



Summary Report

Great Western Flood Investigation

Northern Grampians Shire Council

14 October 2026



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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present.



Artwork by Maurice Goolagong 2023. This piece was commissioned by Water Technology and visualises the important connections we have to water, and the cultural significance of journeys taken by traditional custodians of our land to meeting places, where communities connect with each other around waterways.

The symbolism in the artwork includes:

- Seven circles representing each of the States and Territories in Australia where we do our work
- Blue dots between each circle representing the waterways that connect us
- The animals that rely on healthy waterways for their home
- Black and white dots representing all the different communities that we visit in our work
- Hands that are for the people we help on our journey



14 October 2026

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Dear Trent

Great Western Flood Investigation

Please see the attached Great Western Flood Investigation Summary Report. The Great Western Flood Investigation reporting was separated into six components. This report documents a summary of these deliverables.

Water Technology would like to thank Northern Grampians Shire Council, Wimmera CMA, and the Great Western community members who gave their time to provide their personal observations of flooding and provide feedback on the flood modelling.

Strong contributions from stakeholders and specifically community members have resulted in improved outcomes from this study, which will assist with flood related land use planning, floodplain risk management, flood emergency response and raising community awareness of individual flood risk.

Yours sincerely

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WATER TECHNOLOGY PTY LTD

1 INTRODUCTION

Water Technology was commissioned by North Grampians Shire Council (NGSC) to undertake the Great Western Flood Investigation. The investigation area covers the Great Western township, situated on the Western Highway in the upper reaches of Concongella Creek, a tributary of the Wimmera River. The surrounding local catchments include Concongella Creek, Allanvale Creek and Hyde Park Creek. The study area is shown in Figure 1-1.



Figure 1-1 Study area



The study has produced reliable flood intelligence for use in emergency management situations, assessed the current flood impact/exposure in terms of annual average damages caused by flooding in Great Western, investigated structural and non-structural mitigation options, investigated and made recommendations for establishing a flood warning system for the town.

This report is one of the series documenting the outcomes of the Great Western Flood Investigation. Each reporting stage is shown below:

- **R01 – Data Review Report**
 - *This report documents a summary of the available streamflow, rainfall, topographic and structure data as well as the relevant previous projects and other information relevant to the study. The report also details verification of the available topographic datasets and the proposed hydrologic and hydraulic modelling approach. The report is a draft that will flag data gaps with NGSC.*
- **R02 – Model Development and Calibration Report**
 - *This report documents the process of calibrating the hydrology and hydraulic models to the October 2022 and January 2011 flood events. The calibrated models were validated during the community consultation and demonstrated strong agreement with observed flood behaviour, producing results consistent with the calibrated events.*
- **R03 – Design Modelling Report**
 - *The report details the final design hydrology and hydraulic modelling for the township. The report describes the sensitivity testing parameters and methodologies undertaken for the input parameters for the design methodologies. All design event flood mappings are included in this report.*
- **R04 – Flood Intelligence Report**
 - *This report details the updates required to the Municipal Flood Emergency Plan (MFEP). Buildings and road inundated, and actions to be undertaken during a flood event to minimise flood damages.*
- **R05 – Floodplain Management Plan**
 - *This report outlines recommended measures to manage flood risk within the study area, with a summary of their components, expected effects, and the specific areas of application. The plan will prioritize measures, establish timeframes, and estimate costs and benefits. It will also identify the responsible organizations for each measure's execution*
- **R06 – Summary Report – This Report**
 - *This report documents a summary of the Great Western Flood Investigation, the Data Review (R01), Model Development and Calibration (R02), Design Modelling Report (R03), and Flood Intelligence Report (R04) and Floodplain Management Plan (R05).*

This summary report does not delve into technical detail, instead focuses on project outputs and deliverables produced by the study. Readers will be directed to individual reports should additional information be required. The chapters and sections of this report broadly follow the previous reporting from R01 to R05, with a summary of the key points in each detailed report.



2 DATA REVIEW

The Data Review Report (R01) describes the collation and review of available data relevant to flooding in Great Western. This included the following:

- Previous flood studies and reports covering the area
 - Regional Flood Mapping: Concongella Creek (2014)
 - Western highway Duplication Project (2017)
- Historical flood events and accompanying anecdotal evidence
 - Anecdotal evidence was the best available data for historical floods.
 - Evidence was gathered for the October 2022 and January 2011 flood events. The latter was selected as the primary calibration event based on more readily available information.
- Recorded streamflow
 - The Concongella Creek at Stawell (Gauge ID:415237) stream height and flow gauge is located approximately 12 km downstream of Great Western and 5 km east of Stawell. The gauge records water level, rainfall and stream flow date, were available from 1976 to the present day. This data was used in the hydrologic model calibration.
- Recorded rainfall
 - Both daily and sub-daily rainfall gauges were available at Stawell Aerodrome (Station no: 079105) and Ararat Prison (Station no: 089085).
- Road and drainage infrastructure
 - Township scale stormwater infrastructure, including open roadside drainage and culverts under roads were provided by NGSC, which was being surveyed in 2024.
 - Bridge structures data was collated from both the NGSC Assets Database and surveys during a site visit.
- Topographic data
 - The 2010-2011 Floodplains Light Detection and Ranging (LiDAR) Stage 2 dataset was the most recently available LiDAR and covered most of the study area.
 - Areas not covered by the Floodplains LiDAR was filled using the 2009-10 Victorian State Wide Rivers LiDAR.
 - These LiDAR datasets were verified against the photogrammetry available through the NGCS and it is found that the Floodplains LiDAR elevation transects are consistently lower than NGSC's photogrammetry. All roads (only) in Great Western township were replaced by the NGSC's photogrammetry given it represented the newest data and was considered the most accurate.
- Community Consultation
 - Three community consultations were held in Great Western to form part of the data collation and calibration aspect of the project.
 - During the initial consultation, members of the Great Western community were able to provide a vast history of flooding within township, as well as insights into flood behaviour within the township, providing information on inundation mechanisms, consequences and mitigation options.



3 MODEL DEVELOPMENT AND CALIBRATION

3.1 Overview

The Model Development and Calibration Report (R02) described the hydrologic (RORB) and hydraulic (TUFLOW) model builds in detail, and parameter selection adopted for the study. The report also detailed the calibration modelling of historic events (January 2011 and October 2022).

3.2 Modelling methodology

3.2.1 Flood Frequency Analysis

A flood frequency analysis (FFA) was completed for Concongella Creek at Stawell streamflow gauge (Gauge ID: 415237) using the RMC Best Fit software package. Streamflow data was taken from 1976 to 2024. Maximum daily flows lower than 1.0 m³/s were censored using multiple Grubbs Beck test. The FFA distribution used for this study was the Log Pearson III distribution with Bayesian Inference.

The adopted FFA quantiles are shown in Table 3-1. The four largest historic events and their approximate AEPs are listed in Table 3-2.

Table 3-1 Adopted FFA Quantiles for Concongella Creek at Stawell (Gauge ID: 415237)

AEP (%)	Peak Design Flow (m ³ /s)		
	Log Pearson III	LP3 5% Limit	LP3 95% Limit
20%	52.5	33.7	82.0
10%	101.9	63.9	163.6
5%	166.7	101.2	295.8
2%	273.7	154.2	600.1
1%	369.0	194.2	968.8
0.5%	474.6	230.9	1,514.7
0.2%	627.2	272.6	2,599.7
0.1%	750.2	297.8	3,883.5
0.05%	877.8	319.5	5,589.7

Table 3-2 Approximate AEP of the four largest recorded flows

Year	Flow (m ³ /s)	Approximate AEP
2011	305.4	Between 1% to 2%
1988	159.9	Between 5% to 10%
2016	78.1	Between 10% to 20%
2022	74.2	Between 10% to 20%



3.2.2 Hydrological Model Update

3.2.2.1 Model Extent

The RORB model developed during the Western Highway Duplication Project¹ was reviewed and updated with higher impervious fraction values and additional print point locations, to produce inflows in Concongella Creek, Allanvale Creek and contributing tributaries. No structural changes were made to the RORB model.

There were 87 sub catchments with a total catchment area of approximately 238.0 km² in the RORB model. Great Western township is situated in the middle of the catchment, with reaches all defined as 'natural'. The impervious fractions were updated to 0.1 for farmland and open areas, as the values from the previous project was slightly lower, closer to 0.

Several 'print' locations were added to extract the flows for the hydraulic model. The main inflow locations to the hydraulic model were Concongella Creek and Allanvale Creek. Several other smaller tributaries were also extracted for completeness. This included Hyde Park Creek, Cobey's Creek, Robinsons Creek and Donald Creek, as well as an inflow through the Great Western Racecourse that flows through the west end of the township.

Figure 3-1 illustrates the catchment delineation and RORB model 'print' locations where flows were calculated for use in the hydraulic model.

¹ Western Highway Duplication Project (2017) – Water Technology

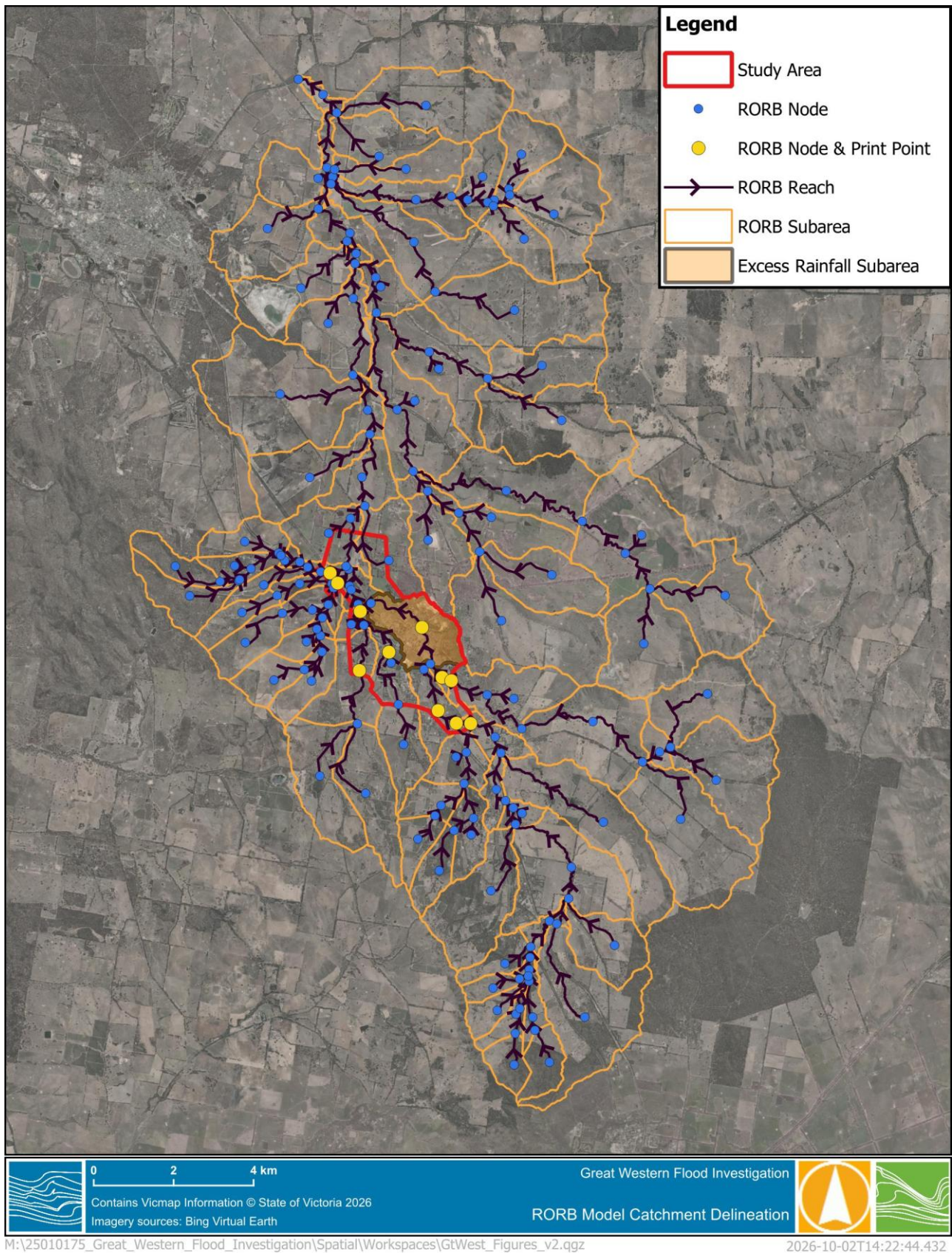


Figure 3-1 RORB Model Catchment Delineation



3.2.2.2 Model Inputs

The RORB model was run for the January 2011 and October 2022 flood events. Spatial patterns used during the Western Highway Duplication Project¹ modelling of January 2011 model calibration were reviewed and adopted. This included a rainfall spatial distribution based on the of rainfall observed at nine daily rainfall stations during. The same method was applied to generate rainfall spatial patterns for the October 2022 flood event undertaken as part of this study.

The January 2011 event was modelled from 12th to 14th of January, and the October 2022 event was modelled from 12th to 14th October. The multiday modelling of the storm events ensured the rainfall bursts occurring during each event were captured.

3.2.2.3 Model Parameter Values

The Kc and m values adopted from the Western Highway Duplication Project were maintained and are shown in Table 3-3.

Table 3-3 RORB Parameter Values

	Kc	m
Intersection Area 1	2.21	0.8
Intersection Area 2	3.09	
Intersection Area 3	4.17	
Intersection Area 4	2.53	
Intersection Area 5	3.41	
Concongella Creek	18.64	

3.2.3 Hydraulic Model Development

3.2.3.1 Model boundaries and extent

The Great Western hydraulic model was built using the TUFLOW HPC software modelling package. The model topography included a gridded 3 m model with x3 Subgrid sampling frequency.

Multiple in-channel and local catchment inflow boundaries (modelled as “2d_sa”) were applied to represent flows from the Concongella Creek and Allanvale Creek, as well as local catchments surrounding Great Western. The inflows were extracted from the RORB model, as discussed in the previous hydrology section.

Excess rainfall hyetographs (modelled as “2d_rf”) were extracted using ARR TUFLOW plugin tool over the Great Western township to model for surface runoffs in town. A filtering cut-off depth and puddle size of 2 cm and 0.02 ha, respectively, were adopted for the post processing the excess rainfall.

Hydraulic structures such as culverts and the underground pit and pipe network within the township were incorporated into the model and modelled as 1D structures.

A flowrate/height tailwater boundary (“HQ” type) with a slope of 0.0025 was applied downstream of the Great Western township to allow water to flow out of the model, with the rate of outflow dictated by the height.

Figure 3-2 displays the hydraulic model extent and boundaries applied within the model.

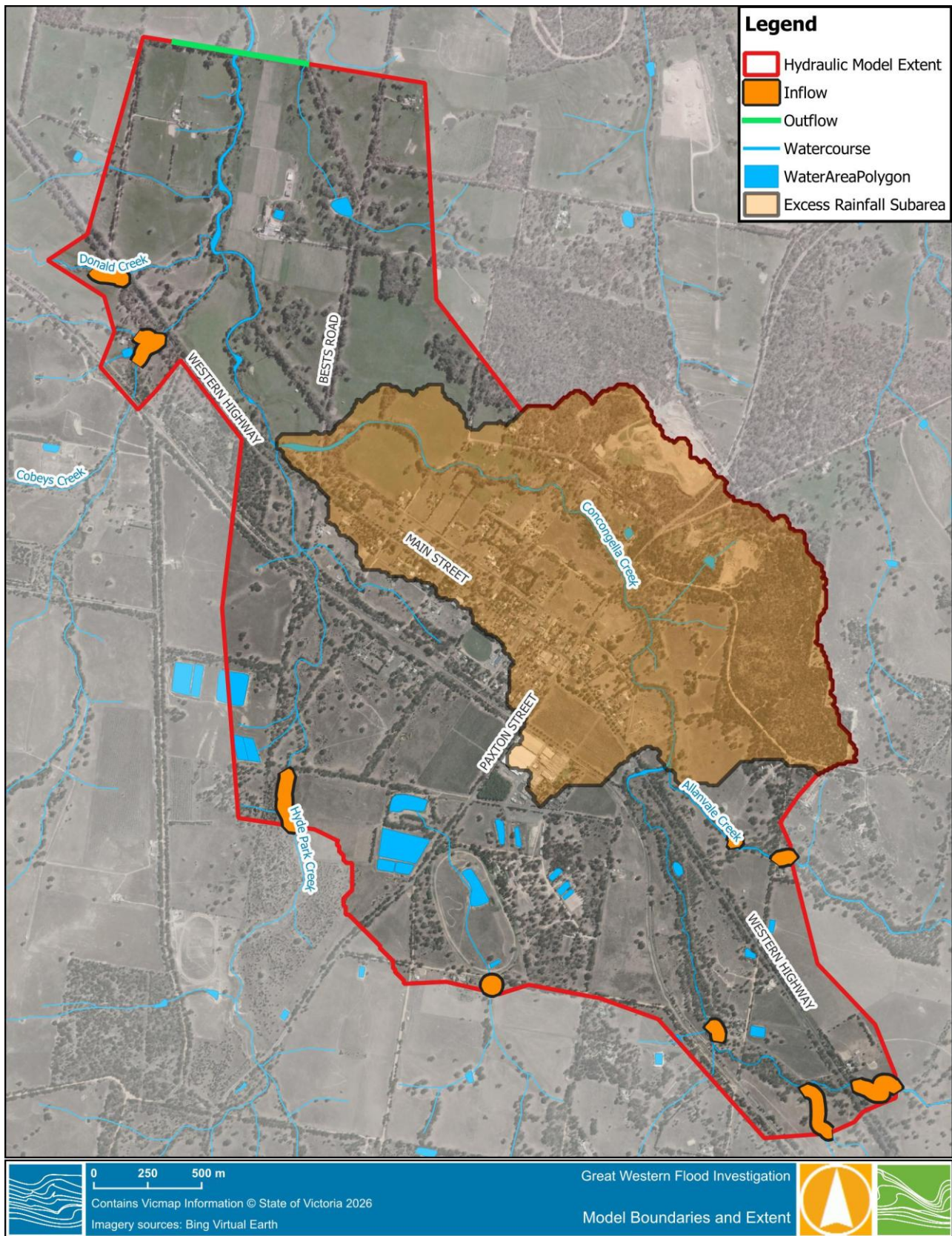


Figure 3-2 Model Extent and Inflow/Outflow Boundaries



3.2.3.2 Model Topography

The LiDAR data used for the development of the study topography was the 2010-11 Floodplains LiDAR Stage 2, captured by the North Central CMA with a 1m resolution. The model topography was represented with a 3 m grid cell size with 3x Subgrid sampling frequency (~1m). Photogrammetry of the township was also captured by NGSC in 2024, this data was clipped and used to represent all the roads (only) in the township, given it represented the newest data and was considered the most accurate.

The topography of the study area is shown in Figure 3-3.

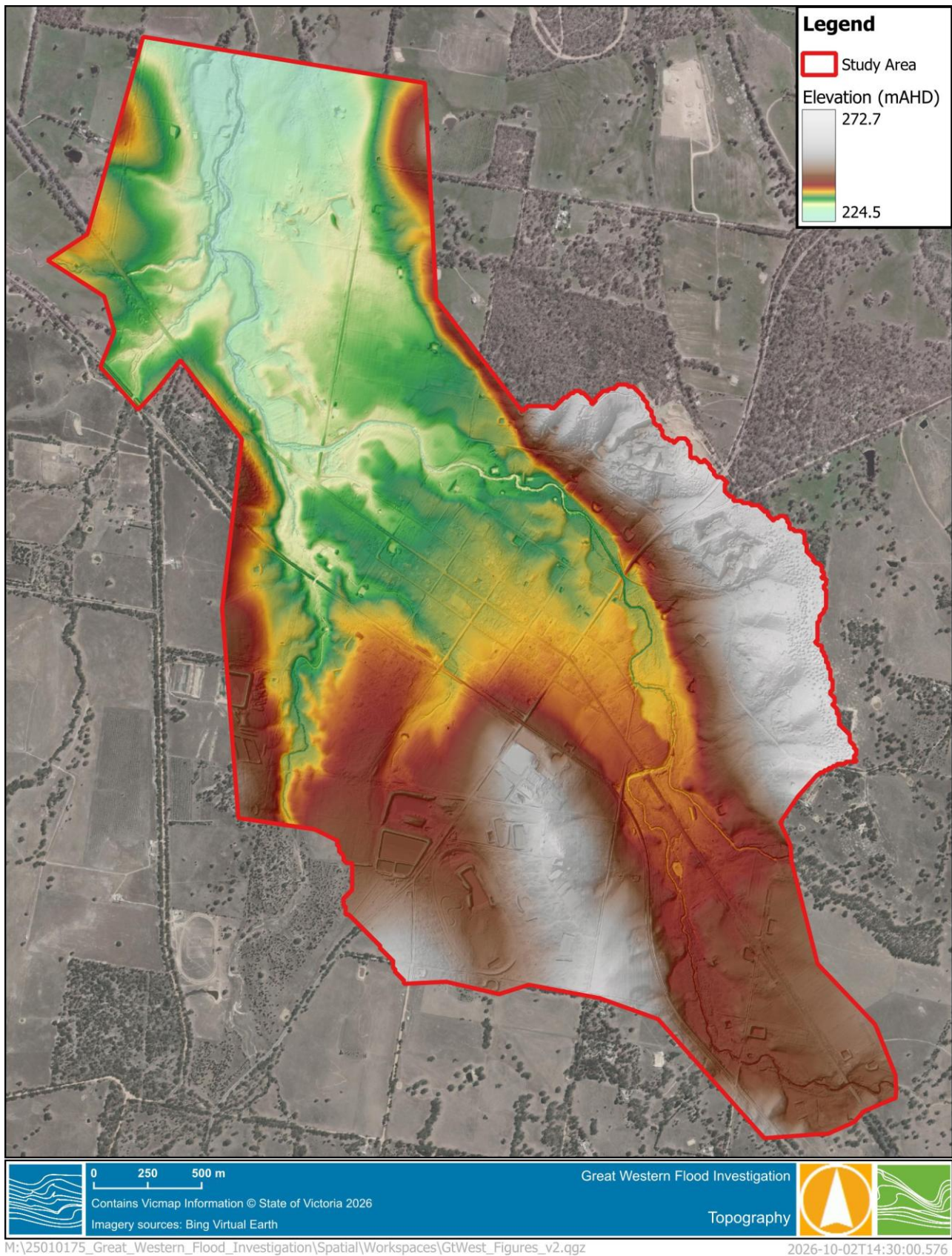


Figure 3-3 Model Topography



3.2.3.3 Hydraulic Roughness

Hydraulic roughness within the 2D model was expressed as Mannings 'n'. The adopted Manning 'n' values are presented in Table 3-4.

Roughness values used in the previous Western Highway Duplication Project² were initially adopted for the current study, with any changes made to the roughness values as part of the model calibration highlighted in the table.

Table 3-4 Manning's 'n' roughness values

Land Use	Manning's n Roughness Coefficient
Residential	0.200
Rural Residential (Part Cleared, Part Treed)	0.045
Industrial	0.300
Quarry	0.030
Cemetery	0.15
Grassed	0.035
Scattered Bush with Heavy Weeds	0.050
Pasture with Small Trees	0.040
Open Space with Moderation Vegetation	0.060
Dense Bush	0.100
Paved Road	0.020
Unpaved Road	0.030
Railway	0.040
Ponds and Other Water Bodies	0.030
Creeks with Minimal Vegetation	0.030
Weedy Sluggish Reaches with Deep Pools	0.060
Clean, Winding Channels with Some Stones and Weeds	0.070
Creeks with Dense Bush	0.080

² Western Highway Duplication Project (2017) – Water Technology

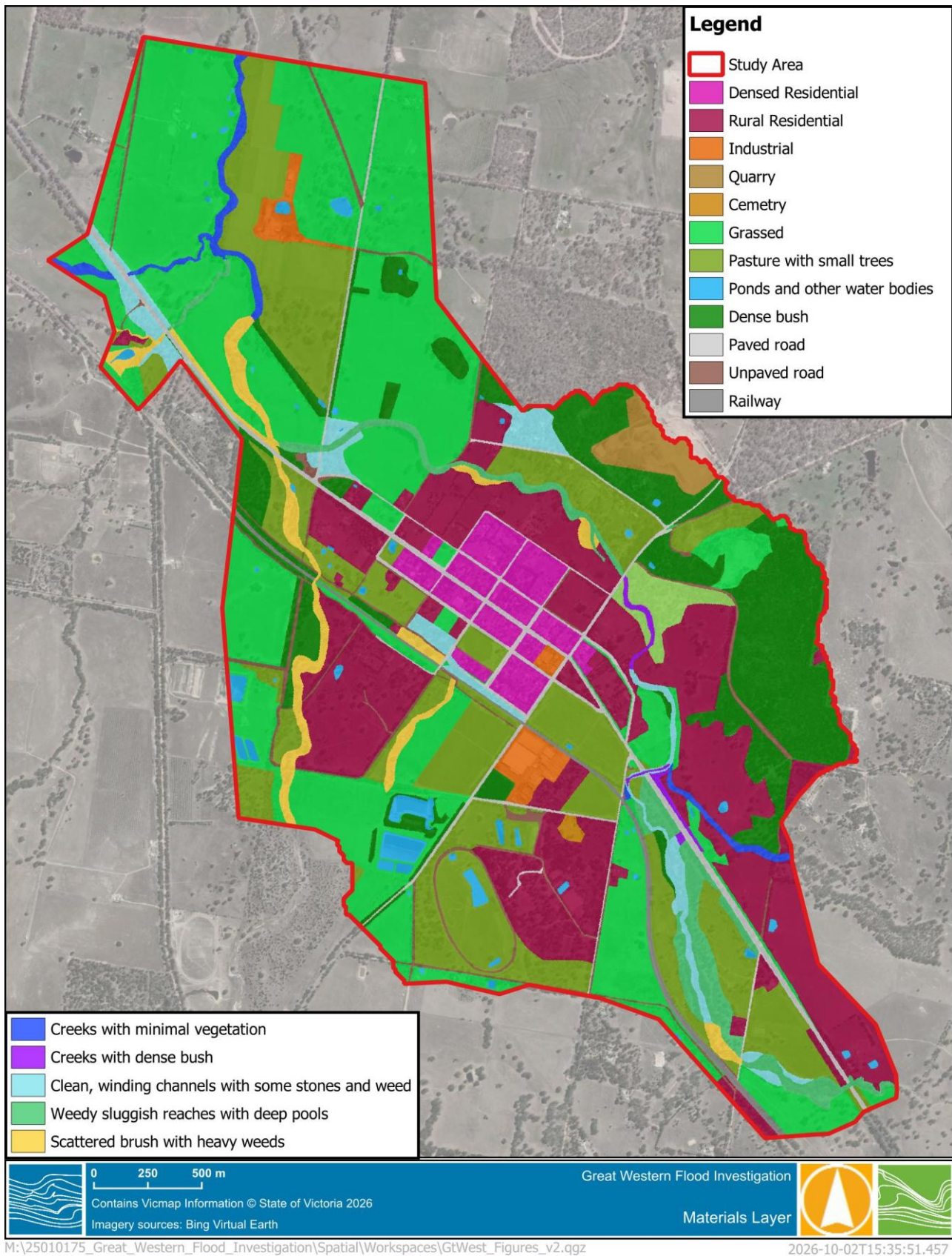


Figure 3-4 Materials Layer



3.2.3.4 Hydraulic Structures

The hydraulic infrastructure in Great Western consists of bridges, culverts, open drains, pits and pipes network.

The major drainage network (open drains, culverts, pits and pipes) was provided by NGCS via Rapid Map in 2024. The survey data, which included pit and pipe dimensions, upstream and downstream invert levels, was used to incorporate the network as 1D pit and pipe structures within the model. Open pipe ends not connected to a pit were modelled as directly connected to the 2D domain

The bridges structural data was collected during the site visits, along with addition culverts that were not available in the NGSC data.

A total of 5 bridges, 21 culverts, 54 pits and 80 pipes were incorporated in the Great Western model.

3.2.4 Calibration and Validation

The model calibration and validation focused on the January 2011 and October 2022 events. The later event is the most recently recorded event, and the former event is the largest flood on record in Great Western.

Hydrology

The RORB model was calibrated to the January 2011 and October 2022 flood events at the Concongella Creek at Stawell gauge. The calibration was based on comparing the modelled hydrograph at this location to gauge recordings. The focus of the RORB model calibration was to determine the RORB parameters, specifically the initial loss and continuing loss values within the catchment.

Hydraulic

The TUFLOW model was calibrated to January 2011 peak flood height survey and flood marks that were available from the Western Highway Duplication Project¹. The calibration process consisted of a systematic comparison of observed and modelled flood levels and flood extents based on the available survey data.

3.2.4.1 January 2011 Event

3.2.4.1.1 Available data

The hydrology component of the January 2011 event calibration was primarily streamflow data at the Concongella Creek at Stawell streamflow gauge, and the hydraulic model results.

Hydraulic model calibration data was collected during two community consultations on 13th August and 3rd December 2025, as well as data extracted from the previous Western Highway Duplication Project¹, and the *Wimmera Region Flood Report - January 2011*³ completed by Water Technology for Wimmera CMA in 2011.

The modelled calibration results were compared to the calibration points and the anecdotal evidence collected from the community consultation.

The following data was used to calibrate/validate the hydraulic model:

- A collage of photos and newspaper articles gathered by a member of the community which provided details on how the event unfolded.
- 11 surveyed flood marks near Great Western were gathered following the January 2011 event, of which 8 of them is within the Study Area. The dataset has a reported survey accuracy of less than 50mm;

³ Wimmera Region Flood Report (2011) – Water Technology

however, it should be noted that peak water levels can be difficult to accurately define and therefore flood survey has inherent uncertainty. Surveyed levels also need to be used with judgment and caution.

- An aerial image flown on drone on Friday 14th January at 10am from the west side of the township. It should be noted that the imagery might be flown after the peak water levels.
- Pin locations of properties that were flooded above floor level.
- Verbal feedback from a community consultation attended by local community members on 13th August and 3rd December 2025.

3.2.4.1.2 Hydrology

The routed hydrographs for Concongella Creek and Allanvale Creek were extracted from the RORB model results. Figure 3-5 shows the creek flow hydrographs calculated using RORB and Figure 3-6 shows the hydrograph comparison at the downstream of the study area comparing the RORB calculated and actual recorded flows at the Concongella Creek at Stawell gauge.

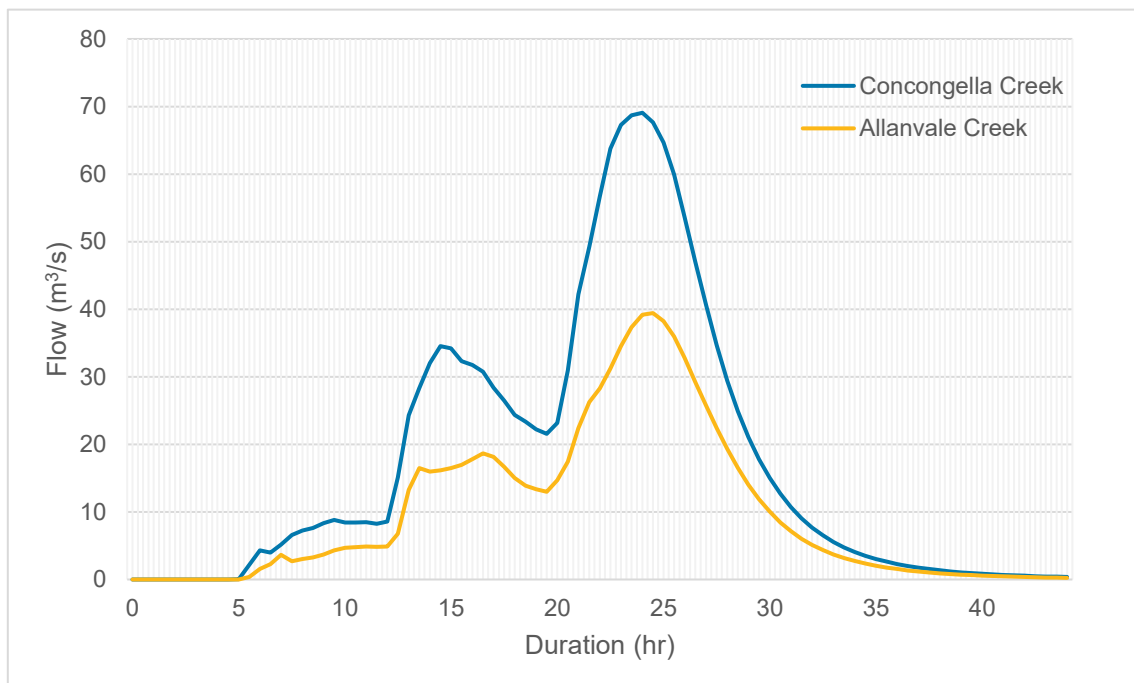


Figure 3-5 Creek Inflow Hydrographs for January 2011 event

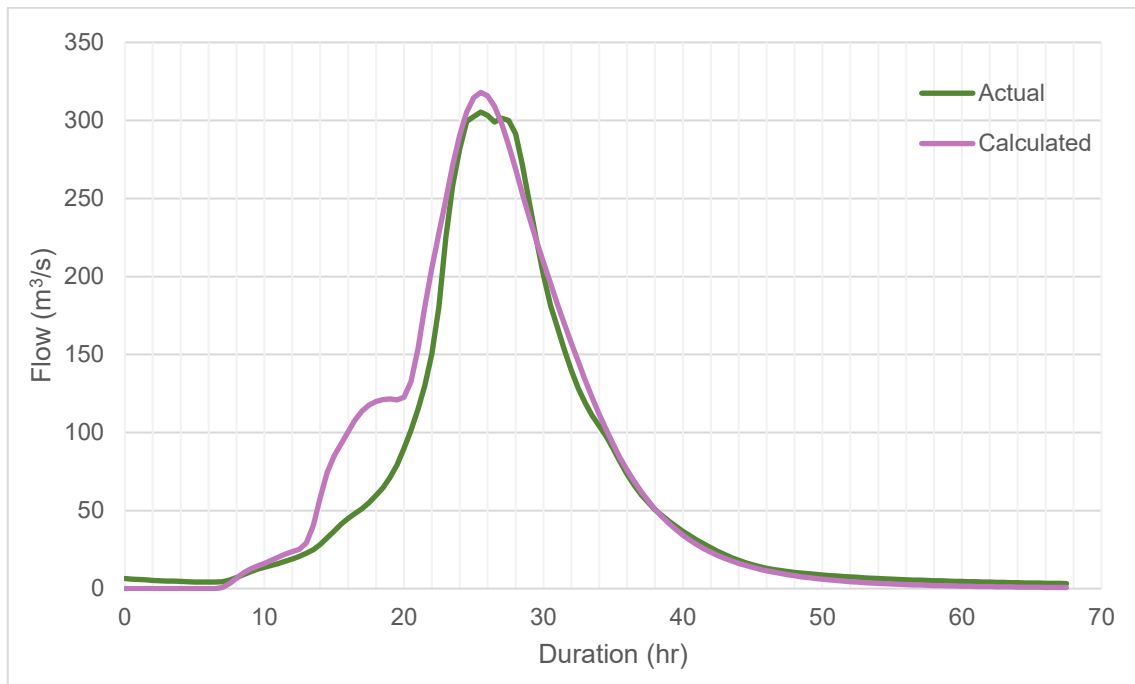


Figure 3-6 Concongella Creek at Stawell - Hydrographs for January 2011 event

3.2.4.1.3 Hydraulics

The flood depth mapping for the modelled January 2011 flood event is presented in Figure 3-7. This map is zoomed into the township to clearly show the area of interest, especially around the Western Highway Bridge over the Concongella Creek and Main Street.

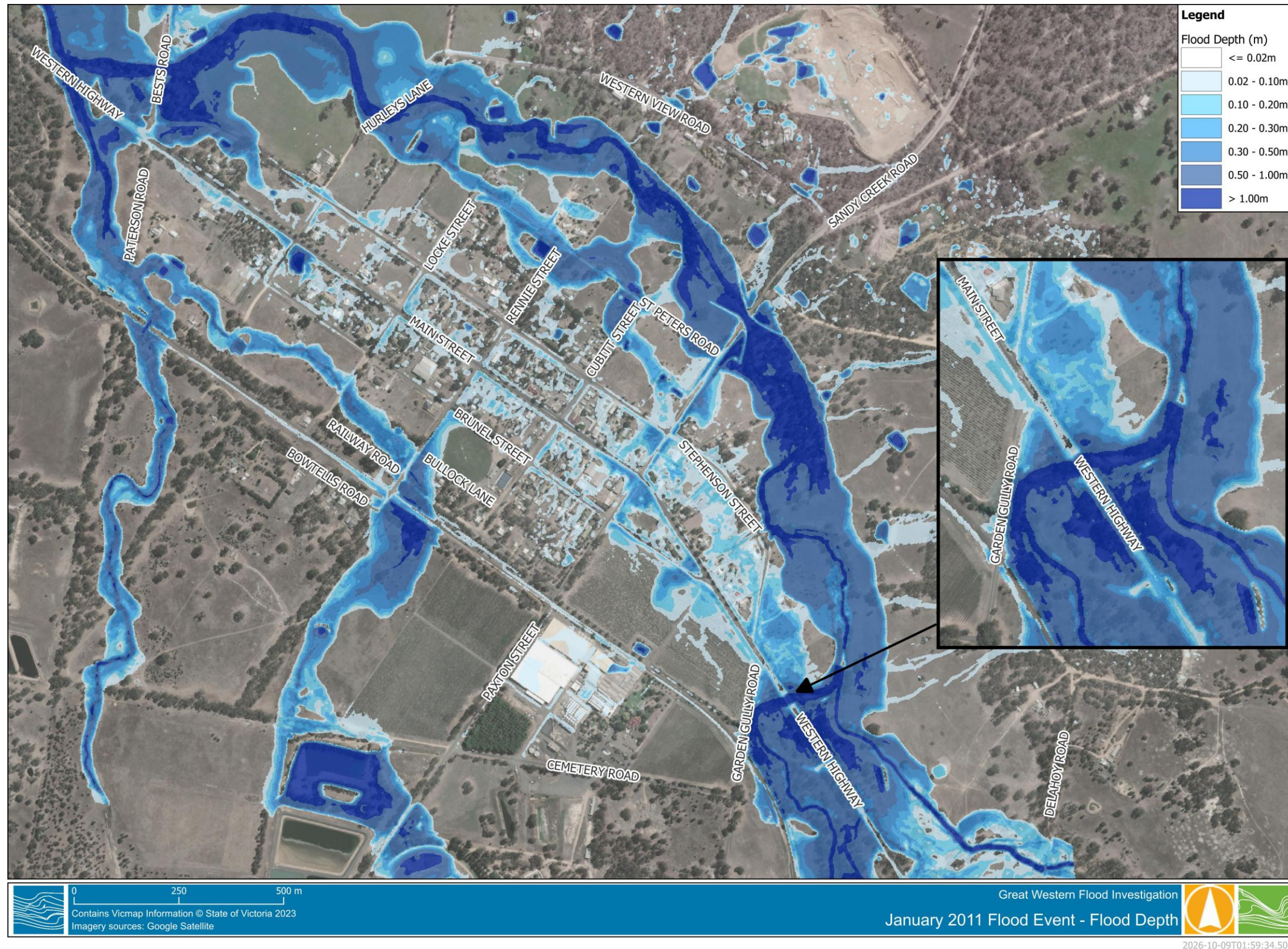


Figure 3-7 Zoomed in Township – January 2011 Flood Depth



Surveyed Flood Points

Of the 8 survey points within the Study Area, 5 points align closely with the modelled water surface elevation, with a maximum difference of +/- 13 cm, as presented in Figure 3-8. 2 survey points, Point A and B, have a water surface elevation difference of 36 cm and 29 cm higher than the surveyed heights, respectively. The remaining point had a surveyed flood height lower than the modelled topography and was disregarded.

While points A and B are upstream of the Western Highway and showed modelled flood levels of around 0.3m above that surveyed, the flood extent in that area matched well with where the survey was taken (understood to be the inundation extent) and observations from the community showed strong agreement with between the observed inundation and that produced by the modelling. Numerous sensitivity tests were also undertaken to confirm if the modelled levels could be reduced to match that surveyed; however, this resulted in a disagreement between the modelled extent and observations made by the community.

It was determined the surveyed flood levels upstream of the Western Highway (Points A and B) likely underestimated flood levels.

Aerial Imagery taken during the flood event

Figure 3-9 shows the flood extent comparison between the aerial imagery and the modelled extent. The arrows demonstrate the corresponding area of flooding between the two extents. The extents agree closely, especially where the puddles are located.

Inundated Properties

Figure 3-10 shows the pin locations where the properties were flooded above floor level. These locations are within the modelled flood extent with high flood depths.



Figure 3-8 January 2011 Calibration Points (only showing 7 survey points that are close to township)



Figure 3-9 Aerial image flown on Friday 14th January 2011 at 10am from the west side of township

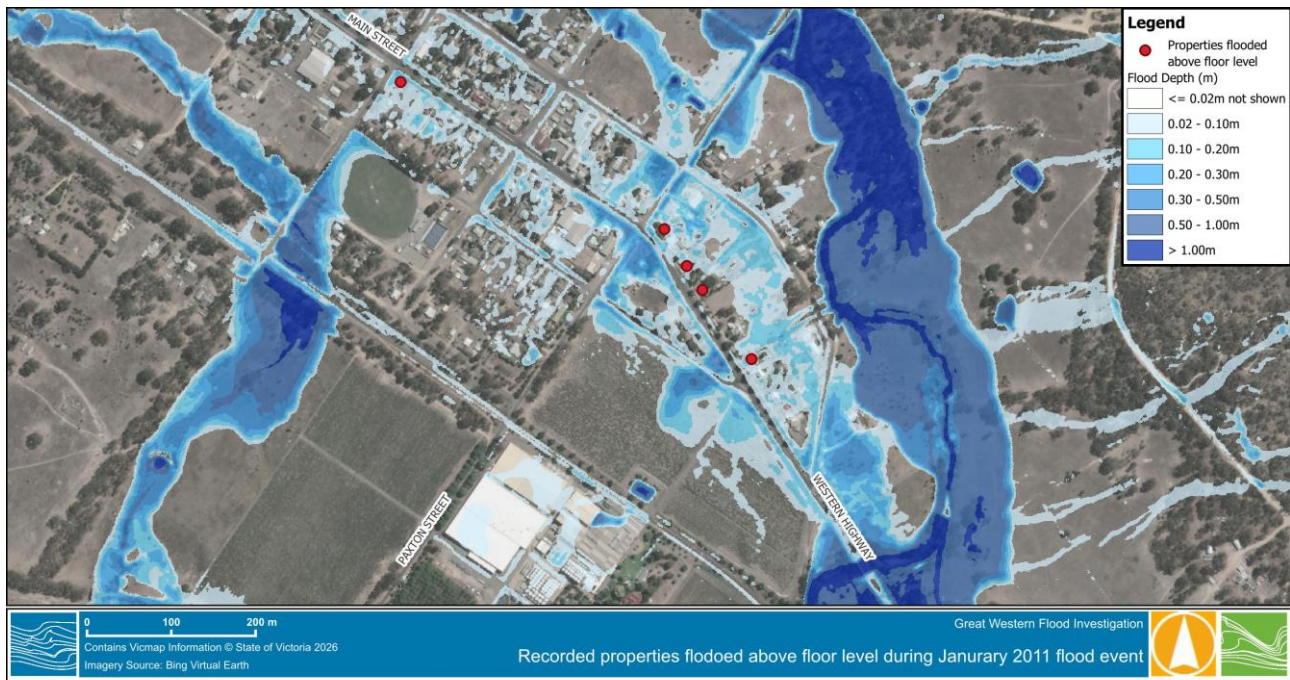


Figure 3-10 Recorded properties flooded above floor level during January 2011 flood event

Outlet Hydrographs

Figure 3-11 shows the modelled TUFLOW and RORB hydrographs at the downstream of the Study Area. The two modelled hydrographs agree very well magnitude, with about 30 minutes difference in timing, throughout the entire event.

There are no gauged water levels at the downstream of Concongella Creek of the Study Area to compare the hydrographs with.

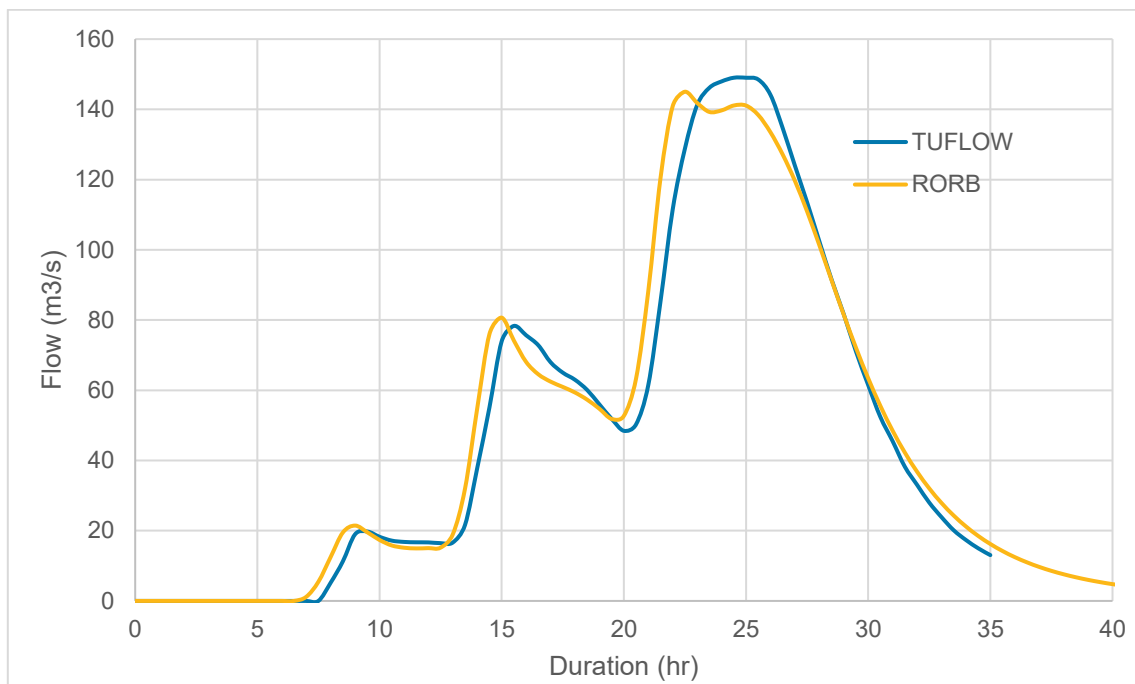


Figure 3-11 Hydrographs at the downstream of Study Area for January 2011

3.2.4.2 October 2022

The October 2022 flood event is the most recent large magnitude flood event in Great Western, but smaller in magnitude compared to the January 2011 flood event.

The calibration inputs for the October 2022 event were based primarily on the January 2011 event, with the assumption that no significant changes or construction occurred between the two flood events that may have a hydraulic impact on the overland flow path.

Calibration data was not abundantly available in comparison to the January 2011 flood event. There was gauge flow data available at the Concongella Creek at Stawell streamflow gauge which was used to calibrate the RORB model.

The following data was used to calibrate/validate the hydraulic model:

- Photos and a drawing provided by a member of the community on the Concongella Creek and an overland flow path next to the town oval.
- Verbal feedback from a community consultation attended by local community members on 13th August 2025.

3.2.4.2.1 Hydrology

The routed hydrographs for Concongella Creek and Allanvale Creek were extracted from the RORB model results. Figure 3-12 shows the creek flow hydrographs calculated using RORB and Figure 3-13 shows a hydrograph comparison the RORB calculated and recorded flows at the Concongella Creek at Stawell streamflow gauge.

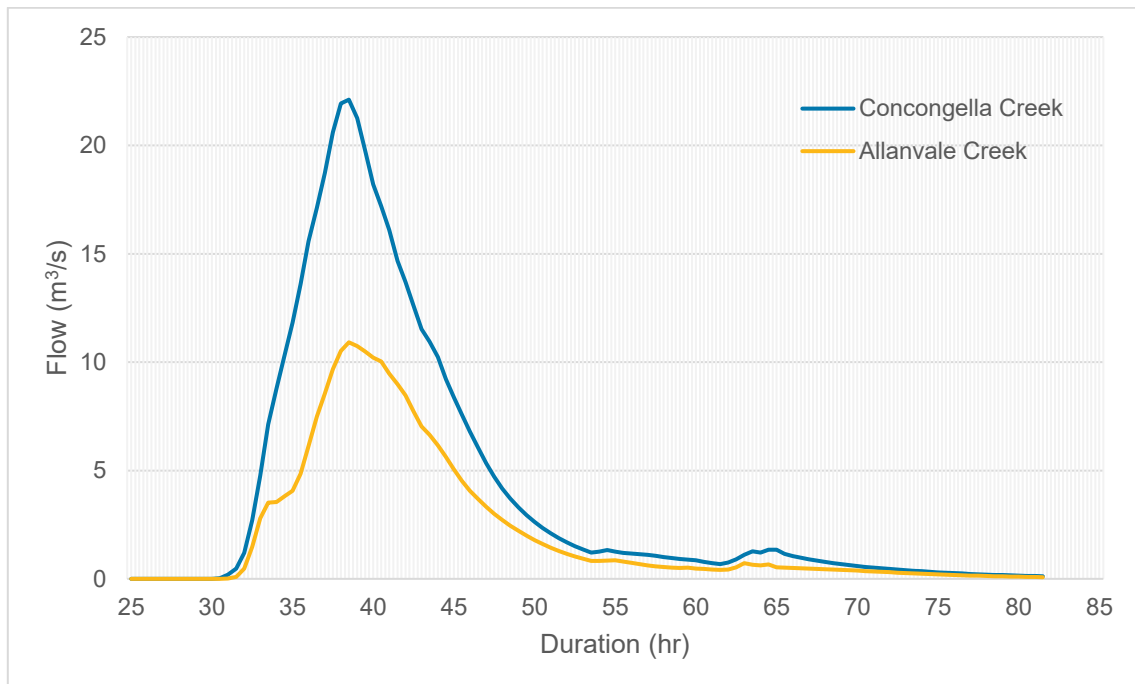


Figure 3-12 Creek Inflow Hydrographs for October 2022 event

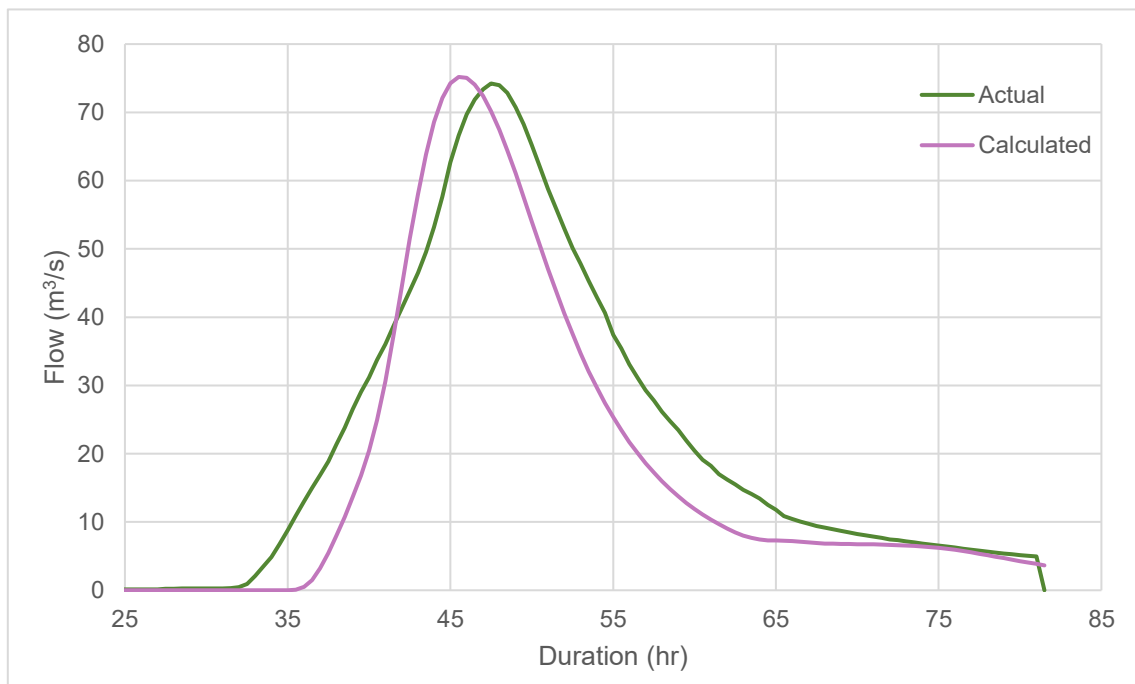


Figure 3-13 Concongella Creek at Stawell Hydrographs for October 2022



3.2.4.2.2 Hydraulics

The flood depth mapping for the modelled October 2022 flood event is presented in Figure 3-14. These maps are zoomed into the township to clearly show the area of interest, especially around the Western Highway Bridge over the Concongella Creek and Main Street.

The modelled flood extent and peak flood levels are compared to the various calibration data sources are discussed in the following sections.

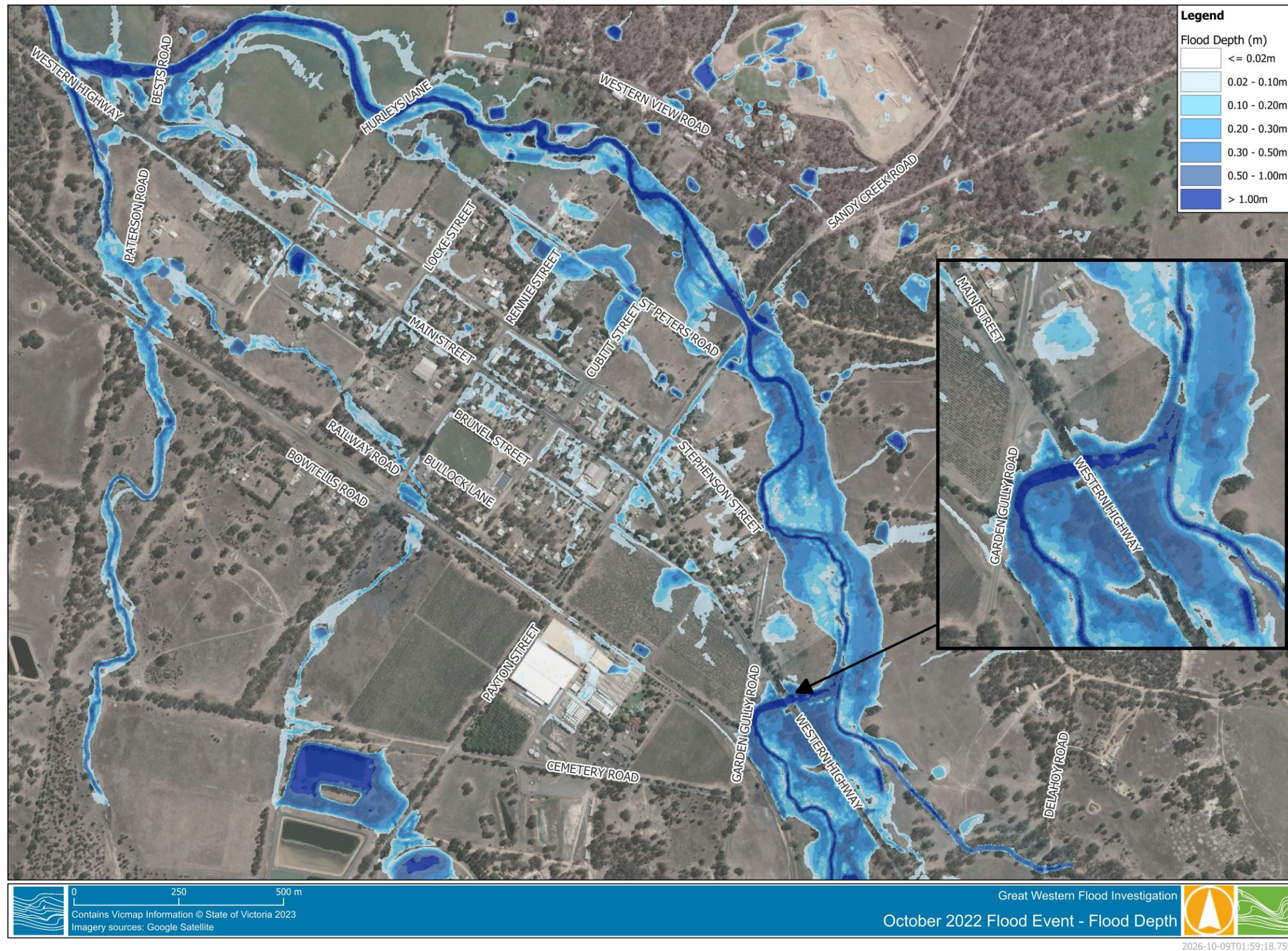


Figure 3-14 Zoomed into Township – October 2022 Flood Depth with 0.2 m Contour



Outlet Hydrographs

Figure 3-15 shows the modelled TUFLOW and RORB hydrographs at the downstream of the Study Area. The two modelled hydrographs agree well for magnitude throughout the entire event, with slight mismatch at the peak.

There are no gauged water levels at the downstream of Concongella Creek of the Study Area to compare the hydrographs with.

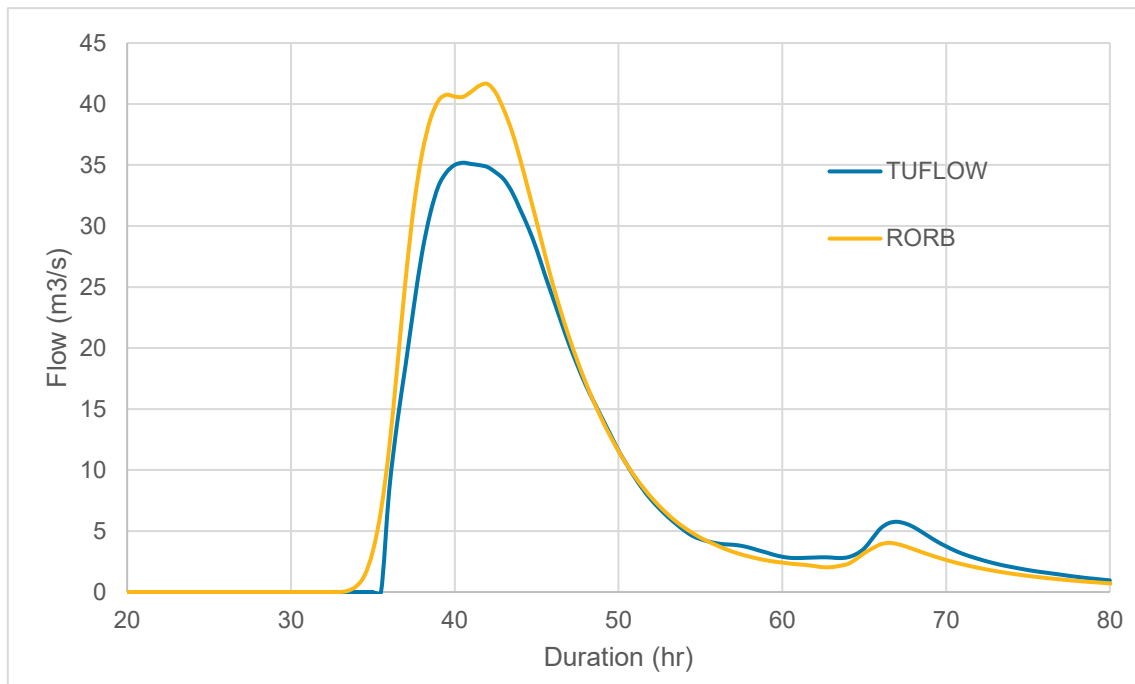


Figure 3-15 Hydrographs at downstream of Study Area for October 2022



4 DESIGN MODELLING

The Design Modelling Report (R03) detailed the process of finalising the design modelling and results from sensitivity testing for Great Western.

4.1 Design Hydrology

The Great Western Flood Investigation has adopted a hydrologic/hydraulic modelling approach with the hydrology modelling completed using RORB software and hydraulic calculations completed within TUFLOW.

Design hydrology was undertaken using both FFA (the process of FFA is detailed in Section 3) and RORB modelling. The following sections of this report outline the methodology undertaken.

4.1.1 Overview

The RORB model developed during the Western Highway Duplication Project¹ was adopted for the current study. Several minor updates were undertaken for the model with updated fraction impervious values on land use and adding additional print points, which were used as hydraulic model inflows along the modelled waterways. These details can be found in the Model Development and Calibration Report⁴ (Water Technology 2026). RORB inflows were extracted at 9 locations for the hydraulic model, including inflow at Concongella Creek, Allanvale Creek, and other tributaries. Additional to the in-channel flows, direct rainfall was added to the sub catchment at Great Western using excess rainfall produced using ARR plugin on QGIS.

Design peak flows were generated using an Ensemble simulation in time series format. An analysis of these peak flows was then undertaken to determine the corresponding critical duration and temporal pattern at model key locations, as outlined in ARR2019. The analysis consists of taking the median peak flows from all ten temporal patterns, and the maximum of the modelled duration, to be the critical duration for the corresponding inflow location. Of the 9 inflow locations, critical durations of four locations that transverse through the township were analysed for each modelled design events.

4.1.2 Design losses

The storm losses 5 mm for initial losses (IL) and 1 mm/hr for continuing losses (CL) were adopted from the Western Highway Duplication Project¹. These values were used for the January 2011 flood event calibration and produced a peak 1% AEP flow at the Concongella Creek at Stawell gauge location which matched the FFA. Adopting these losses did not result in a close match between the RORB model results and those in the FFA. It is found that the losses were too low for the smaller events and too high for the larger events.

Therefore, an adaptive design loss approach was used for modelling the design events to match the peak flow volume produced by FFA for each corresponding design event. Losses were increased for events smaller than a 1% AEP, while for design events larger than 1% AEP the design losses were kept at 5 mm for IL and 1 mm/hr for CL. Using losses lower than these for events larger than a 1% AEP was not considered realistic and it is likely the rating curve at the Concongella Creek at Stawell streamflow gauge becomes less accurate.

Since the design modelling will be undertaken under the present day and future scenario, the adopted losses were adjusted to the climate change factor of Shared Socio Economic Pathway 3-7.0 (SSP3) for the year 2030 (present day) and 2100 (future). These factors are listed in Table 4-1.

The adopted losses for the RORB model are listed in Table 4-2.

⁴ Great Western Flood Investigation Model Development and Calibration Report (2026) – Water Technology



Table 4-1 ARR Data Hub climate change factor for losses

Parameter	Climate Change Factors	
	SSP3-7.0 2030	SSP3-7.0 2100
Initial Losses	x1.04	x1.12
Continuing Losses	x1.08	x1.27

Table 4-2 Adopted initial and continuing losses for baseline, present day and future

AEP (%)	Initial Losses (mm)			Continuing Losses (mm/hr)		
	Baseline (2016)	SSP3-7.0 Year 2030	SSP3-7.0 Year 2100	Baseline (2016)	SSP3-7.0 Year 2030	SSP3-7.0 Year 2100
20%	17.0	17.7	19.0	3.4	3.67	4.32
10%	13.5	14.0	15.1	2.7	2.92	3.43
5%	11	11.4	12.3	2.2	2.38	2.79
2%	7.3	7.6	8.2	1.45	1.57	1.84
1%	5	5.2	5.6	1	1.08	1.27
0.5%						
0.2%						
0.1%						
0.05%						

4.1.3 Critical Durations

The RORB model was run for the 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2%, 0.1%, 0.05% AEP events, and the Probable Maximum Flood (PMF) event. The adopted critical duration and temporal patterns for each design event are detailed in the R03 report.

Based on the RORB results, hydraulic model inputs were prepared for all the durations and associated median peak flow generating temporal pattern, for each design event, to capture the critical duration at the key locations. For the design events where the same critical duration was observed at two key locations, only one temporal pattern was selected for the design event based on the pattern which resulted in the higher downstream peak flow at the Concongella Creek outflow.

4.1.4 Design Flows

The modelled design flows for each design events and climate scenarios, as well as the peak flows produced using FFA, are presented in Table 4-3.

Table 4-3 Design flow for FFA, baseline, present day, and future

AEP (%)	Peak Design Flow (m³/s)			
	Log Pearson III	Baseline (2016)	SSP3-7.0 Year 2030	SSP3-7.0 Year 2100
20%	52.5	51.4	63.0	87.6
10%	101.9	106.4	130.3	183.5



AEP (%)	Peak Design Flow (m ³ /s)			
	Log Pearson III	Baseline (2016)	SSP3-7.0 Year 2030	SSP3-7.0 Year 2100
5%	166.7	167.8	197.3	259.1
2%	273.7	276.8	318.0	401.7
1%	369.0	362.2	415.6	509.7
0.5%	474.6	419.8	477.7	588.9
0.2%	627.2	501.7	571.9	700.0
0.1%	750.2	567.4	652.8	785.8
0.05%	877.8	638.5	731.7	882.6

4.2 Probable Maximum Flood

The Probable Maximum Precipitation (PMP) was interpolated between depths estimated by the Generalised Short Duration Method (GDSM). The rainfall depths were modelled utilising the 'rare' temporal patterns obtained from the ARR DataHub and distributed spatially in line with the 0.05% AEP event.

An initial loss of 0 mm and a continuing loss of 0 mm/hr was applied. All ten temporal patterns were simulated in ensemble for the PMF. The same critical duration and associated temporal pattern for 0.05% AEP was used to simulate the PMF event (2hr TP24 and 6hr TP27).

4.3 Design Hydraulics

Table 4-4 summarises the key model parameters/inputs adopted for the TUFLOW modelling. Further details on the TUFLOW model inputs are described in detail in the R02 report.

Table 4-4 Key TUFLOW parameters summary

Parameter	
Model Build	2026.0.1-iSP-w64
Grid Cell Size	3 m with 3x Subgrid Sampling Frequency (~1 m)
Solution Scheme	GPU HPC
Inflow Boundary	2d_sa source-area boundaries for in-channel flow 2d_rf rainfall boundary for excess rainfall
Outflow Boundary	Height-Flow slope of 0.25%
Hydraulic Roughness	Manning's 'n' varies with land use
1d Elements	Culverts and pipes linked to 2D domain

Design flood modelling for the 20%, 10%, 5%, 1%, 0.5%, 0.2%, 0.1%, 0.05% AEP and PMF events were completed using the calibrated hydraulic model. Flood modelling outputs were applied for flood emergency improvement and planning, and flood maps will be used as guidance for future land use development.



The final flood maps for each design events were created by maximising all runs for each AEP event, including the critical durations and the associated temporal. Then, the maxed grids were filtered with a cut-off depths of >0.02 m and puddles >200 m².

Flood hazard mapping was prepared in line with ARR2019 and the Australian Disaster Resilience Guideline 7-3 Flood Hazard⁵. The hazard classifications are based on the peak depth, velocity and product of depth and velocity.

4.4 Sensitivity Analysis

4.4.1 Overview

Sensitivity testing of model was undertaken for the following parameters:

- Infiltration losses (RORB – hydrology model).
- Land-use Roughness (TUFLOW – hydraulic model).
- Structural Blockage including Open Drain, Pit, Culvert and Bridge (TUFLOW – hydraulic model).

The above scenarios were tested independently for the 1% AEP event at present day (SSP3-7.0 2030).

4.4.2 Design losses

A design losses sensitivity testing was undertaken given the adopted losses for this study were lower than the values recommended from the ARR DataHub. Sensitivity testing was undertaken lowering the initial loss to 20 mm and continuing loss to 2 mm/hr. These values are listed in Table 4-5. These losses have been adopted across numerous flood investigations across western Victoria including the previous Great Western Duplication assessment¹.

Lowering the losses reduced the 1% AEP peak flow approximately 100 m³/s lower than the value produced using the design losses of 5 mm (IL) and 1 mm/hr (CL). The peak flow determined was significantly lower than the peak flow generated by FFA and that recorded for the January 2011 flood event, as listed in Table 4-6.

Table 4-5 Available losses values

	IL (mm)	CL (mm/hr)
ARR DataHub	25	4.6
Adopted Design Losses	5	1

Table 4-6 Modelled peak flows for various losses

Scenario	Losses	1% AEP Peak Flow (m ³ /s)
Design losses	IL=5, CL=1	362.2
Sensitivity test	IL=20, CL=2	260.0

4.4.3 Land-use Roughness Coefficients

Sensitivity to the adopted roughness values was tested by applying a 20% increased and reduction to land use roughness Manning's n values. The roughness values in the hydraulic model were multiplied by 0.8 and 1.2 for the low and high tests respectively.

⁵ Australian Disaster Resilience Guideline 7-3 Flood Hazard, 2017, Australian Institute Disaster Resilience



Figure 4-1 and Figure 4-2 show the difference in water level within Great Western for each roughness test.

The largest flood level changes were observed along the overland flow path across Stephenson Street next to Concongella Creek, and downstream of the creek at Bests Road. Flood levels across the township and Main Street remained largely unchanged. This indicated where the hydraulic model is most sensitive to roughness parameters in and around the waterways.

Flood levels in the waterway have increased up to 0.03 m in the township in the high roughness value test scenario; and a reduction of 0.02 m at the township in the low roughness value test scenario.

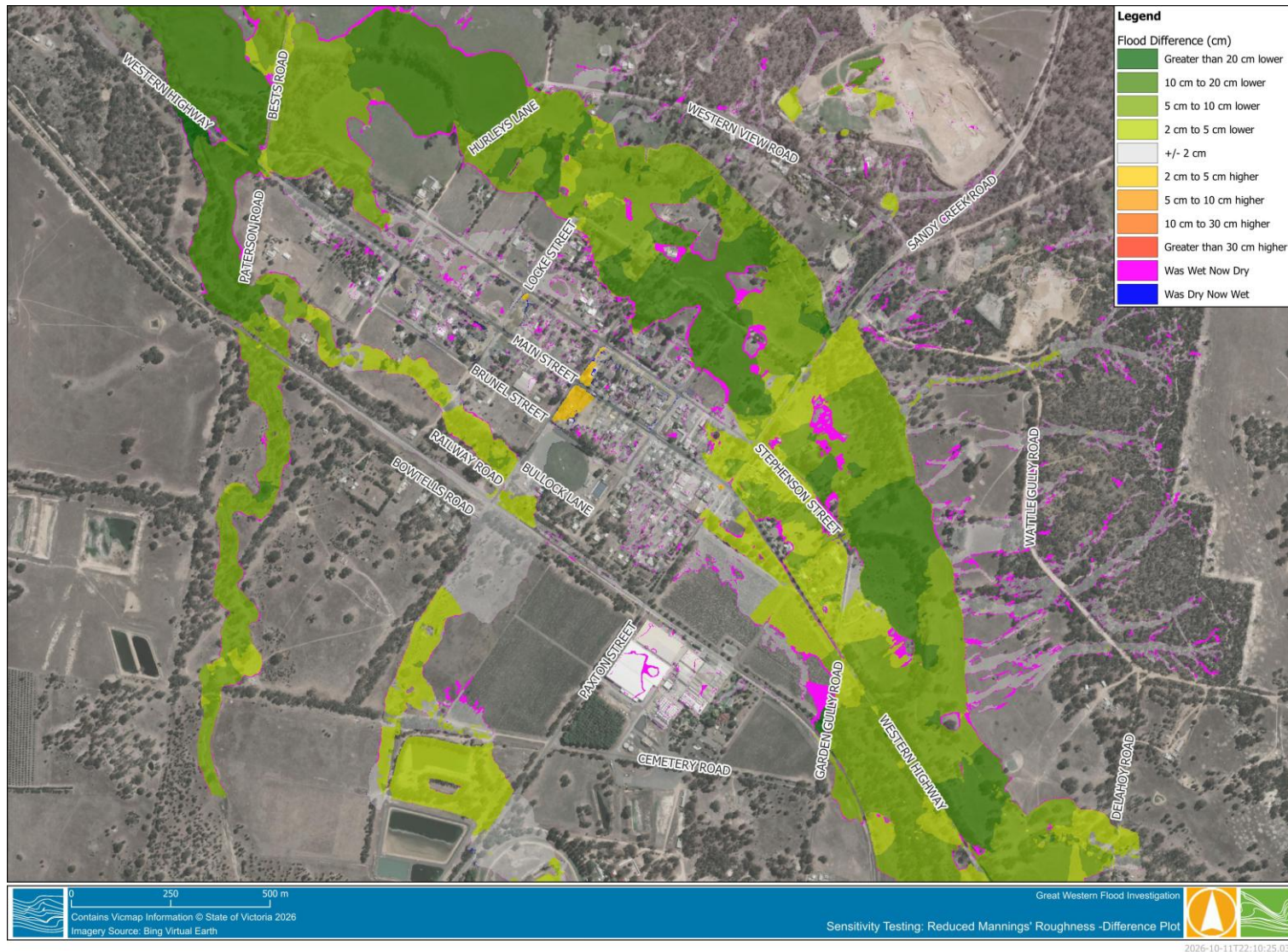


Figure 4-1 1% AEP SSP3-7.0 Year 2030 Difference Plot – Reduced Mannings' Roughness

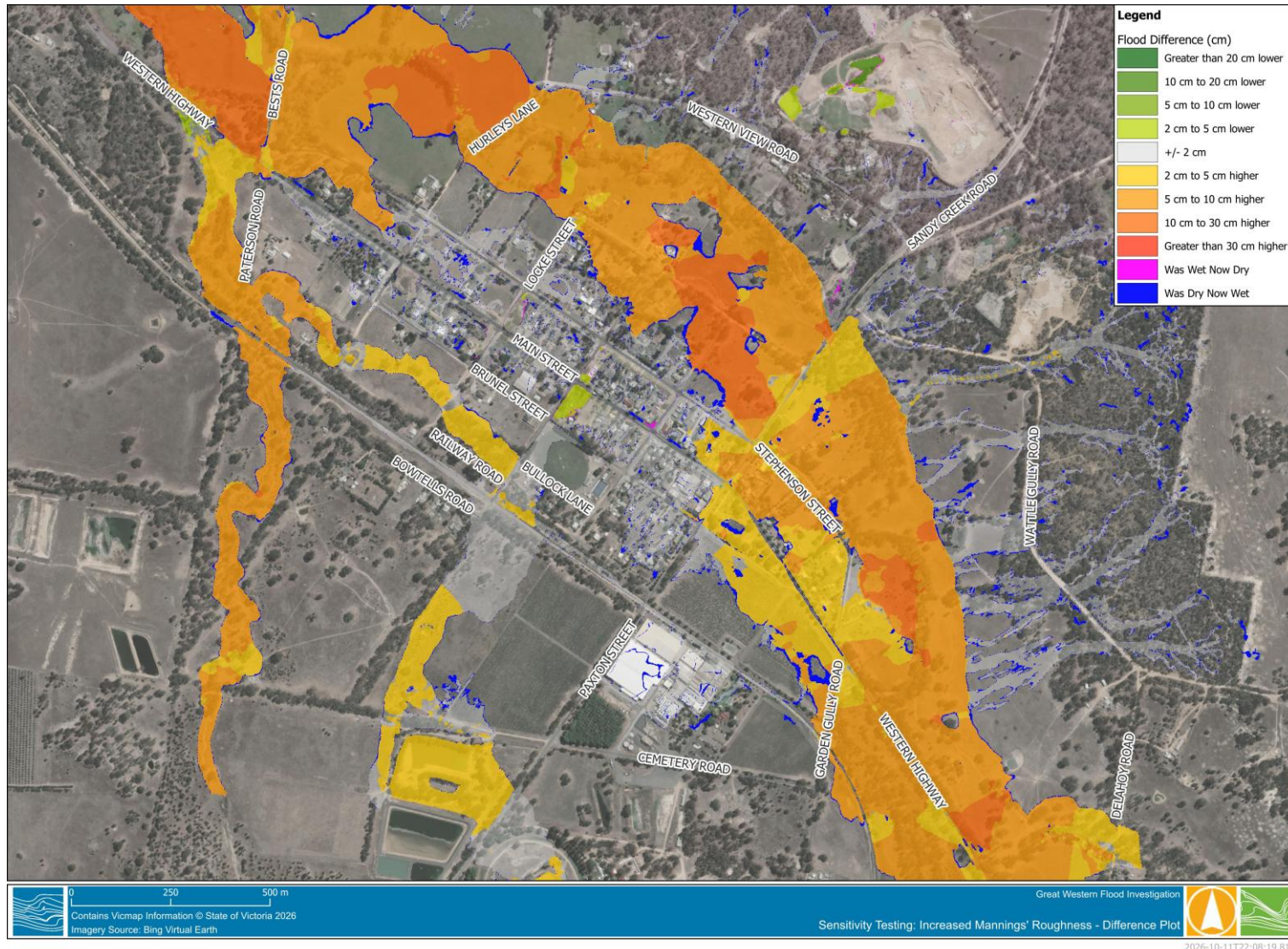


Figure 4-2 1% AEP SSP3-7.0 Year 2030 Difference Plot – Increased Mannings' Roughness



4.4.4 Structural Blockage

The Melbourne Water Blockage Assessment⁶ was conducted for the structural blockage sensitivity testing. The assessment consisted of the following assessment criteria:

- Debris Availability - refers to the presence and quantity of particular types of debris within the source area. The critical types of debris are related to the geometry of the various hydraulic structures located within the catchment and more than one type of debris may need to be considered.
- Debris Mobility - refers to the ease with which the available debris is initially mobilised, then transported across overland flow paths into streams and then towards structures.
- Debris Transportability - refers to the ease with which the mobilised debris is transported down a stream or along a drainage channel to the structure.

These criteria were assessed based on site visits and aerial imagery and the selected criteria are presented in Table 4-7. The assessment resulted in a *Medium* level debris potential (DP_{Medium}).

The ratio of the is used in Table 3.6 to quantify the likelihood of this material bridging the openings and triggering a blockage.

The likelihood of material bridging the openings and triggering a blockage (L_{10}) was assessed using the ratio of the width of the controlling openings of structures (W , e.g. grate clear spacing, kerb inlet height, diameter or width of the culvert or bridge pier spacings) to the length of the longest 10% of debris that could arrive at the site. The likelihood was estimated to be $W \geq L_{10} \leq 3 * L_{10}$.

The percentage of blockage factor to apply is listed in Table 4-8.

Table 4-7 Selected assessment criteria for Great Western

Component	Potential	Detail
Debris Availability	Medium	■ State forest areas with clear understory, grazing land with stands of trees ■ Arid areas, where loose vegetation and exposed loose soils occur and vegetation is sparse. ■ Urban areas that are well maintained with limited debris present in the source area.
Debris Mobility	Medium	■ Low rainfall intensities and large, flat source areas. ■ Receiving streams that frequently overtop their banks. ■ Main debris source areas close to streams
Debris Transportability	Medium	■ Flat bed slopes ($< 1\%$) ■ Stream velocity ($1\text{m} < V < 2.5\text{m/sec}$) ■ Narrow streams relative to horizontal debris dimension ($W < L$) ■ Streams meander with frequent constrictions/snag points. ■ High temporal variability in maximum stream flows

⁶ Project 11: Blockage Of Hydraulic Structures Stage 2 Report February 2013 Engineers Australia



Table 4-8 Percentage of blockage factor to apply

AEP	At Site Debris Potential	Blockage Factor ($W \geq L_{10} \leq 3 * L_{10}$)
1%	Medium	10%

Given the recommended blockage factor using Melbourne Water's Blockage Assessment was quite small, at 10%, it was decided to increase this value to 50% for the sensitivity test to allow a clear assessment on the impacts of structural blockage.

Blockage factors were applied to all culverts and pipes as follows:

- 50% blockage applied to all culverts
- 50% blockage applied to all pits connected to the underground pipe network in the township

Figure 4-3 shows the difference in water level in Great Western when 50% blockage of 1D network is applied. The results show an increased in flood level along the Main Street, particularly at 31, 77 and 78 Main Street, the increase was as high as 0.1 m at 77 and 78, and 0.3 m at 31 Main Street.

Flood level and extents were also increased in general with more water unable to be discharged into the township pipe network into Concongella Creek. This is because the pipes and culverts are at capacity in the 1% AEP design event. The flat terrain of the township is also a major factor contributing towards the pooling of water on the street and properties.

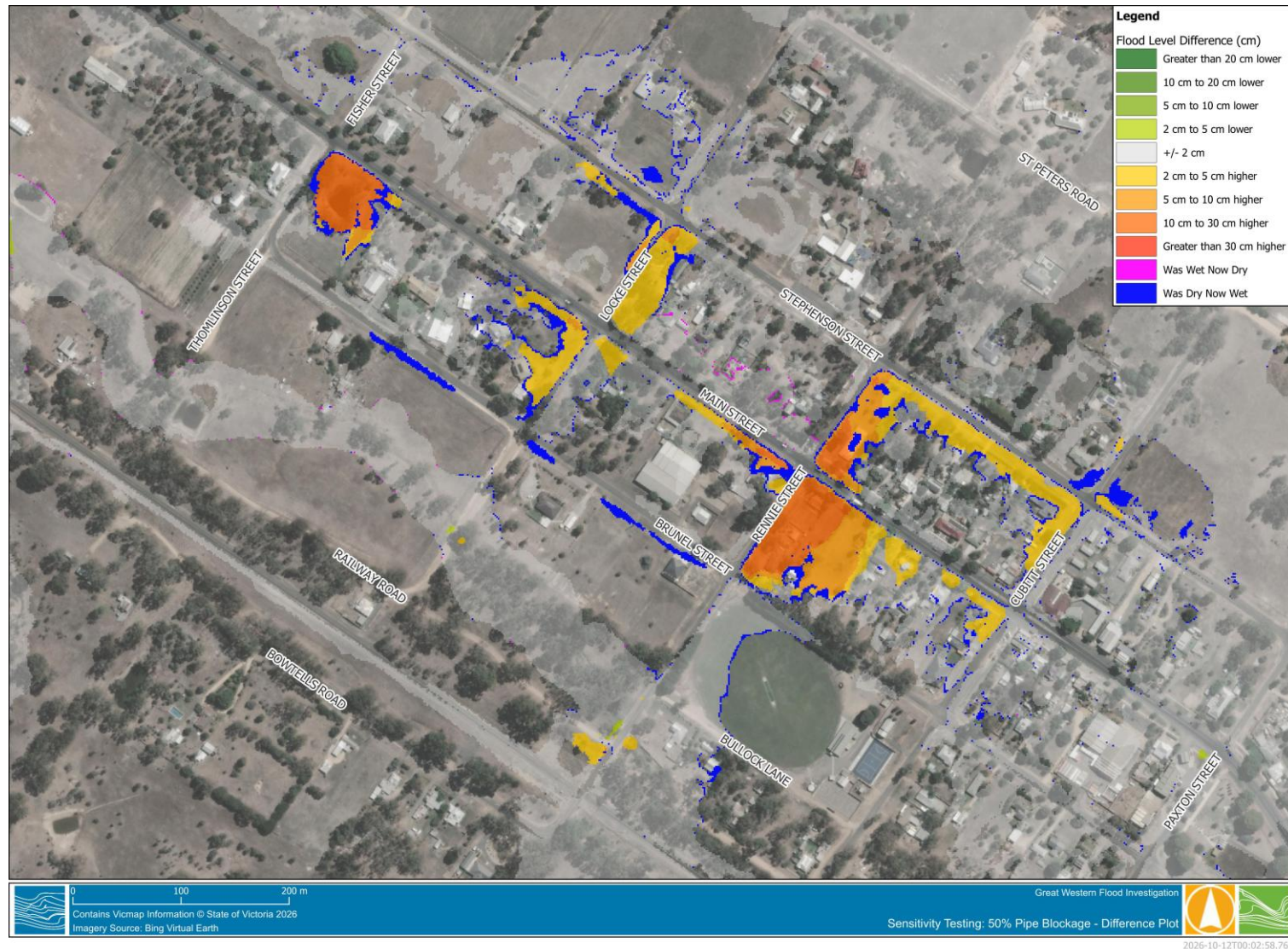


Figure 4-3 1% AEP SSP3-7.0 Year 2030 Difference Plot – 50% Blockage on Pipe Capacity



4.5 Design Event Mapping

4.5.1 1% AEP SSP3-7.0 Year 2030

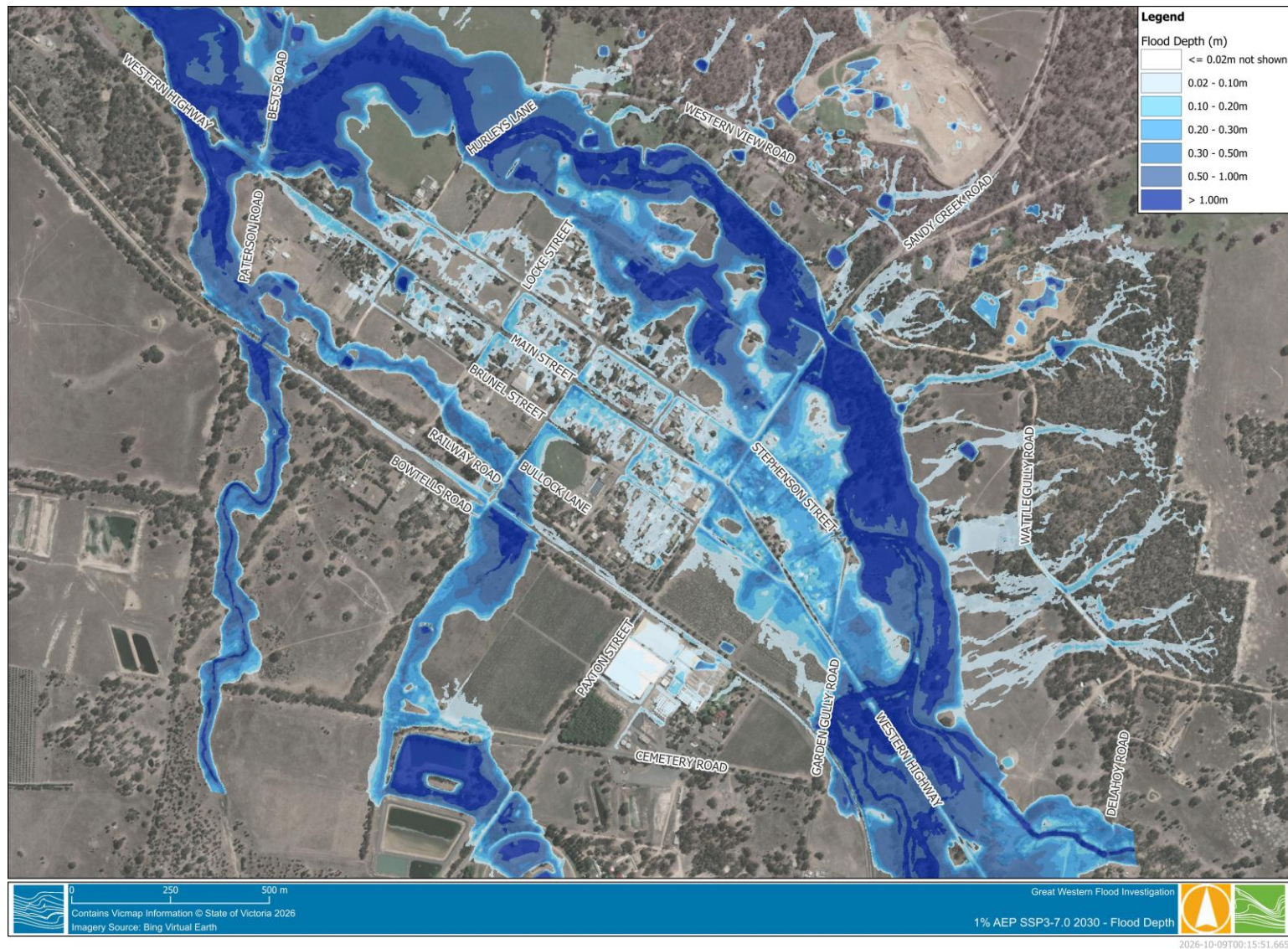


Figure 4-4 Zoomed into Township – 1% AEP SSP3-7.0 Year 2030 Flood Depth

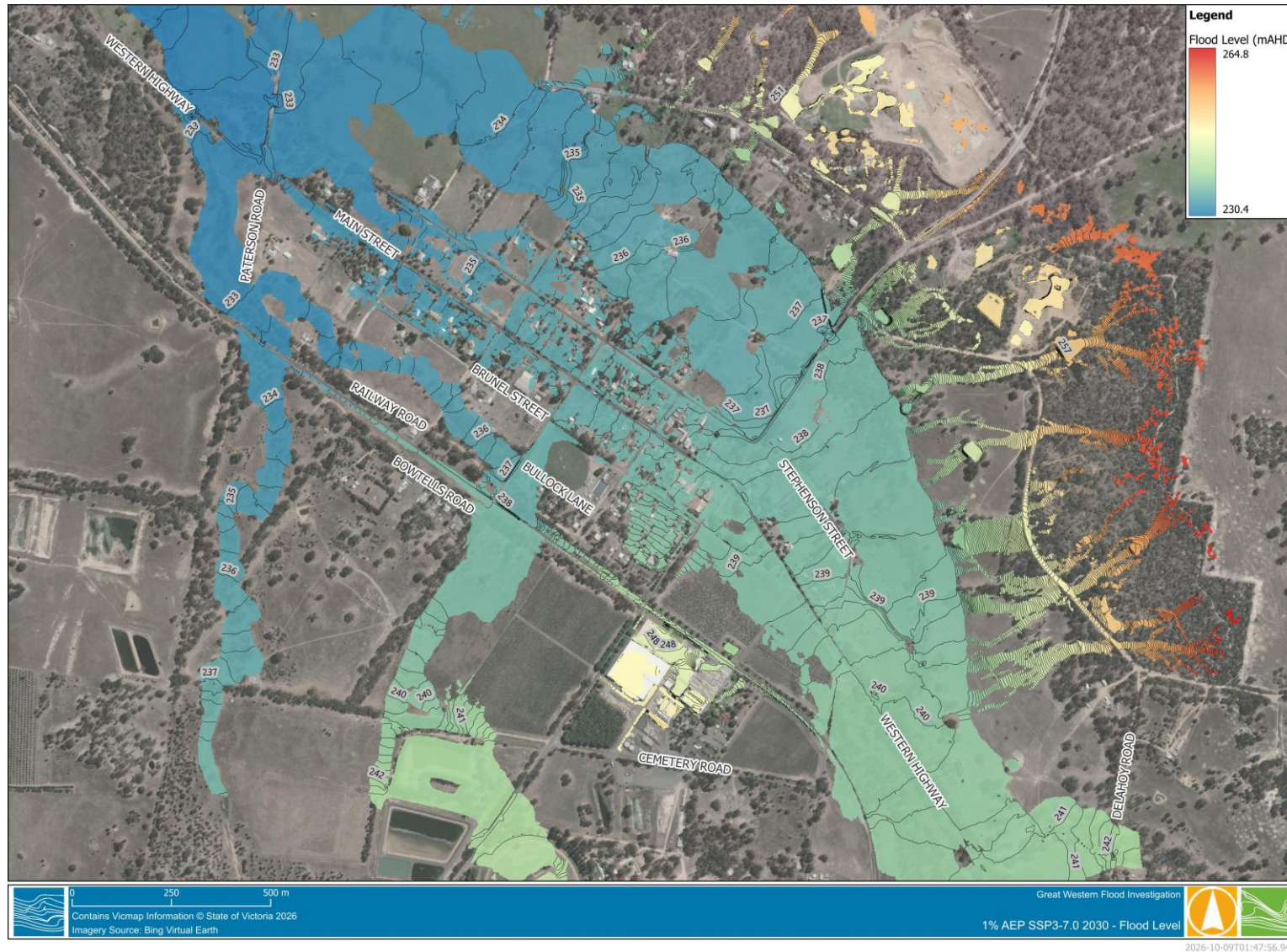


Figure 4-5 Zoomed into Township – 1% AEP SSP3-7.0 Year 2030 Flood Level



Figure 4-6 Zoomed into Township – 1% AEP SSP3-7.0 Year 2030 Flood Velocity

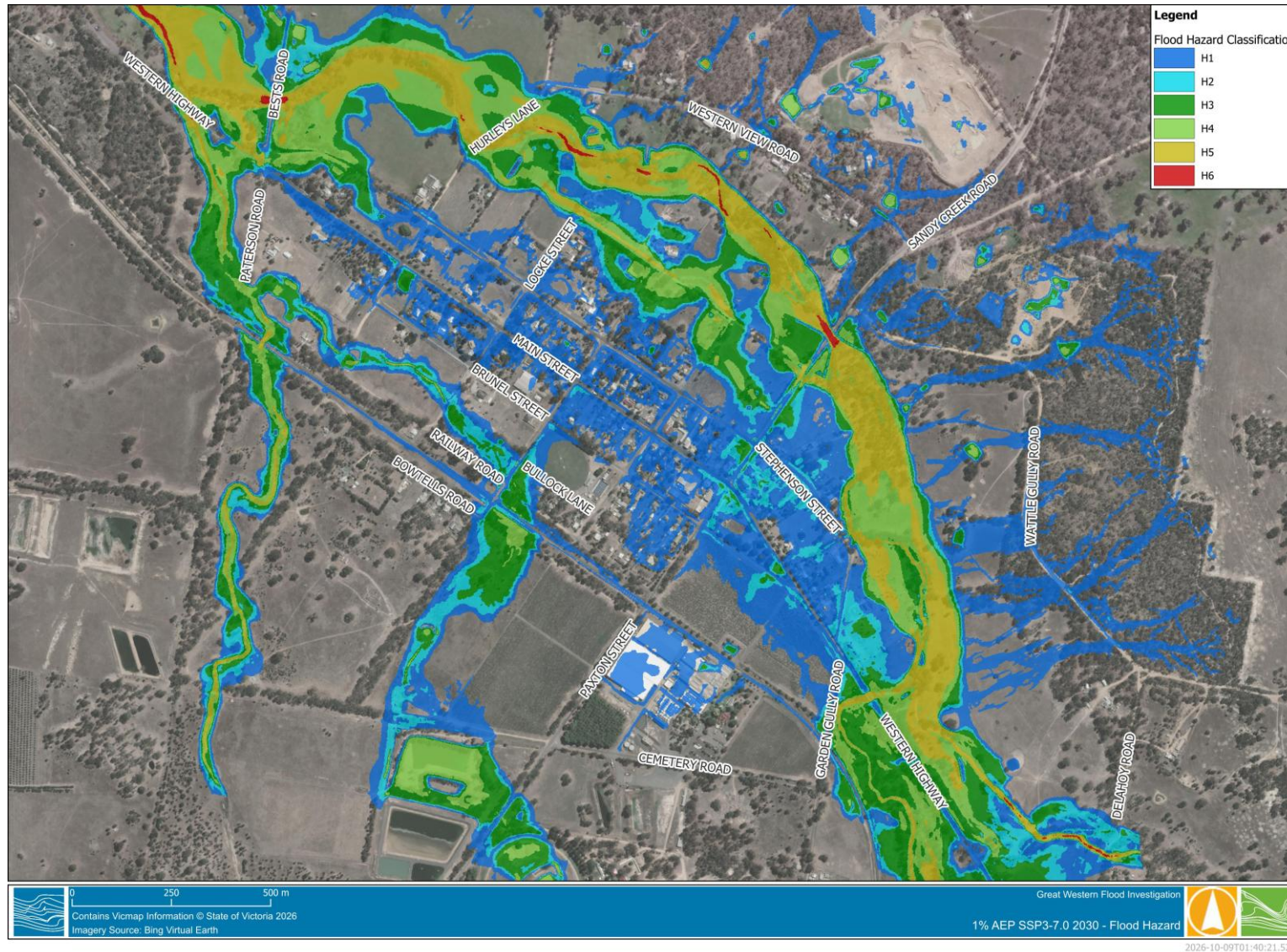


Figure 4-7 Zoomed into Township – 1% AEP SSP3-7.0 Year 2030 Flood Hazard



4.5.2 1% AEP SSP3-7.0 Year 2100

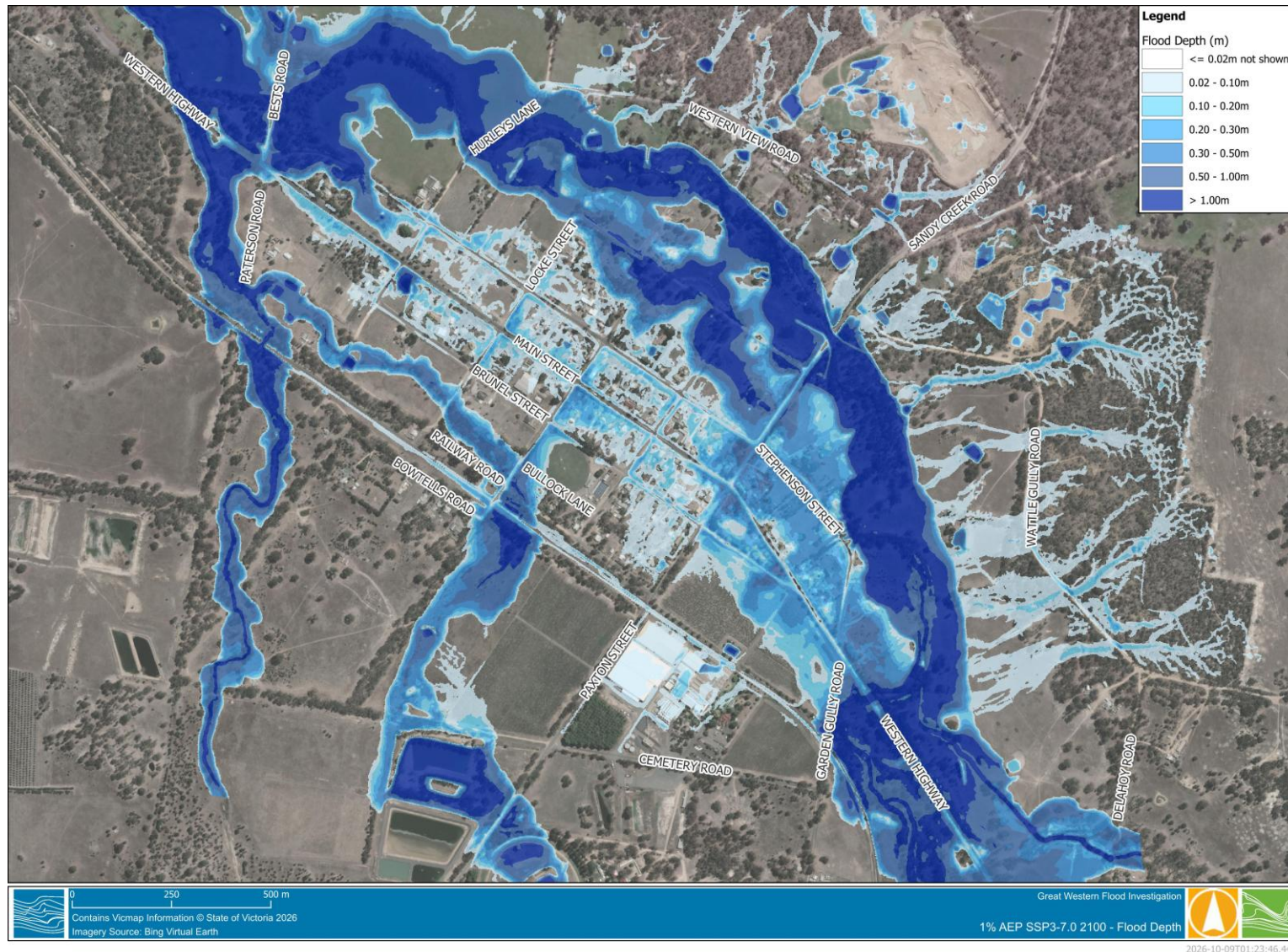


Figure 4-8 Zoomed into Township – 1% AEP SSP3-7.0 Year 2100 Flood Depth

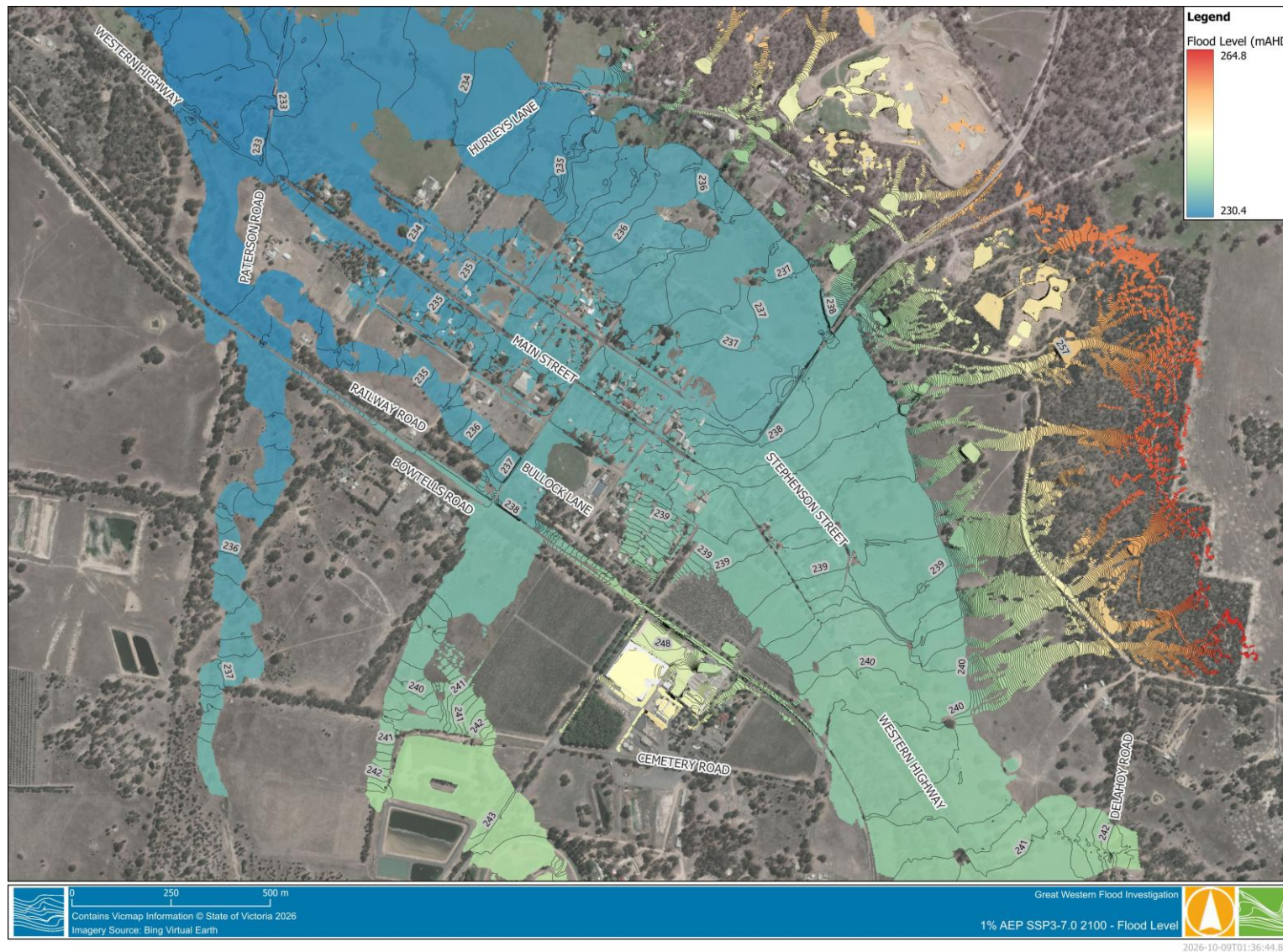


Figure 4-9 Zoomed into Township – 1% AEP SSP3-7.0 Year 2100 Flood Level



Figure 4-10 Zoomed into Township – 1% AEP SSP3-7.0 Year 2100 Flood Velocity

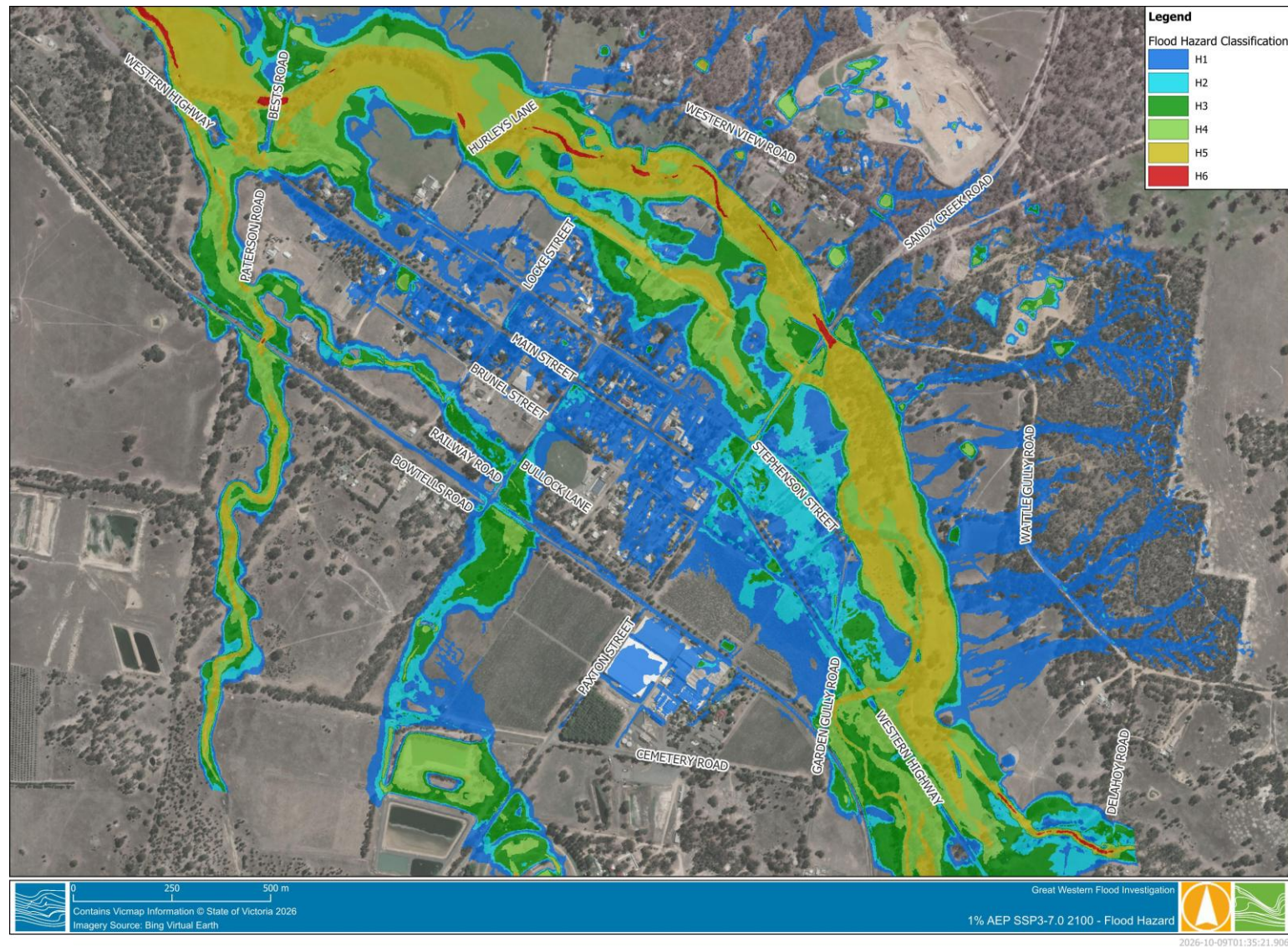


Figure 4-11 Zoomed into Township – 1% AEP SSP3-7.0 Year 2100 Flood Hazard



5 FLOOD INTELLIGENCE AND FLOOD RESPONSE MANAGEMENT

5.1 Flood forecasting and warning

5.1.1 Catchment response times for flood warning arrangements

This section assesses whether Great Western's flood response is better suited to flash-flood or riverine flood-warning arrangements. It first estimates catchment response times, then reviews the warning services currently available and, finally, identifies practical enhancements suited to the rapid onset of flooding at Great Western.

5.1.1.1 Approach

The catchment response times for flood warning were assessed using the framework developed by HARC (2023) and refined by Water Technology (2026). The key elements and their application to this study are outlined below:

- **Calibrated Hydrological Models - RORB**
 - For this study, the calibrated RORB model and loss parameters documented in the Great Western Flood Investigation hydrologic modelling were used.
- **Monte Carlo Simulation Framework:**
 - The framework runs the RORB model 25,000 times to represent catchment and rainfall uncertainty. Each run samples the parameters listed below.
 - Initial Losses: Sampled initial loss are tested to reflect variability in antecedent conditions (e.g, dry, average, wet, saturated).
 - Rainfall depths: Sampled rainfall depths from Bureau of Meteorology 2016 IFD dataset.
 - Rainfall temporal patterns: Sampled from temporal rainfall patterns from ARR (2019) patterns to model how rainfall intensity and distribution impact catchment response.
 - Rainfall frequency (AEP): Sampled from 50% to 0.5%AEP sampled. A uniform sampling across this range is adopted.
 - Rainfall durations: Assessed for rainfall durations from 1 hour to 72 hours
 - Rainfall spatial pattern: Single pattern applied for each rainfall duration using the 1%AEP rainfall depths for that duration.
 - Preburst rainfall: the preburst (as a ratio to the burst depth) is stochastically sampled from the datahub distribution and applied in a uniform temporal pattern over 2 hours prior to the burst regardless of burst duration.
- **Catchment response time**
 - For each RORB model run, the catchment response time is calculated as the time between the centre of mass (CoM) of excess rainfall and the peak flow at the location of interest. This generates a distribution of response times across a wide range of plausible scenarios.
 - Catchment response-time results were filtered to include only model runs in which peak flow exceeded the 10% AEP peak flow, used as a surrogate for the minor flood threshold.
- **Catchment response thresholds**
 - Riverine Flooding: If 70% or more of simulated events have response times > 6 hours.



- Flash Flooding: If less than 70% of simulated events have response times > 6 hours.

5.1.2 Application to Concongella Creek at Great Western

The approach described above was applied to Concongella Creek at the upstream end of the Great Western study area. Table 1-1 presents the RORB modelling parameters used in the assessment.

Table 5-1 Flood warning catchment response times – RORB modelling parameters

Parameter	Value	Comment
Initial loss (mm) – mean	17.7(20%) to 5.2 (1% AEP)	Normally distributed Vary with AEP
Minor flood threshold (m ³ /s)	120	~10% AEP
Continuous loss (mm/h)	3.6 (20%) to 1.1 (1% AEP)	Based on calibration events Vary with AEP
Durations (hours)	1 to 24	
Areal reduction factor	222 km ²	Contributing catchment area to Stawell.
Temporal patterns	ARR2019	Random sample of ARR point and areal temporal patterns (222 km ²)
Prebust	75th Percentile	Applied at a constant rate over 2 hours

The variation of catchment response times is shown in Figure 5-1.

Only 17% of modelled events had catchment response times greater than six hours. Because this is below the 70% threshold for riverine flooding, Great Western is classified as a flash-flooding catchment for flood-warning purposes.

Response times vary materially with design-storm duration. For shorter-duration storms of 1–6 hours, the median response time is 3–4 hours, and all modelled events have response times of less than six hours. For longer-duration storms of 9–24 hours, median response times increase to approximately 5–6 hours.

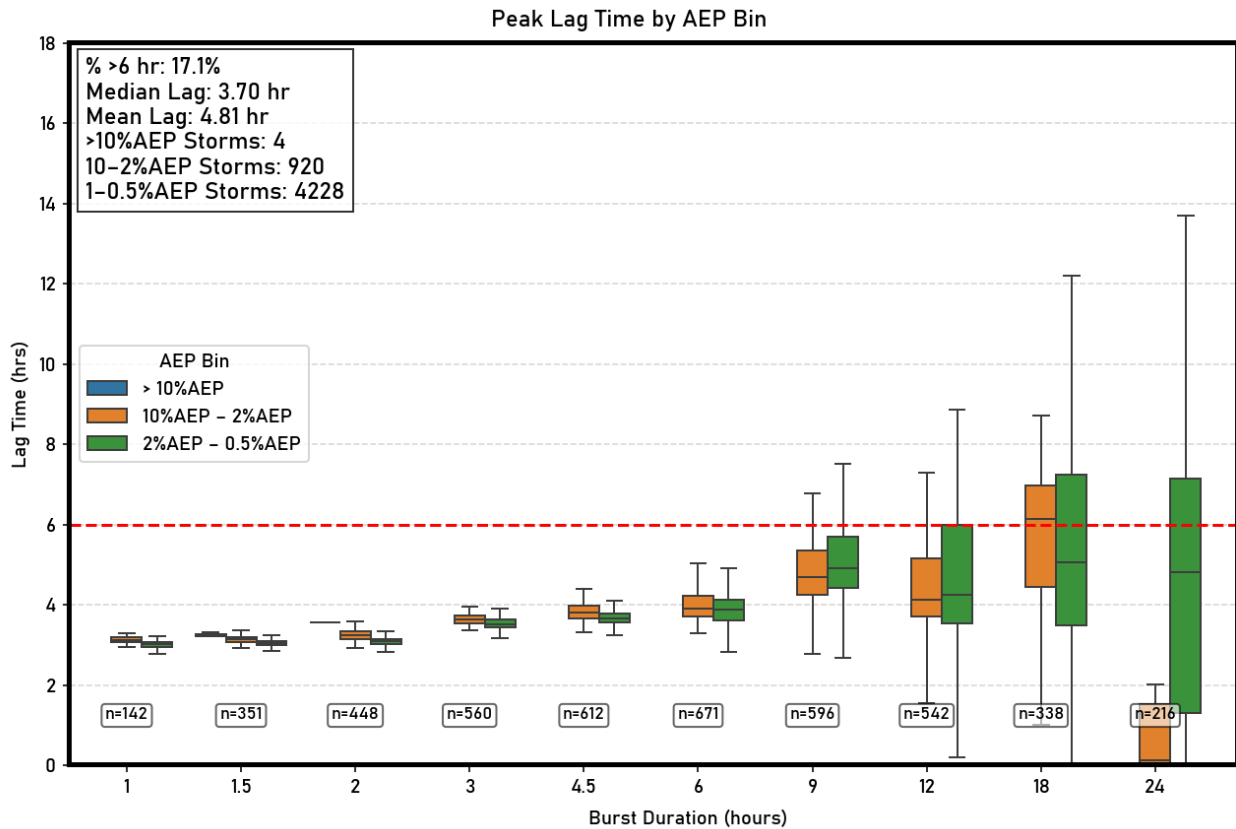


Figure 5-1 Flood warning catchment response times – Results for Concongella Creek at Great Western



5.2 Existing services

Table 1-2 summarises the flood forecasting and warning services currently available for Great Western, including their issuing agencies, severity levels, triggers, indicative lead times, update frequencies and local application.

Table 5-2 Great Western – Flood forecasting and warning services

Issuing agency, product and dissemination channels	Severity levels	Trigger for issue	Lead time	Update frequency	Application to flood warning for Great Western
Bureau of Meteorology Severe Weather warning¹ Available via the Bureau of Meteorology website, social media channels, and the app.	Heavy Rainfall Rainfall intensity corresponding to a 10% to 2% AEP event over durations of 30 minutes to 6 hours. Intense Rainfall Rainfall intensity rarer than a 2% AEP event over durations of 30 minutes to 6 hours, which may lead to flash flooding.	Issued when severe rainfall is occurring in an area, or is expected to develop in or move into an area.	Lead time depends on the weather situation and may range from 1 to 36 hours.	Updated routinely every 6 hours while the threat remains. More frequent updates may be issued if required.	A Severe Weather Warning generally applies to a broad region or district rather than a specific locality or township. Because warnings cover broad areas, Great Western may not flood each time it is included in a Severe Weather Warning. Accordingly, a Severe Weather Warning should be treated as a trigger to monitor local rainfall and flood conditions.



Issuing agency, product and dissemination channels	Severity levels	Trigger for issue	Lead time	Update frequency	Application to flood warning for Great Western
Bureau of Meteorology Severe thunderstorm warning¹ Available via the Bureau of Meteorology website, social media channels, and the app.	Severe Heavy rainfall that may lead to flash flooding. Rainfall intensity corresponding to a 10% to 2% AEP event over durations of 30 minutes to 6 hours. Very dangerous: Intense rainfall that may lead to dangerous and life-threatening flash flooding. Rainfall intensity rarer than a 2% AEP event over durations of 30 minutes to 6 hours.	Issued when a severe or very dangerous thunderstorm is occurring, is likely to occur or has been reported, or when existing thunderstorms are likely to develop into severe or very dangerous thunderstorms.	Severe thunderstorms can be quite localised and can develop, evolve and dissipate quickly. The exact location can be hard to predict, even with short lead times.	Updated while the threat remains.	A Severe Thunderstorm Warning generally applies to a more localised area than a Severe Weather Warning; however, the exact location and development of severe thunderstorms can be difficult to predict. Because thunderstorms can develop and dissipate quickly, Great Western may not experience flash flooding each time it is included in a warning. Accordingly, a Severe Thunderstorm Warning should be treated as a trigger to closely monitor local rainfall, storm movement and flood conditions.



Issuing agency, product and dissemination channels	Severity levels	Trigger for issue	Lead time	Update frequency	Application to flood warning for Great Western
Bureau of Meteorology Flood watch² Available via the Bureau of Meteorology website, social media channels, and the app.	Provides early advice of a developing weather situation that may lead to riverine flooding. May indicate the possible severity of flooding.	Issued when forecast rainfall and catchment conditions indicate that local or riverine flooding is possible.	Can be issued up to 4 days in advance of potential flooding.	Updated at least daily and finalised once all catchments listed in the Flood Watch are covered by Flood Warnings or the risk of flooding has passed.	A Flood Watch generally applies to a broad river basin or forecast area and provides early advice that flooding may develop rather than a location-specific prediction. Because Great Western is affected by local catchment runoff and flash flooding, flooding may occur with limited warning and may not occur each time the town is included in a Flood Watch. Accordingly, a Flood Watch should be treated as a trigger to monitor forecast and observed rainfall, local drainage and creek conditions, and subsequent warnings.



Issuing agency, product and dissemination channels	Severity levels	Trigger for issue	Lead time	Update frequency	Application to flood warning for Great Western
Bureau of Meteorology Flood warning for riverine flooding² Available via the Bureau of Meteorology website, social media channels, and the app.	Generalised: Used when there is insufficient data to make location-specific predictions or during the developing stages of a riverine flood. Minor flooding Flooding of low-lying areas adjacent to watercourses, minor roads and low-level bridges. Moderate flooding Flooding of main traffic routes and some buildings above floor level. Major flooding Flooding of many buildings above floor level and major rail and road routes.	Issued when riverine flooding is likely or occurring at a location or within a catchment specified in the Flood Forecasting and Warning Service Level Specification.	Lead-time targets are specified in the Flood Forecasting and Warning Service Level Specification. Actual lead time depends on the catchment's flood response.	Update-frequency guidance is specified in the Flood Forecasting and Warning Service Level Specification. Actual update frequency depends on the catchment's flood response.	The feasibility of Bureau riverine flood warnings for Great Western is limited as flooding is driven by short-duration, high-intensity local rainfall and rapid runoff from small local catchments. In these circumstances, flooding may develop before a location-specific riverine warning can be issued.



VICSES Storm Available via the Vic-Emergency website, social media channels, and the app.	Each warning level includes action statements that provide clear advice to the community. Calls to action may be used flexibly across all three warning levels, depending on the hazard. Advice An incident has started. There is no immediate danger. Stay up to date in case the situation changes. Watch and Act: There is a heightened level of threat. Conditions are changing and you need to start taking action now to protect you and your family. Emergency warning An Emergency Warning is the highest level of warning. You may be in danger and need to take action immediately. Any delay now puts your life at risk.	Advice May be issued following a Severe Weather Warning or Severe Thunderstorm Warning. Watch and Act: May be issued following a higher-severity Severe Weather Warning or Severe Thunderstorm Warning, such as for intense rainfall, or when impacts are observed. Emergency warning May be issued following a higher-severity Severe Weather Warning or Severe Thunderstorm Warning, such as for intense rainfall, or when significant impacts are observed.	When issued following a Severe Weather Warning or Severe Thunderstorm Warning, the available lead time generally reflects the lead time of the preceding Bureau warning.	Updated while the threat remains.	A VICSES Storm warning may apply to Great Western following a Bureau Severe Weather or Severe Thunderstorm Warning, or when local storm impacts are observed. Because storm location, intensity and impacts can change quickly, the warning level may escalate from Advice to Watch and Act or directly to an Emergency Warning as conditions worsen or significant impacts are confirmed. Accordingly, a VICSES Storm warning should be treated as a trigger to follow the specified calls to action and closely monitor Vic Emergency updates, local rainfall, storm movement and flood conditions.
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Issuing agency, product and dissemination channels	Severity levels	Trigger for issue	Lead time	Update frequency	Application to flood warning for Great Western
VICSES Flash flood Available via the Vic-Emergency website, social media channels, and the app.	The same as for Storm. Advice Watch and Act Emergency Warning	VICSES may issue a Flash Flood warning when impacts are observed, such as road closures or inundation of properties or buildings.	Issued following confirmation of observed impacts. For example, following requests for assistance.	Updated while the threat remains.	A VICSES Flash Flood warning may apply to Great Western when flash flooding is occurring or local impacts, such as road closures or inundation of properties and buildings, are reported. Because flash flooding can develop rapidly from intense local rainfall, warning lead time may be very limited and impacts may occur before a Severe Weather or Thunderstorm, or Storm warning is issued. Accordingly, a Flash Flood warning should be treated as a trigger to follow the specified calls to action immediately and closely monitor VicEmergency updates, local rainfall, road conditions and observed flooding.



Issuing agency, product and dissemination channels	Severity levels	Trigger for issue	Lead time	Update frequency	Application to flood warning for Great Western
VICSES Riverine flood Available via the Vic-Emergency website, social media channels, and the app.	The same as for Storm. Advice Watch and Act Emergency Warning	Advice May be issued following a Flood Watch or Minor Flood Warning. Watch and Act: May be issued following a Moderate Flood Warning or when observed impacts are assessed as moderate. Emergency warning May be issued following a Major Flood Warning or when observed impacts are assessed as major.	When issued following a Bureau riverine flood warning, the lead time reflects that of the Bureau riverine flood warning.	Updated as observed conditions change, and while the threat remains.	The feasibility of VICSES riverine flood warnings for Great Western is limited as flooding is driven by short-duration, high-intensity local rainfall and rapid runoff from small local catchments. In these circumstances, flooding may develop before a location-specific riverine warning can be issued. VICSES riverine flood warnings generally follow a Bureau Riverine Flood Warning.

1. Source: Service Level Specification for Severe Weather and Thunderstorm
2. Source: Service Level Specification for Flood Forecasting and Warning in Victoria



5.3 Possible enhancements

Great Western is in the upper Wimmera catchment and is affected by local rainfall, rapid runoff and rapidly developing flash flooding. The catchment is classified as flash flooding for flood warning, refer to Section 5.1.2. These characteristics limit the usefulness of location-specific riverine flood warnings.

As outlined above, Bureau Severe Weather Warnings, Severe Thunderstorm Warnings and Flood Watches should be treated as triggers to monitor local conditions. VICSES Storm and Flash Flood warnings should prompt the community to follow the specified calls to action. Improving community understanding of these warning products and their official dissemination channels is therefore a practical and sustainable enhancement.

The priority enhancements for Great Western are:

- **Promotion of official warning channels** – encourage residents and businesses to use the VicEmergency app and website and Bureau of Meteorology channels to receive Severe Weather Warnings, Severe Thunderstorm Warnings, Flood Watches, and VICSES Storm and Flash Flood warnings.
- **Preparation of a local flood risk information** – develop a community-facing information that explains Great Western's local flood risk, the purpose and limitations of each warning product, and the actions to take at each VICSES warning level. The information should link to official Bureau and Vic Emergency channels and emphasise that flash flooding can develop before a location-specific warning is issued. It should explain that Bureau warnings are triggers to monitor local rainfall, storm movement, creek conditions, while VICSES warnings require the specified calls to action to be followed promptly, and contain localised impacts and consequences where available.



6 FLOOD MITIGATION ASSESSMENT

6.1 Overview

There are a range of non-structural and structure mitigation options possible to reduce flood damages. The below sections summarise how these both non-structural and structural mitigation measures could be implemented in Great Western.

6.2 Land Use Planning

6.2.1 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 a particular type 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.

6.2.2 Victorian Planning Provision

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 three overlays and one zone associated with mainstream flooding as follows:

- Land Subject to Inundation Overlay (LSIO).
- Floodway Overlay (FO).
- Urban Floodway Zone (UFZ).
- Special Building Overlay (SBO).

The LSIO, FO and SBO overlays were considered relevant to the present study. The definitions of these overlays and their criterion 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.

6.2.3 Flood Related Zones and Overlays

6.2.3.1 Land Subject to Inundation Overlays (LSIO)

The LSIO identifies land liable to inundation by overland flow, in flood storage or in flood fringe areas. In this project, the 1% AEP flood event under the 2030 SSP3-7.0 climate change scenario was used.

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.

6.2.3.2 Floodway Overlay (FO)

The FO identifies waterways, main flood paths, drainage depressions and high hazard areas. The identification of FO has been based on the below criteria:

- 1% AEP SSP3 2030 depths > 0.5 m
- 1% AEP SSP3 2030 velocities > 1.5 m/s
- 1% AEP SSP3 2030 velocity x depth $\geq 0.4 \text{ m}^2/\text{s}$

6.2.3.3 Special Building Overlay (SBO)

The SBO is used to define flooding from overland flows where stormwater infrastructure plays controlling role in the inundation (as opposed to water escaping from a waterway). The overlay is generally used within built up areas where the nature of flooding from stormwater has been identified. This planning control is used to ensure that development within these areas identified as flood prone can be undertaken with due regard for the flood risk and in accordance with appropriate conditions and floor level requirements.

The primary objective of the SBO is:

- *"To ensure that development maintains the free passage and temporary storage of floodwaters, minimises flood damage, is compatible with the flood hazard and local drainage conditions and will not cause any significant rise in flood level or flow velocity."*

SBO extents are recommended as part of this study and for only a select number of areas where inundation has been modelled outside of the designated waterways and infrastructure is a major controlling factor. This primarily inundation at the very top of catchments where a defined waterway is no longer present, i.e., urbanised catchments. Additionally, inundation in areas which have a catchment of 60 Ha or less were included in the delineation of SBO.



Further refinements to the extent of the proposed SBO were undertaken by assessing velocity vectors from the hydraulic model to determine where flows change from overland/stormwater flooding to riverine flooding.

Filtering was applied to the generated SBO extent to remove shallow depths from the proposed overlay to account for any inaccuracies the catchment wide maps might have on a lot-by-lot scale. For this study, the SBO extents filtered out depths less than or equal to 5 cm.

6.2.3.4 Overlay Generation Criterion

In generating the draft overlays, the following principals and guidelines were developed and applied from the existing flood study and in consultation with NGCS and Wimmera CMA:

- Raw gridded model results were smoothed on their fringes to create a plausible representation of the floodway and flood fringe boundaries. This removed the irregular 'saw tooth' edge.
- Irregularities in the floodway and flood fringe boundaries, such as small 'tongues' of flood-prone land extending out from the bulk of the identified flood extent were smoothed where necessary. The underlying Planning Scheme Zone was a consideration in doing this.
- Islands (high ground) within the Floodway Overlay (i.e. marooned by high hazard flooding) were in general covered by the Floodway Overlay due to access being cut. A planning permit application would be therefore filled the less than 1-hectare islands which ensures flooded access hazards are accounted for.
- The removal of isolated patches and paddles (such as dams) which less than 1 hectare and mapped outside of the main floodplain area and not connected to any stormwater infrastructure were removed.
- Each overlay polygon was smoothed by applying the Polynomial Approximation with Exponential Kernel (PAEK) in ArcGIS Pro with parameter as 25m.

An overview of the proposed FO and LSIO for the Great Western catchment are presented in Figure 6-1.

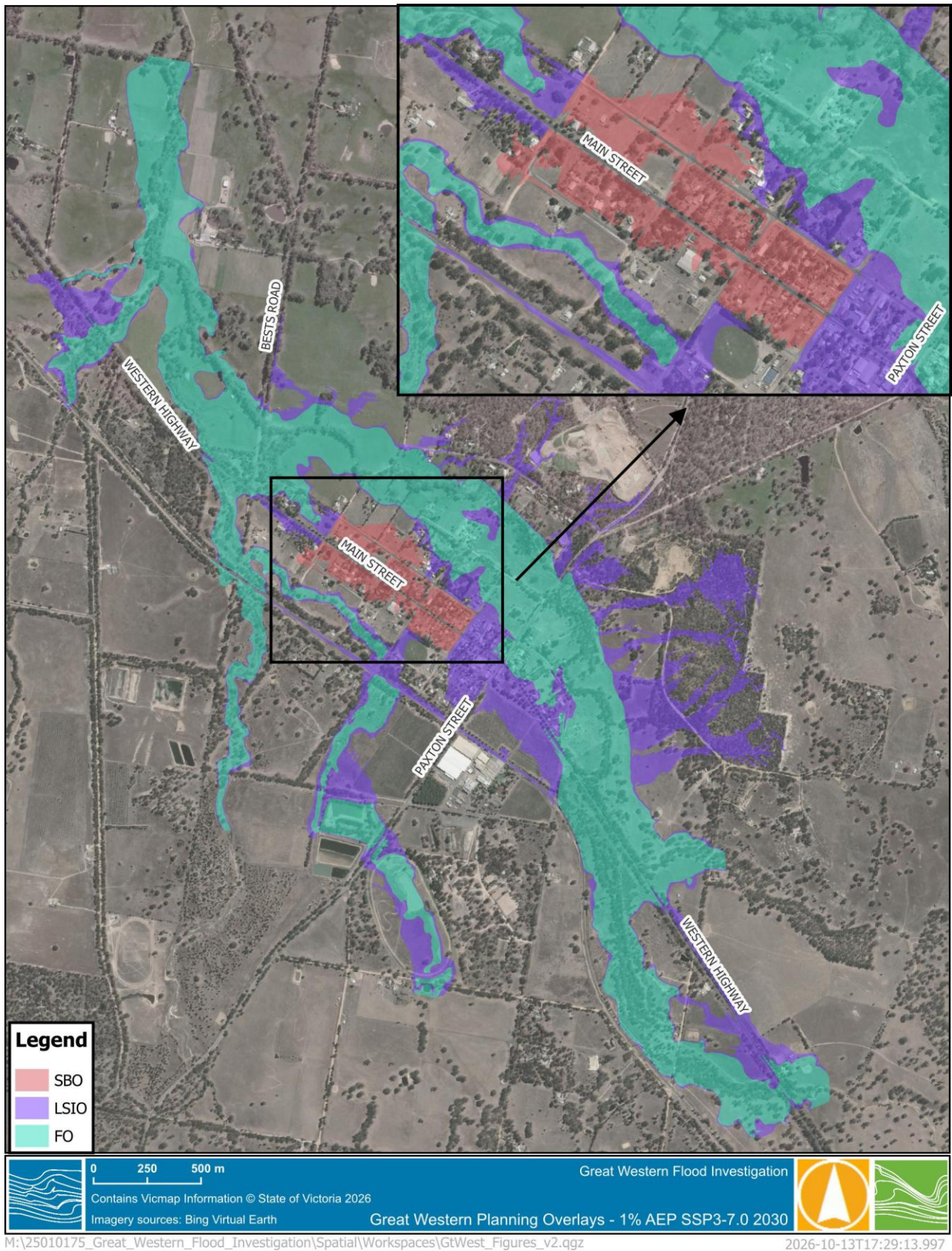


Figure 6-1 Great Western Planning Overlays



6.3 Structural mitigation

6.3.1 Overview

Four mitigation options for Great Western underwent testing in the hydraulic model, with the aim of reducing the impact of flooding on the township. These options were suggested by the community or the project team comprising of members of NGSC, Wimmera CMA and Water Technology. The intent was to reduce inundation of buildings in key areas of impact. These areas included:

- Properties along Stephenson Street, parallel to the Concongella Creek, just after the Western Highway Bridge and confluence of Allanvale Creek.
- Within central Great Western, properties along the Main Street.

The tested mitigation options included:

- Option 1A – Levee on Stephenson Street
 - A levee is to be built on Stephenson Street along the road from Garden Gully Road to Paxton Street.
- Option 1B – Levee on Property Boundary
 - A levee is to be built along between the property boundaries on Stephenson Street and floodplains of Concongella Creek.
- Option 2 – Widened Western Highway Bridge
 - Widened the opening of the Western Highway Bridge by doubling the capacity for flow to pass through the bridge.
- Option 3 – Increased Pipe Capacity x1.5
 - Increased the existing pipe capacity by 50% by enlarging the diameter/width of the pipes.
- Option 4 – Removed Vegetation on Concongella Creek
 - Reducing the Mannings 'n' roughness coefficient of the Concongella Creek to 0.025, mimicking a "very smooth" waterway.

Each of these mitigation design layouts and results are discussed in the following sections.



6.3.2 Option 1A – Stephenson Street Levee

Option 1A investigated building a levee on Stephenson Street, along from the Garden Gully Road, north of the railway track, across the Western Highway, along Stephenson Street till Paxton Street. The intention of this levee was to reduce inundation of areas behind the levee. Figure 6-2 shows the location of the assessed levee on Stephenson Street.

Figure 6-3 shows the change in 1% AEP SSP3-7.0 year 2030 flood levels due to construction of the levee.

Modelling showed a reduction in flood level for properties behind the levee, with a reduction up to 0.25 m along the properties on the east of Main Street and north of Seppelt Vineyard. The levee has also prevented the overland flow path from the breaking of the Western Highway Bridge flow from passing through Stephenson Street, and in turn remained within the waterways.

However, there are properties sitting on the north side of the Stephenson Street with elevated flood levels, as their properties are situated on the waterway side of the levee. Given the negative impact of this option it is unlikely to be viable. It should be noted inundation behind the levee is stormwater runoff rather than inundation from Concongella Creek.

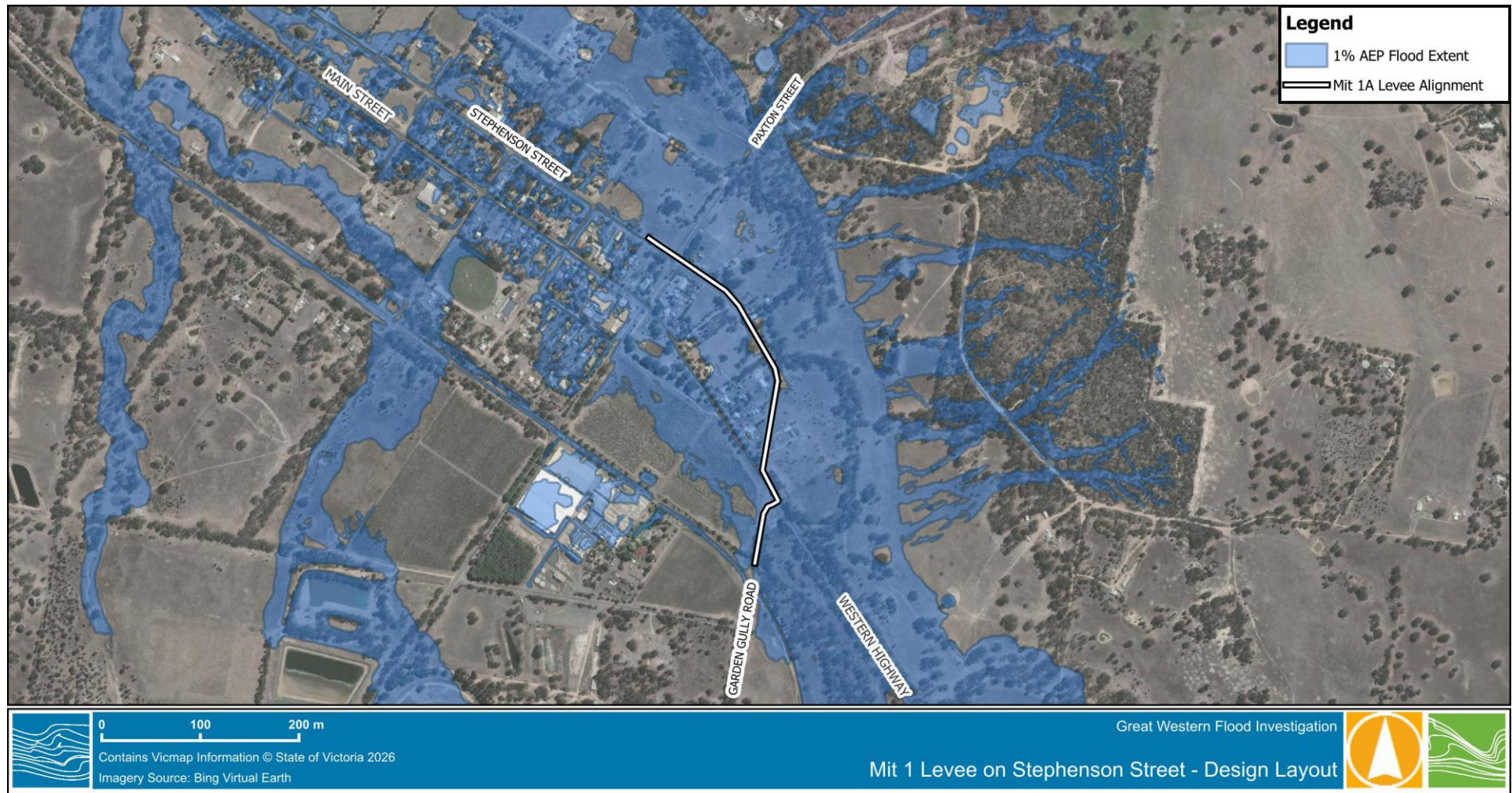


Figure 6-2 Mitigation Option 1A Design Layout

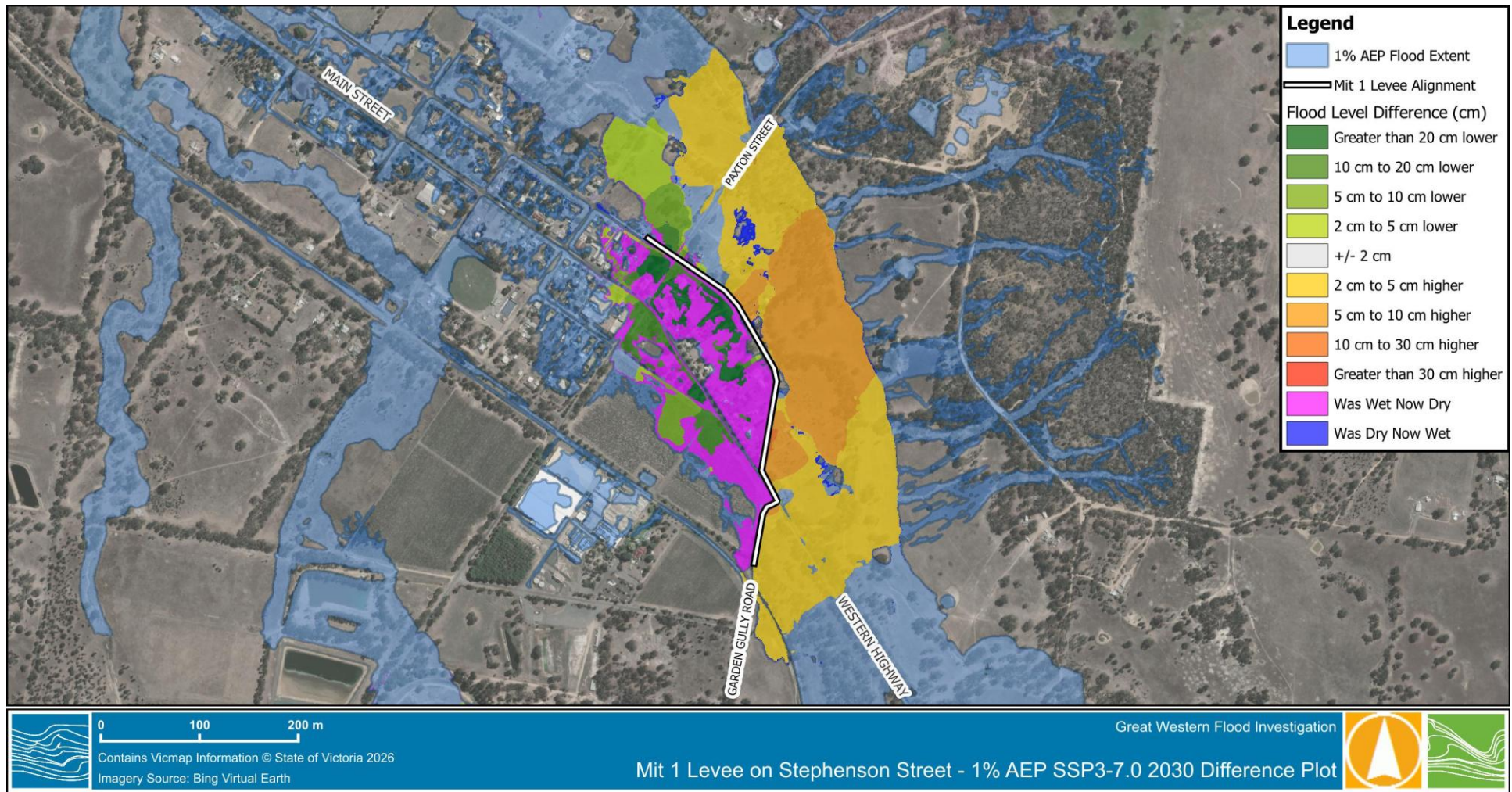


Figure 6-3 1% AEP SSP3-7.0 2030 Difference Plot for Existing vs Mitigation Option 1A



6.3.3 Option 1B – Waterway bank levee

Option 1B is an alteration of Option 1A. Instead of Stephenson Street, the levee was aligned in between properties along the north side of Stephenson Street and Concongella Creek. Some parts of this alignment may be on private land; however, it is an indication of a levee could be built. The modelled levee alignment is illustrated in Figure 6-4.

The change in 1% AEP SSP3-7.0 year 2030 flood level levels caused by the modelled levee are presented in Figure 6-5. The modified levee alignment has successfully reduced the flood impact on the properties on Stephenson Street. The flood level has reduced as much as 0.42 m, with flood level increases limited to within the waterway corridor. The maximum increase in this area was 0.35 m.

It is important to note that the proposed levee does not completely mitigate the potential inundation risk for the properties on Stephenson Street due to the stormwater runoff impacts. With inundation behind the levee caused by stormwater runoff rather than inundation from Concongella Creek.

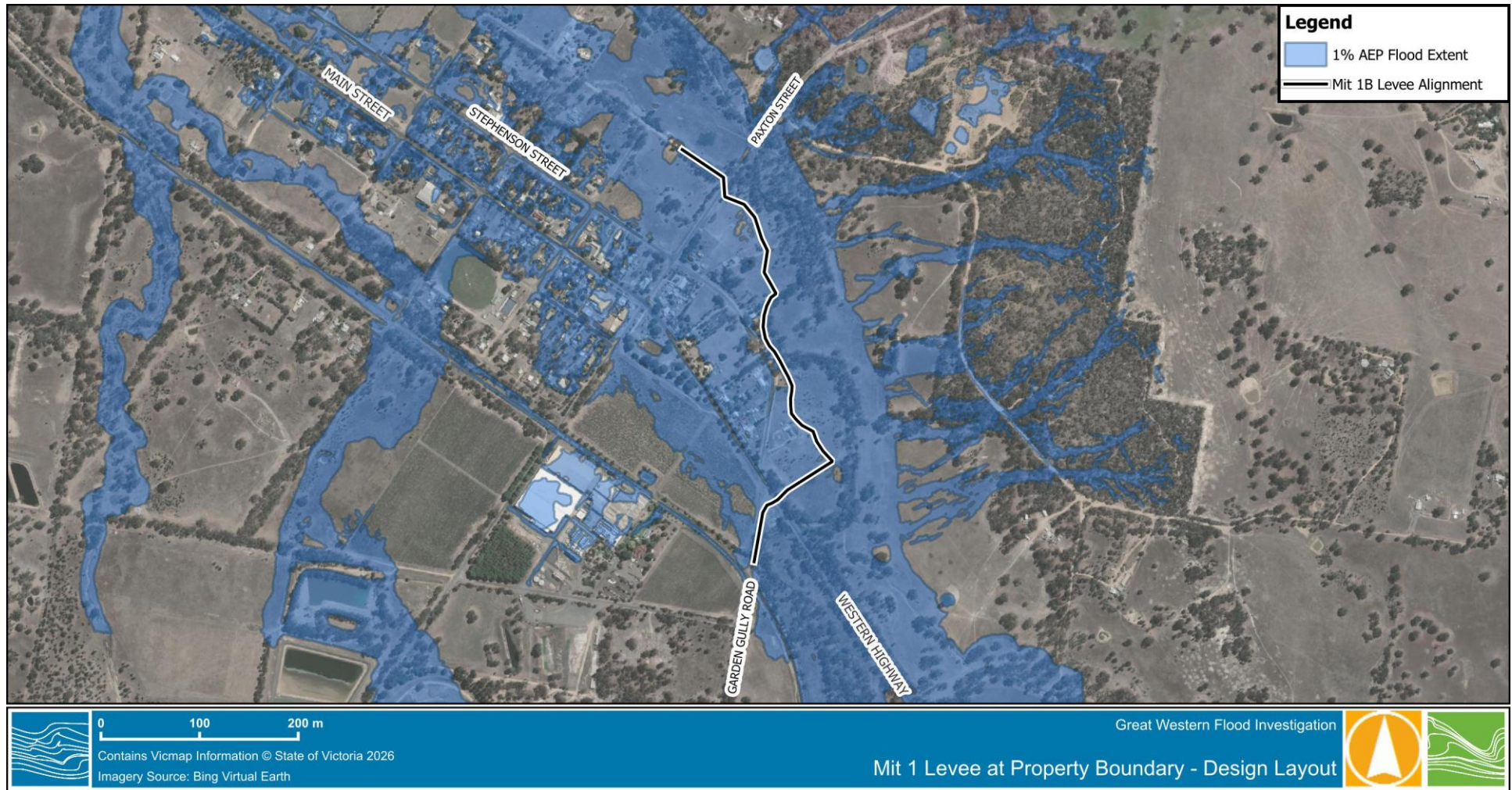


Figure 6-4 Mitigation Option 1B Design Layout

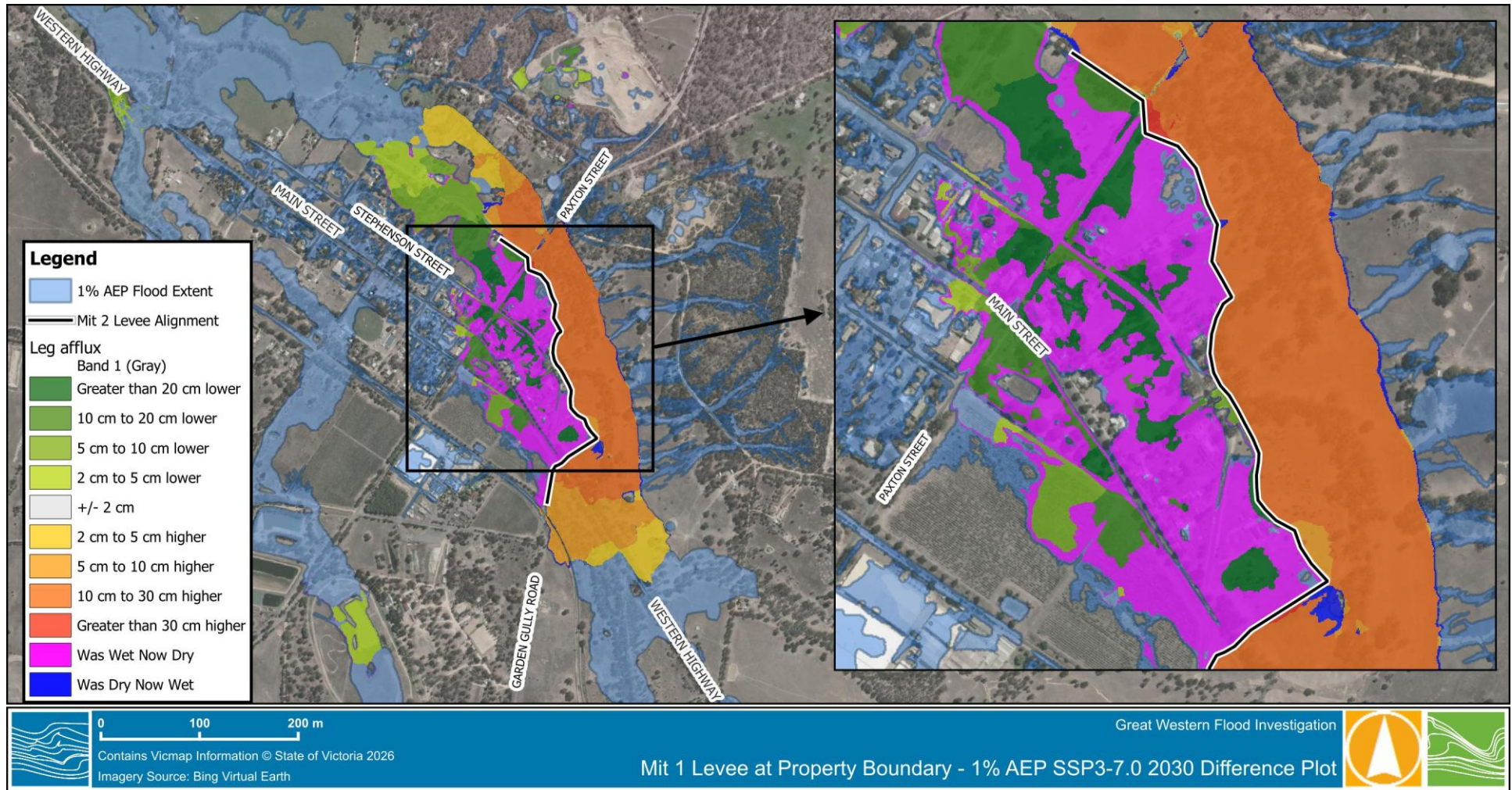


Figure 6-5 1% AEP SSP3-7.0 2030 Difference Plot for Existing vs Mitigation Option 1B



6.3.4 Option 2 – Western Highway Bridge Widening

Option 2 investigates widening the Western Highway Bridge to increase the capacity of the structure. This was modelled by extending the overall bridge length to around double its current size. Figure 6-6 demonstrates the topographic change to the model.

Figure 6-7 shows the change in 1% AEP SSP3-7.0 year 2030 flood levels with inclusion of the bridge widening.

The result shows a minor reduction in flood level with the proposed widened bridge. The flood level was reduced by up to 0.17 m at Seppelt Vineyard and the floodplain just before the Western Highway Bridge. There are no other impacts on the township nor the waterway.

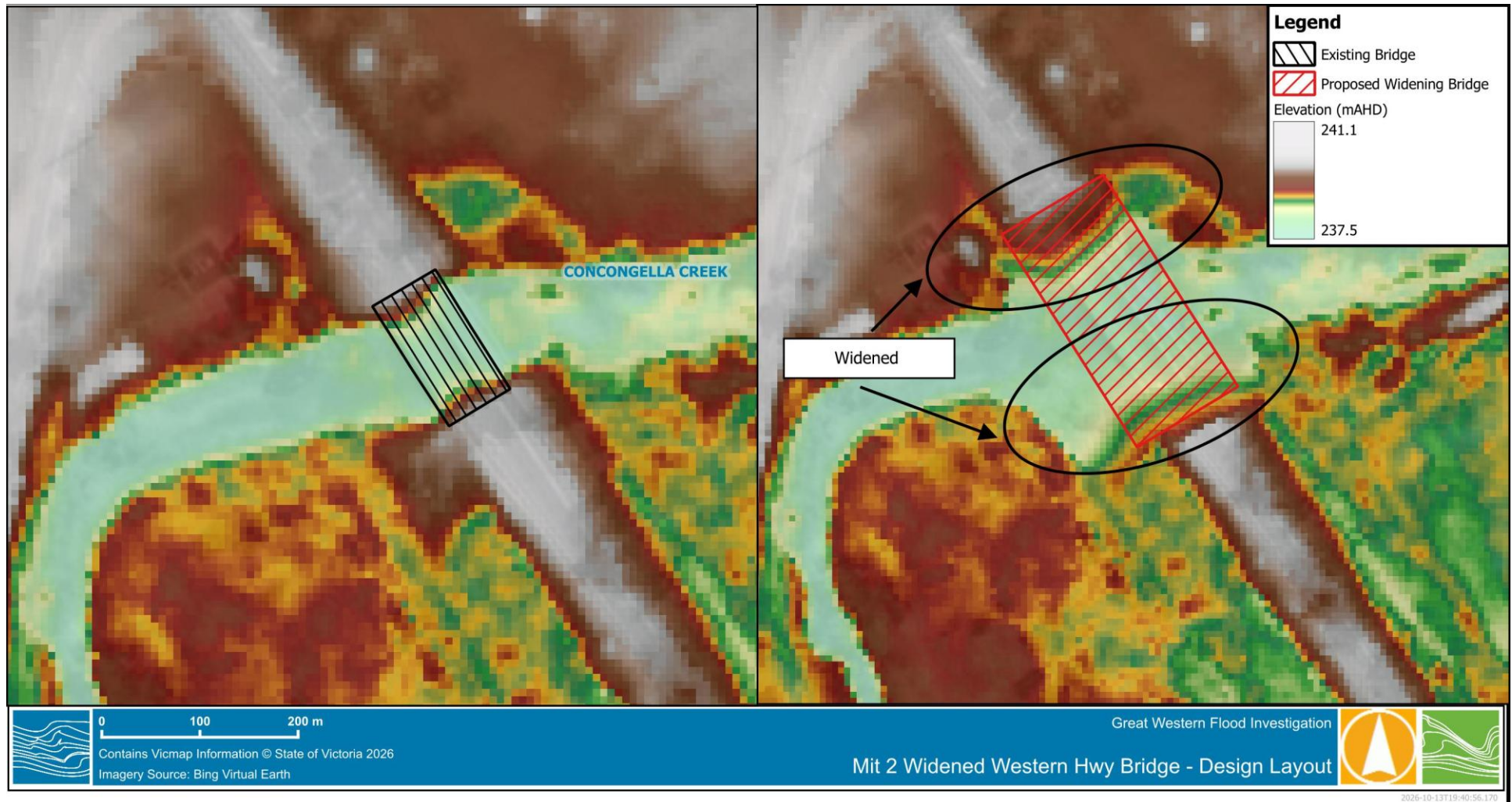


Figure 6-6 Mitigation Option 2 Design Layout

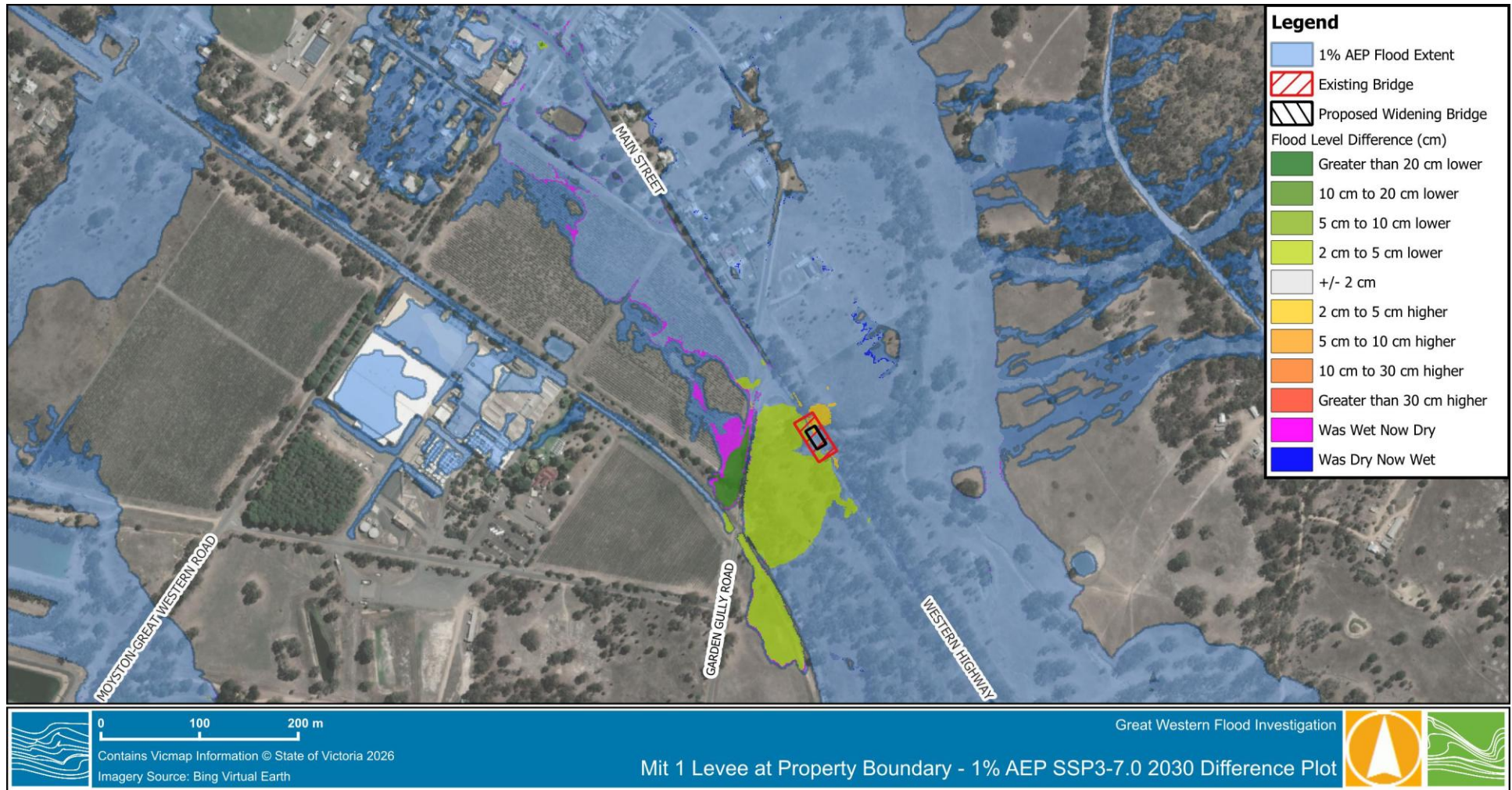


Figure 6-7 1% AEP SSP3-7.0 2030 Difference Plot for Existing vs Mitigation Option 2



6.3.5 Option 3 – Culvert Capacity Increases

Option 3 investigated the potential to increase stormwater culvert capacities within Great Western. The pit and pipe network was increased by 50% in width or diameter.

The change in 1% AEP SSP3-7.0 year 2030 flood level due to the capacity increases is presented in Figure 6-8.

Modelling showed flood level reductions of up to 0.2 m, with several properties along Main Street showing reductions in a flood depth.

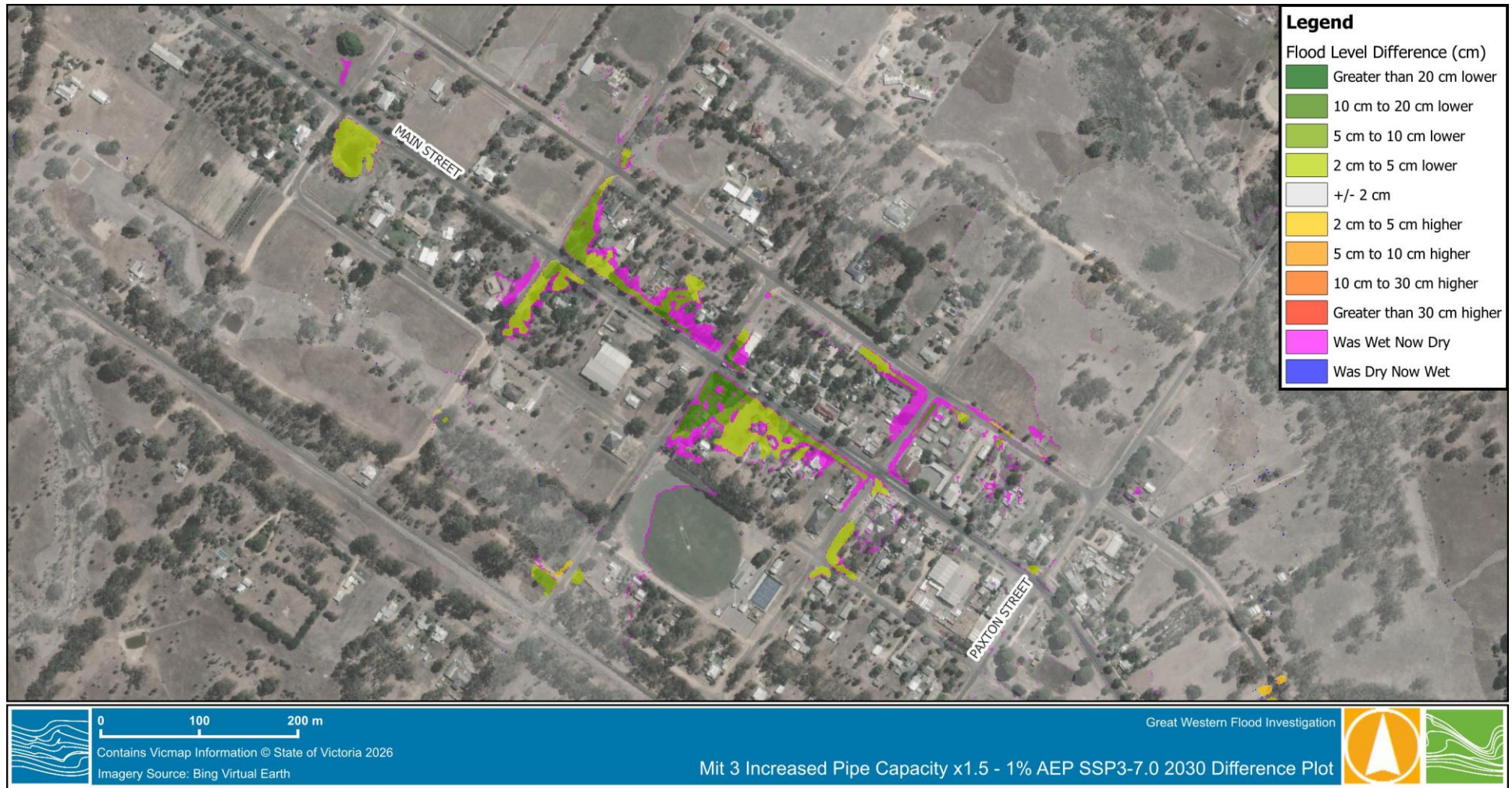


Figure 6-8 1% AEP SSP3-7.0 2030 Difference Plot for Existing vs Mitigation Option 3



6.3.6 Option 4 – Vegetation Removal

Option 4 investigated the potential for vegetation removal along Concongella Creek to improve conveyance. This option was strongly supported by the community during consultation as there is a view the vegetation along Concongella Creek restricts flow, particularly at the Western Highway bridge.

To model this scenario, the adopted Manning's 'n' roughness value was reduced to a uniform 0.025 along Concongella Creek parallel to the township (this is characterised as the "minimum value" in "Main Channels" which are "clean, straight, full stage, no rifts or deep pools"⁷). Table 6-1 shows the amount of change in the roughness values, determined by the calibration and Figure 6-9 visualises the change in land use that was undertaken for this mitigation.

The change in 1% AEP SSP3-7.0 flood levels plot for the vegetation removal is presented in Figure 6-2.

Table 6-1 Modification to Concongella Creek roughness values

Land Use	Existing Conditions	Mitigation 4
Creeks with Minimal Vegetation	0.03	0.025
Weedy Sluggish Reaches with Deep Pools	0.06	
Clean, Winding Channels with Some Stones and Weeds	0.07	
Creeks with Dense Bush	0.08	
Scattered Bush with Heavy Weeds	0.05	

The highest reduction in flood level is 0.28 m, within the waterway, up to 0.02 m for the properties between Main Street and Stephenson Street and up to 0.09 m for properties on the north side of Stephenson Street. The flood extent was also reduced at around the corner of Rennie Street and Stephenson Street.

The vegetation removal shows the best achievable reduction in water levels given the large degree of roughness reduction, complete vegetation removal. While this is unlikely, the modelling does show vegetation removal is likely to provide some reduction in potential flood damage.

It should be noted that the modelled vegetation removal has occurred in areas which are largely privately owned and a coordinated approach to removal would be required if this was to be a viable mitigation option. Vegetation removal also requires ongoing management, with vegetation often growing back quickly.

⁷ Chow, 1959 – Open Channel Hydraulics



Figure 6-9 Mitigation Option 4 Removal Extent

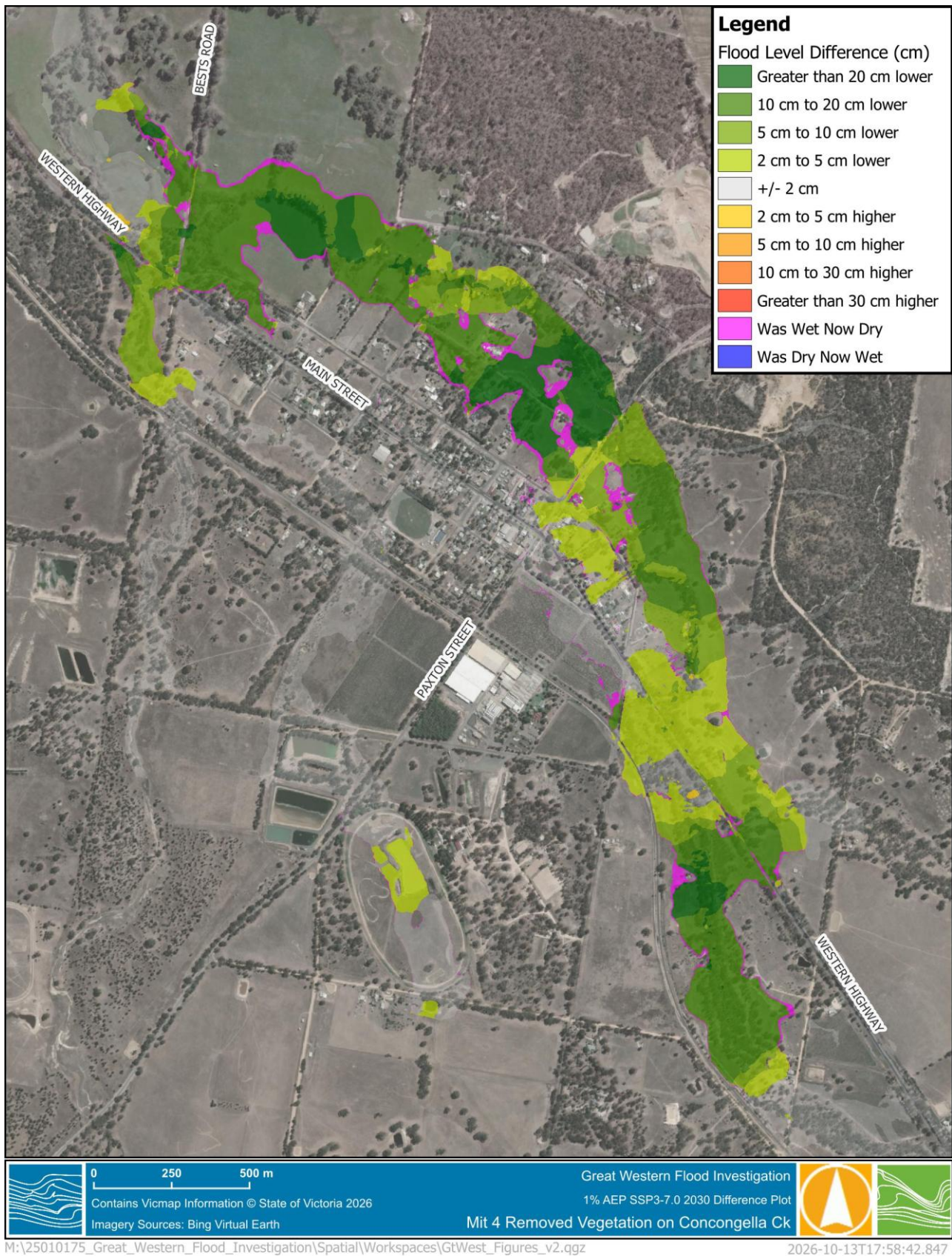


Figure 6-10 1% AEP SSP3-7.0 2030 Difference Plot for Existing vs Mitigation Option 4



6.3.7 Structural Mitigation Summary

Of the options modelled, Mitigation Option 1B (a levee along the waterway bank) was shown to have the greatest potential to reduce flood risk and damage in Great Western. The option aims to prevent overland flow from Concongella Creek and Allanvale Creek spilling into Great Western. While Option 1A (Stephenson Street Levee) had the same intent, the alignment caused undesirable adverse impact. Option 1B reduced adverse flood level increases to areas without dwellings. The inundation risk for properties inside of the levee was reduced to stormwater impacts.

Modelling showed the capacity of the bridge was not a major contributor to flooding in Great Western in large flood events, with doubling of the bridge size (Option 2) showing a flood level reduction of less than 0.1 m immediately upstream of the bridge in a large flood event. This is primarily related to the mechanisms of inundation in Great Western. There is a link between stormwater flooding and riverine flooding, both can cause flood damage along Main Street, between Locke Street and Paxton Street. Stormwater alone can cause flood damage, without the need for Concongella Creek to overtop and flow over Garden Gully Road and into town.

The link between stormwater and riverine flooding was also highlighted in Option 3 (culvert capacity increases), a 50% increase to the pit and pipe network caused reductions of up to 0.2 m in a large inundation event. Strategically increasing culvert capacities is a viable option for Great Western in a bid to reduce flood impact and damage.

Removal of vegetation along Concongella Creek (Option 4) demonstrated the removal of the vegetation could reduce flood levels and extents, particularly within the waterway; however, limited benefit was observed within the township. The flood extent is also reduced at around the corner of Rennie Street and Stephenson Street. It is noted the modelling of vegetation removal shows the best achievable reduction in water levels given the large degree of roughness reduction, particularly in areas which are largely privately owned and a coordinated approach to removal would be required if this was to be a viable mitigation option. Vegetation removal also requires ongoing management, with vegetation often growing back quickly.



7 FLOOD DAMAGES AND COST-BENEFIT ANALYSIS

7.1 Existing Conditions

A summary of the flood damages with respect to each modelled AEP event was assessed with consideration to the number of properties flooded, direct damage cost, and indirect damage cost. Assessment was undertaken for the SSP3 2030 scenario, and is considered the present day scenario (given the time of writing was 2026).

Based on this information, the Average Annual Damage (AAD) has been calculated to be **\$85,958**. The properties flooded above and below floor for the 1% AEP SSP3 2030 event is shown in Figure 7-1. The total cost of flooding with respect to each AEP event is presented in Table 7-1.

The AAD was also calculated for the future SSP3 2011 scenario at **\$150,592**, as shown in Table 7-2.

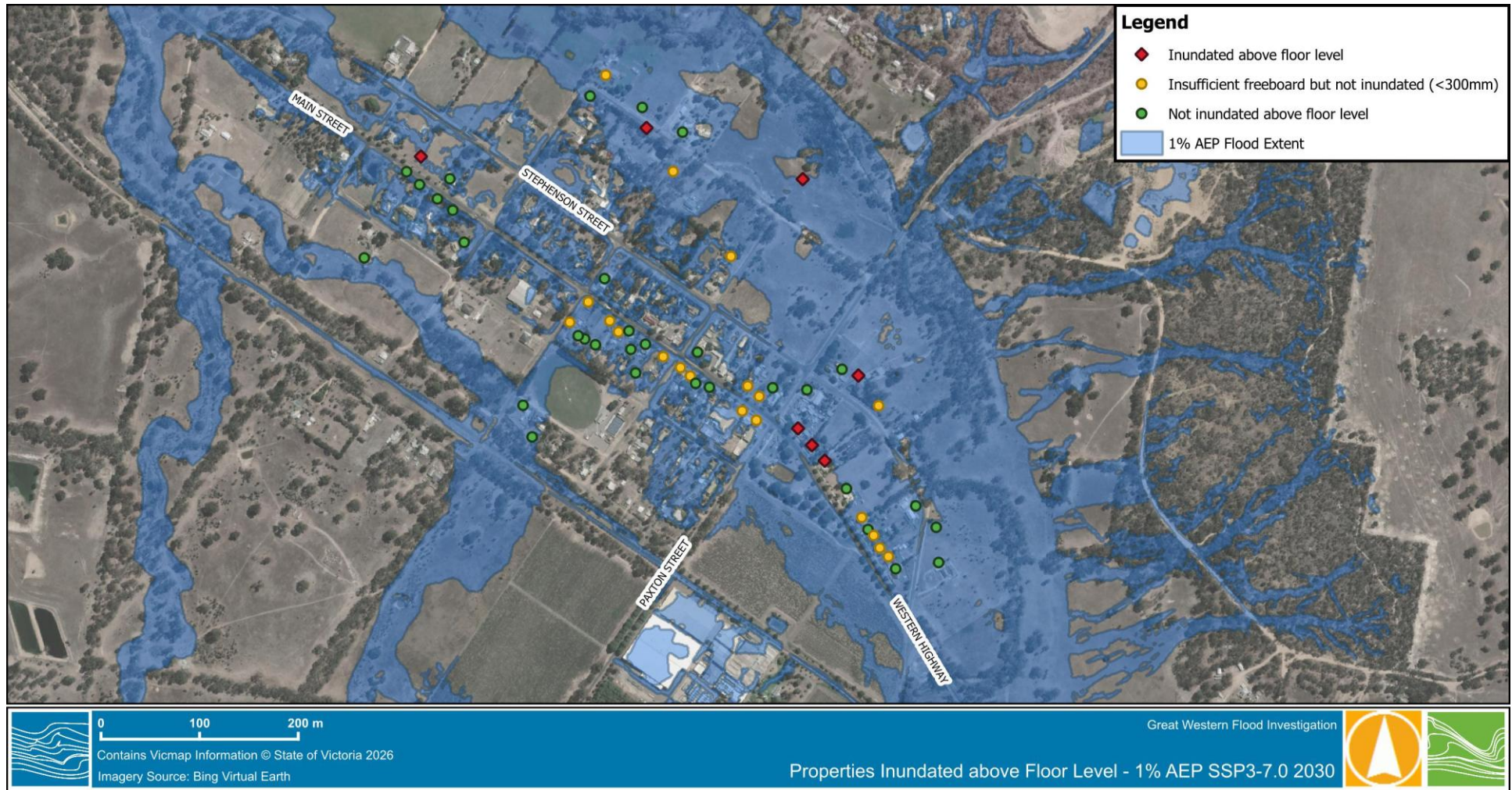


Figure 7-1 1% AEP SSP3-7.0 2030 Properties Inundated above Floor Level



Table 7-1 Existing conditions at present day Average Annual Damage (AAD) - 1% SSP3-7.0 2030

ARI (years)	2000 yr	1000yr	500yr	200yr	100yr	50yr	20yr	10yr	5yr
AEP (%)	0.0005	0.001	0.002	0.005	0.01	0.02	0.05	0.1	0.2
Residential Buildings Flooded Above Floor	14	13	9	6	4	2	0	0	0
Commercial Buildings Flooded Above Floor	2	2	1	0	0	0	0	0	0
Properties Flooded Below Floor	0	0	0	0	0	0	0	0	0
Total Properties Flooded	16	15	10	6	4	2	0	0	0
Direct Potential External Damage Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Direct Potential Residential Damage Cost	\$1,120,689	\$971,025	\$698,601	\$464,804	\$273,760	\$172,321	\$0	\$0	\$0
Direct Potential Commercial Damage Cost	\$11,579	\$5,987	\$1,738	\$0	\$0	\$0	\$0	\$0	\$0
Total Direct Potential Damage Cost	\$1,132,268	\$977,012	\$700,339	\$464,804	\$273,760	\$172,321	\$0	\$0	\$0
Total Actual Damage Cost (<i>0.8*Potential</i>)	\$905,814	\$781,610	\$560,271	\$371,843	\$219,008	\$137,857	\$0	\$0	\$0
Infrastructure Damage Cost	\$590,552	\$564,290	\$526,615	\$490,910	\$428,891	\$352,524	\$203,053	\$122,694	\$40,141
Rural Damage Cost	\$20,534	\$19,241	\$17,952	\$16,941	\$15,677	\$14,366	\$11,413	\$9,203	\$5,960
Total Cost	\$1,516,900	\$1,365,141	\$1,104,838	\$879,694	\$663,577	\$504,747	\$214,466	\$131,896	\$46,101
Intangible Cost (<i>100% of total cost</i>)	\$1,516,900	\$1,365,141	\$1,104,838	\$879,694	\$663,577	\$504,747	\$214,466	\$131,896	\$46,101
Final Total Cost	\$3,033,801	\$2,730,282	\$2,209,676	\$1,759,389	\$1,327,153	\$1,009,495	\$428,932	\$263,793	\$92,201
Average Annual Damage (AAD)	\$85,958								



Table 7-2 Existing conditions at future Average Annual Damage (AAD) - 1% SSP3-7.0 2100

ARI (years)	2000 yr	1000yr	500yr	200yr	100yr	50yr	20yr	10yr	5yr
AEP	0.0005	0.001	0.002	0.005	0.01	0.02	0.05	0.1	0.2
Residential Buildings Flooded Above Floor	21	19	16	14	10	5	2	0	0
Commercial Buildings Flooded Above Floor	2	2	2	2	1	0	0	0	0
Properties Flooded Below Floor	0	0	0	0	0	0	0	0	0
Total Properties Flooded	23	21	18	16	11	5	2	0	0
Direct Potential External Damage Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Direct Potential Residential Damage Cost	\$1,706,884	\$1,486,653	\$1,261,373	\$1,033,155	\$735,704	\$368,049	\$169,366	\$0	\$0
Direct Potential Commercial Damage Cost	\$33,094	\$24,615	\$17,076	\$7,679	\$2,891	\$0	\$0	\$0	\$0
Total Direct Potential Damage Cost	\$1,739,978	\$1,511,268	\$1,278,449	\$1,040,834	\$738,595	\$368,049	\$169,366	\$0	\$0
Total Actual Damage Cost (<i>0.8*Potential</i>)	\$1,391,982	\$1,209,014	\$1,022,759	\$832,667	\$590,876	\$294,439	\$135,493	\$0	\$0
Infrastructure Damage Cost	\$673,038	\$648,497	\$619,498	\$576,386	\$531,584	\$467,056	\$335,768	\$207,000	\$79,364
Rural Damage Cost	\$24,712	\$22,991	\$21,675	\$19,738	\$18,166	\$17,028	\$14,880	\$11,339	\$8,111
Total Cost	\$2,089,733	\$1,880,502	\$1,663,932	\$1,428,791	\$1,140,626	\$778,524	\$486,141	\$218,339	\$87,475
Intangible Cost (<i>100% of total cost</i>)	\$2,089,733	\$1,880,502	\$1,663,932	\$1,428,791	\$1,140,626	\$778,524	\$486,141	\$218,339	\$87,475
Final Total Cost	\$4,179,465	\$3,761,005	\$3,327,864	\$2,857,582	\$2,281,252	\$1,557,048	\$972,281	\$436,677	\$174,950
Average Annual Damage (AAD)	\$150,592								



7.2 Mitigation damages – Option 1B Waterway Bank Levee

Similar to existing conditions, under both the current and future climate, flood damages were calculated for Mitigation Option 1B (a levee along the bank of Concongella Creek). The option had the greatest likely reduction in flood damages. Assessment was undertaken for the SSP3 2030 scenario (present day).

Based on this information, the Average Annual Damage (AAD) for Option 1B was calculated to be **\$69,260**, as shown in Table 7-3.



Table 7-3 Mitigation Option 1B present day Average Annual Damage (AAD) - 1% SSP3-7.0 2030

ARI (years)	2000 yr	1000yr	500yr	200yr	100yr	50yr	20yr	10yr	5yr
AEP	0.0005	0.001	0.002	0.005	0.01	0.02	0.05	0.1	0.2
Residential Buildings Flooded Above Floor	9	8	4	2	1	0	0	0	0
Commercial Buildings Flooded Above Floor	1	1	1	0	0	0	0	0	0
Properties Flooded Below Floor	0	0	0	0	0	0	0	0	0
Total Properties Flooded	10	9	5	2	1	0	0	0	0
Direct Potential External Damage Cost	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
Direct Potential Residential Damage Cost	\$627,772	\$497,171	\$299,676	\$119,891	\$89,810	\$0	\$0	\$0	\$0
Direct Potential Commercial Damage Cost	\$4,986	\$3,587	\$1,734	\$0	\$0	\$0	\$0	\$0	\$0
Total Direct Potential Damage Cost	\$632,758	\$500,758	\$301,410	\$119,891	\$89,810	\$0	\$0	\$0	\$0
Total Actual Damage Cost ($0.8 \times \text{Potential}$)	\$506,206	\$400,606	\$241,128	\$95,913	\$71,848	\$0	\$0	\$0	\$0
Infrastructure Damage Cost	\$495,440	\$474,016	\$443,844	\$402,894	\$380,579	\$300,730	\$194,002	\$122,531	\$40,805
Rural Damage Cost	\$20,455	\$19,149	\$17,834	\$16,448	\$15,653	\$14,277	\$11,381	\$9,111	\$5,959
Total Cost	\$1,022,102	\$893,771	\$702,807	\$515,255	\$468,080	\$315,007	\$205,384	\$131,642	\$46,764
Intangible Cost (100% of total cost)	\$1,022,102	\$893,771	\$702,807	\$515,255	\$468,080	\$315,007	\$205,384	\$131,642	\$46,764
Final Total Cost	\$2,044,203	\$1,787,542	\$1,405,613	\$1,030,510	\$936,161	\$630,014	\$410,768	\$263,283	\$93,529
Average Annual Damage (AAD)	\$69,260								



7.3 Benefit-Cost Analysis

A benefit-cost analysis was undertaken to assess the economic viability of the Mitigation Option 1B. An indicative benefit-cost ratio was based on the construction cost estimates below, and Average Annual Damages calculated above.

A cost estimate for the levee is shown in Table 7-4. The Victorian Levee Guidelines has standard recommendations for levee crest width (2 m), batter slopes (3:1 batter on water side, 2:1 on dry side) and clay core with cut-off trench requirements. Cut-off trench requirements are negotiable depending on the levee material, but if a sandy material is used with no cut-off trench then a wider crest and batter slope is recommended to avoid piping failure. The levee costing meets these requirements with a 2 m crest width, 3:1 batter slopes on both sides.

Costing was based on a 30% contingency cost, along with engineering and administration costs. It should be noted that these costs are based on estimated rates and should be checked during any future design phases. Site specific issues such as underground services and community negotiations around access to the creek and land compensation may increase the cost and will need to be further considered during further design. The levee was designed to the 1% AEP level with the inclusion of a 300 mm freeboard.

The estimated capital cost of the levee was **\$440,125**.

An annual maintenance cost was factored in for the levee works at 3% of the capital costs, \$13,204.

Table 7-4 Mitigation Cost Breakdown – Permanent Works

	Length (m)	Average height (m)	Volume (m³)	Estimated Cost
Levee characteristics	1,256	1.1	7,150	\$283,312
Sub-total 'A'				\$283,312
'A' x Engineering Fee @ 15%				\$42,497
Sub-total 'B'				\$325,809
'B' x Administration Fee @ 9%				\$29,323
Sub-total 'C'				\$355,132
'A' x Contingencies @ 30%				\$84,994
Forecast capital expenditure				\$440,125
Annual maintenance allowance				\$13,204



The results of the benefit-cost analysis are shown below in Table 7-5. For this analysis, a net present value model was used, applying a 6% discount rate over a 30 year project life. The benefit-cost ratio should ideally be equal to or greater than 1, meaning that the long term benefit of flood mitigation equals or exceeds the long term costs. The benefit-cost ratio for Option 1B was 0.11.

Table 7-5 Benefit Cost Analysis

Parameter	Existing Conditions	Levee Option 1B
Average Annual Damage	\$85,958	\$69,260
Annual Maintenance Cost	-	\$13,204
Annual Cost Savings	-	\$3,494
Net Present Value	-	\$49,134
Cost of permanent mitigation		\$440,125
Benefit-Cost Ratio	-	0.11



8 SUMMARY

The Great Western Flood Investigation has produced detailed flood modelling of riverine and stormwater flooding within and surrounding Great Western. The mapping produced is fit for the purposes of flood emergency planning and response alongside statutory and strategic planning. The study has also investigated the current flood impacts in terms of average annual damages and the potential for structural mitigation to reduce those damages. Flood intelligence products were produced and included in a draft update to the Northern Grampians Shire Council Municipal Emergency Management Plan, these are detailed in the Flood Intelligence Documentation. The study makes the following recommendations for each of the stakeholder organisations:

- Northern Grampian Shire Council
 - Endorse the flood study with the aim of adopting the flood study recommendations.
 - Undertake a planning scheme amendment to update the flood related planning overlays to reflect the flood risk mapping produced by this project.
 - Consider the designation of flood prone land as provisioned under the Building Act
 - Discuss with the Bureau of Meteorology and Wimmera CMA for the consideration of potential flash flood monitoring.
 - Review the information within the Flood Intelligence and Flood Warning Report to undertake an update of the Municipal Emergency Management Plan.
 - Undertake a review of the current response, maintenance and operations documentation with Council staff.
 - Investigate pipe and pit upgrades on an ongoing basis, increasing culvert capacities to prevent above floor inundation as culvert upgrades occur.
 - Investigate the potential for vegetation clearance along Concongella Creek downstream of the Western Highway. This is predominantly on private land and a Works on Waterways Permit is likely required with Wimmera CMA.
 - Further consider the potential to progress Mitigation Option 1B. In particular, land tenure and the practical considerations related to increasing the channel capacity through the highlighted reach of drain.
- Wimmera CMA
 - Endorse the flood study and use the flood mapping data to inform floodplain risk management decisions.
 - Upload the Victoria Flood Database mapping data and the excel spreadsheet of property inundation to FloodZoom.
- Victoria State Emergency Service with assistance from Wimmera CMA and the Northern Grampians Shire Council:
 - Continue to engage the community through regular flood awareness programs such as the VICSES FloodSafe program.
 - Update Local Flood Guide.
 - Assist the Northern Grampians Shire Council in updating the MFEP.
 - Review the updated MFEP (when available) and discuss with the Northern Grampians Shire Council the changes proposed by Water Technology prior to adopting the revised document.



Future flood events in Great Western should be monitored carefully and compared to the results of this study, with flood levels marked and surveyed where possible. Where flood behaviour appears to disagree with the findings of the study, the reason for the discrepancy should be investigated and an update to the study should be considered.

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