outlines the flood related Victoria Planning Provisions (VPPs).

- Flood related planning zones and overlay – details the available flood related planning zone and overlays.
- Flood related planning zone and overlays delineation – details the delineation of the flood related planning zone and overlays for the study area

8.3.2 Victorian Planning Provisions

The Victoria Planning Provisions (VPPs) aim to achieve consistency in the application of planning controls for areas subject to flooding throughout the State. The stated objectives are to protect life, property and community infrastructure from flood hazard, and to preserve flood conveyance capacity, floodplain storage and natural areas of environmental significance.

The VPPs provide for two overlays and one zone associated with mainstream flooding as follows:

- Land Subject to Inundation Overlay (LSIO),
- Floodway Overlay (FO),
- Urban Floodway Zone (UFZ).

Only the LSIO and FO overlays were considered relevant to the present study. Details of the definition of these overlays are provided in the following sections.

For each of the overlays, the VPPs specify the appropriate types of land uses and developments which are to be regulated through a system of permits. These are intended to achieve consistency throughout the State, but local variations to these guidelines are allowed in planning permit exemptions through a schedule to a flood overlay and/or performance-based criteria through a local floodplain development plan that has been incorporated into the planning scheme.

8.3.3 Flood Related Planning Overlays

Land Subject to Inundation Overlay (LSIO)

The LSIO identifies land liable to inundation by overland flow, in flood storage or in flood fringe areas affected by the 1% AEP flood.

The permit requirements of LSIO are intended:

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

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

Permit requirements as well as performance based controls can be specified. For Skipton, no LSIO overlay has been proposed. This is discussed further in Section 8.3.4.

Floodway Overlay (FO)

The FO identifies waterways, main flood paths, drainage depressions and high hazard areas. The identification of floodways can be based on NRE's "Advisory Notes for Delineating Floodways" (Edwards, 1998). The advisory notes provide three approaches to the delineation of FO, as follows:

- **Flood frequency**: For flood frequency, Volume A1 of the advisory notes suggest areas which flood frequently and for which the consequences of flooding are moderate or high, should generally be regarded as floodway. The 10% AEP flood extent was considered an appropriate floodway delineation option based on flood frequency.
- **Flood Depth:** For flood depth, regions with a flood depth in the 1% AEP event greater than 0.5 m were considered as FO based on the flood depth delineation option.
- **Flood Hazard:** Flood hazard considers the combination of flood depth and flow velocity for a given design flood event. The flood hazard for the 1% AEP event, as defined by the criteria in Edwards (1998), was considered for the floodway delineation.

The final extent of the floodway overlay proposed for Skipton, based on the consideration of the three approaches, is discussed in following section.

8.3.4 Flood Related Planning Zone and Overlay Delineation

Model outputs (flood extents, flood depth and flow velocity) from the hydraulic analysis were employed to provide information on the flooding characteristics over the study area. Flood related planning maps (at the same scale as the flood inundation mapping) were produced showing areas of potential FO and LSIO based on flooding characteristics.

The flood related planning maps were revised and amended in consultation with the Corangamite Shire and Glenelg Hopkins CMA. Through this consultation, due consideration was given to local social, economic and environmental issues.

For the final land use planning mapping only FO has been recommended as there is only negligible fringing land that could be included within an LSIO. Two Special Areas have been identified within the FO. Specific development controls are recommended for each of these areas to reflect the current level of development and level of flood hazard associated with the land. The draft FO extent is shown in Figure 8-1.

Large floods at Skipton are characterised by extremely high hazard across the vast majority of the floodplain. The floodplain is confined on both sides by steep valley margins, such that an increase in flow results in an increase in depth and velocity without a significant increase in the flood extent. The entire floodplain is inundated from the 5% AEP event. In the 1% AEP event, floodplain depths of up to 2.5 m and floodplain velocities of up to 2 m/s are expected.

The Stage 1 report of Project 10 of the Australian Rainfall and Runoff Revision (Cox et al. 2010) provides new hazard regimes based on a review of research on flood safety for people. Under these hazard regimes the conditions on the Skipton floodplain in the 1% AEP flood would be considered extremely hazardous for adults. Given the frequency of flooding of these areas, and the extreme hazard, the FO is a more appropriate planning control for the Skipton floodplain than LSIO.

It is anticipated that more detailed information will be made available by Corangamite Shire Council upon exhibition of an amendment to the planning scheme.

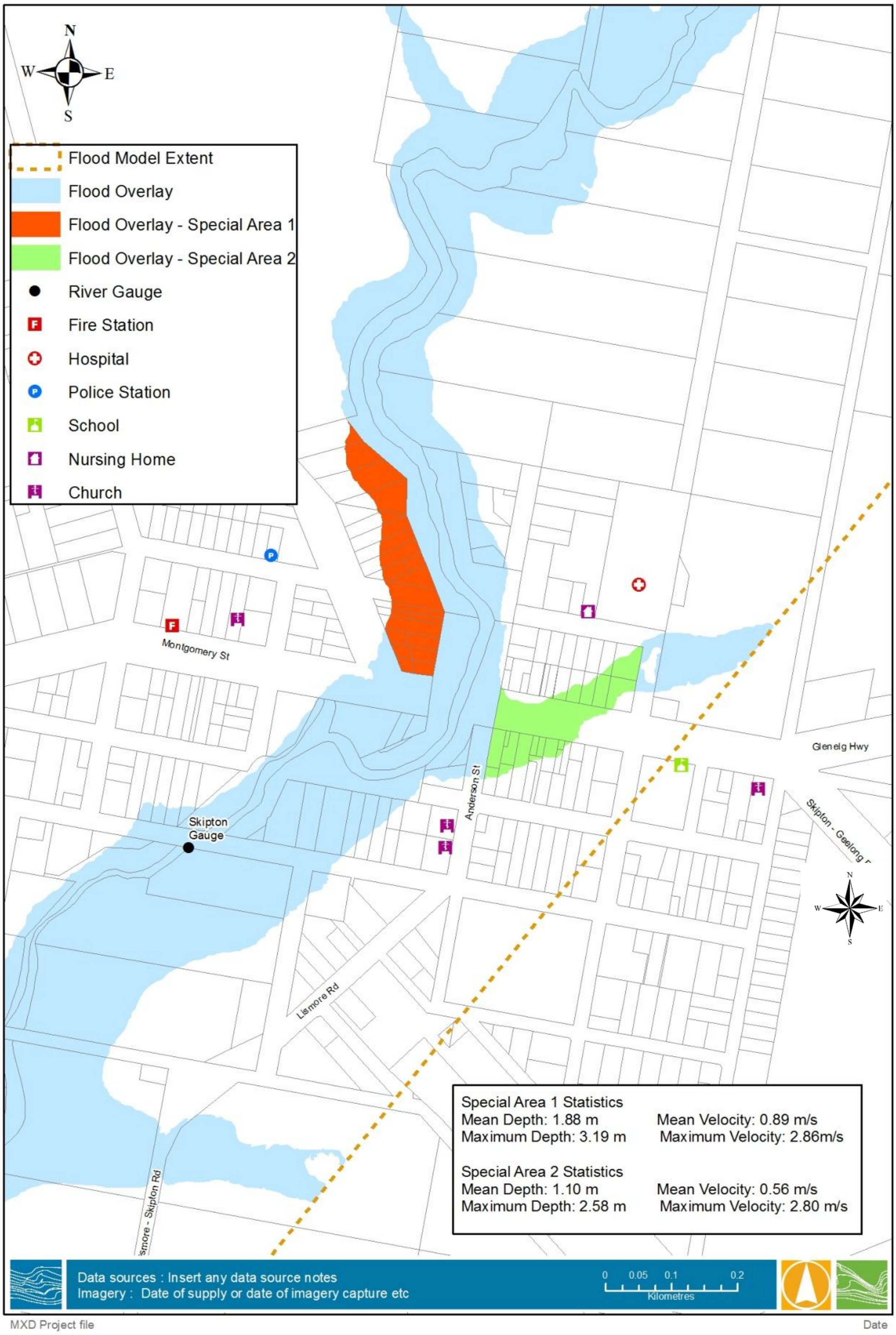

Figure 8-1 Draft Floodway Overlay and Special Areas

8.3.5 Planning Scheme Controls

Draft planning scheme controls have been developed for the FO at Skipton which seek to:

1. Minimise risks to life, health and wellbeing associated with flooding of the township;
2. Maintain to the maximum possible extent, the free passage and temporary storage of floodwaters;
3. Require new development to use materials, design and construction techniques to minimise likely damage by floodwater;
4. Ensure new development will not cause any significant rise in flood level or flow velocity to the detriment of other land holders or property;
5. Ensure flood damage costs are not compounded unduly;
6. Ensure existing development that is affected by flooding is maintained in a manner commensurate with the likely impacts from future flood events.

Further information is provided in the Planning Scheme Amendment documentation currently being prepared by Corangamite Shire Council.

9. STUDY DELIVERABLES

9.1 Overview

The study deliverables provide a comprehensive set of data that support the study outcomes. The deliverables are supplied on a study DVD and consist of background data and outputs as listed below:

- Digital copies of study reports in PDF format.
- Study survey data (LIDAR, structures, cross-sections and floor levels)
- Other input data including rainfall and flow data
- A property database including flood information
- Digital copies of the maps (PDF format)
- GIS datasets for the model results (Mapinfo and ArcGIS format)
- The hydrologic and hydraulic model input files

There is a readme.txt file on the disk that describes the directory structure of the data contained on the disk.

9.2 Mapping Outputs

Details are provided of the study outputs for emergency response, and land use planning mapping including:

- Data sets: grids and shapefiles/tabfiles
- Planning layer
- Flood response inundation maps
- VFD layer updates

9.2.1 Data Sets

The following datasets have been provided. All GIS files were provided in ESRI and MapInfo format.

Grids

Gridded datasets of model results were provided for the following:

- PMF – maximum hazard and water surface elevation,
- Climate change sensitivity (10%, 1% and 0.5% AEP events) – maximum depth, hazard and water surface elevation,
- Design events (10%, 20%, 5%, 2% 1% & 0.5% AEP events) – maximum depth, hazard, velocity and water surface elevation.

Shapefiles/Tabfiles

ERSI shapefiles and MapInfo Tab files were provided for the following:

- Flood depth contours
- Flood extents
- Floor levels
- Mapping limits

- Water surface elevation (flood level) contours

9.2.2 Maps

The flood response inundation maps have been produced for the following design flood events:

- PMF – maximum depth and hazard,
- Climate change sensitivity – maximum depth and hazard for the 10%, 1% and 0.5% AEP events,
- Flood Hazard - 20%, 10%, 5%, 2% 1% & 0.5% AEP events,
- Flood Depth - 20%, 10%, 5%, 2% 1% & 0.5% AEP events,
- Flood Velocity - 20%, 10%, 5%, 2% 1% & 0.5% AEP events.

Each map includes:

- Flood extent,
- Flood level contour at 0.2 m and 1m intervals,
- Depth of inundation,
- Identification of essential services,
- Road/street names
- Cadastral base
- Land marks, including all physical man-made features particularly those affecting flood flows and distribution.
- Gauge height indication for the Mt Emu Creek at Skipton Station 236203A.

Soft copies were provided as PDFs. Related GIS files were provided in ESRI and Mapinfo format.

9.2.3 Flood Extent Mapping (VFD Compliant)

All flood mapping data was prepared to the VFD metadata specifications.

9.2.4 Land Use Planning Maps

A draft FO map has been produced as part of the Planning Scheme Amendment documentation. A copy of this map is included on the study DVD.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 Overview

The Skipton Flood Investigation provides a comprehensive analysis and review of existing and future potential flood risk in the township and surrounding area. The study has involved:

- Collection and review of a range of data relevant to the definition of flooding within the study area.
- A survey analysis to develop a detailed description of the study area topography as a basis for analysis and mapping.
- A rigorous hydrologic analysis to develop robust design flood estimates for the study.
- Development of a detailed hydraulic model that is capable of predicting flood impacts at Skipton under a range of conditions.
- Quantification of flood risk in terms of flood damages.
- Thorough sensitivity testing of the hydraulic results under both existing conditions and for a potential climate change scenario (a 20% increase in rainfall intensity).
- Examination of a range of potential flood mitigation options for the township.
- Review of flood warning and emergency management for Skipton including recommendations for development of a total flood warning system,
- Planning Scheme Amendment documentation for Skipton.

10.2 Key Outcomes

In undertaking this study a number of important aspects of flood risk relevant to Skipton have become apparent. These are summarised as follows.

Skipton Hydrology – flooding in Skipton is a function of both local catchment runoff for more frequent high intensity rainfall events (up to 10% AEP), and overbank flooding from Mt Emu Creek which are typically related to sustained longer duration rainfall throughout the upstream catchment.

Hydraulic Characteristics of Mt Emu Creek at Skipton – Local catchment inflows through Skipton Dam dominate flooding in the township for more frequent events (up to 10% AEP), with significant flooding occurring on the eastern side of Mt Emu Creek and inundation of properties in the main street in particular. For floods greater than 10% AEP overbank flows from Mt Emu Creek increasingly contribute to flooding in the township and there is floodplain flow across both western and eastern floodplains. Because the floodplain of Mt Emu Creek at Skipton is confined on both sides by steep valley margins, flow depths and velocities across the floodplain can be hazardous for the majority of flood events (>10% AEP). As the magnitude of a flood event increases the increase in flow results in an increase in depth and velocity without a significant increase in the flood extent.

Climate Change Risk Profile – Due to the characteristics of the floodplain at Skipton the potential impacts of climate change associated with increased rainfall intensity mean that while there is likely to be an increase in flood depth for a given AEP event there is only limited change in flood extent.

Flood Mitigation – Mitigation of flood risk through structural mitigation options such as the use of upstream storage in Lake Goldsmith, installation of flood flaps, upgrading of local drainage, and clearing of vegetation and debris from the creek amongst many options investigated provides only limited benefit to the township of Skipton. The focus on non-structural measures such as flood warning, emergency management and planning controls for reducing flood risk is therefore more appropriate for Skipton.

Planning Controls – Due to the high hazard nature of flood risk in Skipton the most appropriate planning control for Skipton is a Flood Overlay (FO) rather than a Land Subject to Inundation Overlay (LSIO).

10.3 Recommendations

Following the investigations undertaken for the study and the conclusions reached it is recommended that:

- The GHCMA and Corangamite Shire Council adopt the determined design flood levels and proceed with the planning scheme amendment process.
- The Corangamite Shire Council and GHCMA continue to engage the community in the treatment of flood risks through regular flood awareness programs such as the VICSES FloodSafe program, starting with the development of a local flood guide.
- The Corangamite Shire Council and GHCMA explore further the recommendations for enhanced flood response through co-operation with SES and Police, utilising the flood inundation maps and flood intelligence tools included in the Municipal Flood Emergency Plan (MFEP). Consideration should be given to the use of the MFEP during an emergency.
- The Corangamite Shire Council and GHCMA explore further the recommendations for the development of the proposed total flood warning system for Skipton in conjunction with the BoM and SES.

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