WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Final Hydrology and Hydraulic Report

Upper Thomson River Flood Study

West Gippsland Catchment Management Authority

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EXECUTIVE SUMMARY

West Gippsland Catchment Management Authorities (WGCMA) engaged Water Technology to complete the Upper Thomson River Flood Study. The key objective of this project was to produce contemporary flood mapping and intelligence information for the Upper Thomson River from Cowwarr Weir to Heyfield.

The project conducted a definitive investigation of the floodplain within the study area, including collation of available relevant data, hydrological assessment, determination of robust flood levels, velocities, depths and extents for a range of design flood events. The outputs from this project were designed to meet the flood management requirements of the WGCMA, Local Government Authorities (LGAs) and VicSES. These generally include flood related controls in Municipal Planning Schemes, flood intelligence products for emergency planning and community flood awareness products for educational purposes.

The Thomson River and Rainbow Creek are an essential resource for agriculture, local communities and the natural environment. The Rainbow Creek avulsion is considered an interesting event in Geomorphological academia; however, for groups who live on, use and manage the system, it has presented some significant challenges. Rainbow Creek is a recent feature in the Thomson River floodplain. Formed as a 'breakaway' in the 1950s after a series of floods, the new watercourse crossed through the floodplain. The avulsion led to significant loss of agricultural land, liberating numerous sediments into the Thomson River and the downstream receiving Gippsland Lakes. The development of Rainbow Creek had a significant impact on the farming communities of the Cowwarr and Heyfield districts and changed the way water is managed in the Thomson River.

This project completed a comprehensive review of existing available data and studies during the initial inception phase. This helped the project team gather relevant information and identify data gaps. The Lower Thomson River Flood Study (HARC 2019) provided valuable hydrology analysis which was reviewed and utilised during the project.

A TUFLOW hydraulic model was developed and calibrated, before simulating a range of design flood events. The hydraulic model was calibrated to the 2007 flood event and verified using the 2012 and 2016 floods to determine the appropriate model parameters for design modelling. The model calibration and validation demonstrated the hydraulic model was capable of replicating flood behaviour observed during historic flood events and was applicable for design modelling purposes.

A range of events were modelled including the 0.5%, 1%, 2%, 5%, 10%, 20% and 50% AEP design events as well as the PMF event and Minor, Moderate and Major Flood Class Levels. This provided a full set of modelling deliverables.

Key deliverables included: design flood mapping, Victoria Flood Database (VFD) outputs, proposed planning scheme mapping and sensitivity analysis. Sensitivity was assessed to evaluate the potential impacts of Climate Change and bushfire on flood behaviour within the study area.

Overall, this study has provided detailed mapping outputs and information for WGCMA and other relevant parties to identify flood risk, revise and improve existing flood response and controls and ultimately, to provide information for a safer local community from impacts of flooding in the Upper Thomson River region.

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GLOSSARY OF TERMS

Term	Definition
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.
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.
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 Frequency Analysis (FFA)	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.
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.
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.

Term	Definition
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.
Peak Flow	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	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.
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.
TUFLOW	A hydraulic modelling software package used in this study to simulate the flow of flood water through the floodplain. The model uses numerical equations to describe the water movement.

1 INTRODUCTION

West Gippsland CMA engaged Water Technology to undertake the Upper Thomson River Flood Study. The project objective was to produce contemporary flood mapping and intelligence information for the Upper Thomson River from Cowwarr Weir to Heyfield.

The project undertook a definitive investigation of the floodplain within the study area, including collation of available relevant data, hydrological assessment and determination of robust flood levels, velocities, depths and extents for a range of design flood events.

The project outputs will be used by the CMA, Local Government Authorities (LGAs) and VICSES to meet a range of business requirements. Outputs can be used to define flood related controls in Municipal Planning Schemes, develop flood intelligence products, inform emergency response planning and assist in the preparation of community flood awareness and education products. Furthermore, outputs from the project will be used to support the assessment of flood risk for insurance purposes.

2 BACKGROUND

The Thomson River and Rainbow Creek are an essential resource for agriculture, the community and the natural environment. The Rainbow Creek avulsion is considered a very interesting event in geomorphological academia; however, for groups who live on, use and manage the system, it has presented some significant challenges. Rainbow Creek is a very recent feature in the Thomson River floodplain. Formed as a 'breakaway' in the 1950s after a series of floods, the new watercourse now crosses through the floodplain from Cowarr Weir before re-joining the main Thomson River channel downstream of the Traralgon-Maffra Road. The avulsion led to significant loss of agricultural land, liberating hundreds of thousands of tonnes of sediment into the Thomson River and the downstream receiving Gippsland Lakes. The development of Rainbow Creek had a significant impact on the farming communities of Cowwarr and Heyfield districts and changed the way water is managed in the Thomson River and Rainbow Creek.

Constructed in 1959 (SRW 2019), the Cowwarr Weir has enabled river flows to be managed with a large proportion flows returned to the Thomson River. While the weir has influence on where flow is apportioned for the majority of flow events, it is important to note the structure is not designed to manage rare or extreme flood flows. It is estimated the Thomson River carried approximately 7% of the June 1978 flood event, Rainbow Creek carrying 24%, and the balance carried by the floodplain (Water Technology 2010).

The Thomson River Old Course receives allocated flow via regulation from the Cowwarr Weir, with some water made available for irrigation extraction and water supply. In addition, the system receives natural pulses of flow from Stoney Creek, an ungauged catchment with a rapid response to storm events, influencing the flow regime and quantities within the Thomson River Old Course below its confluence.

The flow regime in the Thomson River Old Course and Rainbow Creek are the cumulative effects of:

- Flow regulation at Thomson Dam.
- Flow diversions at Cowwarr Weir.
- Private diversions downstream of Cowwarr Weir.
- The flow split itself, controlled by the spillway gates at Cowwarr Weir.
- Contributions from ungauged tributaries.

3 DATA REVIEW

3.1 Overview

A review of available data and the existing hydrological model was undertaken prior to any technical analysis. The review provided a summary of the information which was available to be used as the basis for key project inputs. It also identified key data gaps or assumptions required at the start of this project which were consequently filled.

3.2 Previous Studies

Several studies have been carried out in the region over the past 10-years. Their respective study reports were reviewed and relevant summaries are included below.

Thomson River-Rainbow Creek Waterway Management Plan 2020 (WGCMA 2020)

Water Technology developed the hydraulic model of the Thomson River floodplain between Cowwarr Weir and Heyfield to evaluate environmental conditions that might trigger a new avulsion pathway.

The modelled conditions included scenarios with channel blockages, and changed vegetation (either cleared or well vegetated, along regions of the waterways and existing flood-runners). The base model arrangement came from a 2011 study hydraulic model which was calibrated to 2007 and 1978 flood events. This study adopted the roughness conditions from the 2011 study but did not revisit the model calibration and the hydrology was based on Australian Rainfall and Runoff 1987 (ARR1987) approaches. The diversion flow at Cowwarr Weir was based the relationship (stage / flow) used in the 2011, the origin of this arrangement was unclear. The model results were suitable to understand management options and avulsion risk but lacked some of the rigor of a typical flood study.

Lower Thomson River Flood Study, HARC (2019)

The hydraulic and hydrologic assessment of the Lower Thomson River and Latrobe River was completed by HARC between 2016 and 2019. The hydrologic assessment developed a RORB model for the catchment contributing into upper and lower Thomson River, Macalister River and Latrobe River. The RORB model was calibrated for the April 1952, June 1978, September 1993 and June 2007 flood events.

The study estimated the 1% AEP flow at Thomson River @ U/S Cowwarr Weir gauge around 1,000 m^3/s.

The study concluded that flows at Thomson River U/S of Cowwarr Weir increased by 3% when Thomson Reservoir is full. For the 225231 Thomson River @ U/S of Cowwarr Weir catchment, the study adopted a RORB kc of 70, median initial loss (IL) of 20 mm and continuing loss (CL) of 1.0 mm/h for design modelling.

Thomson River Fish Passage Upgrades, Detailed Design Hydraulic Assessment, WT (2009)

Water Technology carried out the detailed design and specifications to successfully re-develop the Thomson Weir Fishway following the concept design undertaken by GHD. The fish passage is located at the Thomson River gauging station at Cowwarr and the fish attractor is located on the Old Thomson River just upstream from the Rainbow Creek confluence.

This report detailed the specific stream conditions that were required as part of the construction of both design components to promote the migration of fish. 2D modelling was used to estimate the flow velocities down the main channel and through the fish passage as well as depth of water in the system for a range of flows.

Pre-fabricated vertical-slot fishway within rock channel walls and weir notch exit as the preferable option which has no impact on the weir discharge capacity during flooding.

Thomson River Flood Study, Hydrologic and Hydraulic Assessment, WT (2011)

The study undertook a detailed hydrologic and hydraulic assessment of the Thomson River, from Cowwarr Weir to the Rainbow Creek confluence as part of their flood response and land use planning responsibilities.

The hydrological model was based on ARR 1987 recommended approaches and used URBS for hydrological analysis. Hydraulic analysis was based on a 10m x 10m cell size in a MIKE21 two-dimensional model. The LiDAR collected by Furgo in 2007 and reissued in 2009 was used for the Digital Elevation Model (DEM). The June 2007 and June 1978 events were used to calibrate the model. The study used 43 surveyed flood levels for calibration of the June 1978 event and 25 surveyed levels for calibration to the June 2007 flood event.

The study estimated a 1% AEP flow upstream at the Thomson River @ U/S Cowwarr Weir gauge of 1,068 m^3/s, based on Flood Frequency Analysis (FFA) of the streamflow data.

The study estimated a 1% AEP inflow from Stony Creek (a tributary which enters the Thomson River downstream of Cowwarr Weir) of 166 m^3/s.

The peak flow at the Thomson River @ U/S Cowwarr Weir gauge during June 1978 to be 1,108 m^3/s and the June 2007 flood event peak flow to be 853 m^3/s.

An estimate flood extent from aerial flood photography was available for part of the study site. West Gippsland CMA also provided aerial video for the June 2007 event. An indicative 1% AEP flood extent was defined for the region, extending across the floodplain between Rainbow Creek and Thomson River.

Hydrological Assessment of the Thomson-Rainbow Catchment, Stage 1, Hof (2010a)

This study provided a detailed review of the hydrological information available for the Thomson River up to and including the floodplain reach to the Rainbow Creek confluence. A FFA was undertaken for the gauging station (225231A).

Hydrological Assessment of the Thomson-Rainbow Catchment, Stage 2, Hof (2010b)

This report detailed the second part of the hydrological assessment of the Thomson-Rainbow Creek catchment, where a rainfall-runoff model (URBS) was developed to provide design flood hydrographs for inclusion in the study. The report provides details of the model, model calibration and uncertainties.

3.3 Data Availability

3.3.1 Streamflow data

Streamflow data is available for the Thomson River @ U/S of Cowwarr Weir (225231). The gauge is five kilometres upstream of Cowwarr Weir. The period of available streamflow data is from 1976 to 2009. Mean daily flows and instantaneous flows are consistently available for this entire period. Cowwarr Weir has been in operation throughout this timeframe.

Other flow gauges throughout the catchment included are presented in Table 3-1 and shown in Figure 3-1.

TABLE 3-1 STREAMFLOW DATA

Gauge No.	Location	Period	Source	Gauge zero (m AHD)
225200	Thomson River @ Heyfield	1992 – 2018	DELWP	35.846
225227	Rainbow Creek @ Cowwarr Weir- Tail Gauge	1995 – 2016	SRW	N/A
225228	Thomson River @ Cowwarr Timber Weir H.G.	2001 – 2018	DELWP	-0.96
225231	Thomson River @ U/S of Cowwarr Weir	1976 – present	DELWP	69.4
225236	Rainbow Creek @ Heyfield	1992 – 2018	DELWP/SRW	33.837
225704	Cowwarr Channel @1 Mile 5 Chain	1992 – 1997	SRW	N/A
225706	Nambrok-Denison Channel No 1 @ Offtake Measuring Weir	1992 – 1997	SRW	N/A
225206	Thomson River @ Cowwarr	1922 – 1952	DELWP	N/A
225226	Rainbow Creek @ Cowwarr Weir (Head Gauge)	1995 – 2016	SRW	N/A
225243	Thomson River @ D/S Rainbow Creek	1996 – present	SRW	N/A
225708	Main Southern Channel @ Thomson River Syphon	1992 – 2016	SRW	N/A
225703	Thomson River Diversion Channel @ Cowwarr Weir	2001 – 2007	DELWP/SRW	N/A
-	Flow Meter @ 1 Mile Creek	-	SRW	N/A

In addition to the main Thomson River inflow there is a tributary stream, Stoney Creek, which enters the Thomson River after the pool at Cowwarr weir. Stoney Creek has a catchment area of approximately 70 km^2 and is ungauged.

FIGURE 3-1 STREAMFLOW GAUGE IN THE STUDY AREA

3.3.1.1 Thomson River @ U/S of Cowwarr Weir (Station 225231)

The Thomson River gauging site @ U/S of Cowwarr Weir is currently located 5 km upstream of Cowwarr Weir on the Thomson River. The gauge was installed in 1976 and is still active at the timing of this reports production. Attributes of the gauge are summarised in Table 3-2, with the location shown in Figure 3-1.

TABLE 3-2 225231 THOMSON RIVER @ U/S COWWARR WEIR GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
1976-current	225231	Natural Rock Bar	Lat: 37°58'30.0"S Long: 146°37'30.0"E	Automated	DELWP	69.4

Mean daily flow and water level data as displayed on the DELWP Water Information Management System are shown in Figure 3-2.

The current rating table is shown in Figure 3-3. There were 196 gaugings measured between 19/02/1976 and 15/10/2019. The reliability of the rating table based on the stage-height relationship is shown in Table 3-4. The maximum gauge record at this location is 4.9 m which occurred in June 1978.

The site is in a confined channel and is reliably rated to 3.8 m. The rating is extrapolated up to 12.2 m.

The Thomson River @ US of Cowwarr Weir streamflow gauge is utilised by the Bureau of Meteorology (BoM) for flood warning purposes. The gauge levels are displayed in near real time on the BoM website. Flood Class Levels (FCLs) have been defined by the BoM for this site and are displayed below in . These flood class levels have been reviewed and are discussed in Section 6.3.

TABLE 3-3 FLOOD CLASS LEVELS, UPSTREAM OF COWWARR WEIR

Flood Type	Minor Level		Moderate Level		Major Level	
Gauge height/height m AHD	M	AHD	M	AHD	M	AHD
	3.7	73.1	4.5	73.9	5.5	74.9

TABLE 3-4 225231 THOMSON RIVER @ U/S COWWARR WEIR GAUGE RATING TABLE RELIABILITY

Gauge Stage Range (m)	Reliability Description
1.8 – 2.01	Rating table extrapolated
2.02 – 3.8	Reliable
3.81 – 4.81	Rating based on meas. > 20 years old
4.82 – 12.2	Rating table extrapolated

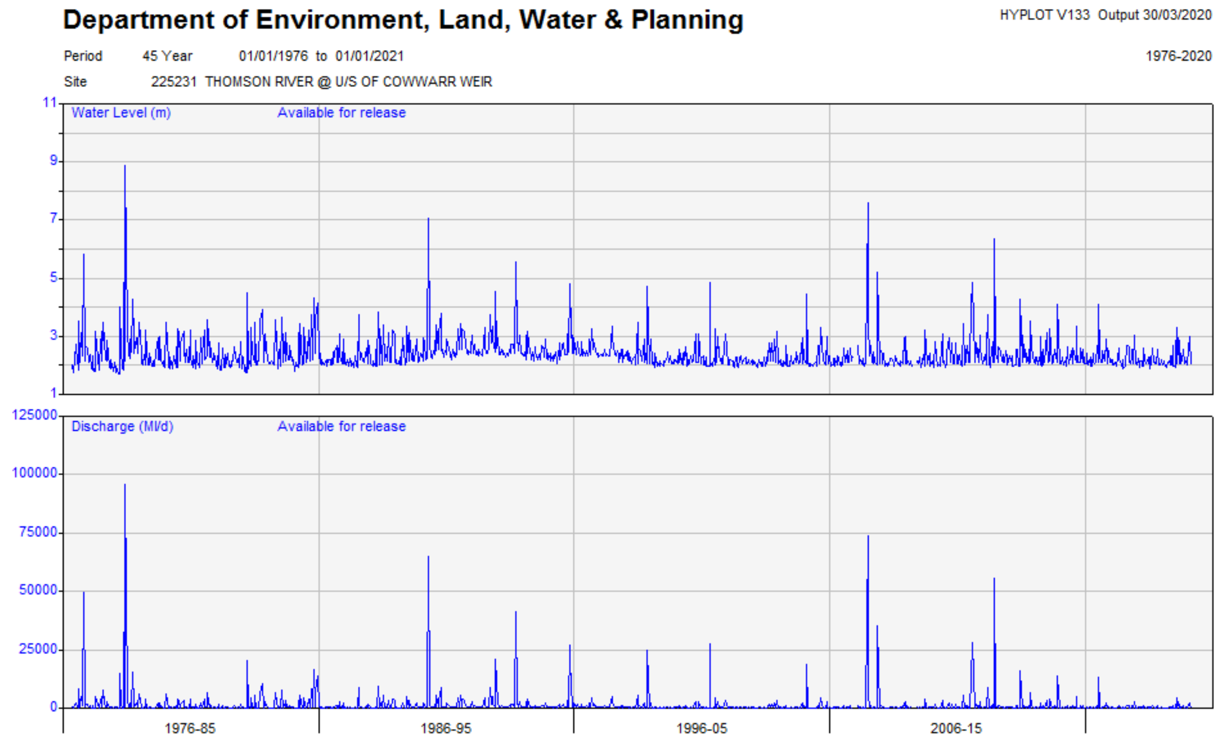


FIGURE 3-2 WATER LEVEL AND FLOW DATA – THOMSON RIVER @ U/S OF COWWARR WEIR (225231)

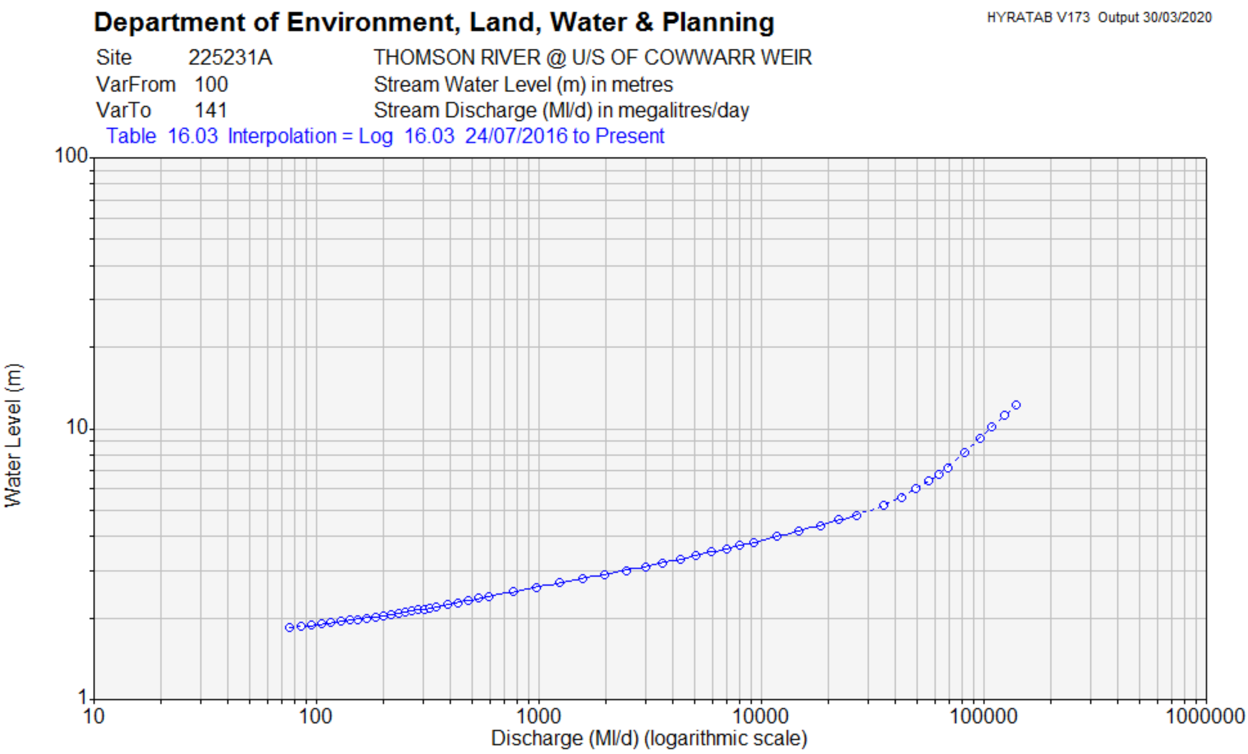


FIGURE 3-3 THOMSON RIVER @ U/S OF COWWARR WEIR GAUGE RATING CURVE (225231)

3.3.1.2 Thomson River @ Heyfield (225200)

The Thomson River @ Heyfield gauge is currently located at the corner of Commercial Road and Traralgon-Maffra Road on the Thomson River. The gauge was installed in 1889.

Attributes of the gauge are summarised in Table 3-5, with the location shown in Figure 3-1.

TABLE 3-5 THOMSON RIVER @ HEYFIELD GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
1992-current	225200	Natural Log in Stream Bed	Lat: 37°59'07.6"S Long: 146°46'48.5"E	Telemetry	DELWP	35.846

Mean daily flow and water levels as displayed on the DELWP Water Information Management System are shown in Figure 3-4.

The rating table at this location is shown in Figure 3-5 (DELWP). There were 67 gaugings between 19/03/1908 and 10/02/2014. The reliability of the rating table is shown Table 3-6. The maximum gauge record is 2.262 m, which occurred on 18/08/1921.

TABLE 3-6 THOMSON RIVER @ HEYFIELD GAUGE RATING TABLE RELIABILITY

Gauge Stage Range (m)	Reliability Description
0.11 – 0.8	Reliable
0.81 – 1.1	Rating Extrapolated within x 1.5 max flow
1.11 – 4.5	Rating table extrapolated

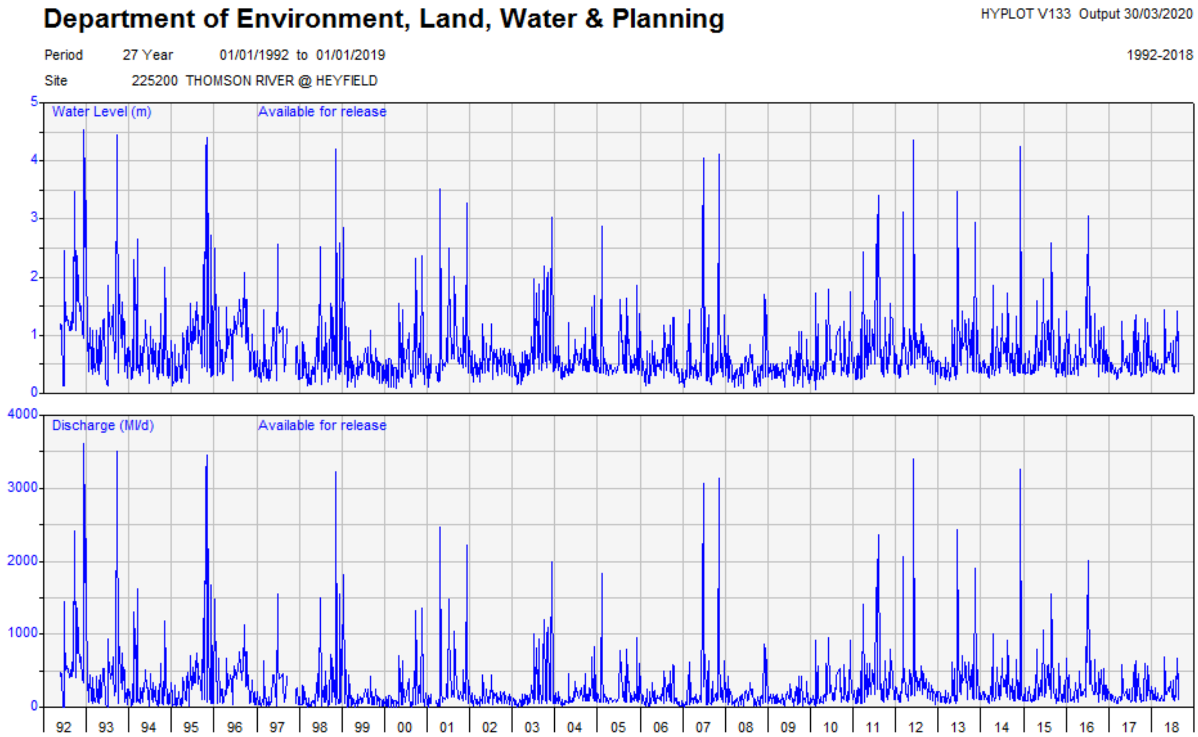


FIGURE 3-4 WATER LEVEL AND FLOW DATA– THOMSON RIVER @ HEYFIELD

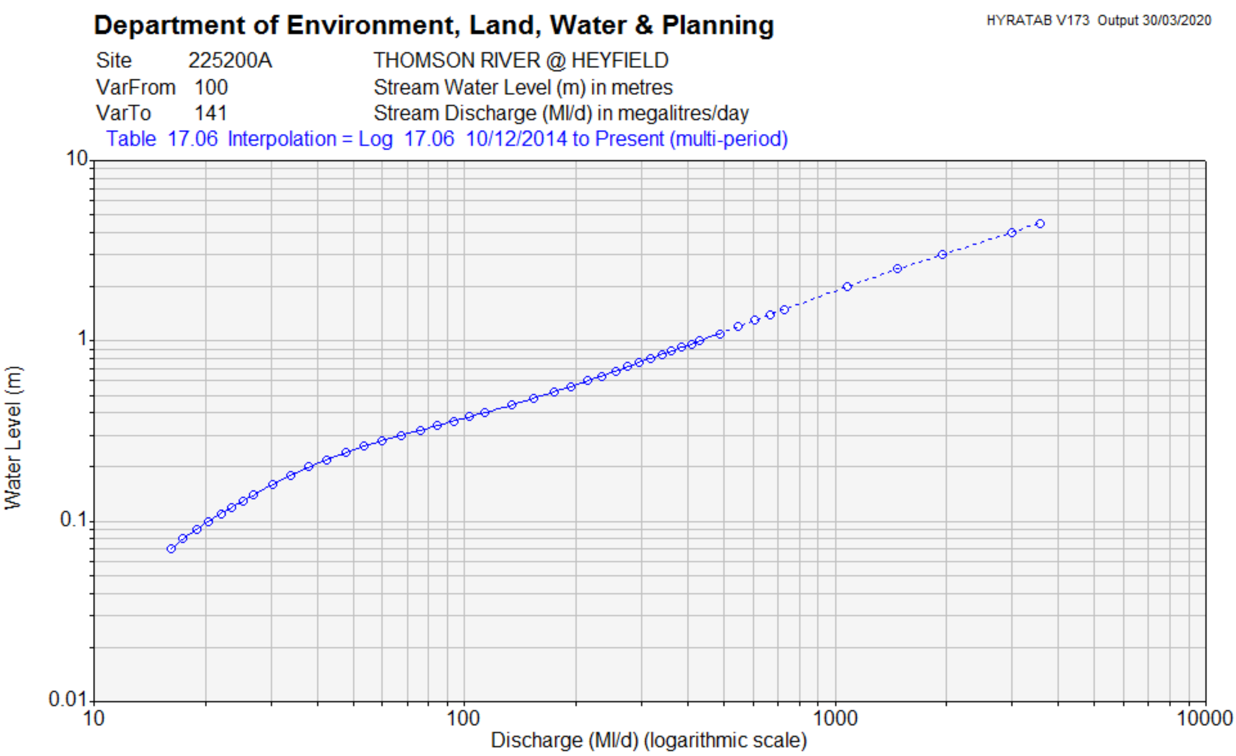


FIGURE 3-5 THOMSON RIVER @ HEYFIELD WEIR GAUGE RATING CURVE

3.3.1.3 Rainbow Creek @ Cowwarr Weir- Tail Gauge (225227)

Rainbow Creek @ Cowwarr Weir Tail Gauge is a low flow gauging site, owned by Southern Rural Water. This site is not intended for measuring peak stream flows, but metering water usage and distribution from the weir (location shown in Figure 3-1). There is little information available from DELWP regarding this gauge as it is privately owned; however, some details are provided in Table 3-7. The gauge was installed in 1995 and available flow and level information from the BoM website is shown in Figure 3-5 and Figure 3-6.

TABLE 3-7 RAINBOW CREEK @ COWWARR WEIR - TAIL GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
1995 – 2016	225227A	-	Lat: 38°00'00.0"S Long: 146°40'12.0"E	-	BoM SRW	-

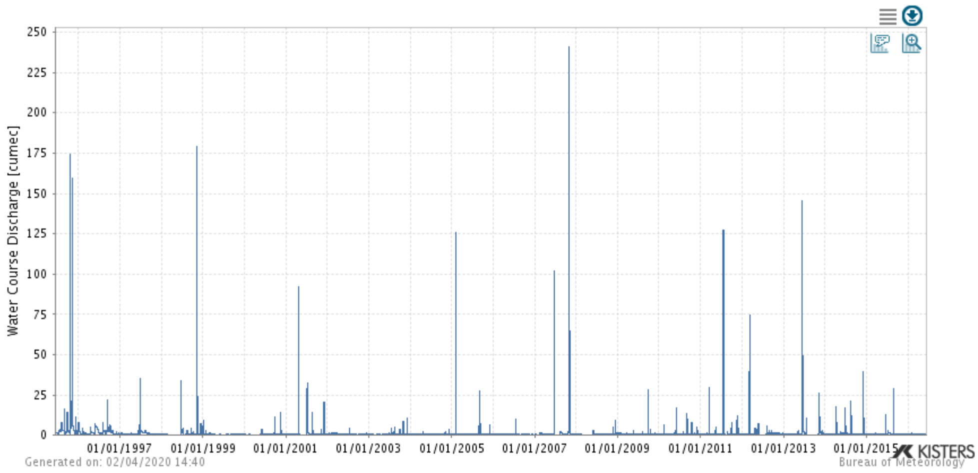


FIGURE 3-6 FLOW DATA – RAINBOW CREEK @ COWWARR WEIR - TAIL GAUGE

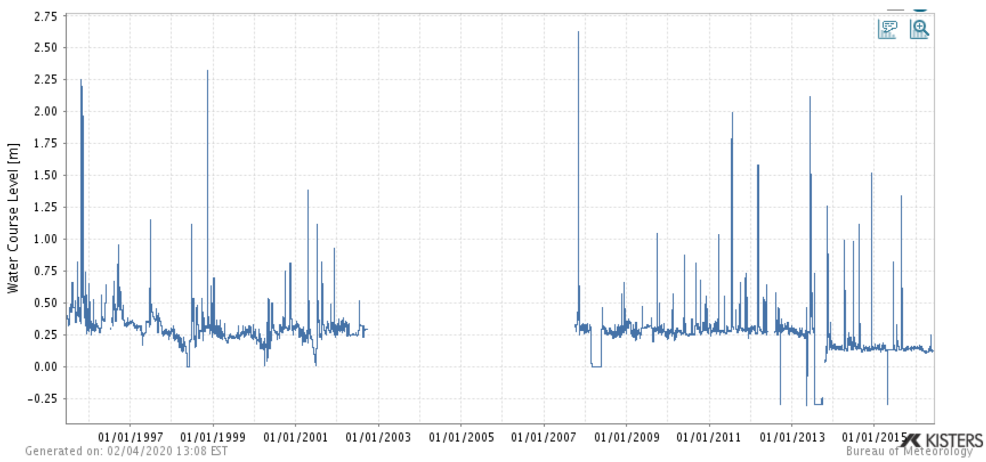


FIGURE 3-7 WATER LEVEL DATA – RAINBOW CREEK @ COWWARR WEIR - TAIL GAUGE

3.3.1.4 Thomson River @ Cowwarr Timber Weir H.G. (225228)

The Thomson River @ Cowwarr Timber Weir H.G. is located just north of Downings Road on the Thomson River. The gauge was installed in 1958 and is active at the time of writing.

Attributes of the gauge are summarised in Table 3-8, the gauge location is shown in Figure 3-1.

TABLE 3-8 THOMSON RIVER @ COWWARR TIMBER WEIR H.G. GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
1958 – Present	225228	Artificial; Timber weir	Lat: 37°59'48.0"S Long:146°39'28.7"E	Manual	DELWP	-0.960 m AHD

The available mean daily flow and water level data as displayed on the DELWP Water Information Management System is shown in Figure 3-8.

The rating table is shown in Figure 3-9 (DELWP). There were 71 gaugings measured between 18/12/1959 and 01/06/2017. The reliability of the rating table is shown in Table 3-9. The maximum gauged flow was on 23/6/1975. This site is reliably rated to 0.5 metres.

TABLE 3-9 THOMSON RIVER @ COWWARR TIMBER WEIR H.G. GAUGE RATING TABLE RELIABILITY

Gauge Stage Range (m)	Reliability Description
0 – 0.50	Rating Table 10 - Reliable
> 0.51	Rating table exceeded

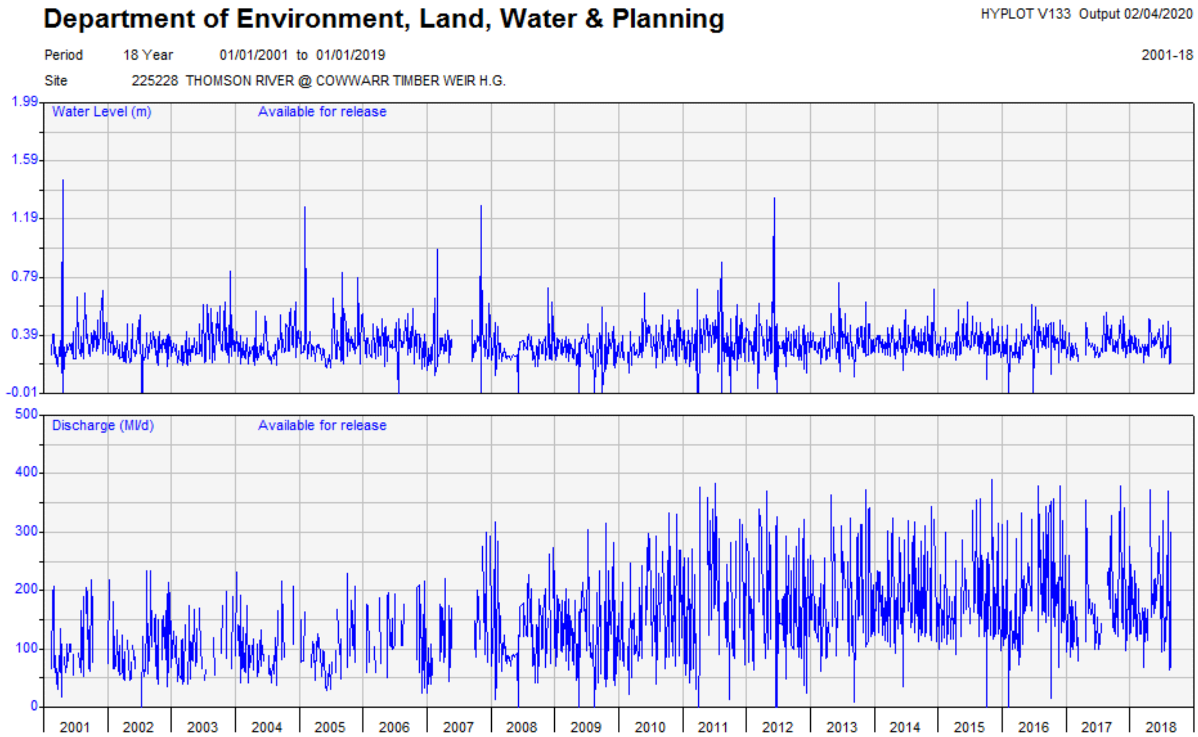


FIGURE 3-8 WATER LEVEL AND FLOW DATA – THOMSON RIVER @ COWWARR TIMBER WEIR H.G.

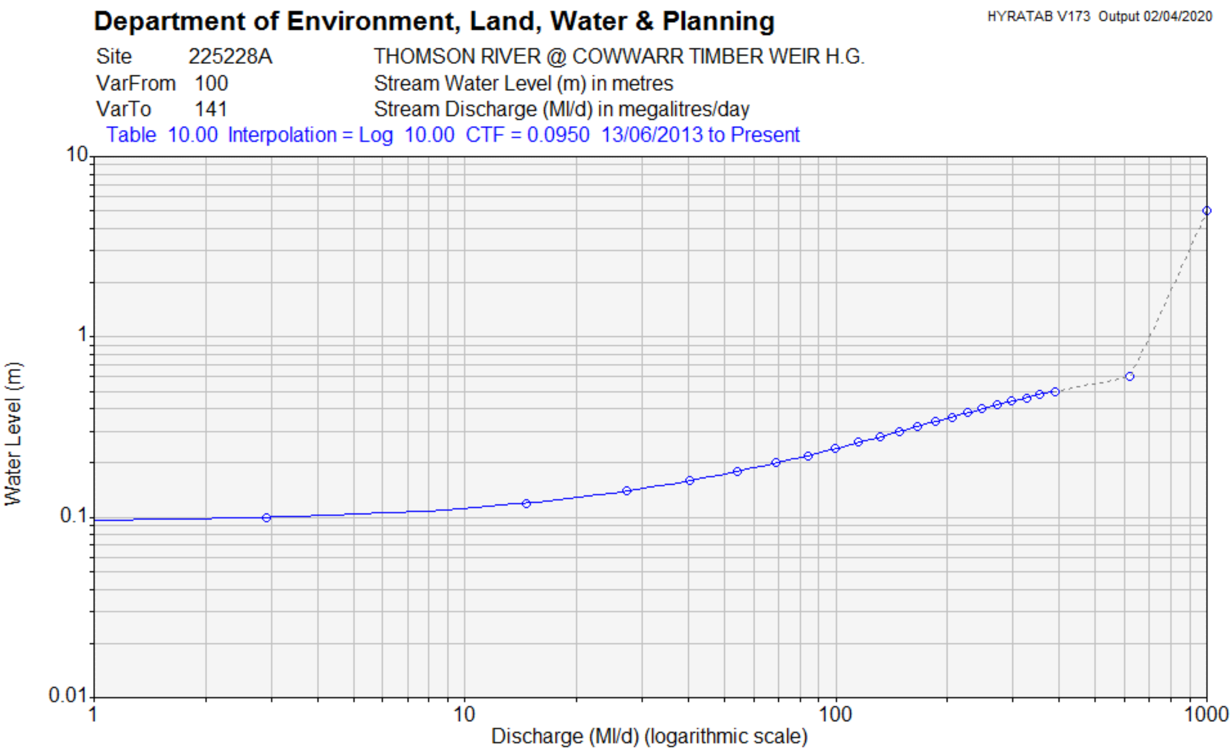


FIGURE 3-9 THOMSON RIVER @ COWWARR TIMBER WEIR H.G. GAUGE RATING CURVE

3.3.1.5 Rainbow Creek @ Heyfield (225236)

The Rainbow Creek @ Heyfield gauge is located just west of Traralgon-Maffra Road, on Rainbow Creek. The gauge was installed in 1992.

Attributes of the gauge are summarised in Table 3-10, the gauge location is shown in Figure 3-1.

TABLE 3-10 RAINBOW CREEK @ HEYFIELD GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
1992 – present	225236	Natural – Bed and Bank	Lat: 38°00'07.7"S Long: 146°46'48.0"E	Telemetry	DELWP	33.837

The available mean daily flow and recorded water levels as displayed on the DELWP Water Information Management System are shown in Figure 3-10.

The current rating table is shown in Figure 3-11 (DELWP). There were 52 gaugings between 03/03/1992 and 11/01/2018. The reliability of the rating table is shown in Table 3-11. The maximum gauge level is 1.14 m occurring on 11/6/1993. The rating curve has been extrapolated at low and high flows.

TABLE 3-11 RAINBOW CREEK @ HEYFIELD GAUGE RATING TABLE RELIABILITY

Gauge Stage Range (m)	Reliability Description
0.3 – 0.54	Rating table extrapolated
0.55 – 1.1	Rating based on meas. > 20 years old
1.11 – 1.8	Rating table extrapolated

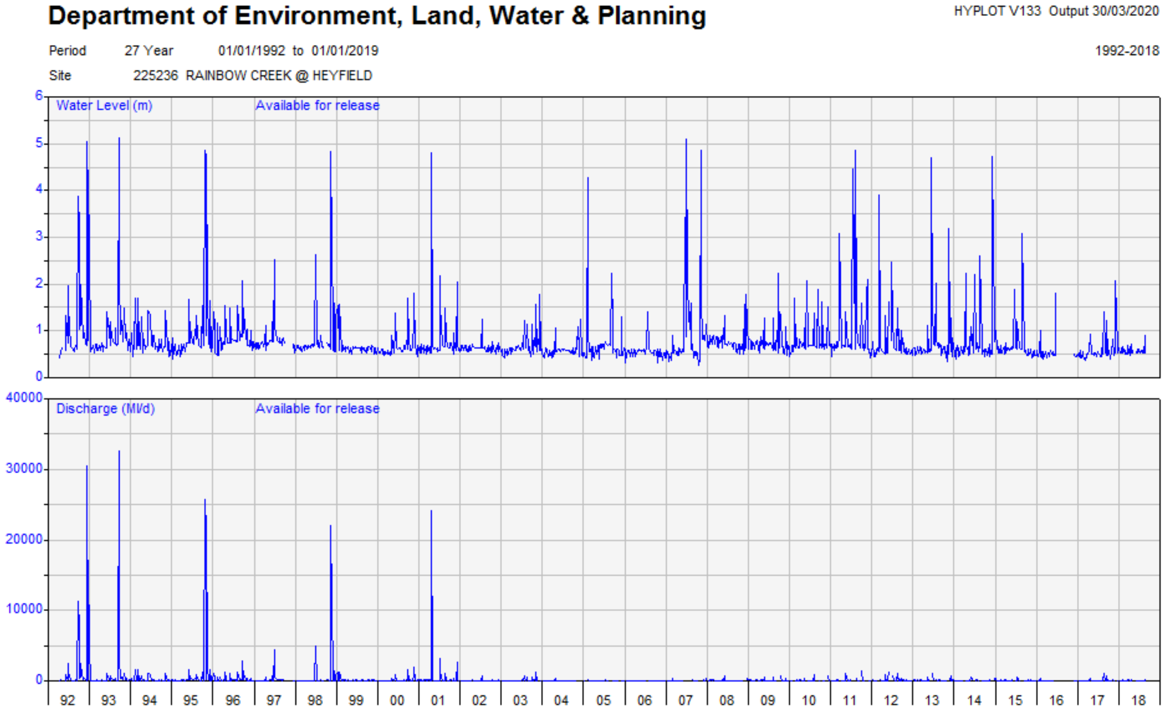


FIGURE 3-10 WATER LEVEL AND FLOW DATA– RAINBOW CREEK @ HEYFIELD

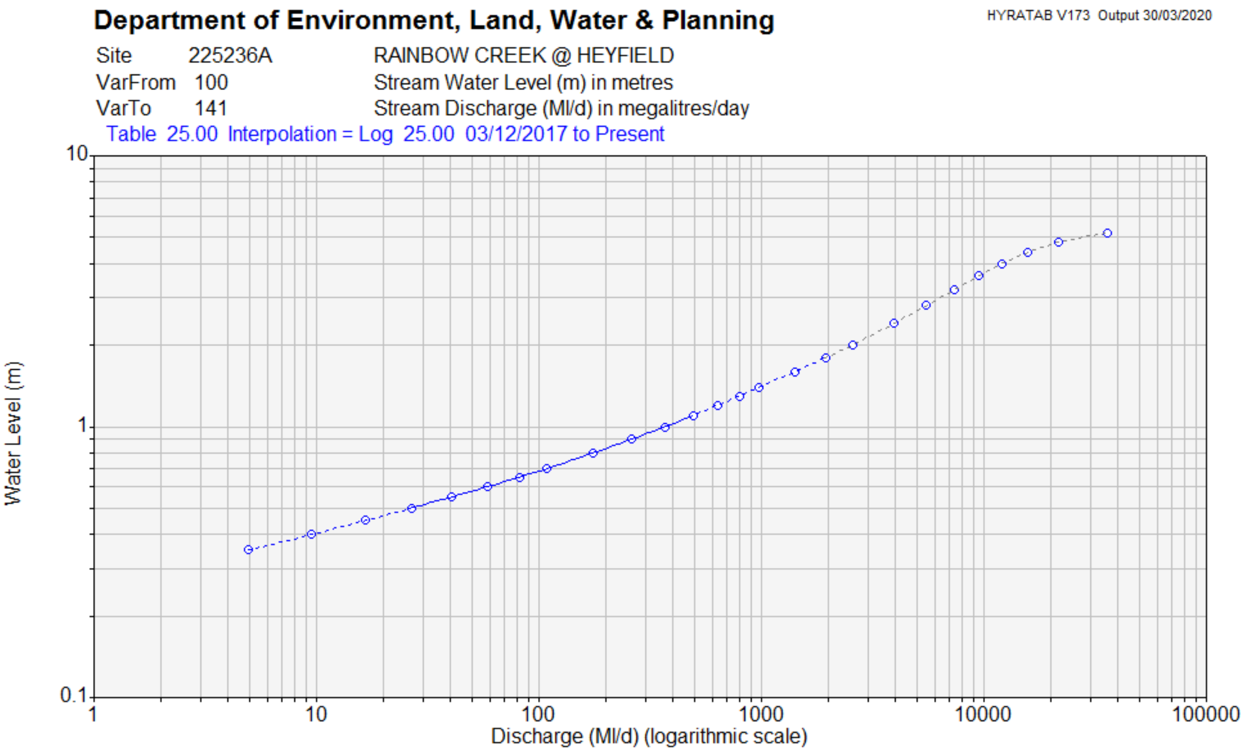


FIGURE 3-11 RAINBOW CREEK @ HEYFIELD WEIR GAUGE RATING CURVE

3.3.1.6 Cowwarr Channel @ 1 Mile 5 Chain (225704)

The Cowwarr Channel @ 1 Mile 5 Chain gauge is located at the corner of Hagues Lane and Toongabbie-Cowwarr Road. The gauge was installed in 1994. The attributes of the gauge are summarised in Table 3-12, with the location shown in Figure 3-1.

The available mean daily flow and recorded water levels as displayed on the BoM website are shown in Figure 3-12 and Figure 3-13 respectively.

TABLE 3-12 COWWARR CHANNEL @ 1 MILE 5 CHAIN GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
1994 – 2008	225704	-	Lat: 38°00'36.0"S Long: 146°39'36.0"E	-	BoM SRW	-

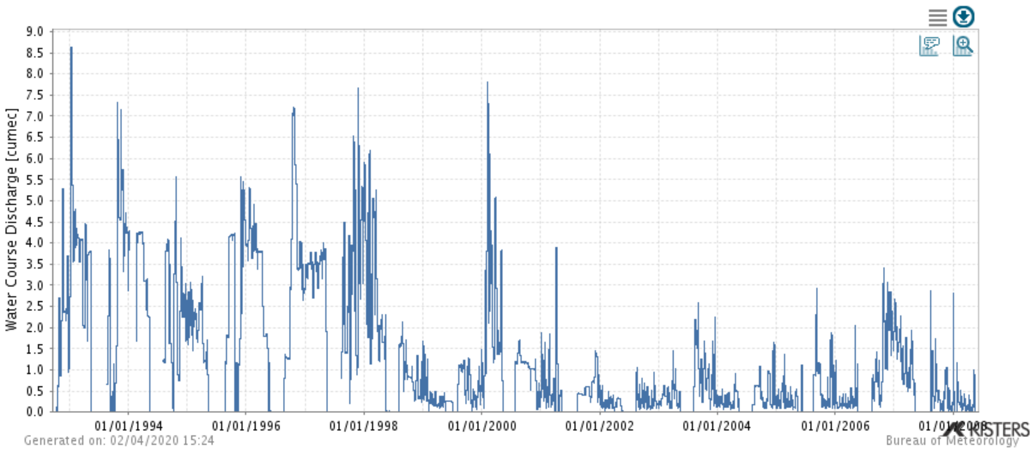


FIGURE 3-12 FLOW DATA – COWWARR CHANNEL @ 1 MILE 5 CHAIN

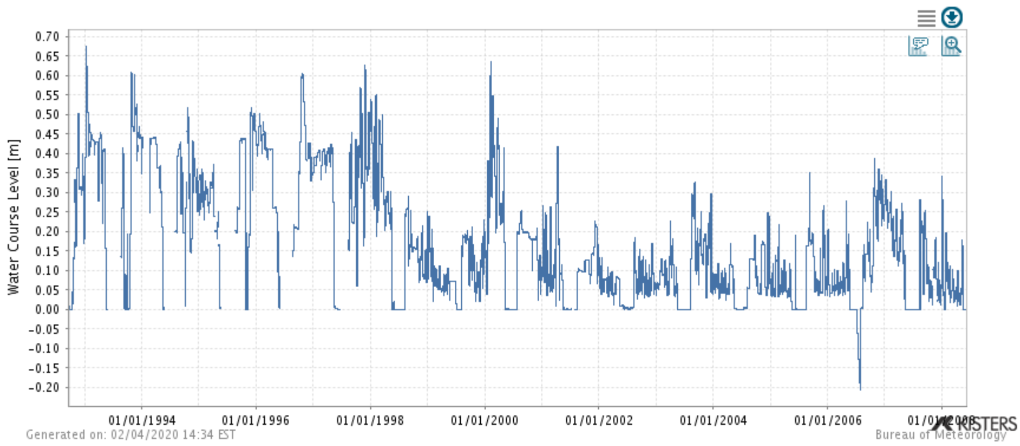


FIGURE 3-13 WATER LEVEL DATA – COWWARR CHANNEL @ 1 MILE 5 CHAIN

3.3.1.7 Nambrok-Denison Channel No 1 @ Offtake Measuring Weir (Station 225706)

Nambrok-Denison Channel No 1 @ Offtake Measuring Weir is a low flow gauging site owned by Southern Rural Water. The site is not intended for measuring peak stream flows, but metering water usage and distribution. There is little information available from DELWP regarding this gauge as it is privately owned; however, some details are provided in Table 3-13. The location of the gauge is shown in Figure 3-1.

No rating curve information for the gauge was available but flow and water level data was available from the BoM website as shown in Figure 3-14 and Figure 3-15.

TABLE 3-13 NAMBROK-DENISON CHANNEL NO 1 @ OFFTAKE MEASURING WEIR GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
1992 – 2008	225706	-	Lat: 38°00'36.0"S Long: 146°47'24.0"E	-	BoM SRW	-

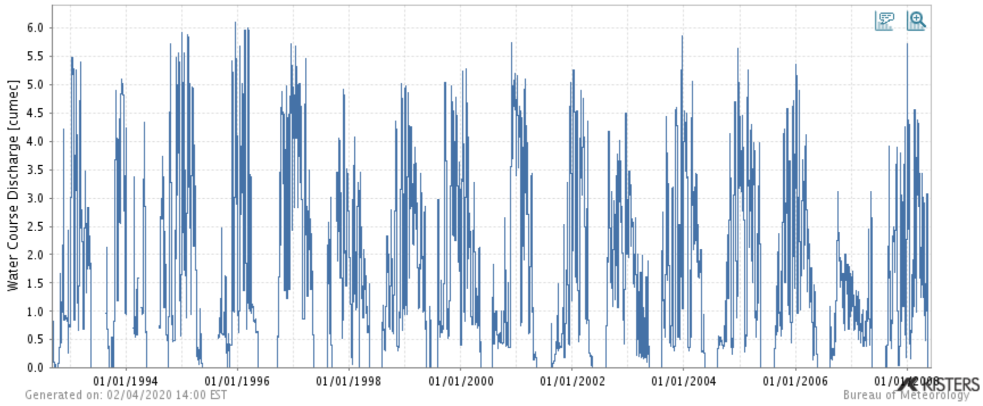


FIGURE 3-14 FLOW DATA – NAMBROK-DENISON CHANNEL NO 1 @ OFFTAKE MEASURING WEIR GAUGE

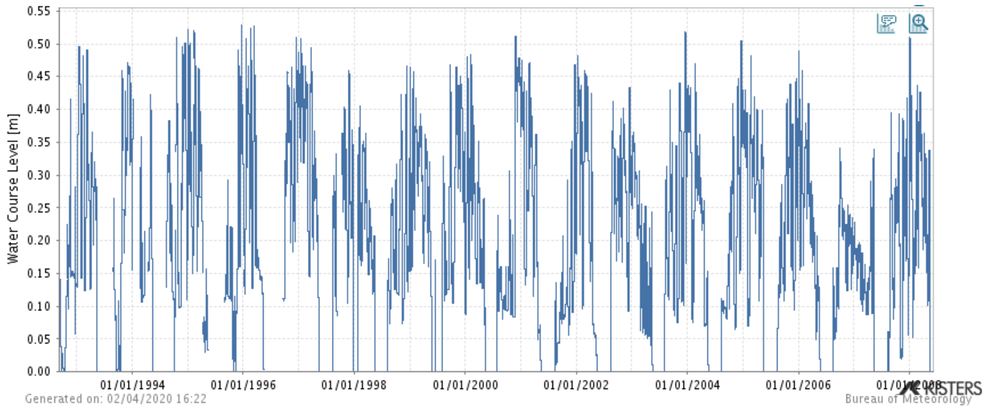


FIGURE 3-15 WATER LEVEL DATA – NAMBROK-DENISON CHANNEL NO 1 @ OFFTAKE MEASURING WEIR GAUGE

3.3.1.8 Rainbow Creek @ Cowwarr Weir (Head Gauge) (Station 225226)

Rainbow Creek at Cowwarr Weir is a low flow gauging site, owned by Southern Rural Water. This site is not intended for measuring peak stream flows, but metering water usage and distribution. There is little information available from DELWP regarding this gauge as it is privately owned; however, some details are provided in Table 3-14. The gauge location is shown in Figure 3-1.

The available flow and water level data available from the BoM website is shown in Figure 3-16 and Figure 3-17 respectively.

TABLE 3-14 RAINBOW CREEK @ COWWARR WEIR H.G. GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
1995 – 2016	225226	-	Lat: 38°00'00.0"S Long: 146°39'36.0"E	-	SRW	Unknown

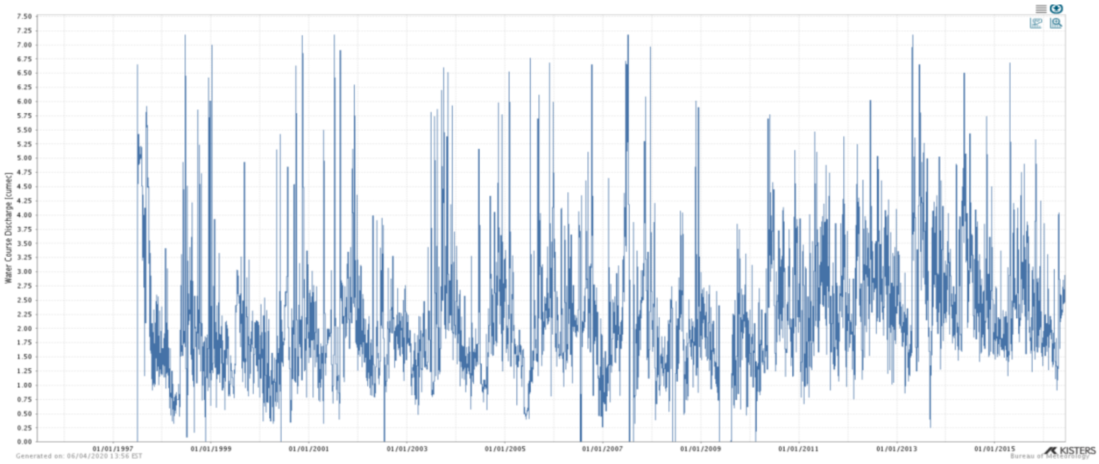


FIGURE 3-16 FLOW DATA – RAINBOW CREEK @ COWWARR WEIR H.G.

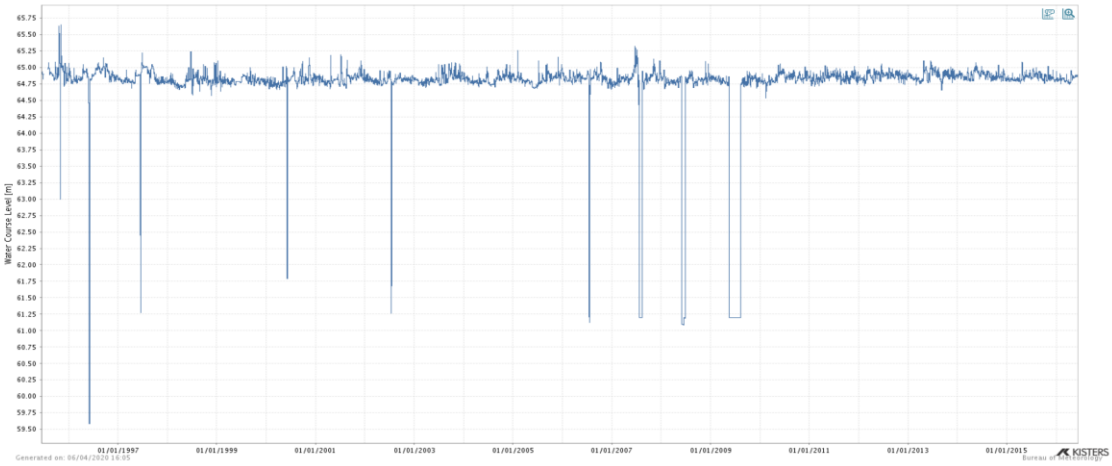


FIGURE 3-17 WATER LEVEL DATA – RAINBOW CREEK @ COWWARR WEIR H.G.

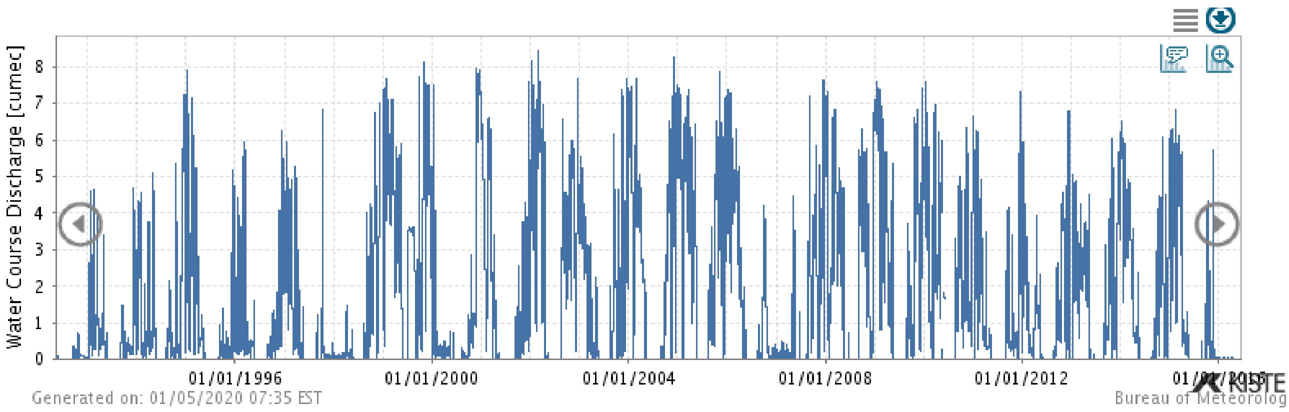
3.3.1.9 Main Southern Channel @ Thomson River Syphon Station (225708)

Main Southern Channel @ Thomson River Syphon Station is a low flow gauging site, owned by Southern Rural Water. This site is not intended for measuring peak stream flows, but metering water usage and distribution. There is little information available from DELWP regarding this gauge as it is privately owned; however, some details are provided in Table 3-15, with the gauge location shown in Figure 3-1.

The available flow and water level information available from the BoM website for the gauge is shown in Figure 3-18.

TABLE 3-15 MAIN SOUTHERN CHANNEL @ THOMSON RIVER SYPHON GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
1992 – 2016	225708	-	Lat: 38°00'00.0"S Long: 146°47'24.0"E	Unknown	SRW BOM	Unknown



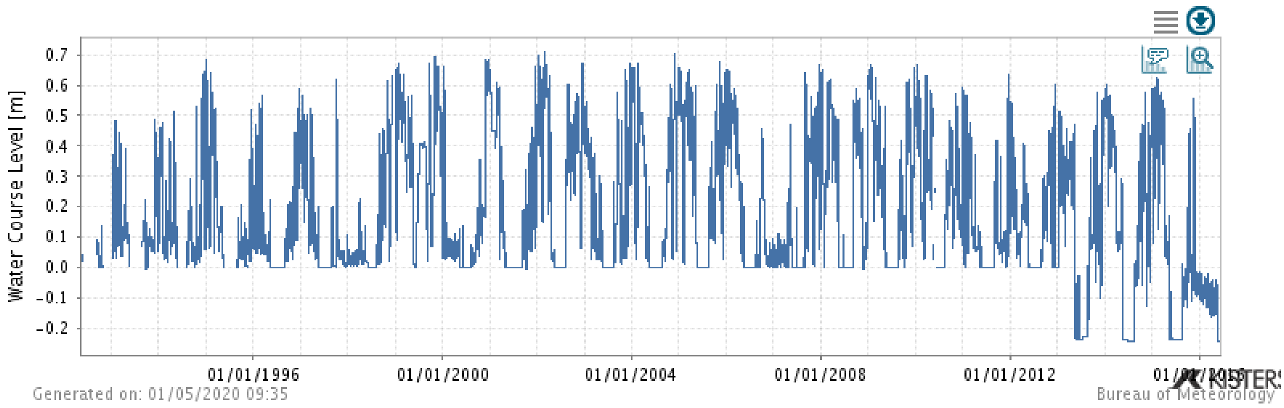


FIGURE 3-18 FLOW DATA AND WATER LEVEL– MAIN SOUTHERN CHANNEL @ THOMSON RIVER SYPHON GAUGE

3.3.1.10 Thomson River Diversion Channel @ Cowwarr Weir (Station 225703)

Thomson River Diversion Channel @ Cowwarr Weir is located on the Thomson River Diversion Channel (Figure 3-1). The gauge started recording flow in 2001. Attributes of the gauge are shown in Table 3-16.

TABLE 3-16 THOMSON RIVER DIVERSION CHANNEL @ COWWARR WEIR GAUGE DESCRIPTION

Record Period	Site	Control	Lat-Long	Method of Observation	Source	Gauge Height at Zero (m AHD)
2001 – 2007	225703	Natural; Clay, silt and rock	Lat37°59'55.6"S Long146°39'30.3"E	-	DELWP/ SRW	Unknown

The available mean daily flow and water level data is shown in displayed on the DELWP Water Information Management System is shown in Figure 3-19.

There have been two gaugings measured between 02/07/2003 and 03/08/2004. The maximum gauge record is 0.788 m, recorded on 02/07/2003.

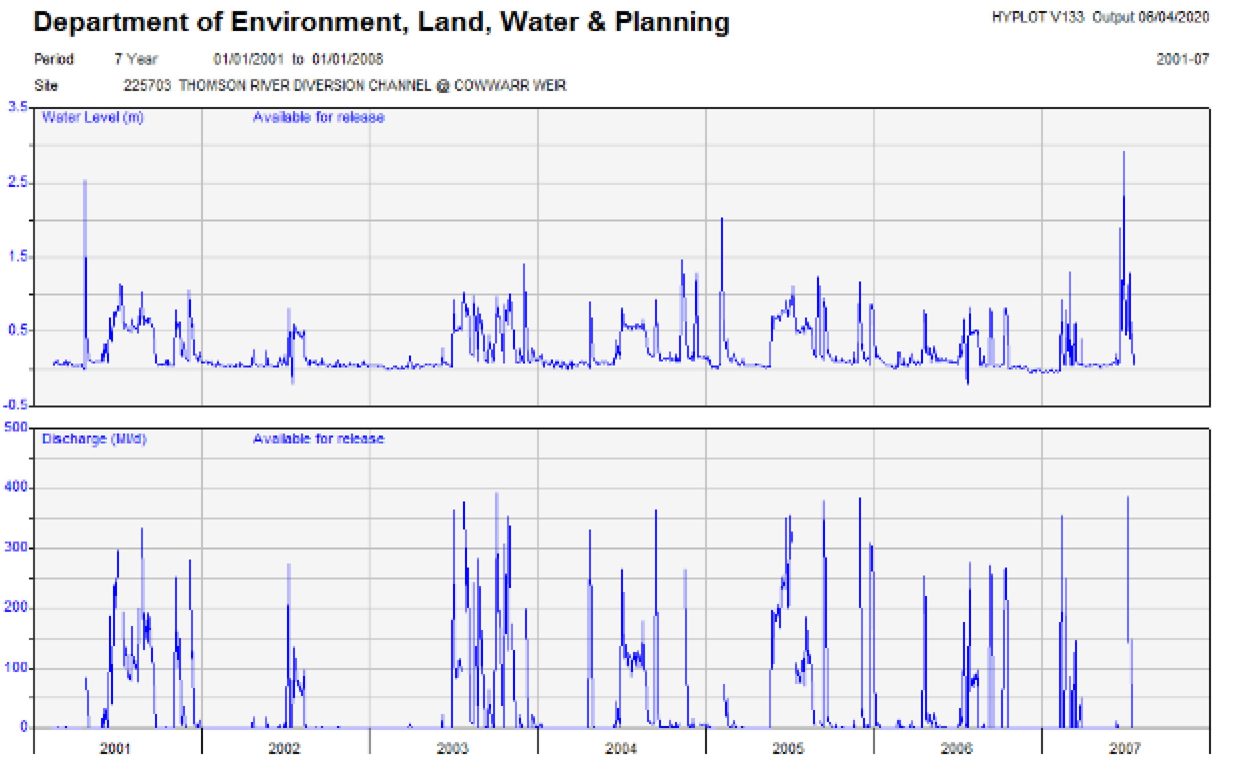


FIGURE 3-19 FLOW AND WATER LEVEL DATA - THOMSON RIVER DIVERSION CHANNEL @ COWWARR WEIR GAUGE

3.3.1.11 Flow Meter @ 1 Mile Creek (no AWRC ID)

An SRW-owned flow meter is located within the hut at Cowwarr Weir. This measures the flow discharging into 1 Mile Creek; records are maintained by SRW and are not published by BoM or DELWP.

3.3.2 Topographical and Survey Data

Topographic data within the study area was available from the following datasets:

- 2007/2008 1 m Resolution *Southern Rural Water*
- 2009/2010 1 m Resolution *WPG CMA ISC Rivers*
- 2018 1 m Resolution *WGCMA Thomson River*

Comparing the available LiDAR datasets showed marked differences. The older 2010 LiDAR was on average 200 mm higher than the newer 2018 LiDAR. This phenomenon (i.e. the 2010 data ~200mm too high) has been observed with other local 2010 ISC LiDAR (e.g. this was seen in the Traralgon Flood Study and has been an issue across numerous studies within the Glenelg Hopkins CMA region).

To validate the available LiDAR datasets, topographic survey was undertaken by a licensed surveyor (Beveridge Williams). Survey was captured along three well-defined roads. All levels were measured by Global Navigation Satellite System (GNSS) and verified to Permanent Survey Marks (PSMs).

The survey and LiDAR elevations were compared at each survey point location and the difference calculated. A summary of comparison statistics is provided in Table 3-17, showing the LiDAR from 2007/08 and 2018 to be in reasonable agreement with the survey results with mean differences of -0.079 m and -0.018 m respectively). while the 2009/2010 LiDAR was significantly higher than the survey levels (mean elevation +0.199 m).

TABLE 3-17 LIDAR VALIDATION STATISTICS WITH RESPECT TO RECORDED SURVEY POINTS

LiDAR Title/Year(s)	Maximum	Minimum	Mean	Standard Deviation
2007/2008 Southern Rural Water	0.063	-0.201	-0.079	0.048
2009/2010 WPG CMA ISC Rivers	0.372	0.045	0.199	0.040
2018 WGCMA Thomson River	0.206	-0.146	-0.018	0.048

The LiDAR datasets were also checked at four available PSMs, these included:

- Tinamba - PSM 38
- Winnindoo - PSM 33
- Toongabbie North - PSM 13
- Toongabbie North - PSM 22

The location of the PSMs is shown in Figure 3-20. The 2018 LiDAR was on average 70 mm higher than the benchmarks, this was a reasonable result as often the actual benchmarks sit ~100 mm below ground level. The older 2010 LiDAR was on average 270 mm higher, supporting the potential the 2010 ISC LiDAR is roughly 200 mm too high.

Given the relatively close match between the 2018 LiDAR at the available survey locations and the clear issues with the 2010 LiDAR data, the 2018 dataset was adopted for use in this project.

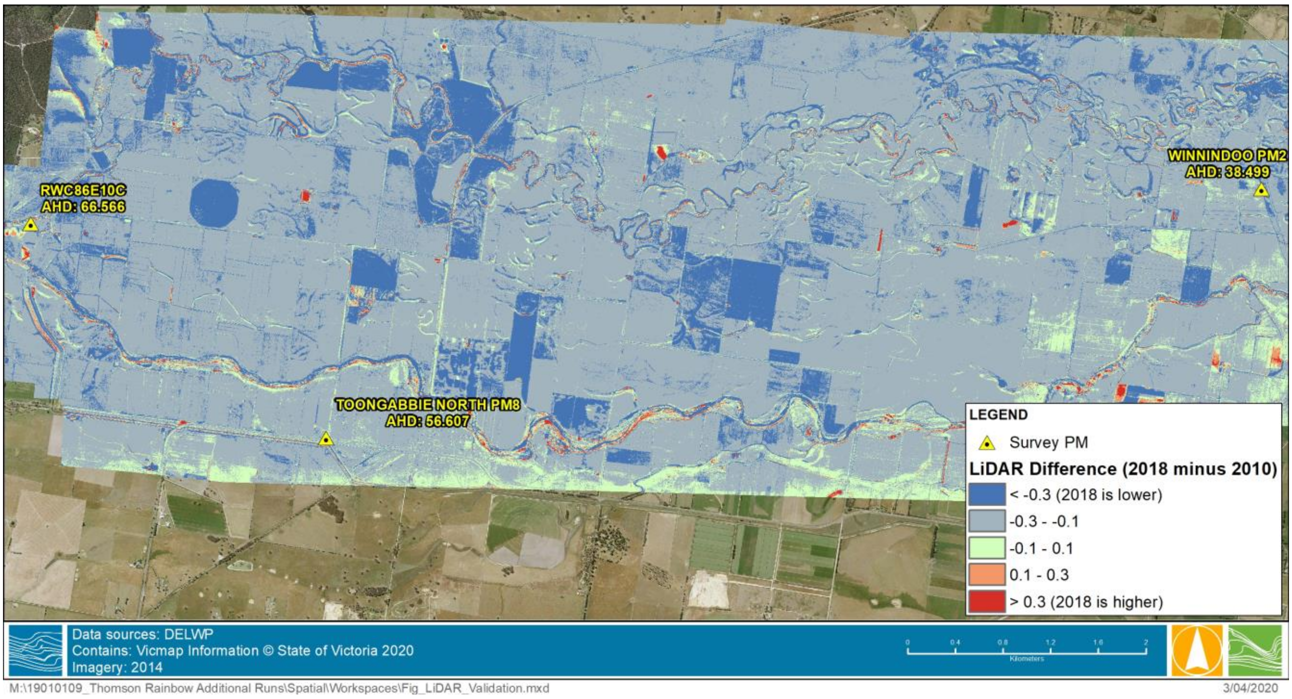


FIGURE 3-20 LIDAR DIFFERENCE AND VALIDATION

3.3.3 Landform Change

Analysis in the Thomson Rainbow Management Plan suggest the Thomson/Rainbow system is active (currently in a state of change), with channel and floodplain morphology changes observed in analysis of topographic datasets and in the field. The geomorphological processes of deposition and scour are observed in the comparison of LiDAR datasets (Figure 3-20), with deposition tending to be dominate in the old Thomson River course (red cells) and scour (dark blue cells) tending to be observed in Rainbow Creek. It is important to note these changes occur periodically and are often linked to flood events. At this time, this state of change is not at a rate that is likely to affect any flood levels recommended for the floodplain (particularly for rare floods like the 1%AEP event).

3.3.4 Hydraulic Structures

At a regional scale, hydraulic structures of interest are those that have the potential to impact the wider flood extent. These have been generally limited to levees, channels banks, road embankments, bridges and weir crossings.

Available information and data for these structures has been collected from both Wellington Shire Council and VicRoads. Cowwarr Weir and three roads namely, Traralgon-Maffra Road, Cowwarr-Seaton Road and the Gippsland Plains Rail Trail are the major hydraulic structures within the floodplain. Figure 3-24 shows the location of these roads.

3.3.4.1 Cowwarr Weir

3.3.4.1.1 OVERVIEW

Cowwarr Weir is a regulating structure in the Macalister Irrigation District (MID). It is operated by Southern Rural Water and is a concrete gravity structure with three steel vertical lift spillway gates for regulating water supply from the Thomson River to the MID.

In 1959, the Cowwarr Weir and diversion channel were constructed at the point where the breakaway course of the Rainbow Creek begins. The weir allows control of water flow along the breakaway and to divert water to the area south of the Thomson River along the Cowwarr Channel to supplement water from Lake Glenmaggie for irrigation in the Nambrok-Denison area. The Cowwarr Weir was constructed before the construction of Thomson Dam. The construction of Thomson Dam began in 1976 and was opened in 1983.

Figure 3-21 shows the general layout of the Cowwarr Weir and diversion channels. The weir has a sluice which is used to maintain routine flows to the Rainbow Creek; however, during a flood its capacity is quickly exceeded, requiring the spillway gates to operate to maintain pool height.

There is an offtake from the Cowwarr Weir pool that supplies water to the Main Cowwarr Channel based on irrigation demand.

There is a secondary channel that runs from the Cowwarr weir pool to the Thomson River (entering the Thomson D/S of the knife-edge) called the by-wash. This channel is normally closed with manually operated undershot gates; however when flood discharges to Rainbow Creek exceed 500 ML/d, the undershot gates are opened.

FIGURE 3-21 COWWARR WEIR OVERVIEW

While Cowwarr Weir has a relatively small capacity (387 ML) compared with flood flow volumes, it has an impact on high flows in the Old Thomson River and Rainbow Creek. The weir spillway gates are automatically raised during high flows to regulate the proportion of flow in each channel. Episodes of zero flow in the Old Thomson River occur during the non-irrigation period when the weir is dewatered for maintenance. Under normal conditions during the irrigation season Cowwarr Weir is maintained at or near the full supply level. Spillway gates are operated such that 70% of inflow to Cowwarr Weir passes along the Old Thomson River channel and 30% along Rainbow Creek.

Figure 3-22 shows the as constructed drawing of the Cowwarr Weir as provided by SRW.

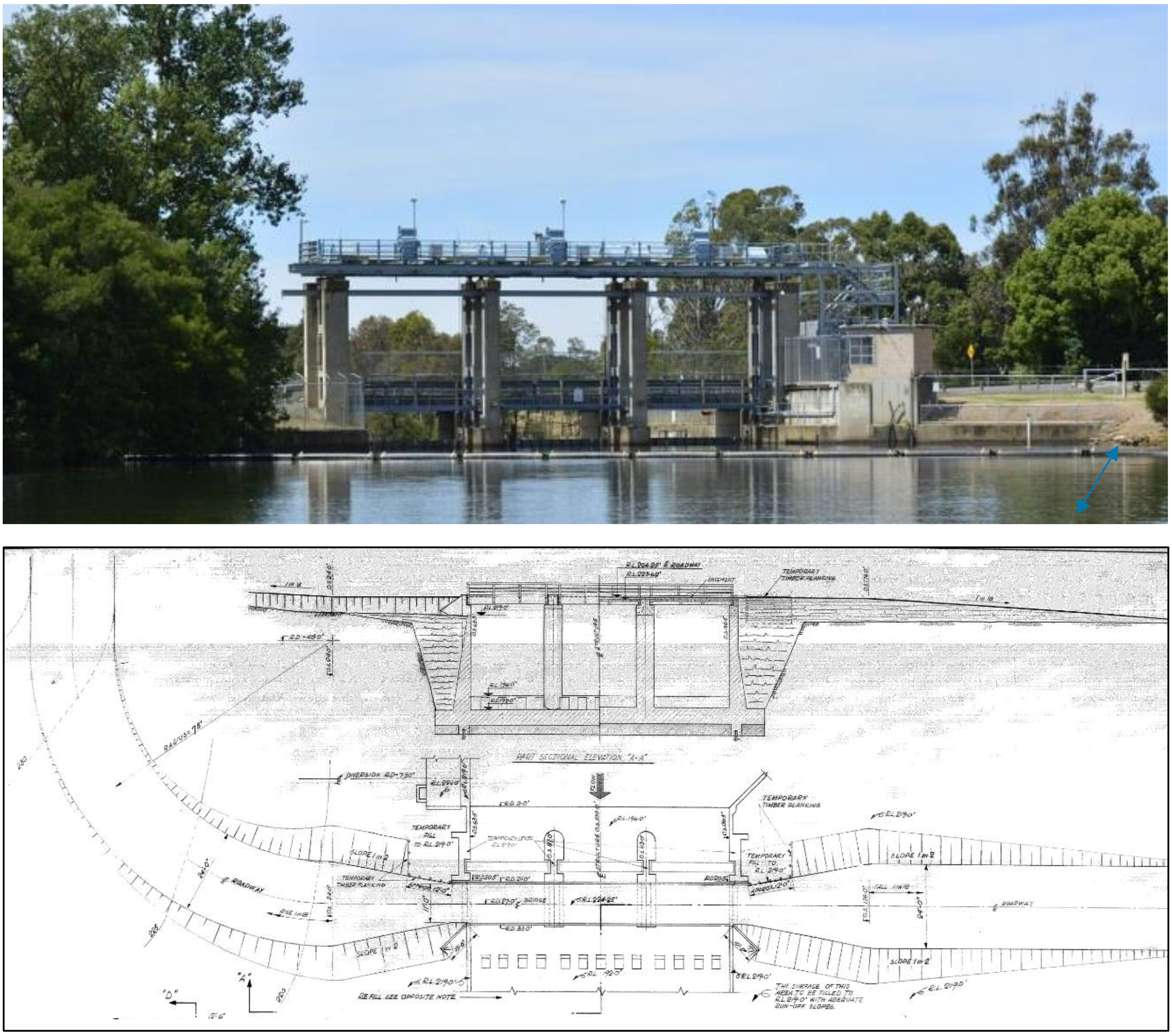


FIGURE 3-22 [TOP] COWWARR WEIR (SOURCE: GOOGLE); [BOTTOM] AS CONSTRUCTED DRAWING

3.3.4.1.2 OPERATIONAL RULES

Cowwarr Weir has a nominal storage capacity of approximately 387 ML at Full Supply Level (FSL- 65.00 m AHD) based on a capacity survey completed in late 2013. This volume fluctuates according to the levels of silt in the weir. Figure 3-23 shows bathymetry survey from 2013. Figure 3-23 also shows the stage-storage relationship and a long section through spillway extracted from LiDAR. As the Weir is not operated as a storage basin the pool capacity has a little significance for operational purposes and has no flood storage capacity.

The current operating regime at Cowwarr Weir excludes all medium flows in the Thomson River (between about 40 to 1200 ML/d) from discharging into Rainbow Creek. Rainbow Creek only carries low flows, thus exhibiting a drastically altered seasonal flow regime (SKM 2001).

The spillway gates have been designed to operate automatically to control the weir pool level during floods but an operational presence is still required at the site to ensure the automatic system is working correctly and can be manually intervene if required. In this mode, the three flood gates in the main weir structure automatically control flood flows through the Weir to Rainbow Creek with the remaining split of flood flows directed down the Thomson River. The movement of each gate is correlated with the rise in pool level above FSL and by a

Programmable Logic Controller (PLC) which monitors and controls the levels of the pool and Weir gates. The pool level signal is taken from a pair of submersible pressure level sensors.

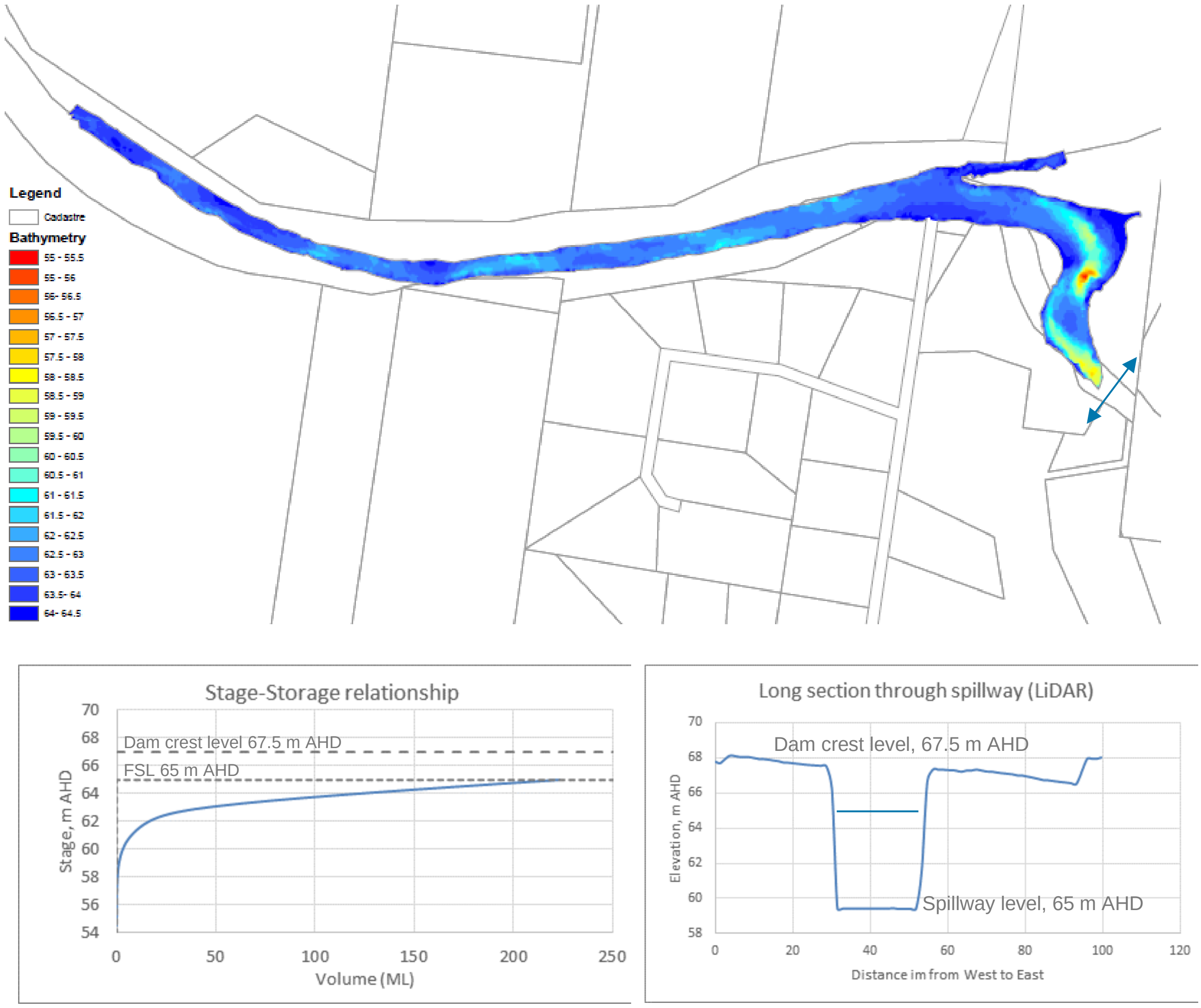


FIGURE 3-23 [TOP] COWWARR WEIR BATHYMETRY IN 2013 AND [BOTTOM] STAGE-STORAGE CURVE AND LONG SECTION AT SPILLWAY FROM LIDAR (SOURCE: SRW)

3.3.4.2 Bridges & Culverts

3.3.4.2.1 OVERVIEW

As this study is of a regional scale, only key bridge and culvert structures were included in the hydraulic model. Data on these structures was collected from Vic Roads and Wellington Shire Council.

Table 3-18 shows the list of modelled waterway structures, supported by comments and dimensions where available. Bridges identified in Table 3-18 can be cross-referenced with feature labels in Figure 3-24 (structures without plans are shown with a black box). There are six culverts located along the Cowwarr and Nambrok-Denison Channels which will have minimal impact on flood levels, particularly for rare events. Other structures located along the main river channels include:

Unknown Rd - Rainbow Bridge

Downings Rd - Thomson Bridge

Downings Rd - Stoney Bridge

Cowwarr-Seaton Rd - Thomson Bridge

Rices Ln - Rainbow Bridge

Rail-Trail - Rainbow Bridge

TABLE 3-18 WATERWAY STRUCTURES

ID	Name	Source	Type	Plans	Comment
-	Cowwarr-Seaton (Harkins) Rainbow Bridge	WSC	Bridge	Y	Concept plans only.
-	Unknown Rainbow Bridge	Unknown	Bridge	N	No plans supplied, unknown dimensions
-	Downings Thomson Bridge	Unknown	Bridge	N	No plans supplied, unknown dimensions
-	Downings Rainbow Bridge	WSC	Bridge	Y	Jarvis Norwood Construction plans show Rainbow Ck, however road alignment is indicative of Thomson..
-	Downings Stoney Bridge	Unknown	Bridge	N	No plans supplied, unknown dimensions
-	Thomson River Factory Bridge	VicRoads	Bridge	Y	Detailed plans supplied by VicRoads & WSC.
-	Cowwarr-Seaton Thomson Bridge	Unknown	Bridge	N	No plans supplied, unknown dimensions
-	Rices Rainbow Bridge	Unknown	Bridge	N	No plans supplied, unknown dimensions
-	Rail-Trail Rainbow Bridge	Unknown	Bridge	N	No plans supplied, unknown dimensions
SN5564	Culvert	VicRoads	Culvert	Y	Box & Lid, 3 No 2x0.31m*0.31m
SN5565	Rainbow Ck Bridge	VicRoads	Bridge	Y	Detailed plans supplied by VicRoads & WSC.
SN7567	Culvert	VicRoads	Culvert	Y	RC Box & Lid, 5 No 1.2mx0.9m
SN8815	Culvert	VicRoads	Culvert	N	No plans supplied, unknown dimensions
SN9526	Irrigation Channel	VicRoads	Culvert	N	No plans supplied, unknown dimensions
SN9527	Culvert	VicRoads	Culvert	N	No plans supplied, unknown dimensions
SN9528	Culvert	VicRoads	Culvert	N	No plans supplied, unknown dimensions
SN9529	Irrigation Channel	VicRoads	Culvert	N	No plans supplied, unknown dimensions

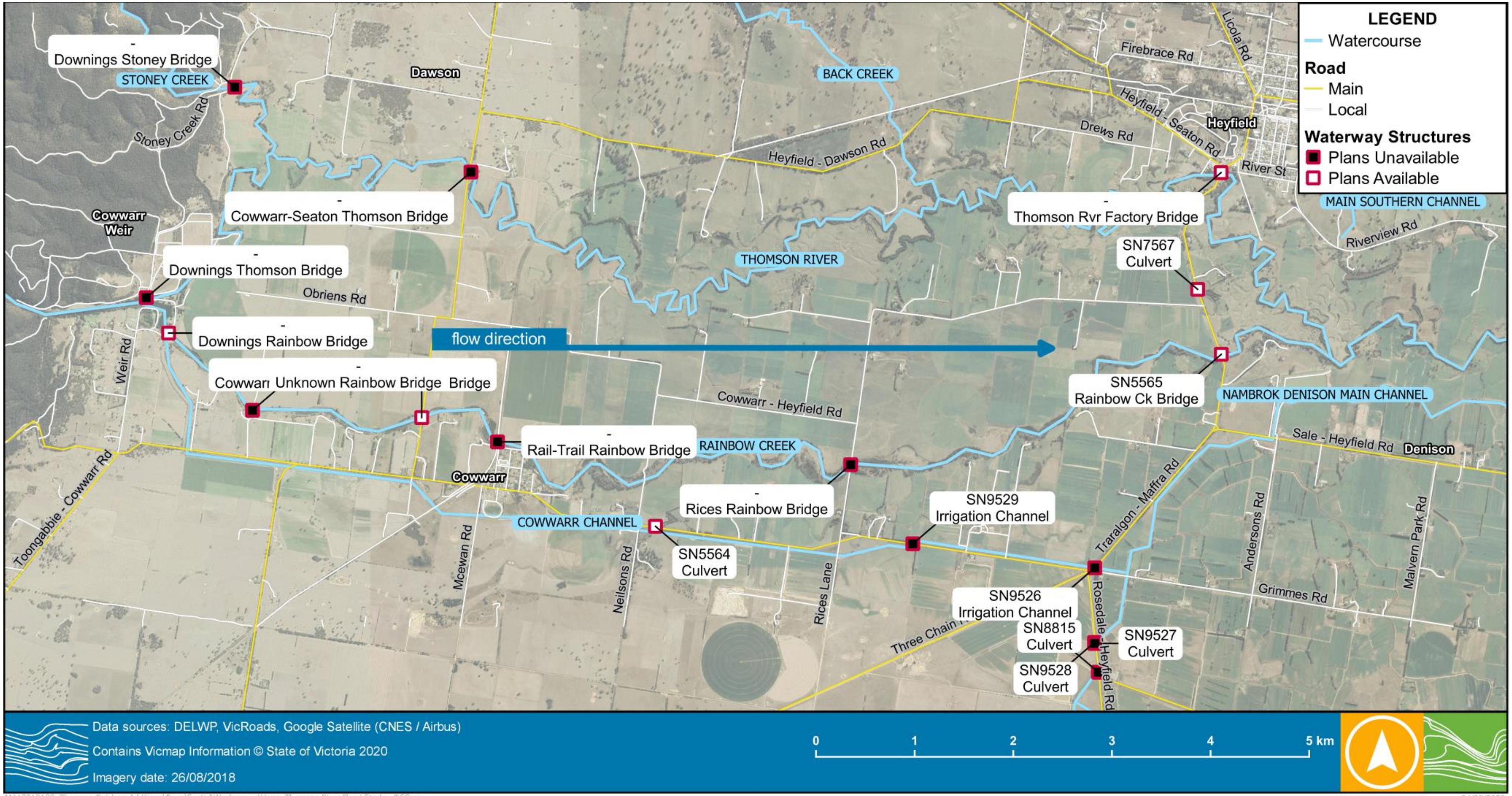


FIGURE 3-24 WATERWAY STRUCTURES

3.3.4.2.2 FACTORY BRIDGE ON THOMSON RIVER

The Factory Bridge on the Thomson River is one of the two major bridges in the study area. The structure, found on the Traralgon-Maffra Road was modelled using a layered flow constriction in TUFLOW. The bridge site and the as constructed drawings collected from Vic Roads are shown in Figure 3-25. The bridge has three sets of piers each 550 mm wide. The bridge deck is 1,100 mm deep.

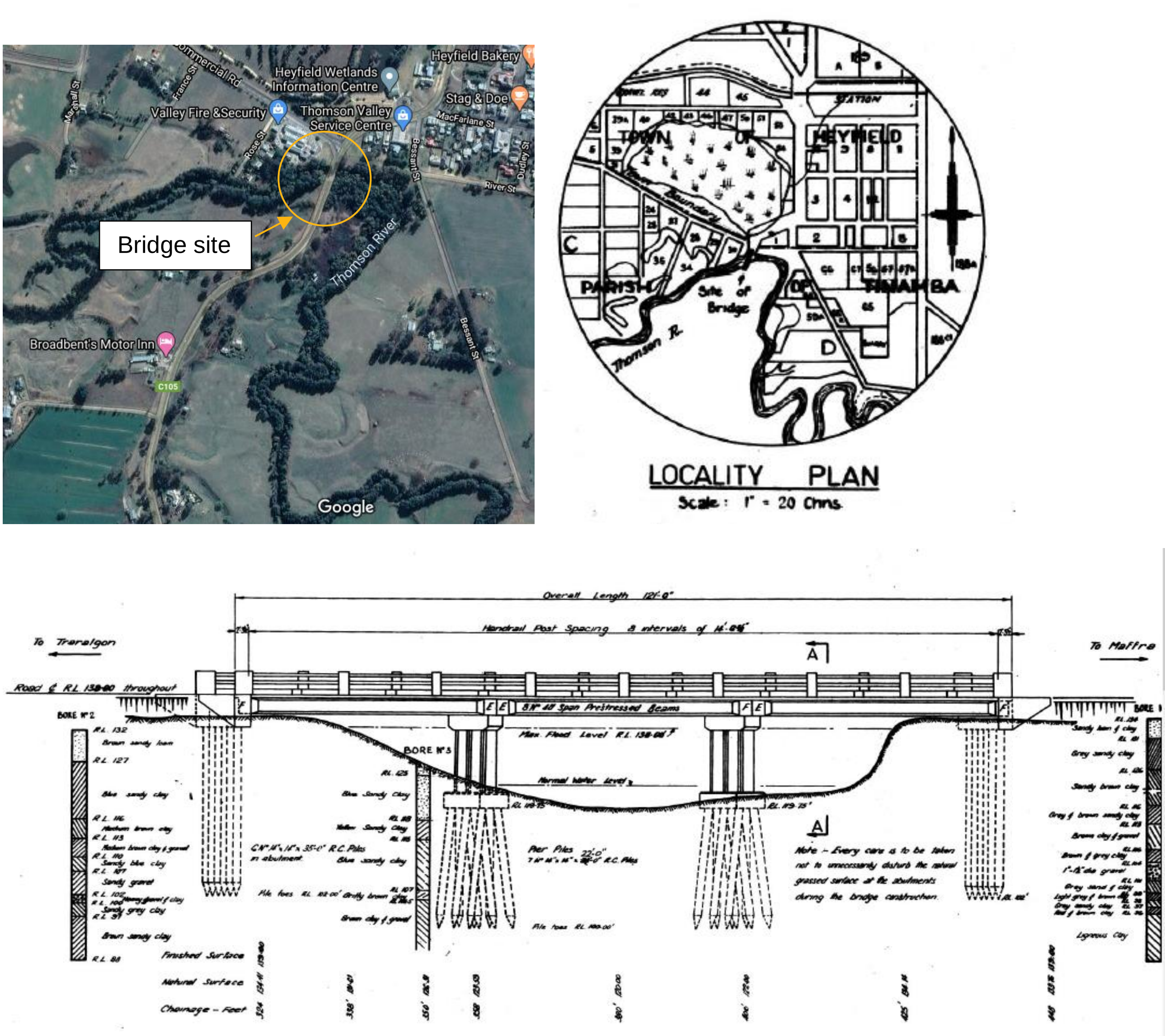


FIGURE 3-25 THE FACTORY BRIDGE ON THOMSON RIVER

3.3.4.2.3 TRARALGON-MAFFRA ROAD BRIDGE ON RAINBOW CREEK

The other major bridge crossing is the over the Rainbow Creek between Rosedale and Heyfield also located on Traralgon-Maffra Road. A layered flow constriction representing the waterway area under the bridge was used in the TUFLOW model. The deck obvert, thickness, number of piers, pier diameter and guard rail height were used to specify the structure geometry. Figure 3-26 shows the bridge location and the as constructed drawing from Vic Roads.

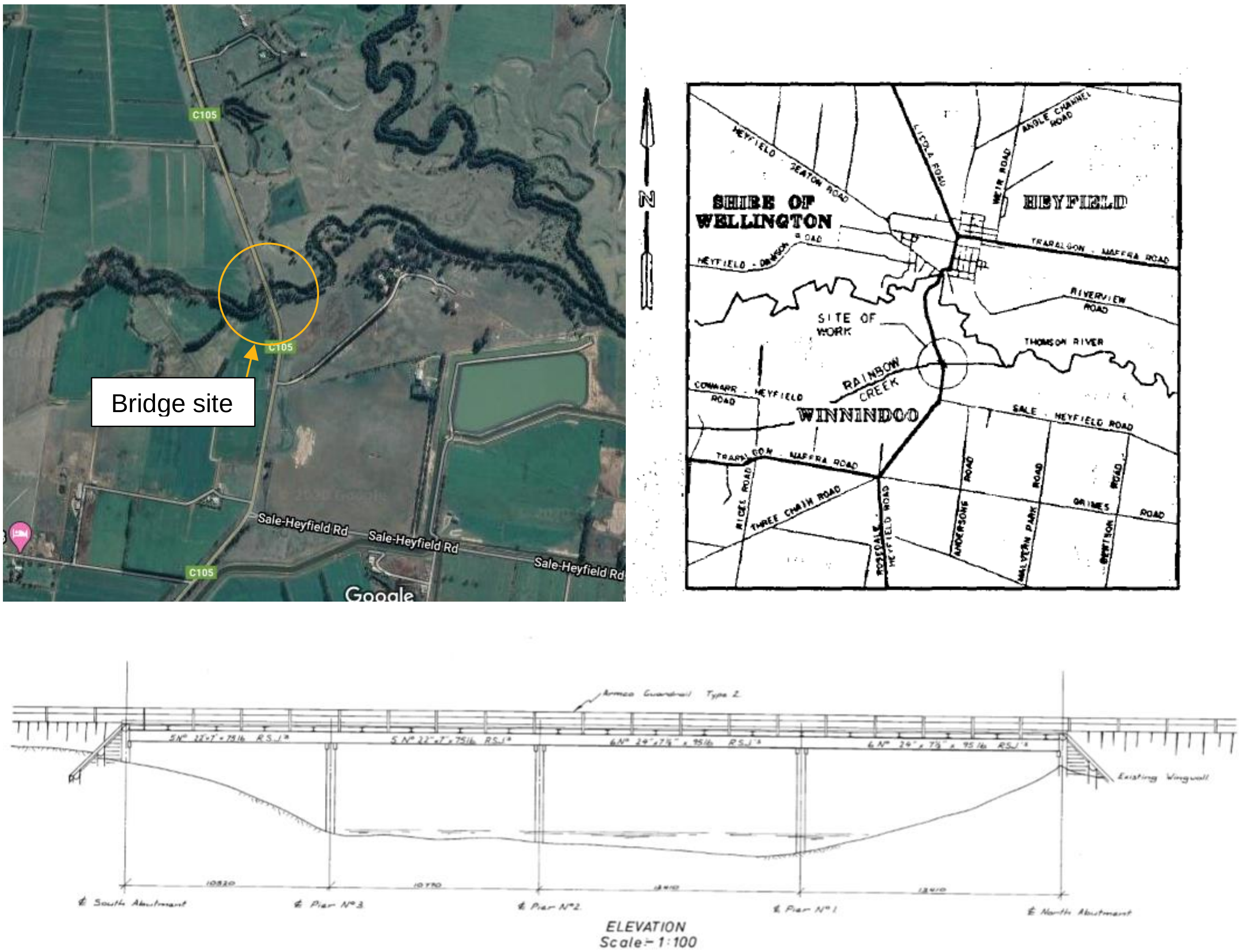


FIGURE 3-26 TRARALGON-MAFFRA ROAD BRIDGE SITE ON RAINBOW CREEK AND AS CONSTRUCTED DRAWING

3.3.5 Historic Flood Information

Oblique historic flood photos and aerial photos were provided by WGCMA, this information was supplemented by information from Trove. Figure 3-27 shows some flood imagery from the 2007 flood. Observed flood levels were collected at 80 sites during the June 1978 flood event and at 25 sites during June 2007 flood event. The Victorian Flood Database (VFD) holds a great deal of flood related data across the study area.

The spatial coverage of available flood marks collected during 1978 and 2007 and the 1% AEP flood extent from the Victorian Flood Database are shown in Figure 3-29.

FIGURE 3-27 FLOODING IN NOV 2007 FLOOD, HEYFIELD

FIGURE 3-28 RAINBOW CREEK AT COWWARR WEIR (LEFT) & HEYFIELD (RIGHT)- 5 JUNE 2012

FIGURE 3-29 100 YEAR FLOOD EXTENT AND OBSERVED HEIGHT 1978 & 2007 FLOOD (VFD)

4 HYDROLOGY

4.1 Overview

The hydrological approach used to produce design flood hydrographs within this study consisted of two main components: a Flood Frequency Analysis (FFA) based on gauged flow records, followed by a calibrated rainfall runoff model to determine the hydrographs for the required design flood events.

The RORB model developed by HARC (2019) as part of the Lower Thomson River Flood Study was made available and used for this study. The RORB model was used to estimate both historic and design hydrographs.

4.2 Review of HARC RORB modelling

4.2.1 Overview

A detailed RORB model was developed by HARC as part of the Lower Thomson River Flood Study in 2019. There were two components to the HARC RORB model:

- Model calibration.
- Design modelling.

4.2.2 Model Calibration

The HARC (2019) RORB model was calibrated for the April 1952, June 1978, September 1993 and June 2007 flood events. The RORB model used sub-daily rainfall records to determine event temporal patterns. Daily rainfall depths were determined by interpolating the AWAP rainfall data and applying to the RORB model subarea centroids. Baseflow was manually separated from the total flow hydrograph at each of the streamflow gauges.

The RORB model was calibrated at three streamflow gauges:

- Thomson River @ U/S of Cowwarr Weir - 225231
- Thomson River @ Wandocka - 225212
- Thomson River @ Bundalaguah - 225232

The Thomson River @ U/S of Cowwarr Weir gauges represents an inflow to the current study area and the Thomson River @ Wandocka gauge is the downstream end of the study area. The 2019 RORB model ignored the flow distribution between the Thomson River and Rainbow Creek downstream of the Cowwarr Weir; rather the study calibration focussed on the routing between the three gauges.

The model calibration determined the RORB model kc of 70 at Thomson River @ U/S of Cowwarr Weir gauge, 50 at Thomson River @ Wandocka gauge and 75 at Thomson River @ Bundalaguah gauge, and an m of 0.8. The RORB model appears to match recorded flow at each of the gauge locations.

4.2.3 Design Modelling

The RORB design modelling adopted initial and continuing loss values based on modifying the median initial and continuing losses to achieve a match between the RORB model and the FFA results.

RORB was run using a Monte-Carlo simulation to estimate flood frequency quantiles for flood events with AEPs of 10%, 5%, 2% and 1%. In all RORB model simulations, a value of 0.8 was adopted for the routing non-linearity parameter, m. The value of the routing delay parameter, kc, was adopted from the values identified from calibration of flood events.

4.3 RORB model modification

Design modelling undertaken by HARC utilised their in-house version of the RORB software. When compared to the publicly available version, the most noticeable difference in their in-house version is that a series of spatial patterns of rainfall can be applied in the Monte Carlo Simulation for design modelling. To replicate the design flow estimates stated in the Lower Thomson River Flood Study (HARC 2019) in the publicly available version, an analysis of each spatial pattern was undertaken to find the specific spatial pattern that produces the similar flow estimates within the Thomson River catchment.

Following this, several other structural changes made to the RORB model, these included:

- Additional sub area delineation of the Stoney Creek, Back Creek, Two Mile Creek and an unnamed tributary catchment.
- Additional 'print points' enabling inflows to be extracted from additional locations to be placed in the TUFLOW model.

4.3.1 Summary

Review of the 2019 HARC RORB model determined it was fit for purpose as a base structure to for updated model calibration and design modelling undertaken during this project.

4.4 RORB model calibration

4.4.1 June 2007

Stoney Creek and Thomson River inflow hydrographs for the 2007 flood event were developed as part of the 2011 (Water Technology) and 2019 (HARC) studies. Comparing the hydrology from the previous studies show peak flows are higher in the 2019 study with the Thomson River inflow 295 m³/s greater than the 2011 estimate. A peak flow comparison is shown in Table 4-1. The updated modelling (2021) has additional inflows at Back Creek, Two Mile Creek and the unnamed tributary catchment contributing to the differences between the previous studies.

TABLE 4-1 COMPARISON OF PEAK FLOWS ADOPTED FROM THE 2011 (WATER TECHNOLOGY) AND 2018 (HARC) STUDIES

Inflow Name/Location	2011 Hydrology (m^3/s)	2018 Hydrology (m^3/s)	Difference (m^3/s)
Thomson River (Cowwarr Weir)	593.3	888.2	294.9
Stoney Creek	75.5	81.5	6.0
Unnamed Trib	N/A	N/A	40.3
Back Ck		N/A	31.9
Two-Mile Ck		N/A	35.3

During the preliminary phase of the 2007 event calibration, too much volume was found within Thomson River resulting in a poor calibration to the gauged peak flow. After some investigation of the existing RORB model, the project team found Stoney Creek and other smaller tributaries inflows appeared to be high. As these catchments were modelled as single sub-areas, it was identified that this may have been limiting attenuation in the RORB model.

Given the previous RORB model was focussed at a larger regional scale and did not involve hydraulic modelling to confirm routing parameters through the intermediate gauge lcoations, and following discussion with the WGCMA, the RORB model was updated with additional detail (as shown in Figure 4-1) and a dummy gauging station was added immediately to control the flow estimates through a modified K_c. The K_c was scaled based on the calibrated K_c at Wandocka gauge and the average flow distance in these sub-areas. Rainfall losses (i.e. IL and CL) for these sub-areas were adjusted to provide a more detailed approach and reduce peak inflows and volumes from these tributaries. A summary of the updated RORB model parameters for 2007 event is shown in Table 4-2 below. The calibration results are discussed in further detail in Section 5.6.2.

TABLE 4-2 SUMMARY OF CALIBRATION PARAMETERS FOR JUNE 2007 EVENT

Gauge	kc	m	IL (mm)	CL (mm/h)
225221 Macalister River@Stringy Creek	62	0.8	25	0.1
225204 Macalister River@Lake Glenmaggie	23	0.8	20	0.1
225231 Thomson River@Cowwarr Weir	70	0.8	50	0.6
Dummy (DS of StoneyCk, BackCk, Two-MileCk)	*26.91**	*0.8*	*85*	*5*
225212 Thomson River@Wondocka	32.31*	0.8	65	2
226005 Latrobe River@Thoms Bridge	113	0.8	120	1.2
226228 Latrobe River@Rosedale	90	0.8	90	4
Catchment outlet	75	0.8	20	4

*K_c was scaled based on the original K_c = 50 and average flow distance = 26.48km

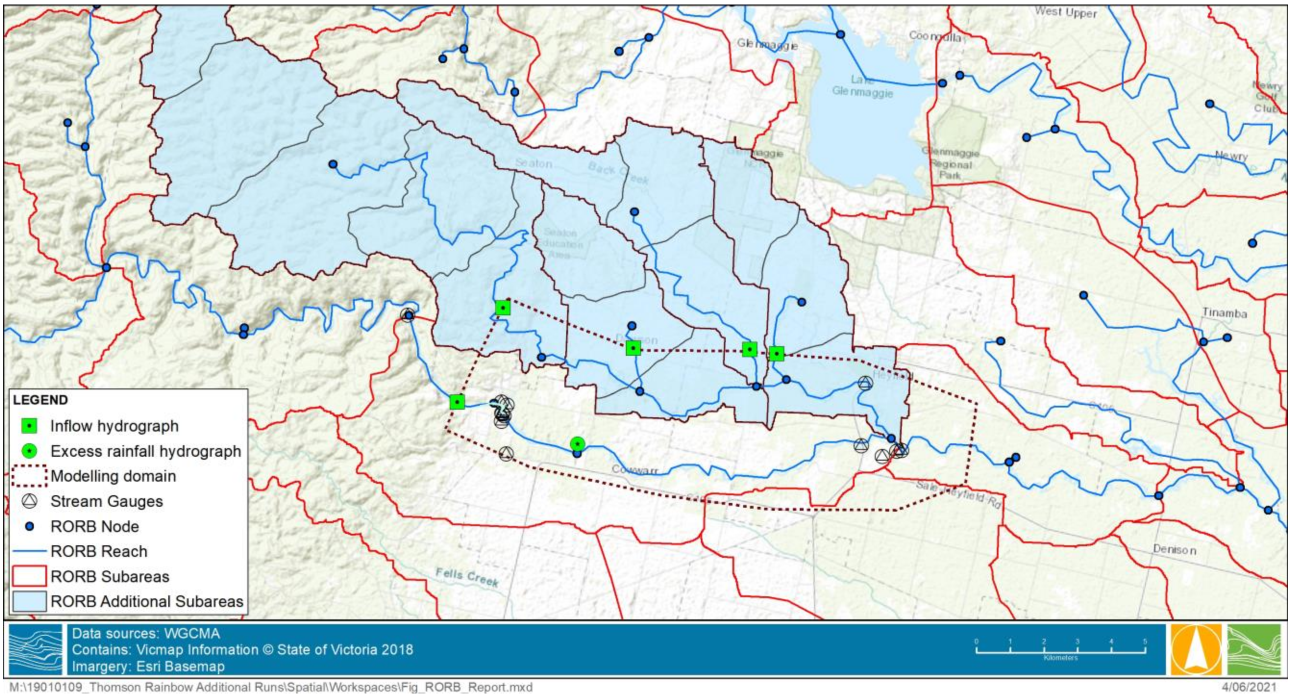


FIGURE 4-1 ADDITIONAL SUB-AREAS ADDED IN RORB MODEL

4.4.2 Validation Events (2012 and 2016)

The 2007 flood event was used as the primary joint calibration (RORB/TUFLOW) event with 2012 and 2016 events being used for validation. Given the HARC study used the 2007 event as a calibration event, inflows could be extracted directly for use in the hydraulic model. With no RORB modelling results for 2012 or 2016 events, minor waterway inflows were scaled based on the 2007 inflows with the peak flow lag retained (e.g. the Stoney Creek peaking 10 hours prior to the Thomson River) inline with the project methodology proposed. Scaled hydrographs between the events is presented in **TABLE 4-3**. Observed flows shown in green, modelled flows in orange and scaled flows shown in blue.

Figure 4-2 displays the RORB estimated hydrographs of 2007 event and comparison with the scaling hydrographs for 2012 and 2016 events. As a result of the joint calibration process, inflow hydrographs for 2007 event were shifted forward by 8 hours to provide a better match of timing with the gauged record.This is likely to be an issue with the rainfall temporal pattern used in the RORB model rather than the routing in the RORB or TUFLOW models.

TABLE 4-3 PEAK FLOW RELATIONSHIPS IN PAST EVENTS IN THE THOMSON AND TRIBUTARIES

Location	2007		2012			2016		
	ML/d	m³/s	ML/d	m³/s	% 2007 Peak flow	ML/d	m³/s	% 2007 Peak flow
Thomson River @ US Cowwarr (225231A)	**73609***	**852***	**55416***	**641***	75%	**12853***	**149***	17%
Thomson River (Cowwarr Weir)	76740°	888°	57773!	669!		13400!	155!	
Stoney Ck (u/s of Thomson/Stoney Confluence)	7042°	81.5°	5301!	61!		1230!	14!	
Unnamed Trib	3482°	40.3°	2621!	30!		608!	7!	
Back Ck	2756°	31.9°	2075!	24!		481!	6!	
Two-Mile Ck	3050°	35.3°	2296!	27!		533!	6!	
Excess Rainfall	12753°	147.6°	9601!	111!		2227!	26!	

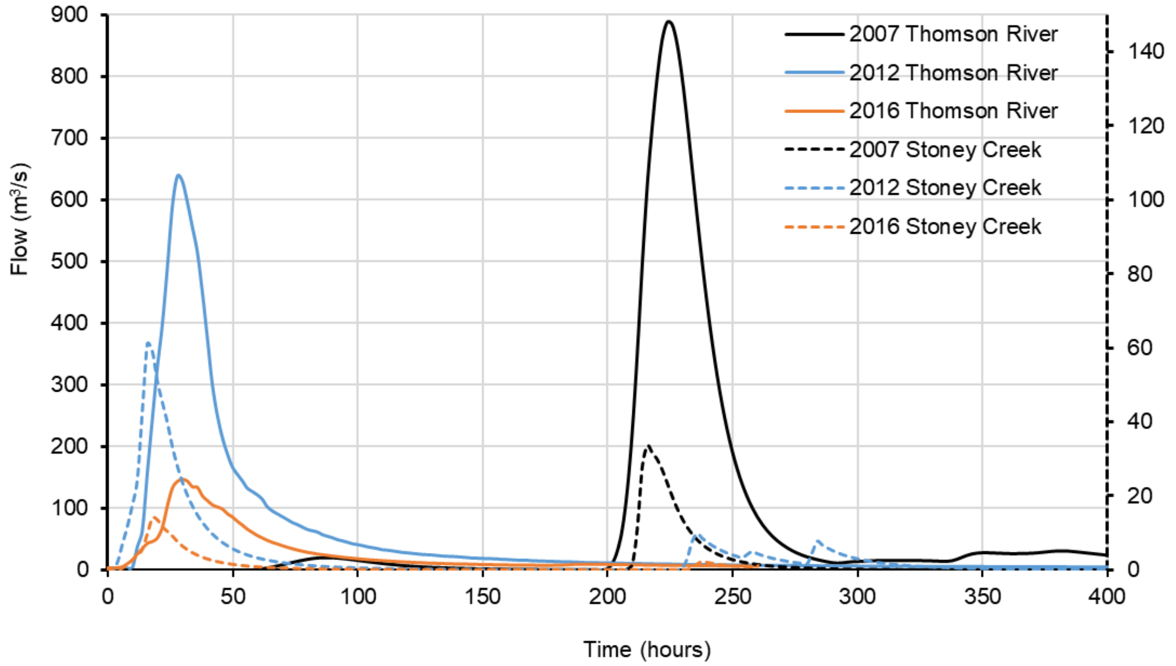


FIGURE 4-2 COMPARISON OF ESTIMATED HYDROGRAPHS FOR 2007, 2012 AND 2016 EVENTS

4.5 Design Hydrology

The updated Thomson River hydrology was based on four key steps; these were as follows:

1. Confirmation of design flows from previous HARC modelling

2. Modification of RORB model to include additional information
3. The updated RORB model was then ran to produce design flow hydrographs for the hydraulic modelling.
4. Sensitivity testing was also undertaken to understand the potential impact of climate change and catchment runoff conditions due to bushfires.

4.5.1 Design modelling validation

Three key steps were required to confirm the design flows from the updated RORB model closely matched the design flows from the 2019 HARC study.

1. Confirmation of design rainfall inputs used in the HARC modelling
   - Deign rainfall depth – The design rainfall depth extracted from HARC design file
   - Spatial pattern – 10 different spatial patterns was extracted from HARC design file
   - Temporal pattern – the ARR datahub temporal pattern extracted in the HARC design file
2. Losses – Losses specified in HARC report were used in the updated design modelling.
3. Using the inputs described above, RORB results were validated to those previously produced by the 2018 HARC modelling.

The updated RORB model results were validated against the 2018 design modelling using a hydrograph for the 24hr, 1% AEP event, comparing hydrographs at Wondocka, as shown in Figure 4-3. To account for the addition subareas included in RORB during calibration modelling, slight adjustments were made to the selected Spatial Pattern and the adopted design parameters from HARC were adjusted as summarised in .

TABLE 4-4 SUMMARY OF THE PARAMETERS ADOPTED FOR DESIGN MODELLING IN RORB

Gauge	kc	m	IL (mm)	CL (mm/h)
225221 Macalister River@Stringy Creek	62	0.8	20	2.5
225204 Macalister River@Lake Glenmaggie	23	0.8	20	1.5
225231 Thomson River@Cowwarr Weir	70	0.8	20	1
Dummy (DS of StoneyCk, BackCk, Two-MileCk)	27*	0.8	20	2.5
225212 Thomson River@Wondocka	32*	0.8	20	2
226005 Latrobe River@Thoms Bridge	80	0.8	20	1.5
226228 Latrobe River@Rosedale	68	0.8	20	1.5
Catchment outlet	75	0.8	20	1.5

*K_c was scaled based on the original K_c = 50 and average flow distance = 26.48km

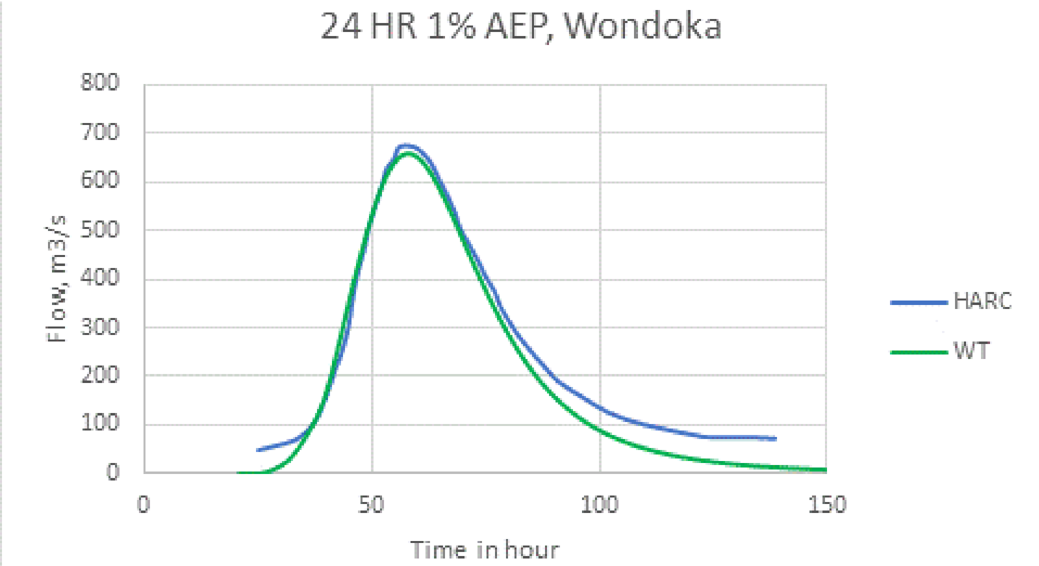


FIGURE 4-3 HARC AND WATER TECHNOLOGY COMPARISON (WONDOCKA GAUGE - 1% AEP 24 HOUR)

4.5.2 Design hydrographs

The updated RORB model for this study was run to produce design flood hydrographs for the 0.5%, 1%, 2%, 5%, 10%, 20% and 50% AEP flood events at key locations (u/s Cowwarr Weir, Stoney Creek and tributaries).

A Monte Carlo simulation was ran and the critical duration of 24-hour was found across all the AEP events.

Ensemble runs for each AEP were then undertaken to select the appropriate Temporal Patterns that produce peak flows at U/S Cowwarr Weir gauge that match those values from the HARC report. A summary of the peak flow comparison at U/S Cowwarr Weir gauge between the 2019 and updated study is shown in the Table 4-5 along with the corresponding Temporal Patterns used for the design modelling. A peak flow comparison at the U/S of Cowwarr Weir gauge using the determined FFA flows, is shown in Figure 4-4.

TABLE 4-5 COMPARISON OF DESIGN PEAK FLOWS AT U/S COWWARR WEIR GAUGE

AEP	RORB (HARC 2019) (m^3/s)		FFA (HARC 2019) (m^3/s)		Updated Deign Modelling (WT 2021)		
	With baseflow	Without baseflow	With baseflow	Without baseflow	MC (m3/s)	Adopted Design Flows (m^3/s)	TPs
20%	-	-	-	-	336	336	TP3
10%	424	412	-	-	445	413	TP7
5%	582	567	604	589	574	582	TP9
2%	750	730	860	840	764	748	TP3
1%	930	906	1088	1064	894	908	TP1
0.5%	-	-	1351	1315	1033	1036	TP1

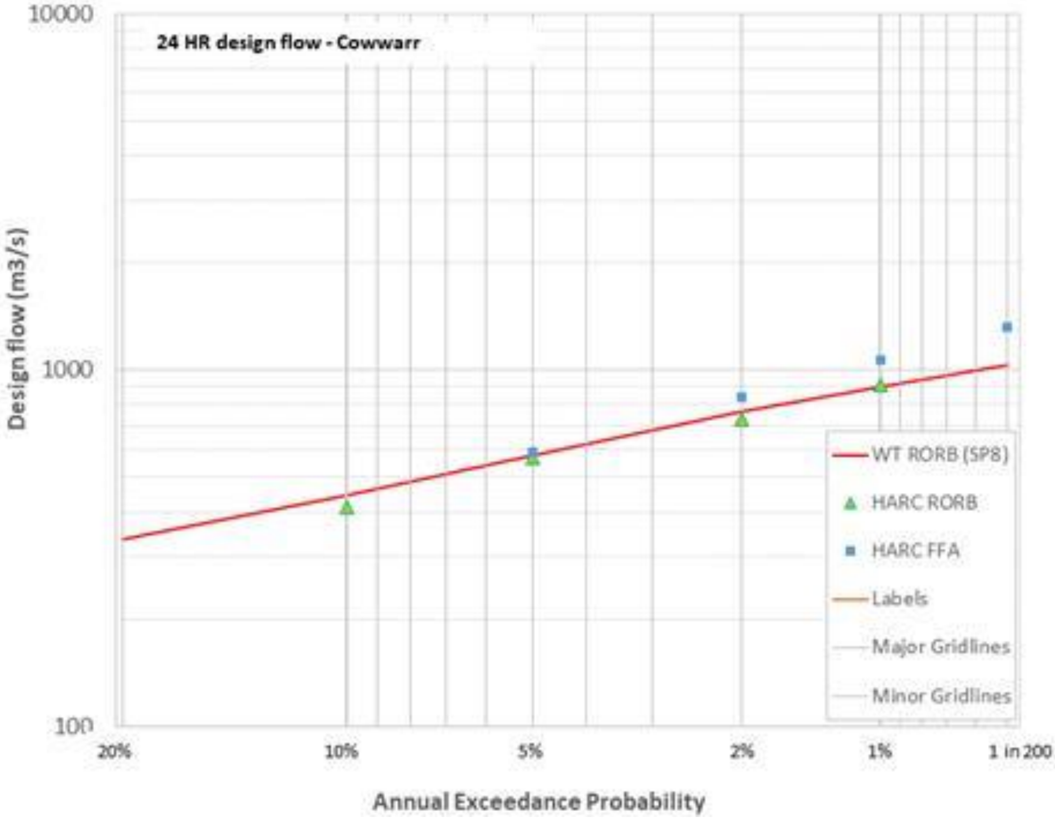


FIGURE 4-4 PEAK FLOW COMPARISON WATER TECHNOLOGY 2021 AND HARC 2018

4.5.3 PMF Estimates

The Probable Maximum Flood (PMF) is defined as a flood generated by the most severe combination of critical meteorological and hydrologic conditions. The PMF was generated from Probable Maximum Precipitation (PMP), under the worst catchment conditions that can be reasonably expected to occur based on the recommendations provided in Book 8 of ARR 2019.

The PMF assessment was undertaken using the developed RORB model with the following assumptions:

4. Thomson Dam is initially at FSL.
5. Initial loss is 0 mm and the continuing loss is 1 mm/h.
6. The temporal pattern chosen selected from the Monte Carlo sample to maximise the outflow.

4.6 Probable Maximum Flood (PMF)

The Probable Maximum Precipitation (PMP) was estimated using the GSAM approach for PMF estimation in accordance with ARR2019. GSAM suggests that the PMF would occur in between 24-hour to 72-hour event durations. The PMP estimates curve derived for the Upper Thomson River catchment is displayed in Figure 4-5

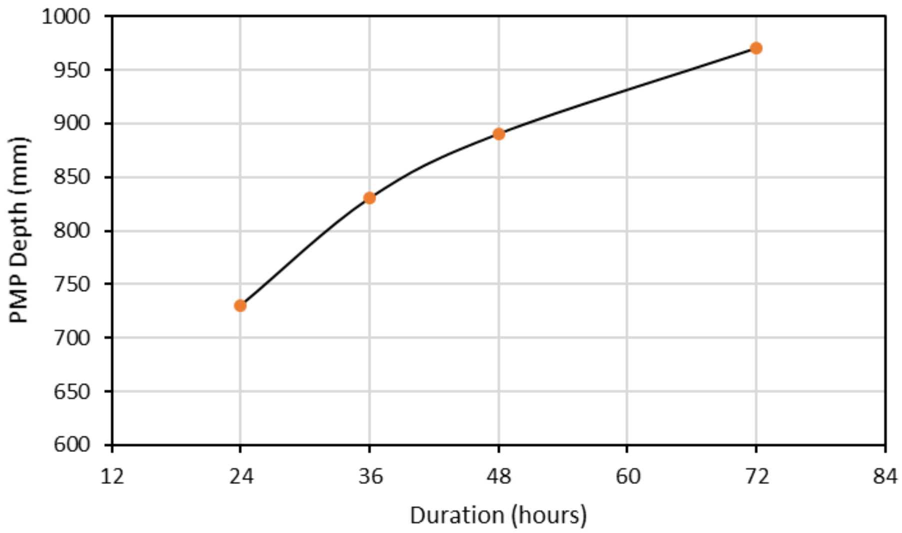


FIGURE 4-5 GSAM PMP ESTIMATES CURVE

The following conditions were applied in the RORB model to produce the PMF hydrographs as agreed with WGCMA and Table 4-6 shows the corresponding peak flows for each PMF event duration. The critical duration of the PMF is 24-hour and the inflow hydrographs for this duration were extracted from RORB for the hydraulic model.

The Thomson Dam is initially at FSL

Initial loss is 0 mm and the continuing loss is 1 mm/h.

Temporal pattern 10 was used and found to produce maximum the outflow.

TABLE 4-6 SUMMARY OF PEAK FLOWS AT KEY LOCATIONS FOR PMF EVENTS

Duration (hour)	Rainfall (mm)	225231 U/S Cowwarr Weir (m^3/s)	225212 Wondocka (m^3/s)
24*	730	6920	7818
36	830	4406	5024
48	890	3804	4465
72	970	2337	2992

*Critical duration for Upper Thomson catchment

4.7 Sensitivity Testing

4.7.1 Storage Drawdown

The median storage level of 429.2 m AHD in Thomson Dam was used in the updated design hydrologic modelling. This is consistent with that specified in the 2018 HARC report and provides a suitable match with the FFA determined flows at the Wondoka and Cowwarr gauging stations.

4.7.2 Spatial Patten

Sensitivity of the 10 spatial patterns was tested, the peak flow which matched closest to the HARC 2018 peak flow at U/S Cowwarr Weir gauge was attained by using the spatial pattern number 8.

4.7.3 Climate Change

Climate change modelling was completed in accordance with the ARR2019 recommended increases to design rainfall intensity. ARR2019 offers advice on increased design rainfall intensities associated with a range of climate change scenarios. Projected changes from Global Climate Models (GCMs) can be explored for fourteen 20-year periods and the four Representative Concentration Pathways (RCPs) for greenhouse gas and aerosol concentrations that were used to drive the GCMs. The RCPs are designated as 2.6, 4.5, 6.0 and 8.5, and are named according to radiative forcing values (W m-2) in the year 2100 relative to pre-industrial values. Use of RCP 8.5 (high concentrations) was recommended for this assessment.

The study area is in the 'Southern Slopes Mainland' NRM 'cluster. The ARR2019 data hub indicates design rainfall intensities will increase in the order of 16.3% for the RCP8.5 scenario for 2090 in the Thomson River catchment. The recommended climate change factors are highlighted in Table 4-7.

TABLE 4-7 INTERIM CLIMATE CHANGE FACTOR (SOURCE: HTTP://DATA.ARR-SOFTWARE.ORG/)

Projected Year	RCP 4.5	RCP 8.5
2030	0.648 (3.2%)	0.811 (4.0%)
2050	1.081 (5.4%)	1.446 (7.3%)
2090	1.496 (7.6%)	3.090 (16.3%)

The design RORB model was rerun with the climate change rainfall intensity along with the adopted design parameters. Table 4-8 shows the impact of the climate change scenario on design flows at the U/S of Cowwarr Weir gauge and the Wandocka gauge, both with an increase in peak flow of around 25%.

TABLE 4-8 COMPARISON OF DESIGN FLOWS UNDER CLIMATE CHANGE AT KEY LOCATIONS

Location	Flow (m3/s)		
	1% AEP - Existing	1% AEP – Climate change	Difference
225231 Cowwarr	908	1122	24%
225212 Wandocka	966	1208	25%

4.7.4 Bushfire

Over 90% of the Thomson River catchment is forested. Work to establish bushfire impacts on the upper Thomson River catchment was completed in the Lower Thomson Flood Study (HARC, 2019). This was achieved by introducing a changed runoff co-efficient as detailed in Burned Area Emergency Response report

(BAER, 2009), using the ratio of the burnt runoff coefficient to the unburnt runoff coefficient, the proportion of unburnt catchment losses can be estimated and the burnt catchment IL and CL values can be calculated. Table 4-9 shows the runoff coefficient determined in the Lower Thomson Flood Study (HARC, 2019). The RORB model was rerun using the burnt catchment losses to produce inflow hydrographs for TUFLOW to assess the bushfire impacts. The calculated burnt catchment losses compared with unburnt catchment losses are shown in Table 4-10. The impacts of bushfire on design flows at U/S Cowwarr Weir and Wondocka gauge are summarised in Table 4-11 with an increase in peak flows between 10-20% at the two gauges.

TABLE 4-9 RUNOFF COEFFICIENT FOR BURNT AND UNBURNT CATCHMENT AT EACH GAUGE LOCATIONS (HARC 2019)

Gauge locations	Equivalent runoff coefficient - current catchment conditions (unburnt)	Equivalent runoff coefficient -with burnt forest areas (burnt)
Macalister River @ Stringy Creek	0.61	0.94
Macalister River @ Lake Glenmaggie	0.8	0.94
Thomson River @ Cowwarr Weir	0.87	0.95
Thomson River @ Wondocka	0.66	0.91
Thomson River @ Bundalaguah	0.74	0.91
Latrobe River @ Thoms Bridge	0.62	0.77
Latrobe River @ Rosedale	0.68	0.79
Remaining catchment	0.68	0.74

TABLE 4-10 BURNT AND UNBURNT CATCHMENT LOSSES

Gauge locations	IL (unburnt)	CL (unburnt)	IL (burnt)	CL (burnt)
Macalister River at Stringy Creek	20	2.5	3.1	0.4
Macalister River at Lake Glenmaggie	20	1.5	6.3	0.5
Thomson River at Cowwarr Weir	20	1	8.1	0.4
Dummy (DS of StoneyCk, BackCk, Two-MileCk)	20	2.5	5.3	0.7
Thomson River at Wondocka	20	2	5.3	0.5
Latrobe River at Thoms Bridge	20	1.5	12.3	0.9
Latrobe River at Rosedale	20	1.5	13.1	1
Catchment outlet	20	1.5	16.5	1.2

TABLE 4-11 COMPARISON OF DESIGN FLOWS UNDER BUSHFIRE AT KEY LOCATIONS

Location	Flow (m3/s)		
	1% AEP - Existing	1% AEP – Bushfire	Difference
Cowwarr	908	11,052	16%
Wandocka	966	1,169	21%

5 HYDRAULICS

5.1 Modelling Approach

An existing TUFLOW model was developed during the Thomson Waterway Management Plan (TWMP) (Water Technology, 2020), this model was used as starting base model for this project and was modified to provide additional detail where required. The model represented waterways and floodplains in 2D using the available LiDAR and bathymetry datasets, 2D shapes representing waterway structures and 1D pipes/culverts where appropriate. The model used a 2 m resolution (discussed further in Section 5.2) and inflows from the RORB modelling (detailed in Section 5.5).

The general layout of the TUFLOW model is shown in Figure 5-1.

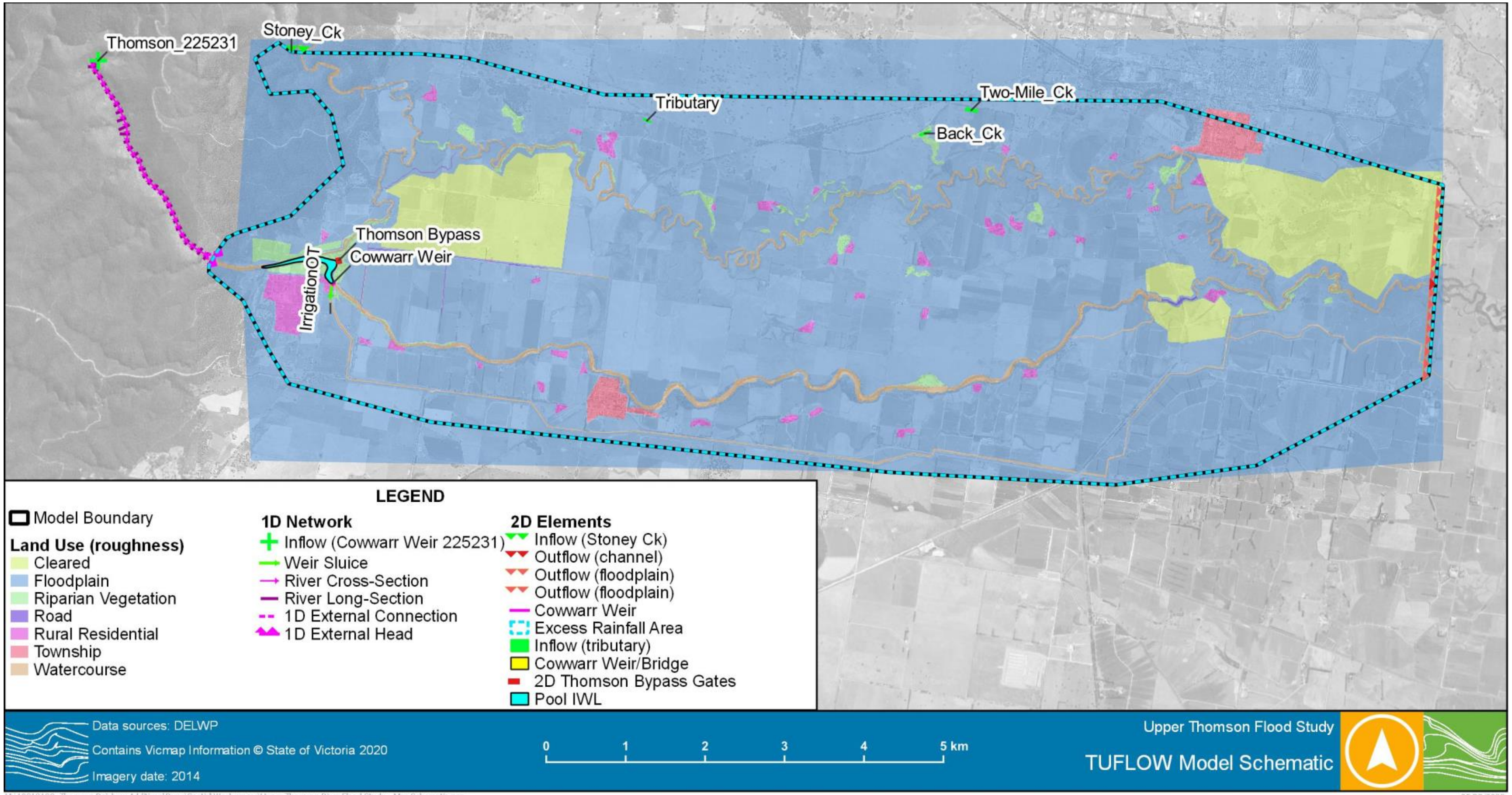


FIGURE 5-1 TUFLOW MODEL SCHEMATIC

5.2 Topography

The 2018 LiDAR datasets were adopted to create the model topography for all modelling events. In addition, the bathymetry data was used to refine the channel topography from the section of Thomson River at Cowwarr Weir to the U/S of Cowwarr Weir gauge.

5.3 Waterway Structures

5.3.1 Bridges and Culverts

The TWMP TUFLOW model was 2D only, with bridges represented within the LiDAR based topography. To improve model's representation of topographic and hydraulic conditions, hydraulic structures were included as either 1D elements or 2D layered flow constrictions.

Structural plans were supplied by VicRoads and Wellington Shire Council for six bridges and culverts in PDF format. Of the structures identified, eleven were missing data (further detail surrounding these structures is discussed in Section 3.3.4).

5.3.2 Thomson River Bywash

The Thomson Bywash inflow from the weir pool is represented by three topographic (Z-shape) features in the TUFLOW model:

- 2D Z-shape which represents the flood gates closed (100% blockage).
- 2D variable Z-shape to represent the flood gates at 0% channel blockage (open gates).
- 2D layered flow constriction imposed by three main vertical layers (the pier supports below the deck; the deck itself; and the railing above the deck).

A '*trigger point*' located 3 m upstream of the gates which measures the water level in the weir pool. When the water level exceeds 65.55 m AHD, the variable Z-shape removes the structure (representing 0% blockage), and the gates in an open position.

Survey levels were reviewed for the Cowwarr Weir surrounds including the bridge over the Thomson River Bywash. The survey levels of the road suggest a deck level of 66.26 m AHD, however neighbouring topography (on the bridge approaches) varies up to 66.46 m AHD). To ensure to road bridge was well-represented in the model a conservative estimate of 66.50 m AHD was adopted for the road crown level. The dimensions of the flood gates and frame were estimated based on visual inspection of historic photography. A summary of the model elements for the bywash are shown in Table 5-1.

Since the model is intended to measure maximum flood levels, once the gates are triggered to an 'open' state, they are assumed to stay open for the remainder of each event.

TABLE 5-1 DIMENSIONS AND LEVELS ADOPTED FOR THOMSON RIVER BYWASH

Element	m AHD	m	Blockage
Gate/Bridge Invert	64.42		
Gate Obvert	65.55		
Gate Envelopes (w) x 8		1.00	
Gate Supports (w) x 3		0.30	
Bridge Side walls (w) x 2		1.00	
Bridge Deck Obvert (underside)	66.00		
Bridge Deck Crown	66.50		
Blockage Below Deck			27%
Blockage at Deck			100%
Blockage Above Deck			5%

5.3.3 Cowwarr Weir

Discharge of flows from the pool to downstream of the weir, is controlled by the vertical position of gates at the weir. The gate positions are "*correlated to the rise in pool level above FSL and by a Programmable Logic Controller (PLC) which monitors and controls the levels of the pool*" (SRW 2019). A table of gate opening intervals was analysed from the Eastern Storages Flood Plan 2019. The table indicates Flood Classification Levels at specific discharge rates for the Thomson River @ U/S Cowwarr Weir streamflow gauge which we have adopted to determine 'triggers' for weir discharge rates in the model. It is thought the degree of influence the gates have over flood levels during infrequent events may be negligible, however more frequent floods (i.e. 50%, 20% AEP) may be more sensitive to changes in gate levels. To this end, a strategy to represent the operational program of flow discharge to Rainbow Creek in the TUFLOW model was developed.

The gate openings levels were primarily based on holding a constant water level in the Weir pool at 65.0 m AHD, and are a function of flowrate, measured upstream at the Thomson River @ U/S Cowwarr Weir streamflow gauge. The adopted modelling approach addresses a linkage between flows at the gauge site, and discharge rates at the weir. Flowrates are metered at the intersecting cross-section at 225231 U/S Cowwarr Weir and a 1D element at the spillway gates transfers a (variable) flowrate from upstream to downstream of the weir based on the PLC.

A 1D river channel was developed from the 225231 U/S Cowwarr Weir streamflow gauge, through to the edge of the 2D model boundary (1 km upstream of Cowwarr Weir). The river channel was represented by topographic cross-sections at 100 m intervals, including an intersection at the 225231 U/S Cowwarr Weir gauging site. Flows were delivered to a 1D inflow node just upstream of the gauge site, carried through the channel and connected to the 2D model boundary.

Several topographic (Z-shape) elements and 1D controls comprise the weir and spillway gates at Cowwarr Weir:

- 1D structure with operating controls to adjust flow rates (transfers flows from upstream of the gates, to downstream representing the sluice).
- 2D Z-shape (spillway gates in closed position; 100% blockage).
- 2D variable Z-shape (spillway gates in fully raised position).
- 2D layered flow constriction (weir piers, road bridge and railing; downstream of spillway gates).

- 2D layered flow constriction (weir piers and railing on upstream side of bridge).

The dimensions of these features and their impacts on flow constriction is shown in Table 5-2.

It was assumed if water levels reach 66.0 m AHD in the weir pool, the gates would be in a fully open positioned as per manual operation protocol. In addition, the gate operation table suggests gates should be fully raised if flows reach or exceed 60,000 ML/d (694.4 m^3/s). Since the model is intended to measure maximum flood levels, the gates are assumed to stay in an open position for the remainder of each model run (i.e. do not close as flows recede below 60,000ML/d). A summary of the model controls between the upstream gauge level and Cowwarr Weir discharge rates is shown in Table 5-3. For example, when the flowrate reaches 92.6 m^3/s at 225231 U/S Cowwarr Weir (beginning of moderate flood condition), 42.8 m^3/s are discharged via the spillway gate element at Cowwarr Weir. Gate discharge rates have been calculated by the minimum range value from the gate operating table.

Table 5-2 Dimensions and levels adopted for Cowwarr Weir

Element	m AHD	m	Blockage
Bridge Deck Obvert	66.79		
Bridge Deck Crown	67.47		
Bridge Road (w)		3.66	
Bridge Road (d)		0.69	
Piers x 2 (w)		1.52	
Bridge Flow Constriction (below deck)			14%
Bridge Flow Constriction (deck)			100%
Bridge Flow Constriction (above deck)			7%
Spillway gate x 3 (w)		6.40	
Spillway gate (h)		6.48	
Spillway gate Invert (closed)	58.78		
Spillway gate Obvert (closed)	65.26		
Spillway gate (d)		0.61	
Spillway gate Obvert (max-open)	73.42		
Spillway gate Flow Constriction (closed)			100%

TABLE 5-3 MODEL OPERATIONAL CONDITIONS FOR DISCHARGE RATES AT COWWARR WEIR

Step	Flood Condition	225231 U/S Cowwarr Weir		Spillway gate Discharge		
		ML/d	m3/s	ML/d	m3/s	% of flow[!]
01	Sub-Minor	0	0.0	0	0.0	0%
02	Sub-Minor	1,143	13.2	373	4.3	33%
03	Sub-Minor	2,286	26.5	931	10.8	41%
04	Sub-Minor	3,429	39.7	1,488	17.2	43%
05	Sub-Minor	4,571	52.9	2,042	23.6	45%
06	Sub-Minor	5,714	66.1	2,594	30.0	45%
07	Sub-Minor	6,857	79.4	3,145	36.4	46%
08	Minor	8,000	92.6	3,694	42.8	46%
09	Minor	9,538	110.4	4,241	49.1	44%
10	Minor	11,075	128.2	4,786	55.4	43%
11	Minor	12,613	146.0	5,329	61.7	42%
12	Minor	14,150	163.8	5,870	67.9	41%
13	Minor	15,688	181.6	6,409	74.2	41%
14	Minor	17,225	199.4	6,947	80.4	40%
15	Minor	18,763	217.2	7,482	86.6	40%
16	Moderate	20,300	235.0	8,016	92.8	39%
17	Moderate	21,569	249.6	8,548	98.9	40%
18	Moderate	22,838	264.3	9,780	113.2	43%
19	Moderate	24,106	279.0	11,351	131.4	47%
20	Moderate	25,375	293.7	12,906	149.4	51%
21	Moderate	26,644	308.4	14,444	167.2	54%
22	Moderate	27,913	323.1	15,965	184.8	57%
23	Moderate	29,181	337.7	17,469	202.2	60%
24	Moderate	30,450	352.4	18,958	219.4	62%
25	Moderate	31,719	367.1	20,429	236.4	64%
26	Moderate	32,988	381.8	21,885	253.3	66%
27	Moderate	34,256	396.5	23,324	270.0	68%
28	Moderate	35,525	411.2	24,747	286.4	70%
29	Moderate	36,794	425.9	26,153	302.7	71%
30	Moderate	38,063	440.5	27,544	318.8	72%
31	Moderate	39,331	455.2	28,918	334.7	74%
32	Major	40,600	469.9	30,276	350.4	75%
33	Major	42,756	494.9	31,619	366.0	74%
34	Major	44,911	519.8	33,667	389.7	75%
35	Major	47,067	544.8	36,255	419.6	77%
36	Major	49,222	569.7	38,780	448.8	79%
37	Major	51,378	594.7	41,242	477.3	80%
38	Major	53,533	619.6	43,643	505.1	82%
39	Major	55,689	644.5	45,981	532.2	83%
40	Major	57,844	669.5	48,259	558.6	83%
41[#]	**Extreme Flood**	**60,000**	**694.4**	**GATES CLEAR**		

[#]Final step added for modelling purposes, based on operational protocol.
***225231 U/S Cowwarr Weir** flowrate intervals based on linear interpolation between known Flood Classification Levels at minor, moderate and major, and the 'extreme' flood level as outlined in the Eastern Storages Flood Plan 2019.
***Gate Discharge** flowrate based on the minimum range value adopted from the gate opening table .
[!]Percentage estimates excludes the inputs from catchments downstream of Upstream of Cowwarr Weir Gauging Station.

5.3.4 Cowwarr Irrigation Offtake

The irrigation channel offtake at Cowwarr Weir is managed by Southern Rural Water and its flow diversion was represented in the hydraulic model by a 1D pipe structure. The inlet is located on the south-west wall of the weir, adjacent the weir spillway gates. Flow will be carried ~180 m south to the outlet on the upstream end of the irrigation channel.

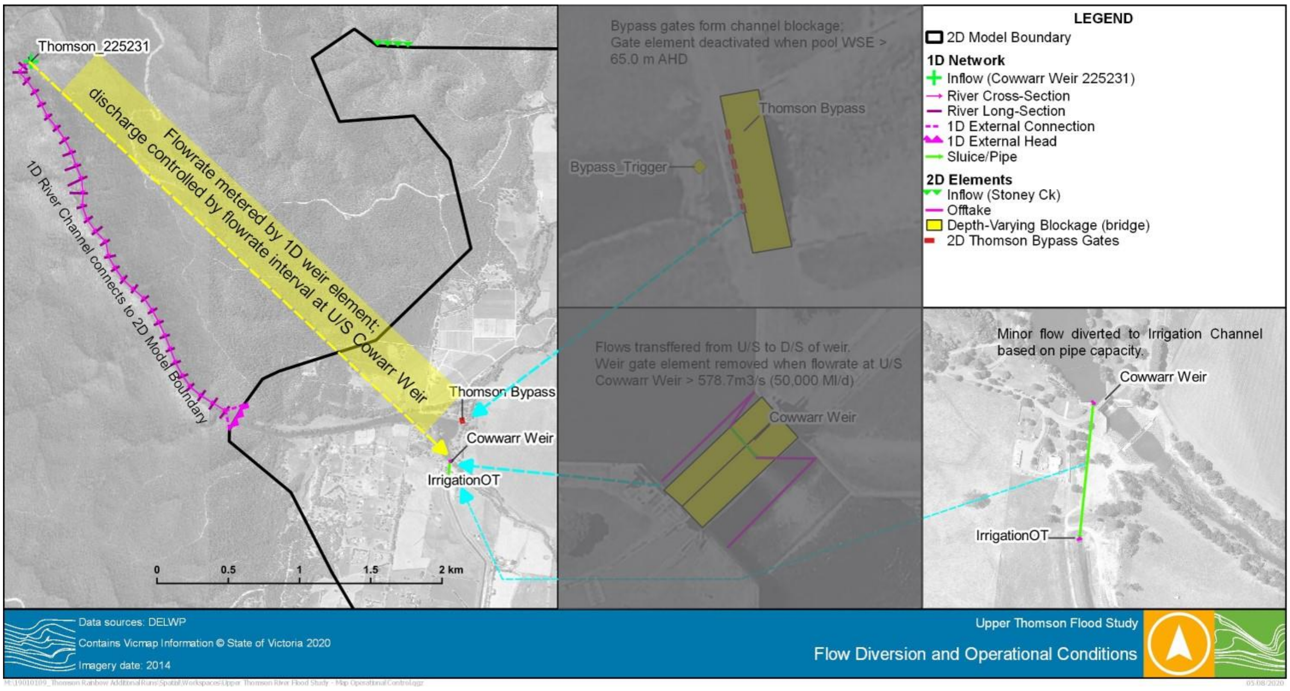


FIGURE 5-2 TUFLOW MODELLING SCHEMATIC - COWWARR IRRIGATION OFFTAKE

It has been assumed the channel has a maximum capacity of 950 ML/d (11.0 m^3/s). During low flow conditions diversion rates are based on irrigation demand and not linked to inflows. For the purpose of the model schematisation, it was assumed the offtake would be operating at full capacity during flood events. Similar to the weir linkage to the gauge at 225231 U/S Cowwarr Weir, the offtake was assumed to be inactive during low-flow conditions (sub-*minor* flows). Once *minor* flows are recognised at the 225231 U/S Cowwarr Weir site (92.6 m^3/s), the offtake 1D element activates with a steady flowrate of 11.0 m^3/s; and deactivates again once flows return to sub-minor levels at 225231 U/S Cowwarr Weir.

5.4 Hydraulic Roughness

Channel and floodplain conveyance is highly impacted by hydraulic roughness. Surface roughness was represented using a Manning's 'n' coefficient based on the type of landcover or land use.

A hydraulic roughness layer was developed during the Thomson River Flood Study (Water Technology, 2011) and remained unchanged throughout the TWMP. The adopted land-use and assigned roughness values were also adopted for this study and are shown in Figure 5-3.

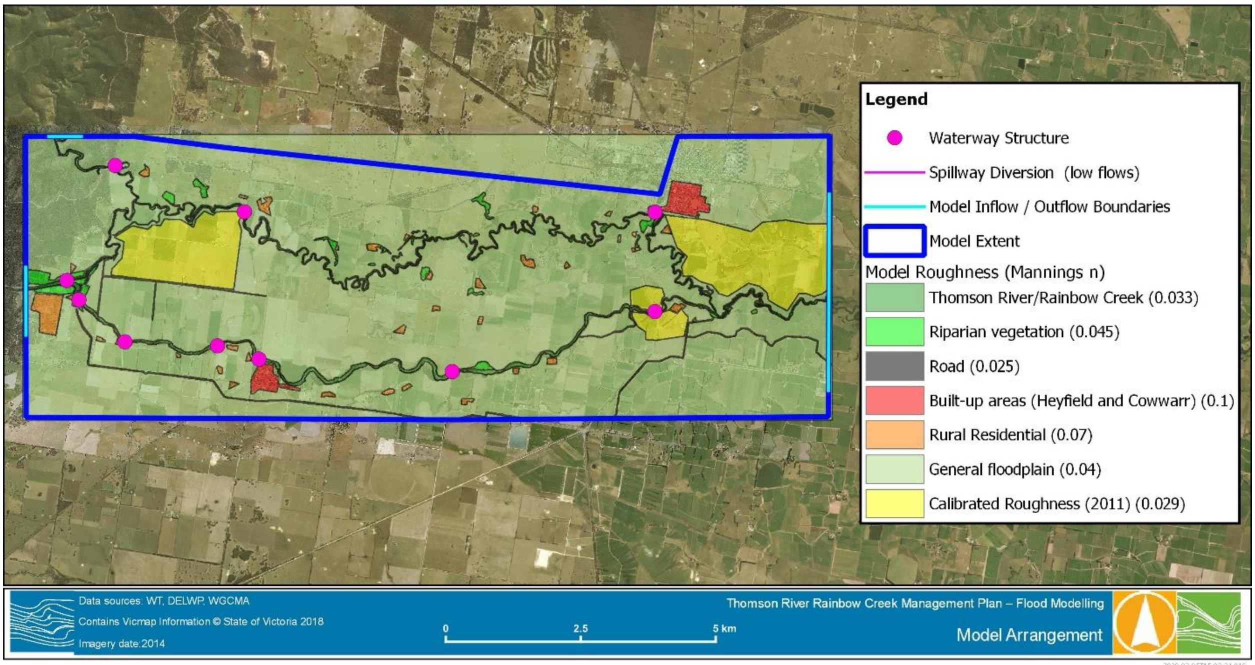


FIGURE 5-3 TUFLOW MODEL EXTENT & ROUGHNESS VALUES (MANNING'S N COEFFICIENT)

5.5 Boundary Conditions

During the TWMP two model inflow points were located upstream of the Cowwarr Weir and Stoney Creek. This project expanded these inflows to include three minor inflows: Back Creek, Two Mile Creek and an unnamed waterway from Dawson.

Downstream outflow boundaries were modelled as head vs flow (HQ), based on a generalised slope of the land running west to east, approximately 3 km downstream of Heyfield. The three boundaries (Figure 5-1) representing changes in slope on the northern and southern sides of the Thomson River, and in the river channel itself were:

- Outflow channel 0.0841 m/m
- Outflow north 0.1025 m/m
- Outflow south 0.2037 m/m

5.6 Hydraulic Model Calibration

5.6.1 Overview

As discussed in Section 4.4, the 2007 flood event was used as the primary calibration event with 2012 and 2016 being used for further validation of the modelling. Calibration of the 2007 event was achievable given it was previously modelled in the existing RORB model developed as part of the Lower Thomson River Flood Study (HARC 2018) and inflows from smaller catchments (Stoney Creek, Back Creek, Two-Mile Creek) can be directly extracted for input into the hydraulic model.

With no RORB modelling results for 2012 or 2016 events, minor inflows were estimated by scaling the hydrographs to match the proportional difference from the 2007 event and retaining the lag of the peak flows (e.g. the Stoney Creek peaking 10 hours prior to the Thomson River). The scaled peak flows are summarised earlier in Table 4-3.

5.6.2 Calibration Results

5.6.2.1 June 2007

Table 5-4 summarises the 2007 event model calibration. Figure 5-4 to Figure 5-8 display the comparison of modelled and observed water level/flow hydrographs at the Thomson River at Heyfield, Rainbow Creek at Heyfield and Thomson at DS Rainbow Creek gauges. The modelled water level/flow hydrographs of the three gauges show a good match to gauged hydrograph shape.

The modelled peak water level at Thomson River at DS Rainbow Creek has a good match with the gauged shape. It is noted that the gauge zero is assumed at this location based on LiDAR levels. The modelled flood peak arrived 4.75 hours later than recorded and is 121 mm higher than the estimated peak flood level.

The modelled peak level for the Rainbow Creek at Heyfield streamflow gauge matches well to the gauged level (153 mm higher than recorded), and the general shape and timing also matches well. The modelled peak flow is higher than the recorded, but the shape matches well in general. This may indicate an issue with the gauge rating at high flows.

The modelled peak water level at Thomson River at Heyfield streamflow gauge matches well with the gauged level (79 mm higher than recorded), with a 1 hour difference in timing of peak levels. The modelled peak flow is much higher than recorded and has more volume coming through on the receding tail. Further analysis was undertaken at the gauged rating curve and comparison was made with the modelled results. Figure 5-9 shows the modelled rating curve and the gauged rating curve for the Thomson River at Heyfield gauge. There are a limited gaugings used to derive the existing gauged rating curve and flows above 10 m^3/s are extrapolated. The plot shows the gauged rating curve does not match the gauge ratings well and the high flows may be underestimated at the gauge.

TABLE 5-4 SUMMARY OF CALIBRATION PERFORMANCE FOR 2007 EVENT

Location	Peak Water level (m AHD)			Time to Peak		
	Gauge	Modelled	Diff (mm)	Gauge	Modelled	Diff (hrs)
Rainbow Creek @ Heyfield	38.94	39.09	153.1	224.00	228.25	4.25
Thomson River @ Heyfield	39.90	39.98	79.2	232.50	234	1.00
Thomson River @ DS Rainbow Creek	37.49	37.61	121.4	224.00	228.75	4.75

*Gauge zero for DS Rainbow Creek gauge is assumed to be 32 m AHD (TBC)

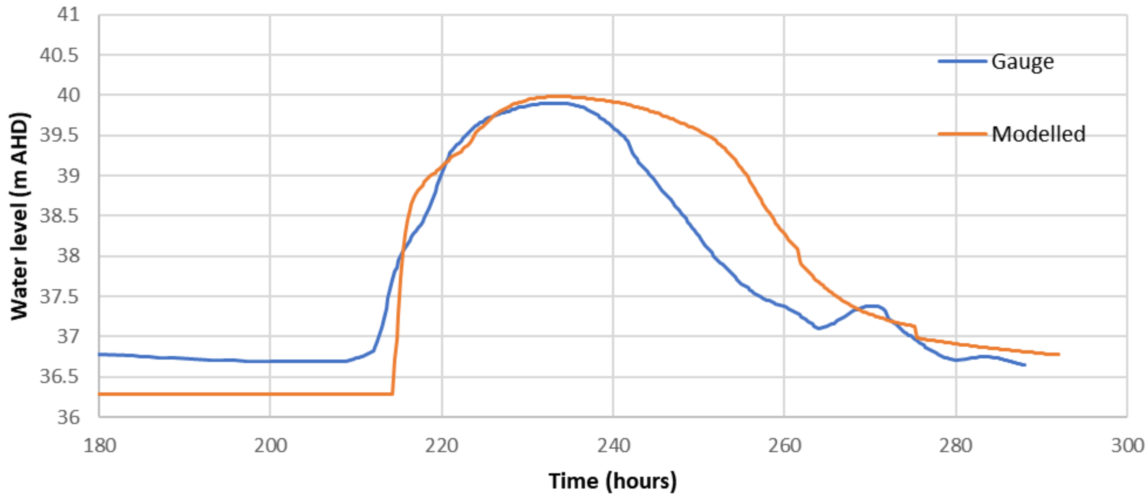


FIGURE 5-4 MODELLED AND GAUGED WATER LEVEL HYDROGRAPHS AT THOMSON RIVER @HEYFIELD

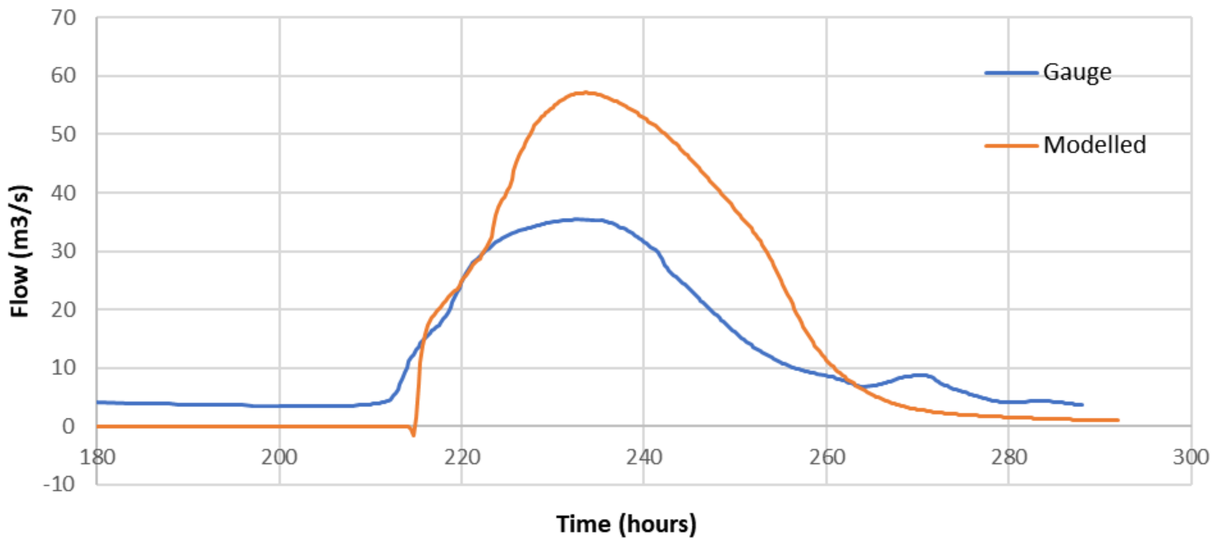


FIGURE 5-5 MODELLED AND GAUGED FLOW HYDROGRAPHS AT THOMSON RIVER @HEYFIELD

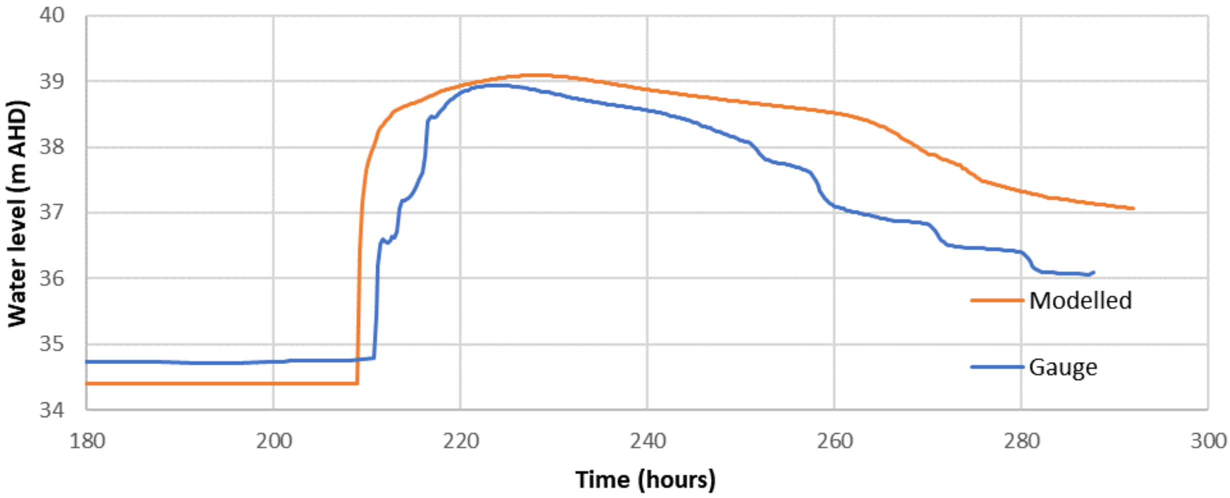


FIGURE 5-6 MODELLED AND GAUGED WATER LEVEL HYDROGRAPHS AT RAINBOW CK @HEYFIELD

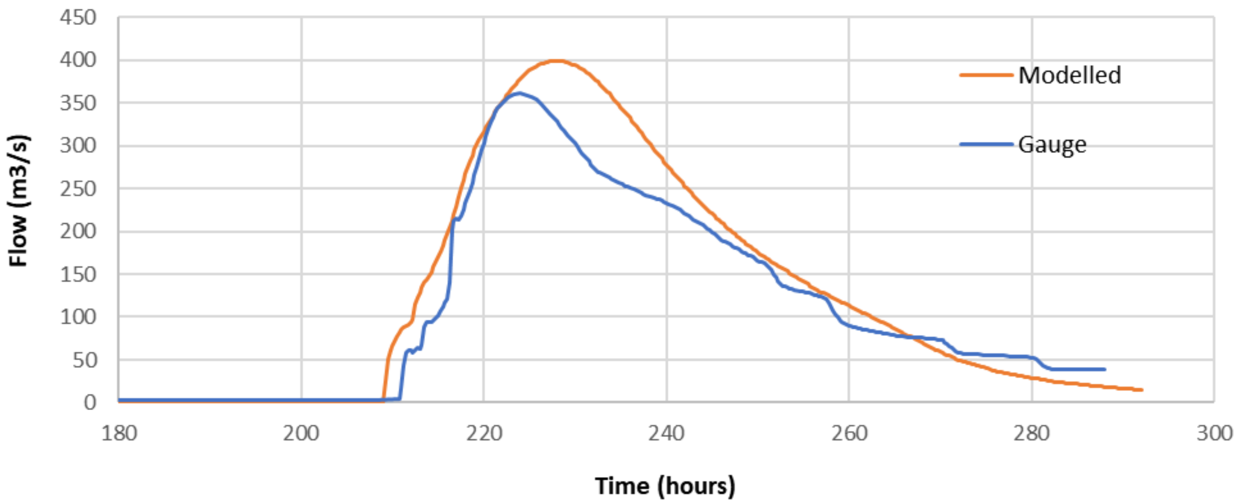


FIGURE 5-7 MODELLED AND GAUGED FLOW HYDROGRAPHS AT RAINBOW CK @HEYFIELD

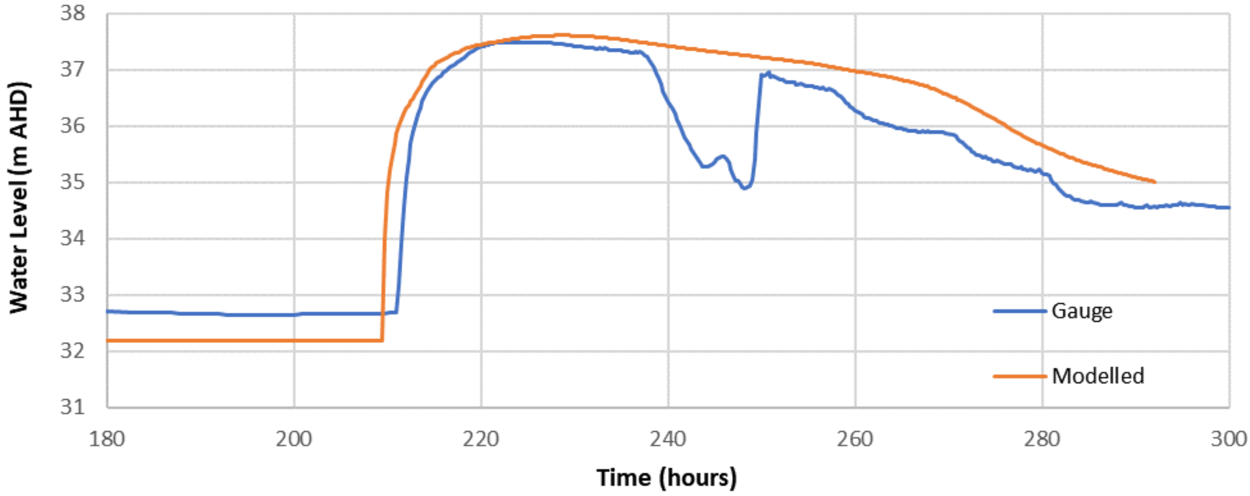


FIGURE 5-8 MODELLED AND GAUGED WATER LEVEL HYDROGRAPHS AT THOMSON RIVER @DS RAINBOW CK

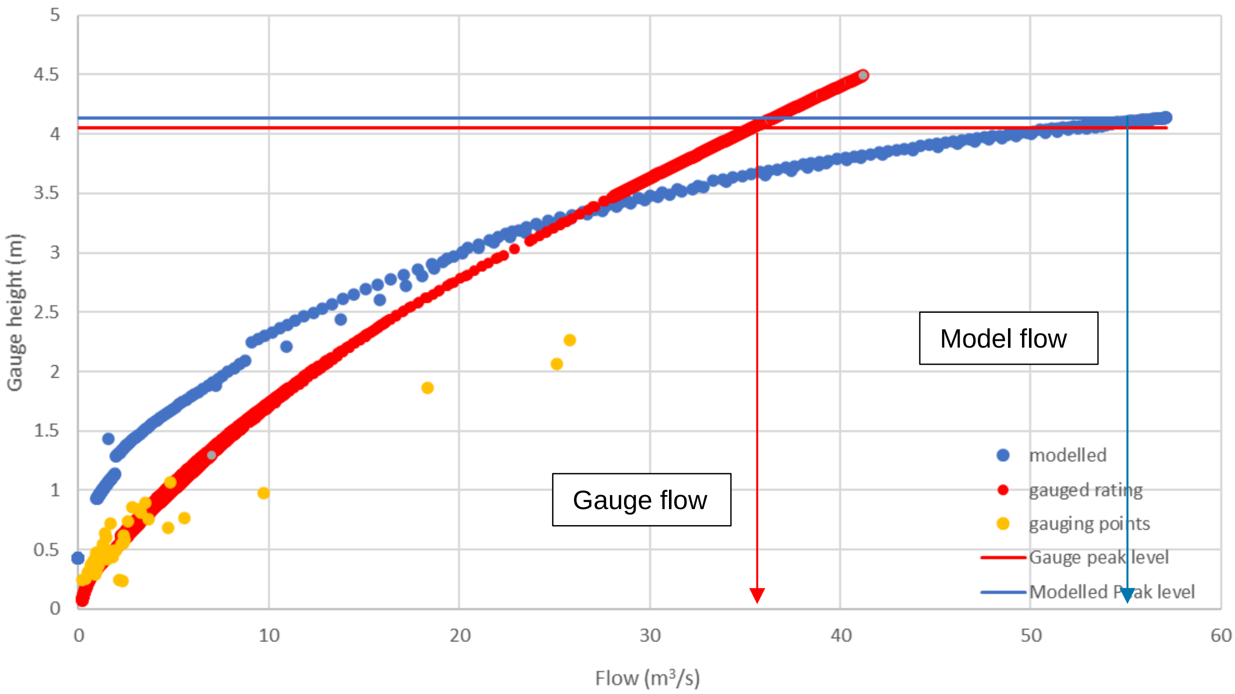


FIGURE 5-9 COMPARISON OF MODELLED AND GAUGED RATING

Figure 5-10 and Figure 5-11 display modelled depths, along with a comparison of modelled and observed water levels for the 2007 event. There are 4 flood marks outside of the modelled flood extent. For the remaining 19 flood marks, 10 are within 200 mm of the observed values. The modelled water levels at the downstream end of the model tend to be higher than that observed with two flood marks slightly above 200mm higher and one with a 700 mm difference (higher), it should be noted that this point is likely to be erroneous or may be a result of local runoff. There is one point showing the modelled level is 5 m lower than the observed value, also likely the result of an incorrect recorded level. The location of this flood mark is on the edge of the modelled extent and for the purposes of this study is assumed to be an extent mark rather than an accurate level mark. It is also assumed that all observed flood marks were captured at the peak of the event.

Overall, the model is replicating the flood behaviour of the 2007 event well. Modelled water levels/flows at the downstream gauges show a good match to recorded peak levels and timing and the comparison with the surveyed flood marks also indicate the model is replicating the flood extent and levels.

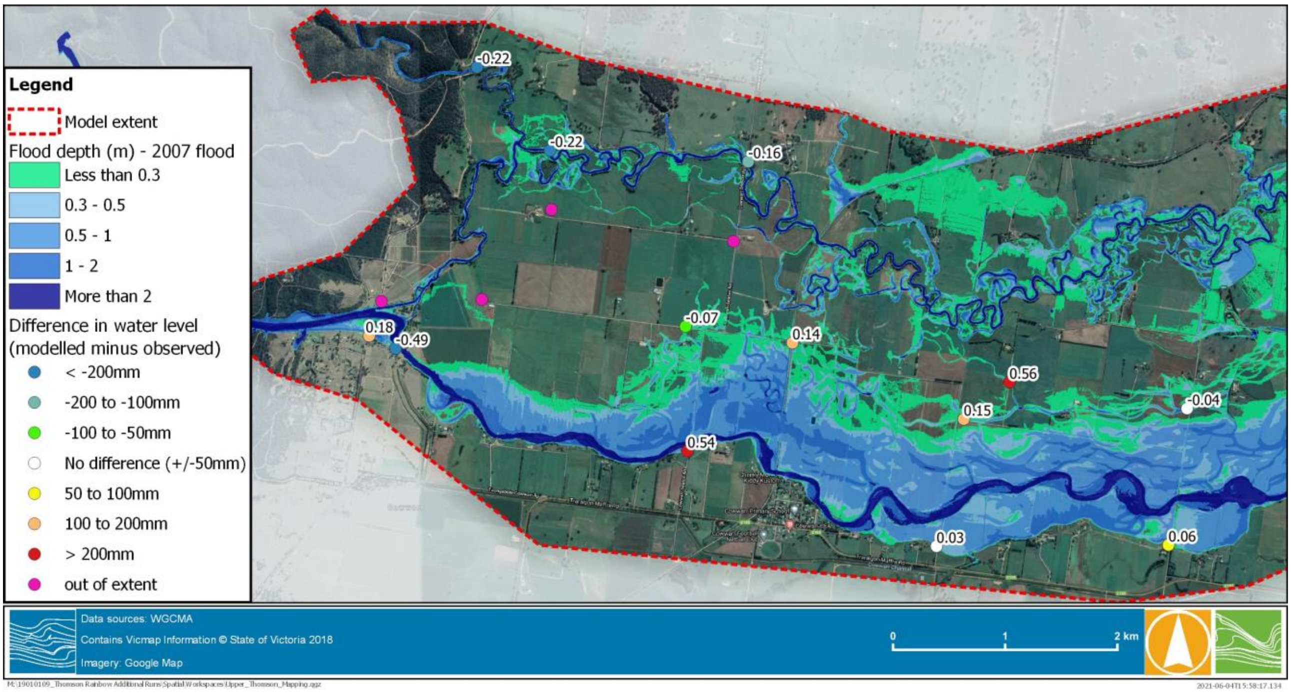


FIGURE 5-10 COMPARISON BETWEEN MODELLED AND OBSERVED FLOOD LEVELS - UPSTREAM

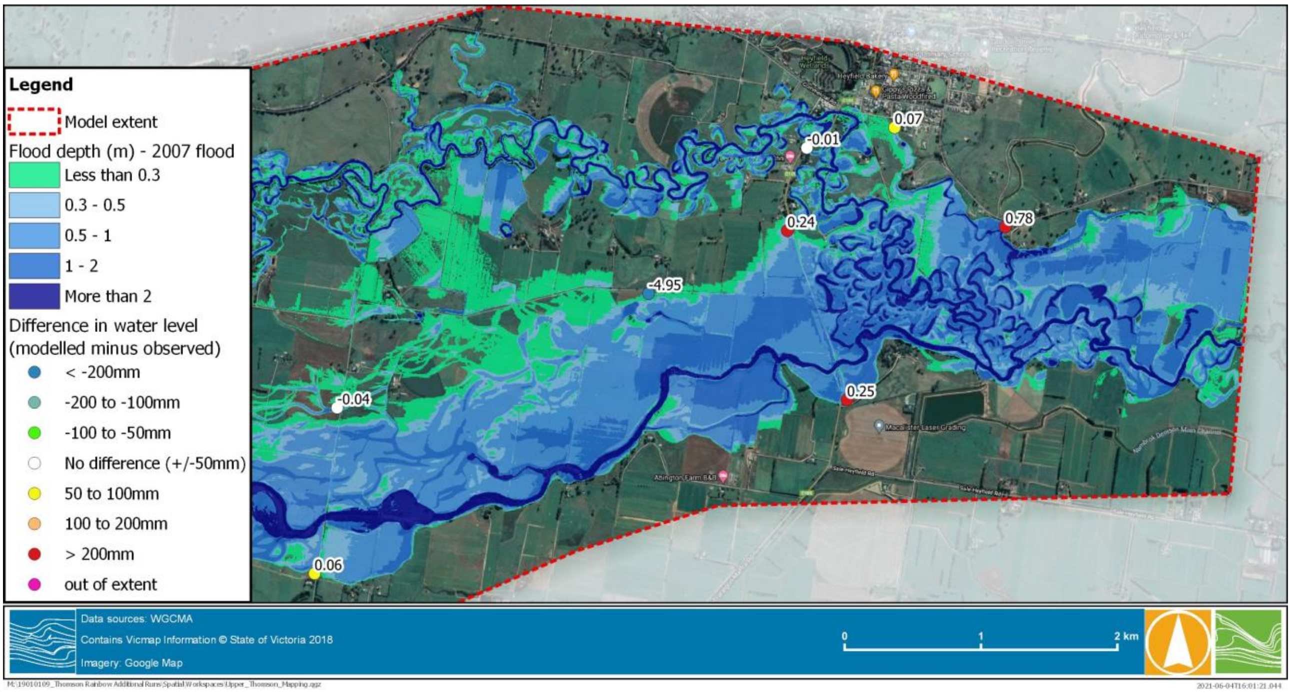


FIGURE 5-11 COMPARISON BETWEEN MODELLED AND OBSERVED FLOOD LEVELS - DOWNSTREAM

5.6.2.2 June 2012

Table 5-5 summarises comparison of modelled and observed gauge records for the 2012 flood event. Figure 5-12 to Figure 5-15 display the modelled water level hydrographs for the Thomson at Heyfield (Figure 5-13 shows the flow hydrograph), Rainbow Creek at Heyfield and Thomson at Rainbow Creek DS gauges respectively. The modelled water level hydrographs of the three downstream gauges show a good match to the gauged hydrographs in shape with the Thomson River at Heyfield providing a close fit to recorded gauge level (115 mm lower). The modelled peak arrives 11 hours earlier than that observed. The modelled peak flow is also significantly higher than the gauged peak. This is likely the result of uncertainty in gauged rating curve and high flows are being underestimate at the gauge as previously identified.

The peak water levels at Rainbow Creek at Heyfield and Rainbow Creek at DS Rainbow Creek gauges are between 125-150 mm lower than the recorded values. The modelled water level hydrographs match the shape well in comparison to the recorded hydrographs with less than 3 hours differences in timing of peak.

Overall, the modelled water level hydrographs at these downstream gauges show a good match to the gauge data.

TABLE 5-5 SUMMARY OF CALIBRATION PERFORMANCE FOR 2012 EVENT

Location	Peak Water level (m AHD)			Time to Peak		
	Gauge		Diff (mm)	Gauge	Modelled	Diff (hrs)
Rainbow Creek @ Heyfield	39.08	38.93	-150.0	33.25	32.00	-1.25
Thomson River @ Heyfield	40.20	40.09	-114.8	35.00	23.75	-11.25
Thomson River @ DS Rainbow Creek	37.59	37.47	-124.8	35.00	32.25	-2.75

*Gauge zero for DS Rainbow Creek gauge is assumed to be 32 m AHD (TBC)

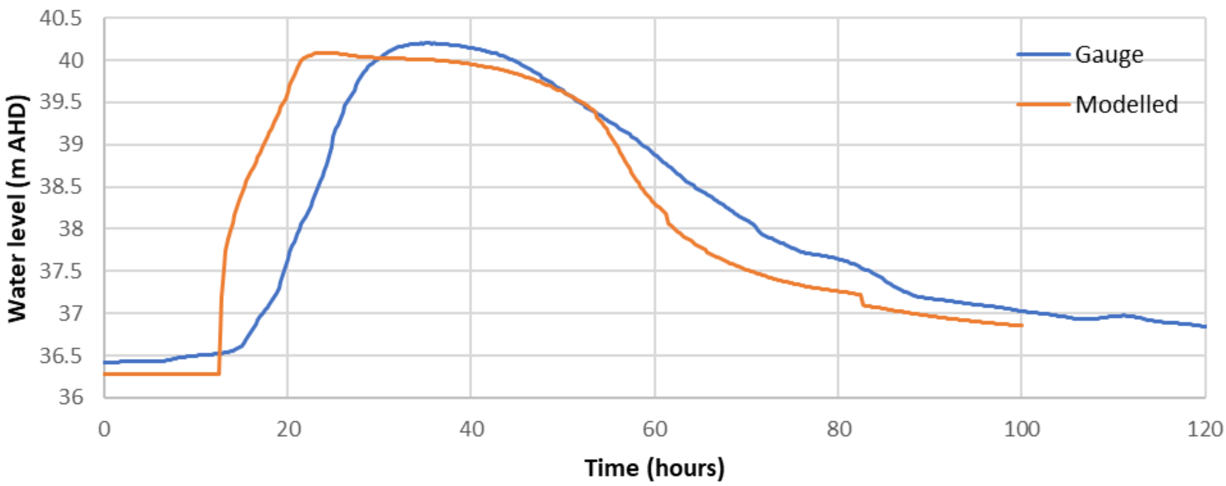


FIGURE 5-12 MODELLED AND GAUGED WATER LEVEL HYDROGRAPHS AT THOMSON RIVER @ HEYFIELD

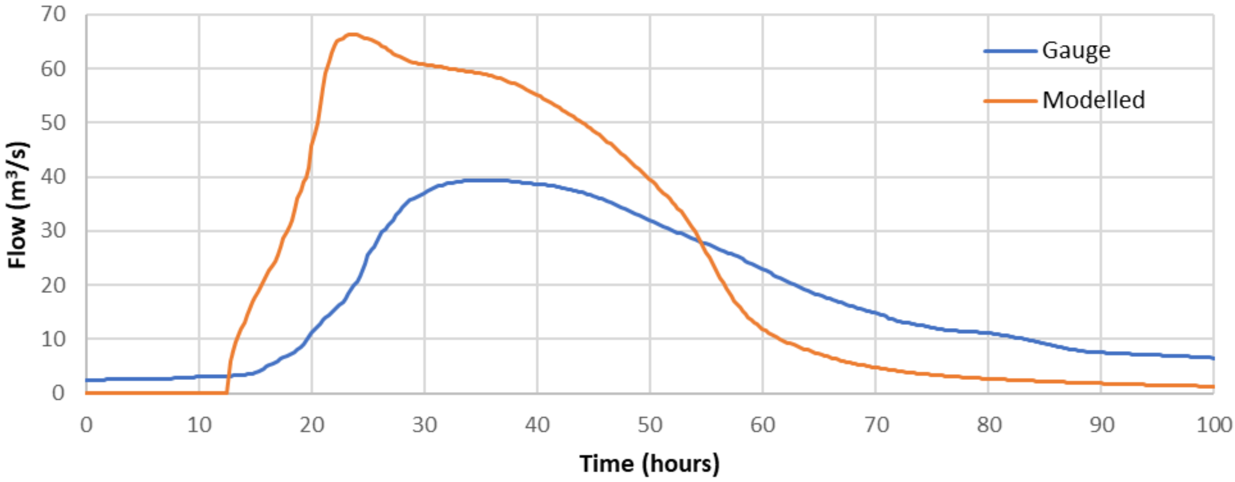


FIGURE 5-13 MODELLED AND GAUGED FLOW HYDROGRAPHS AT THOMSON RIVER @ HEYFIELD

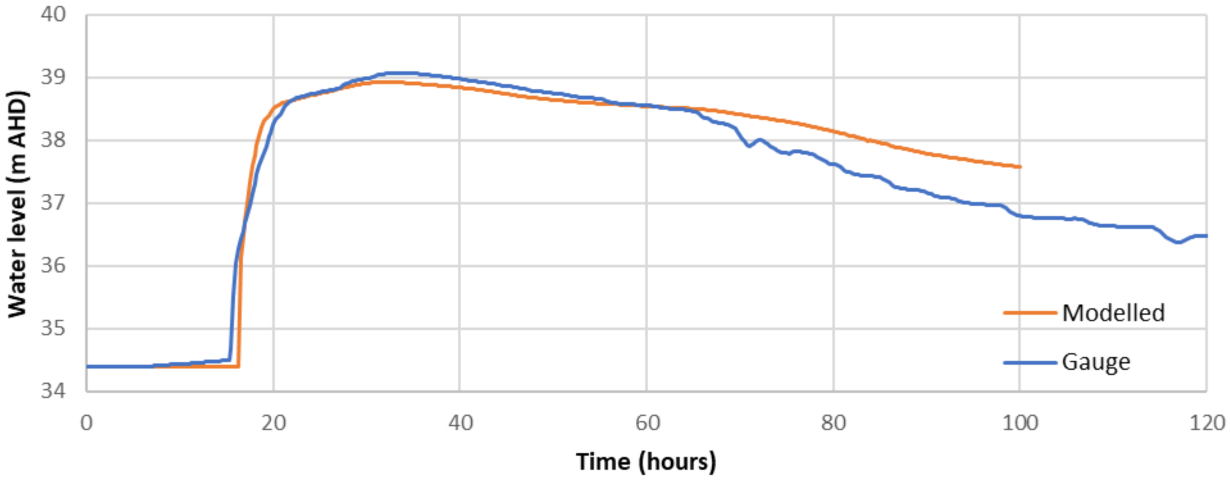


FIGURE 5-14 MODELLED AND GAUGED WATER LEVEL HYDROGRAPHS AT RAINBOWCK @ HEYFIELD

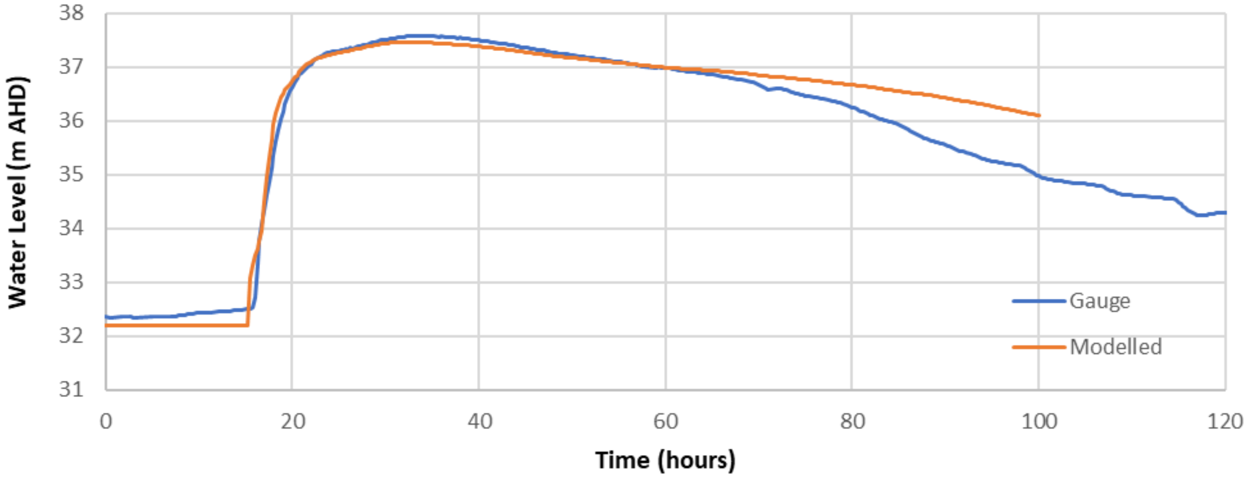


FIGURE 5-15 MODELLED AND GAUGED WATER LEVEL HYDROGRAPHS AT THOMSON RIVER @DS RAINBOWCK

5.6.2.3 July 2016

Table 5-6 summarises the comparison between modelled and observed gauge records for 2016 flood event. Figure 5-16 to Figure 5-18 display the modelled water level hydrographs for the Thomson River at Heyfield, Rainbow Creek at Heyfield and Thomson River at Rainbow Creek DS gauges respectively. The modelled water level hydrographs show a reasonably good match to those gauged in shape, with the exception of the Thomson River at Heyfield gauge. The modelled peak level is 220 mm higher and the timing of peak flood level arrives 13 hours earlier than recorded.

In contrast, the modelled peak water level at Thomson River at DS Rainbow Creek is within 55 mm of the recorded values and the Rainbow Creek at Heyfield gauge is just above 100 mm higher. Both their modelled water level hydrographs match the shape extremely well.

TABLE 5-6 SUMMARY OF CALIBRATION PERFORMANCE FOR 2016 EVENT

Location	Peak Water level (m AHD)			Time to Peak		
	Gauge	Modelled	Diff (mm)	Gauge	Modelled	Diff (hrs)
Rainbow Creek @ Heyfield	38.46	38.56	102.90	36.00	34.25	-1.75
Thomson River @ Heyfield	38.90	39.12	218.60	42.75	29.50	-13.25
Thomson River @ DS Rainbow Creek	36.96	37.01	54.50	38.75	33.75	-5.00

*Gauge zero for DS Rainbow Creek gauge is assumed to be 32 m AHD (TBC)

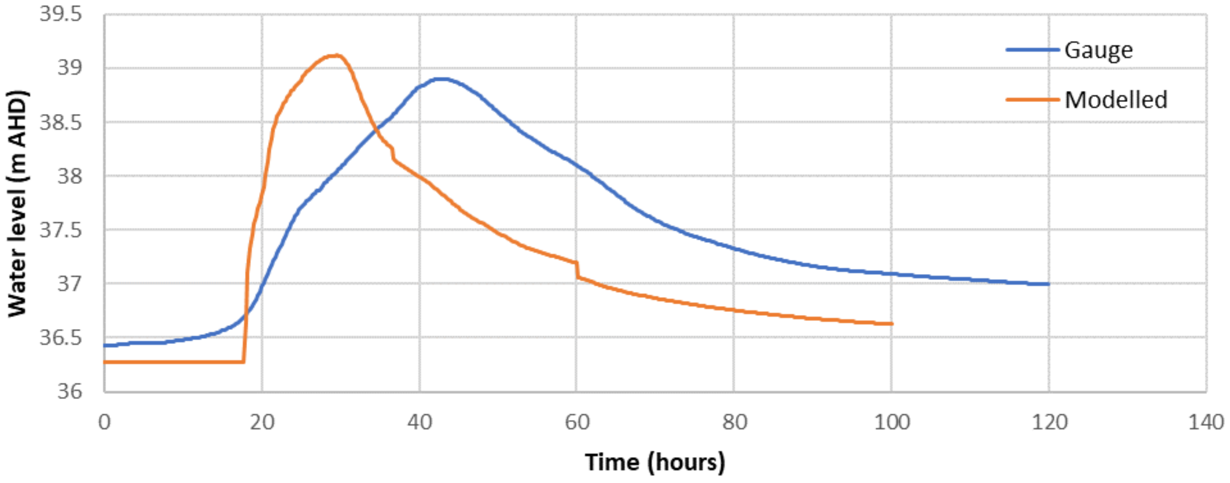


FIGURE 5-16 MODELLED AND GAUGED WATER LEVEL HYDROGRAPHS AT THOMSON RIVER AT HEYFIELD

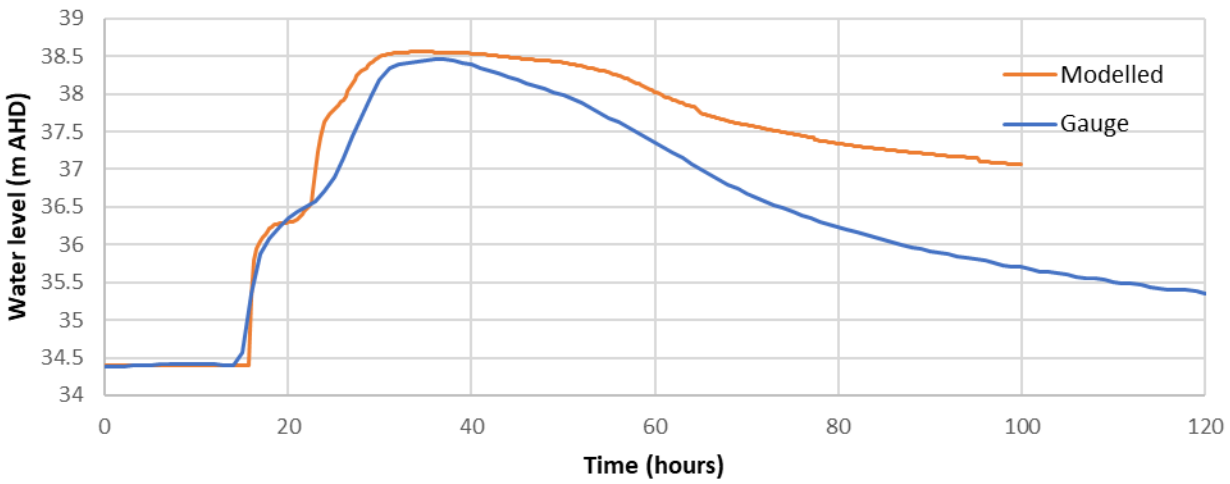


FIGURE 5-17 MODELLED AND GAUGED WATER LEVEL HYDROGRAPHS AT RAINBOW CREEK AT HEYFIELD

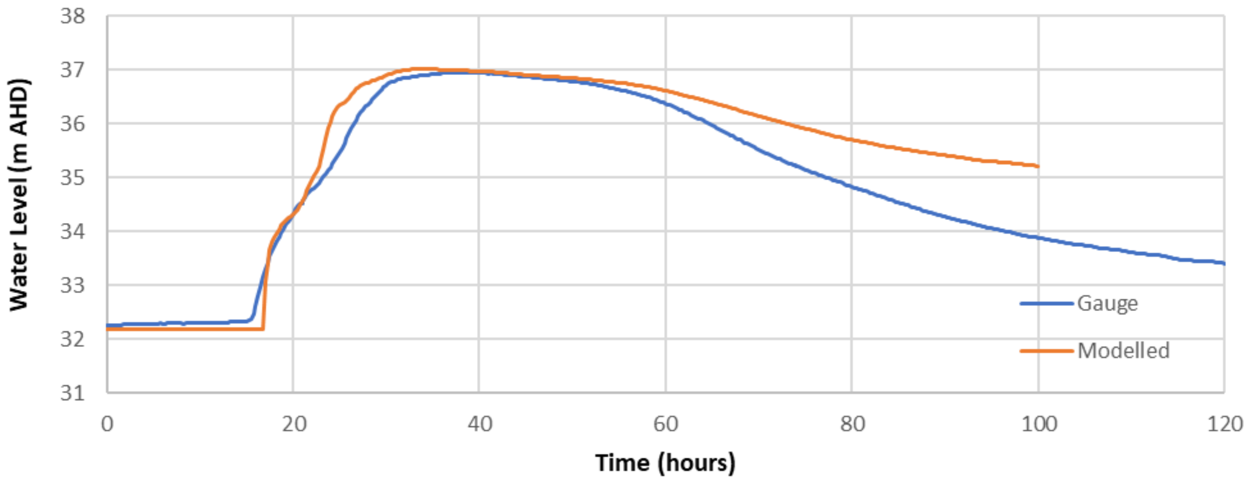


FIGURE 5-18 MODELLED AND GAUGED WATER LEVEL HYDROGRAPHS AT THOMSON RIVER AT DS RAINBOW CREEK

Summary

The overall performance of the hydraulic model calibration is considered acceptable given the modelled water levels match at the observed flood marks and gauging station records reasonably well for the 2007 flood. The model runs of 2012 and 2016 floods also verify the hydraulic model can replicate flood behaviour well.

WGCMA reviewed and considered the calibration results acceptable before proceeding to design modelling.

5.7 Design Flood Mapping and Sensitivity Analysis Results

5.7.1 Design Event Modelling

As specified in the project brief, the design and flood class level events modelled in the hydraulic model included 0.5%, 1%, 2%, 5%, 10%, 20% and 50% AEP events as well as for the PMF event, Minor, Moderate and Major Flood Class Levels at the Thomson River at US Cowwarr Weir streamflow gauge.

Figure 5-19 to Figure 5-22 display the mapping outputs of the 1% AEP event, including flood depth, water level, velocity and hazard. Gridded results for each design event were used create the VFD outputs as part of the project deliverables and they were provided to WGCMA for planning and responding to future flood events. Figure 5-23 shows the extent comparison between the existing flood overlay and the modelled 1% AEP flood event.

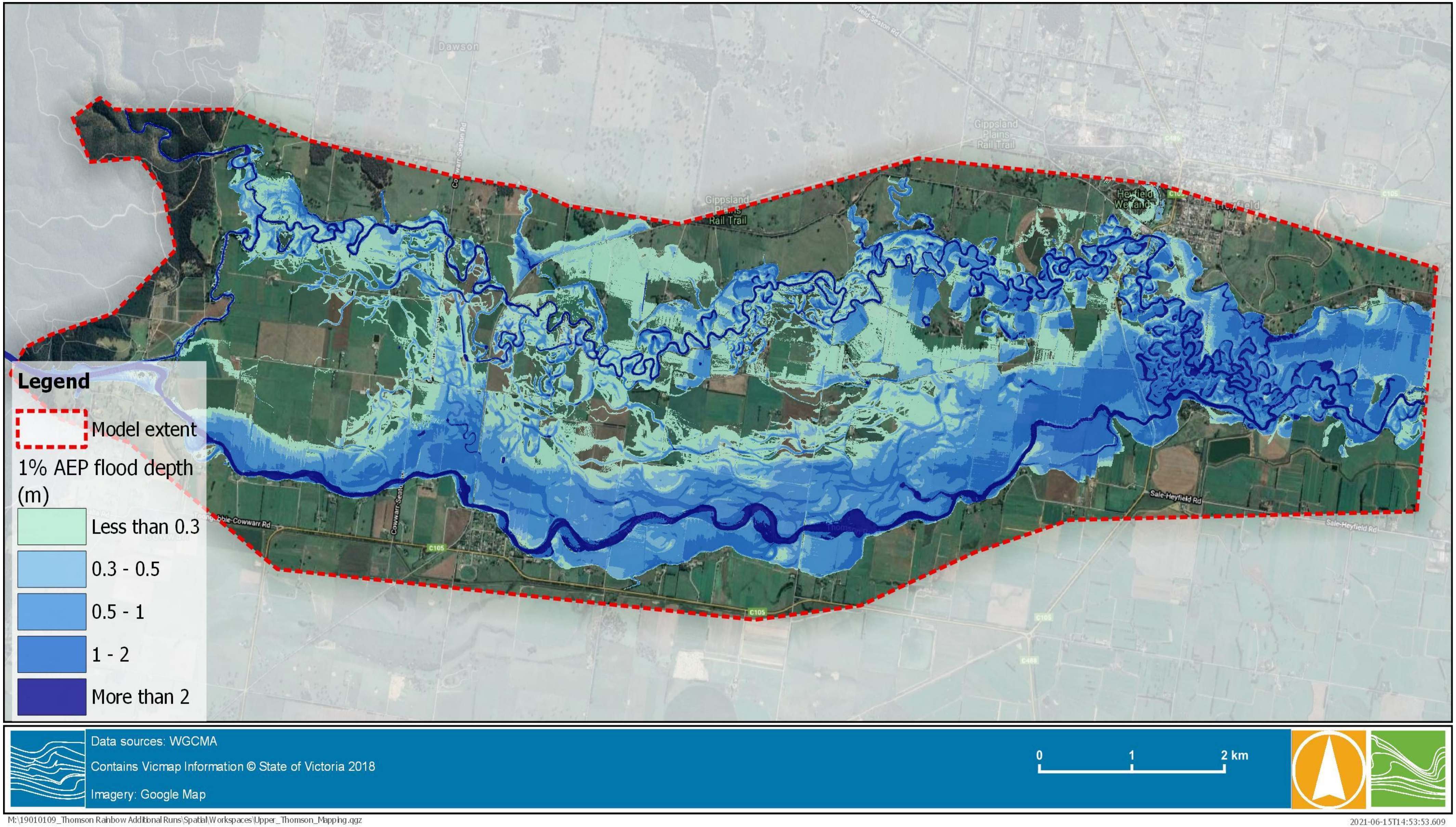


FIGURE 5-19 1% AEP FLOOD DEPTH IN UPPER THOMSON RIVER CATCHMENT

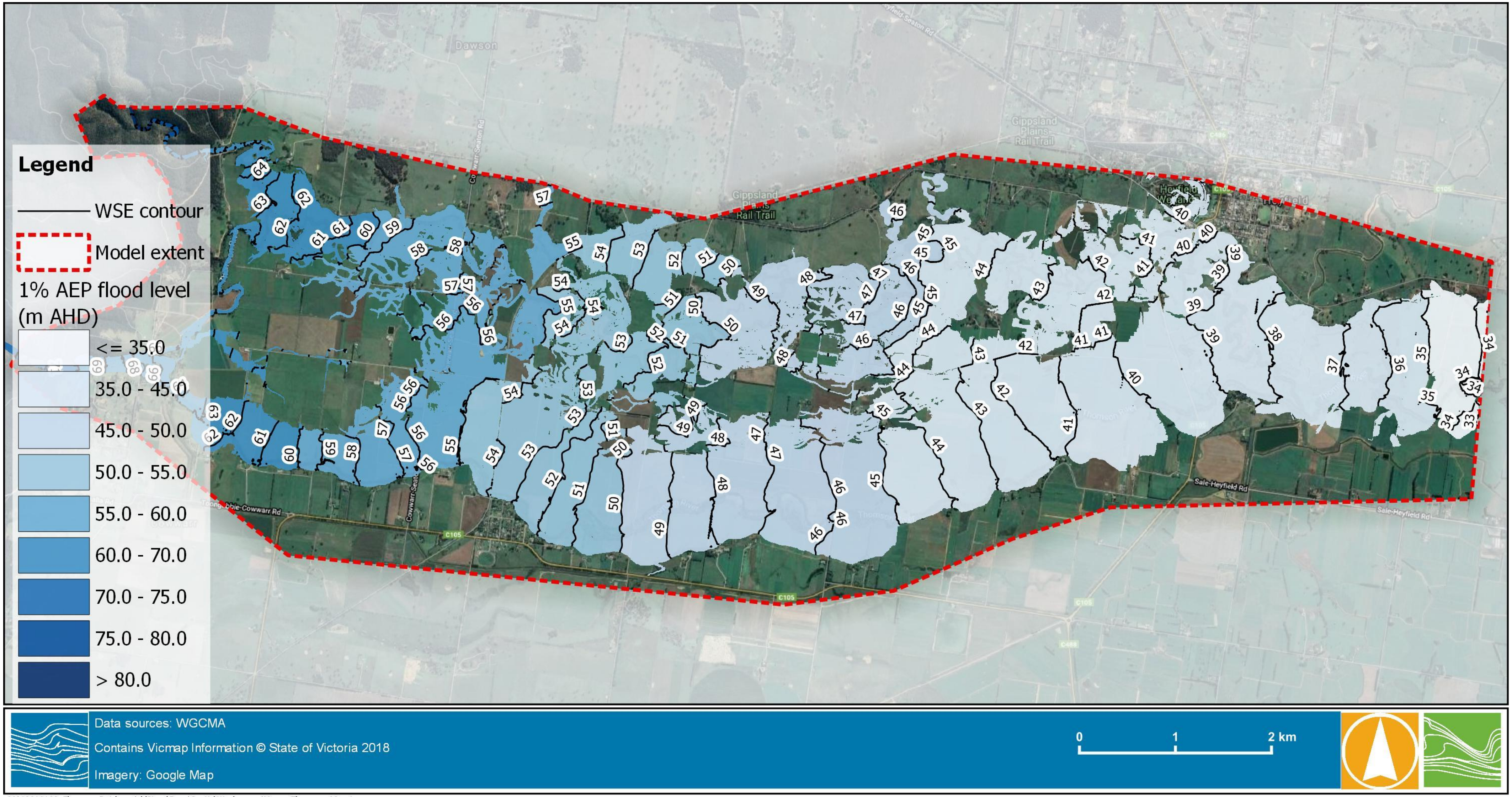


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FIGURE 5-20 1% AEP FLOOD LEVEL IN UPPER THOMSON RIVER CATCHMENT

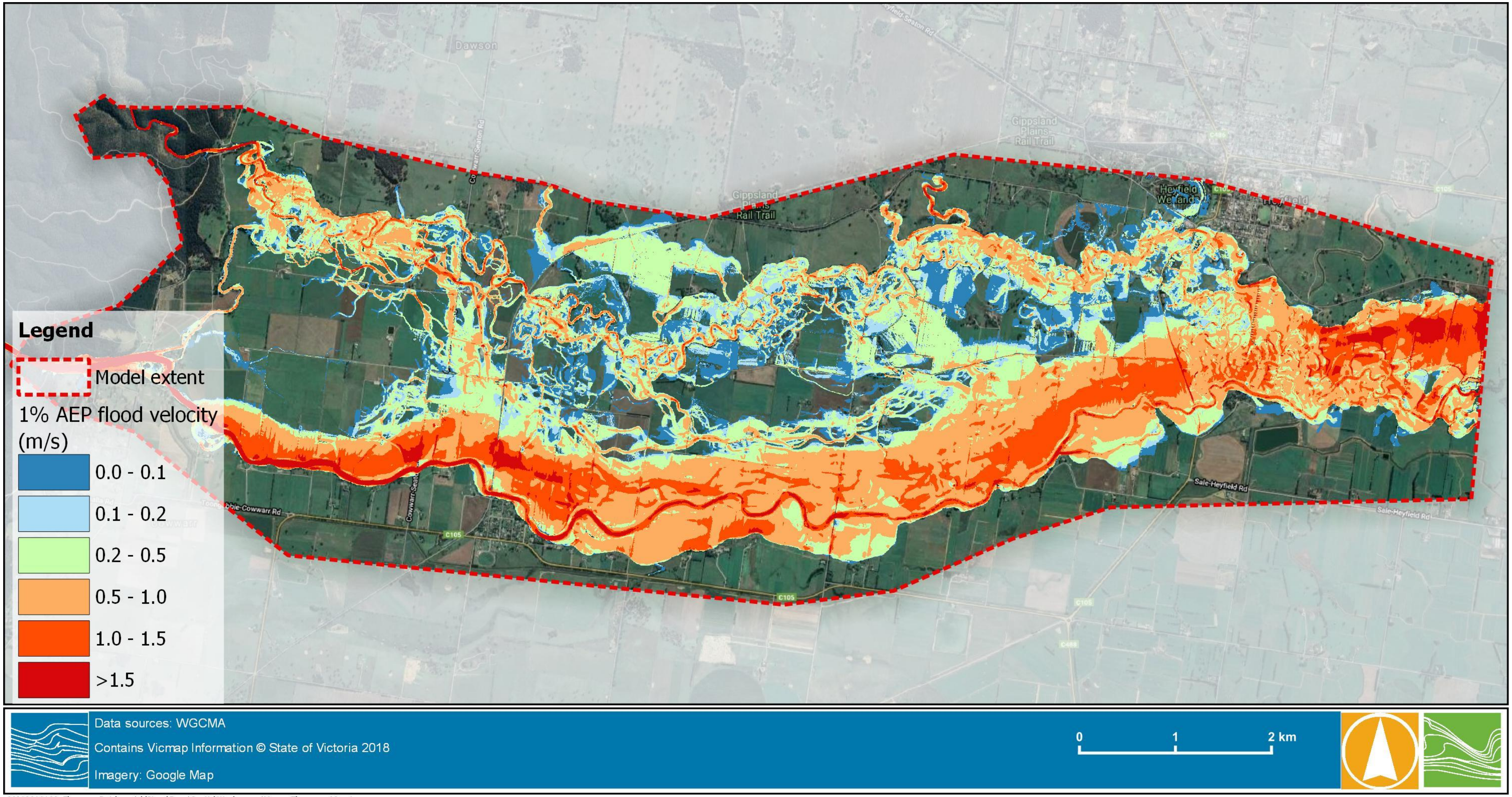

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FIGURE 5-21 1% AEP FLOOD VELOCITY IN UPPER THOMSON RIVER CATCHMENT

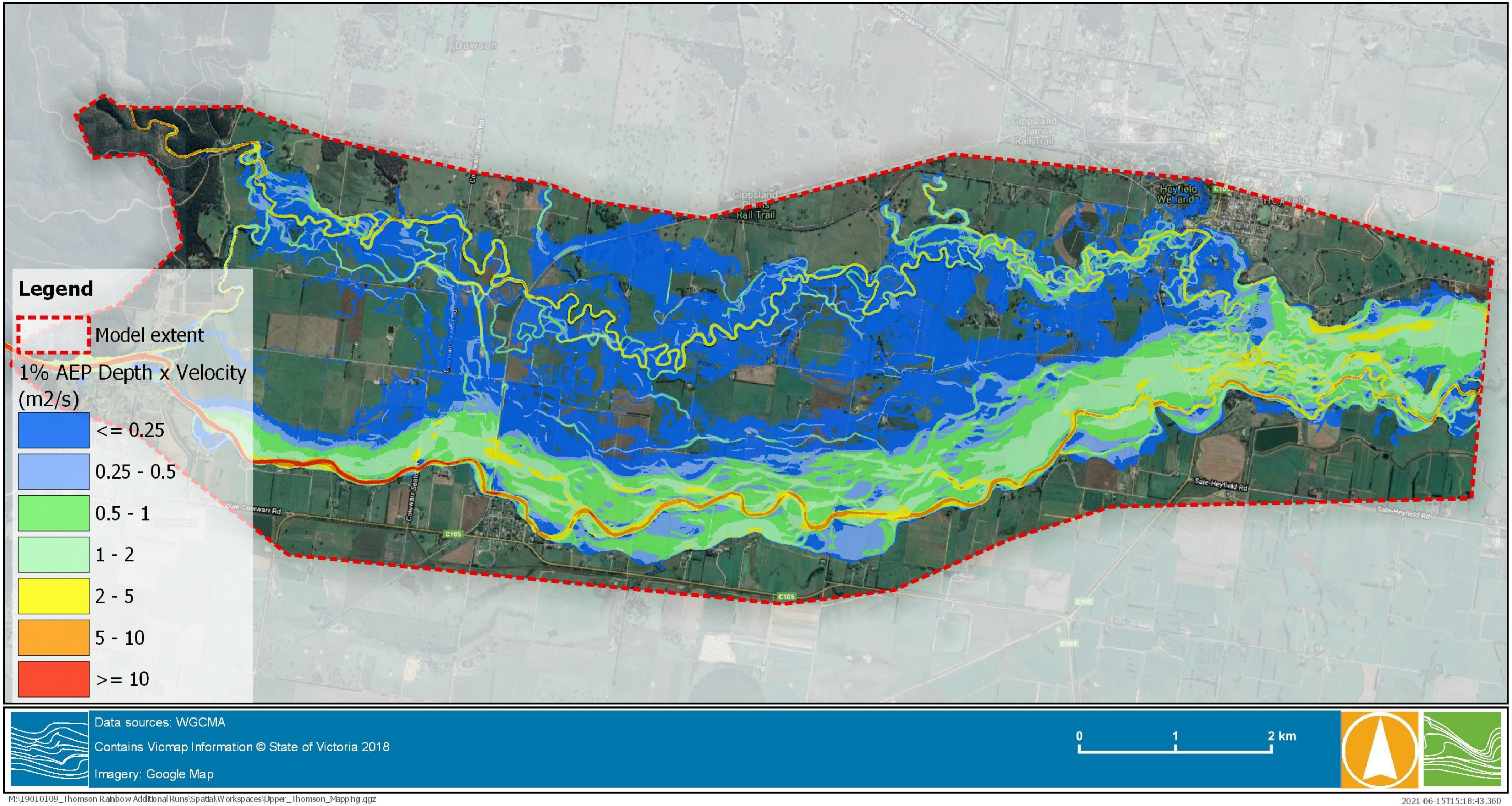

FIGURE 5-22 1% AEP FLOOD HAZARD IN UPPER THOMSON RIVER CATCHMENT

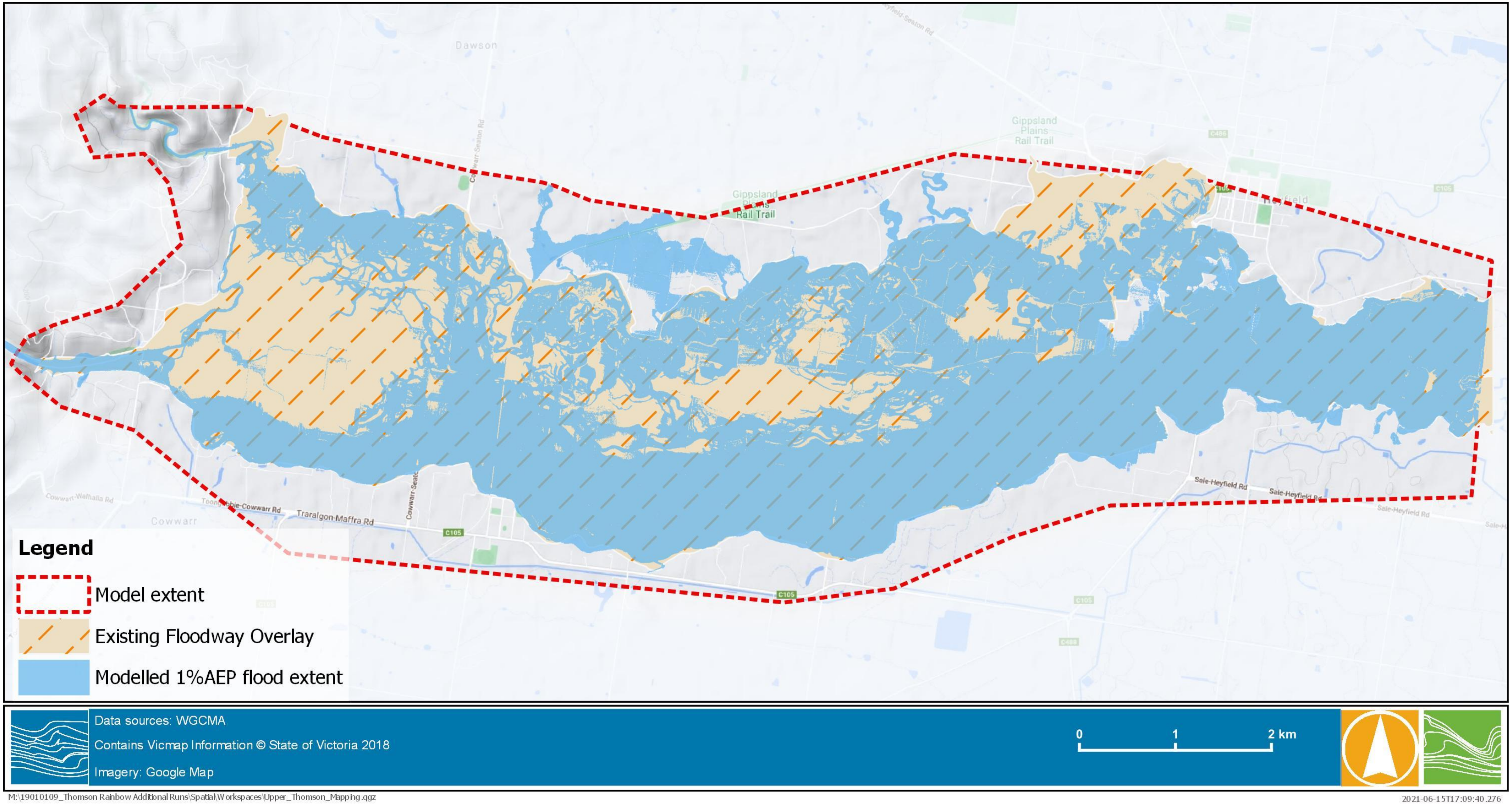

FIGURE 5-23 COMPARISON OF THE EXISTING FLOOD OVERLAY AND THE 1%AEP FLOOD EXTENT

5.7.2 Sensitivity Analysis

Sensitivity analysis was undertaken for bushfire and climate change scenarios using the 1% AEP event. Difference plots were created to identify the impacts of both scenarios on flood levels and extent and consequently, the flood risk to the local community.

5.7.2.1 Bushfire Impacts

The assessment of bushfire impact was conducted by the reduction of the loss parameters (as discussed in section 4.7.4). The 1% AEP event was simulated in a post bushfire scenario. Figure 5-24 shows the changes in water levels under post bushfire conditions. The increases in water level were more noticeable in the floodplain areas along the Rainbow Creek than the Thomson River. The average increase in water level was just above 10 cm with some areas immediately downstream of Cowwarr Weir exceeding 15 cm. In contrast, most of the floodplain along the Thomson River were increased by less than 5 cm.

The increase in flood extent was found to be more significant immediately downstream of Cowwarr Weir.

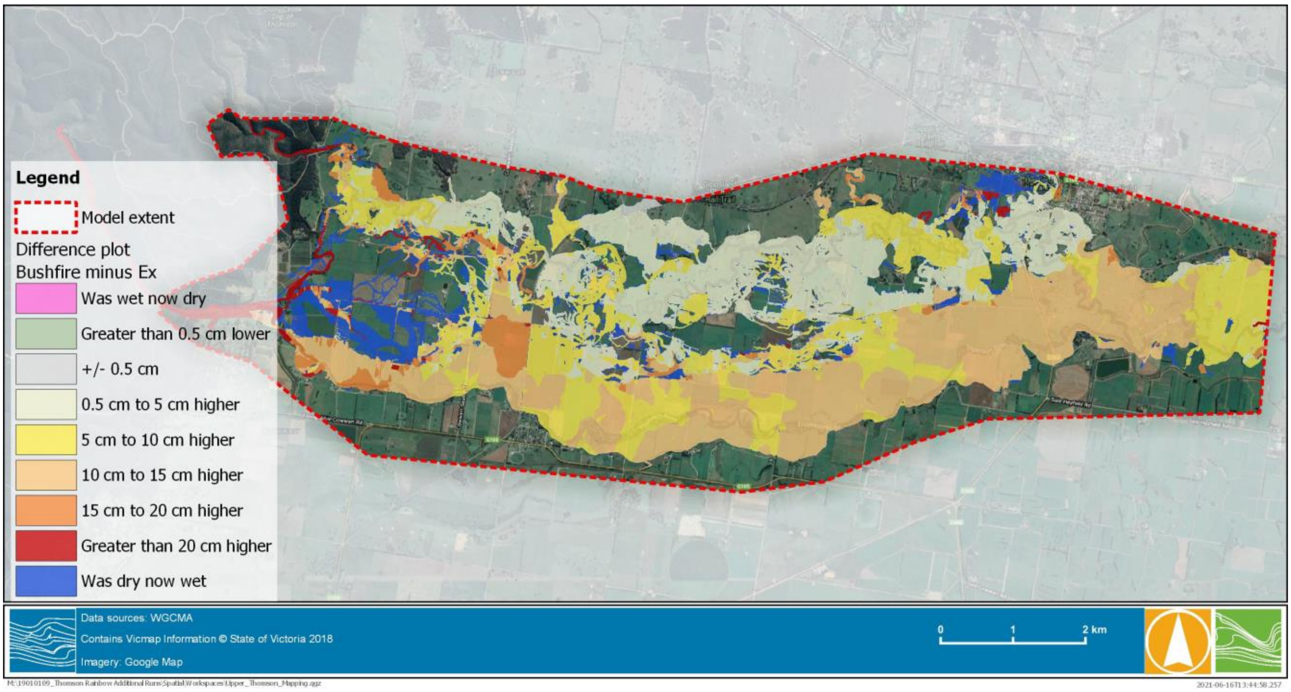

FIGURE 5-24 COMPARISON OF WATER LEVELS BETWEEN BUSHFIRE CONDITION AND EXISTING CONDITION

5.7.2.2 Climate Change Impacts

As discussed in Section 4.7.3, the 2090 RCP 8.5 climate change scenario was modelled, this was equivalent to a 16% increase in rainfall intensity. The 1% AEP event was simulated with the increase in rainfall intensity to represent the climate change conditions. Figure 5-25 shows the difference in water level under climate change conditions. The increase in water level were found to be more noticeable in the floodplain areas along the Rainbow Creek than the Thomson River. The average increase in water level is above 15 cm with some areas immediately downstream of Cowwarr Weir exceeding 20 cm. In contrast, most of the floodplain along the Thomson River were increased by less than 5 cm.

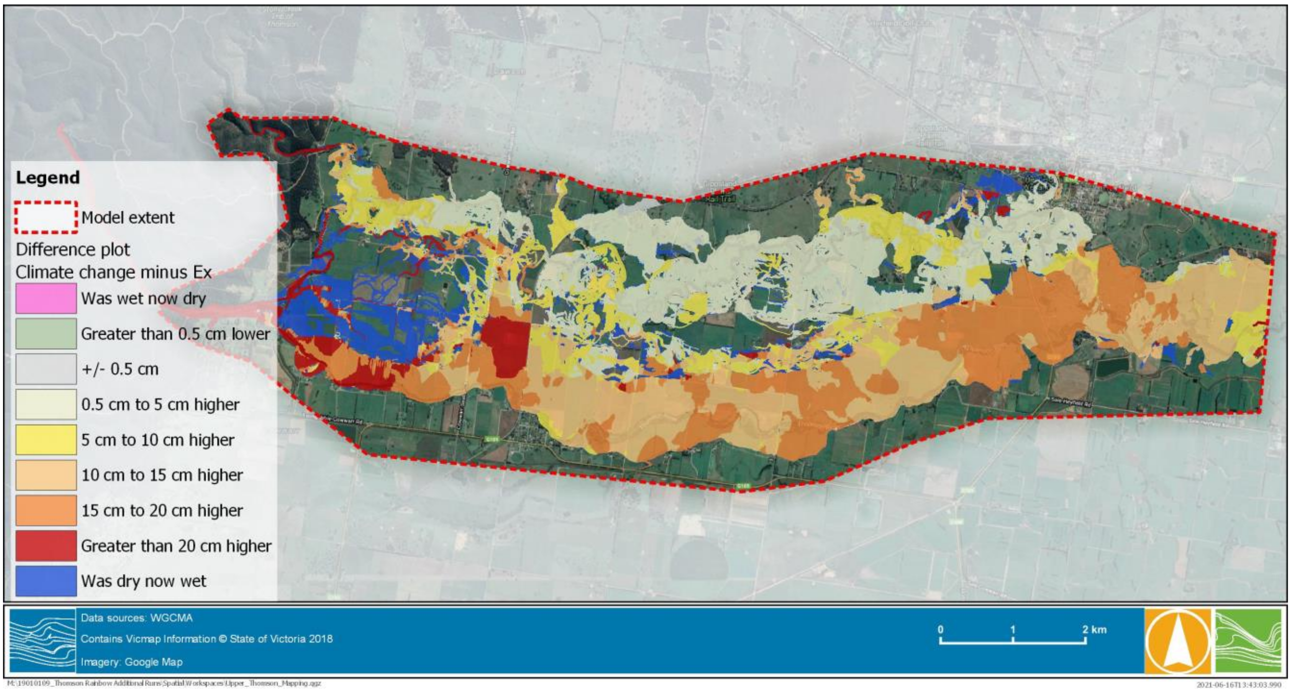

FIGURE 5-25 COMPARISON OF WATER LEVELS BETWEEN CLIMATE CHANGE AND EXISTING CONDITIONS

6 FLOOD INTELLIGENCE IMPROVEMENTS

6.1 Planning Scheme Mapping

Planning maps and GIS layers for proposed Land Subject to Inundation Overlay (LSIO) and Floodway Overlay (FO) were produced using the 1% AEP event results and compliant with the following criteria as discussed with WGCMA:

- LSIO where depth of flooding is greater than 0.05 m
- FO where depth of flooding is greater than 0.3 m or velocity is greater than 1.5 m/s

6.2 Planning Controls in Upper Thomson River Catchment

In assessing how flood controls should be applied within the Upper Thomson River Catchment area, consideration must be given to both the extent of 1% AEP flood event as produced by the hydraulic model and the nature of the flood risk. Figure 6-1 shows the draft planning overlays produced for this study based on the above criteria and comparison with the existing FO.

LSIO – defines the floodplain fringe within the 1% AEP flood extent

LSIO are planning scheme controls that apply to land affected by flooding associated with waterways, natural flow paths and drains. Such areas are commonly known as floodplain. The LSIO is used to identify flood fringe areas of the floodplain where flooding depths are typically low.

FO – defines the high hazard portion of the floodplain

FO applies to land that is identified as carrying active flood flows associated with waterways, natural flow paths and drains. The overlay is characterised by areas impacted by deep and or fast flowing floodwaters during the 1% AEP flood event.

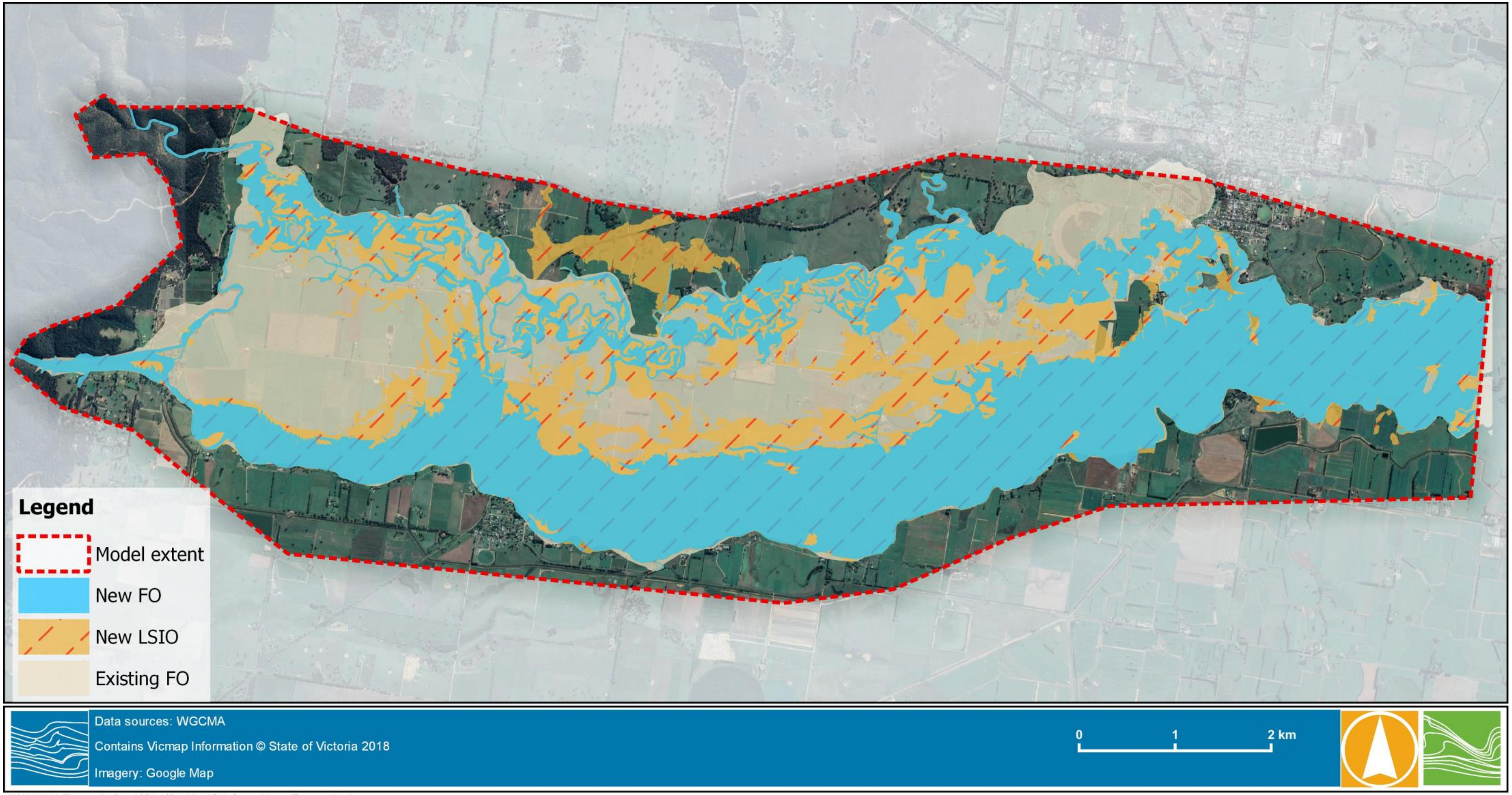

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FIGURE 6-1 PROPOSED FLOOD RELATED PLANNING CONTROLS

6.3 Flood Warning

A reliable flood warning system is imperative to mitigate flood risk for regions that frequently suffer from flood events. A robust system provides a means of gathering information about impending floods and enables relevant people or parties to take timely actions to reduce damage and prevent casualties caused by flooding. The design modelling completed in this study aims to offer an opportunity to revise and make appropriate update on current existing flood warning system.

6.3.1 Flood Class Levels at Thomson River @ U/S of Cowwarr Weir

The existing flood warning system for the Lower Thomson floodplain utilises the Thomson River at U/S of Cowwarr Weir gauge (225231). The hydraulic model was used to produce mapping outputs for gauge heights between 3.0 m to 9.0 m at a 0.5 m increment.

Table 6-1 summarises the gauge height between 3.0 m to 9.0 m, and the associated flow rates and magnitudes of flood events (i.e. design or historic floods and current flood class levels). These are also presented in the existing gauge rating curve shown in Figure 6-2. Table 6-1 below along with the associated model results can be used to create flood intelligence tools to enable an effective and timely response for an impending flood.

TABLE 6-1 GAUGE HEIGHT AND ASSOCIATED DESIGN EVENT MAGNITUDE

Gauge height (m)	Approximate flow (m^3/s)	Event magnitude
3.0	29	-
3.5	70	-
3.7	93	Minor flood level
4.1	147	2016
4.5	235	Moderate flood level
5.0	336	20%
5.2	413	10%
5.5	470	Major flood level
6.0	582	5%
6.4	639	2012
7.0	748	2%
7.6	888	2007
8.0	908	1%
8.6	1036	0.5%
8.9	1109	1978

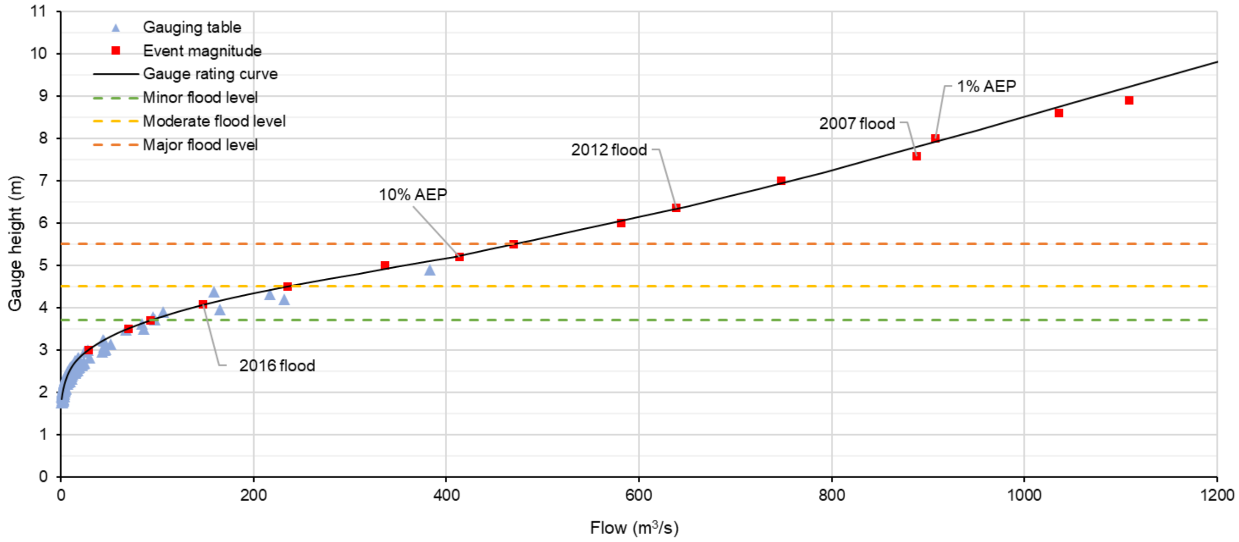

FIGURE 6-2 RATING CURVE, FLOOD CLASS LEVELS AND DESIGN EVENTS – U/S COWWARR WEIR GAUGE

6.3.2 Identification of key floodplain locations and vulnerable infrastructure

Figure 6-3 to Figure 6-5 show a range of design flood extents within the study area and the key infrastructure inundated. During flood events the regional road network often becomes inundated. This presents risk to community, who may become isolated and seek to evacuate and to emergency services responding during the event. Modelling results show several roads within the study area impacted by floodwater during relatively frequent flood events. Table 6-2 summarises the major roads which become overtopped during the modelled design events. Consideration should be given of the below table in planning for suitable evacuation routes.

TABLE 6-2 MAJOR ROADS OVERTOPPED

Road name	Design event overtopped
Traralgon-Maffra Rd	Minor flood
Cowwarr - Seaton Rd	Moderate flood
Cowwarr - Heyfield Rd	Moderate flood
Rices Lane	Moderate flood
Bessant St	Moderate flood
Neilsons Rd	20% AEP
Cross St	20% AEP
Church St	20% AEP
Marshall St	10% AEP
France St	10% AEP
Rose St	5% AEP
Commercial Rd	5% AEP
River St	1% AEP
Obriens Rd	0.5% AEP
Stagg St	0.5% AEP

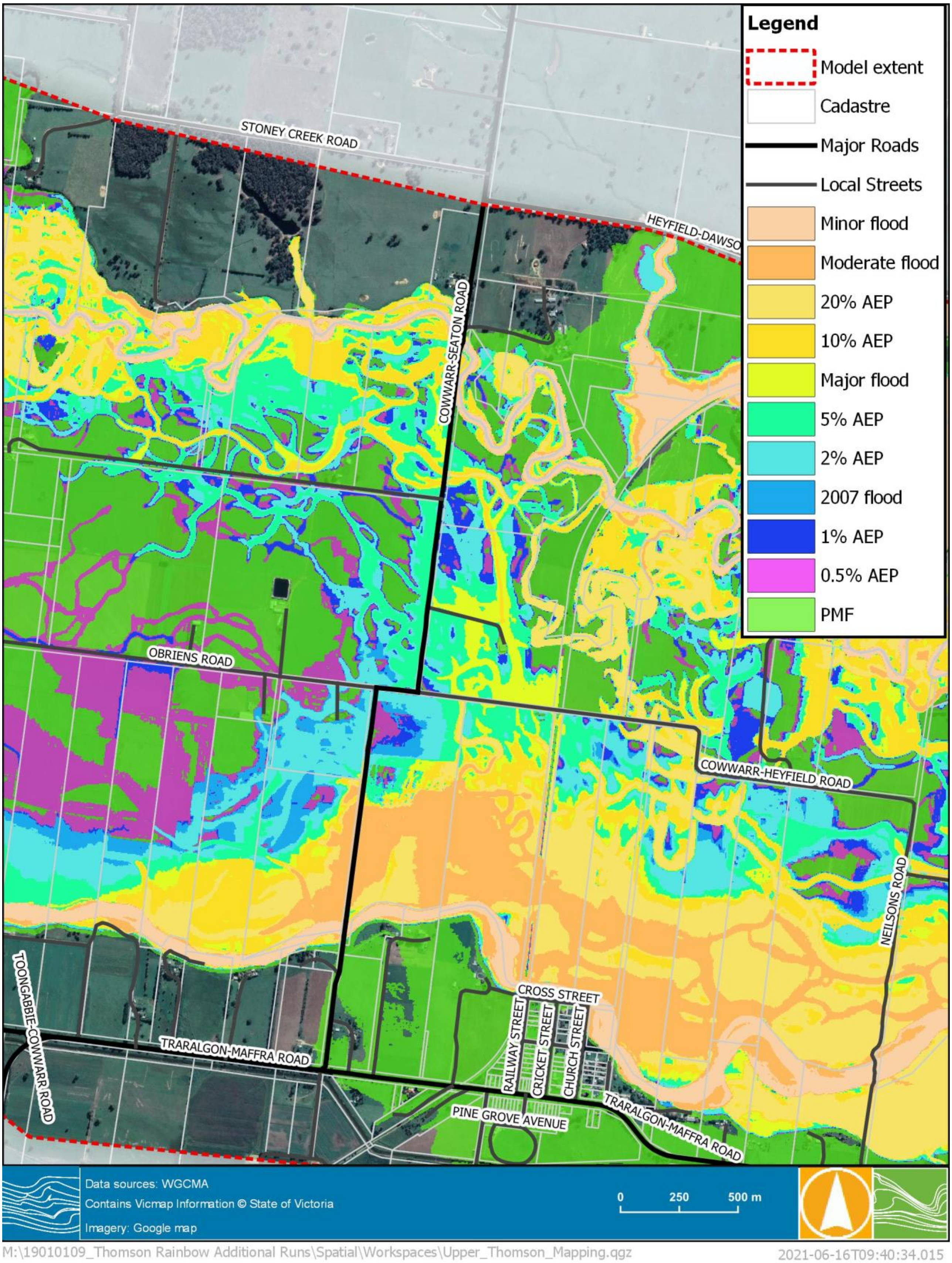

FIGURE 6-3 ROADS IMAPCTED IN DESIGN MODELLING EXTENTS - UPPER REGION

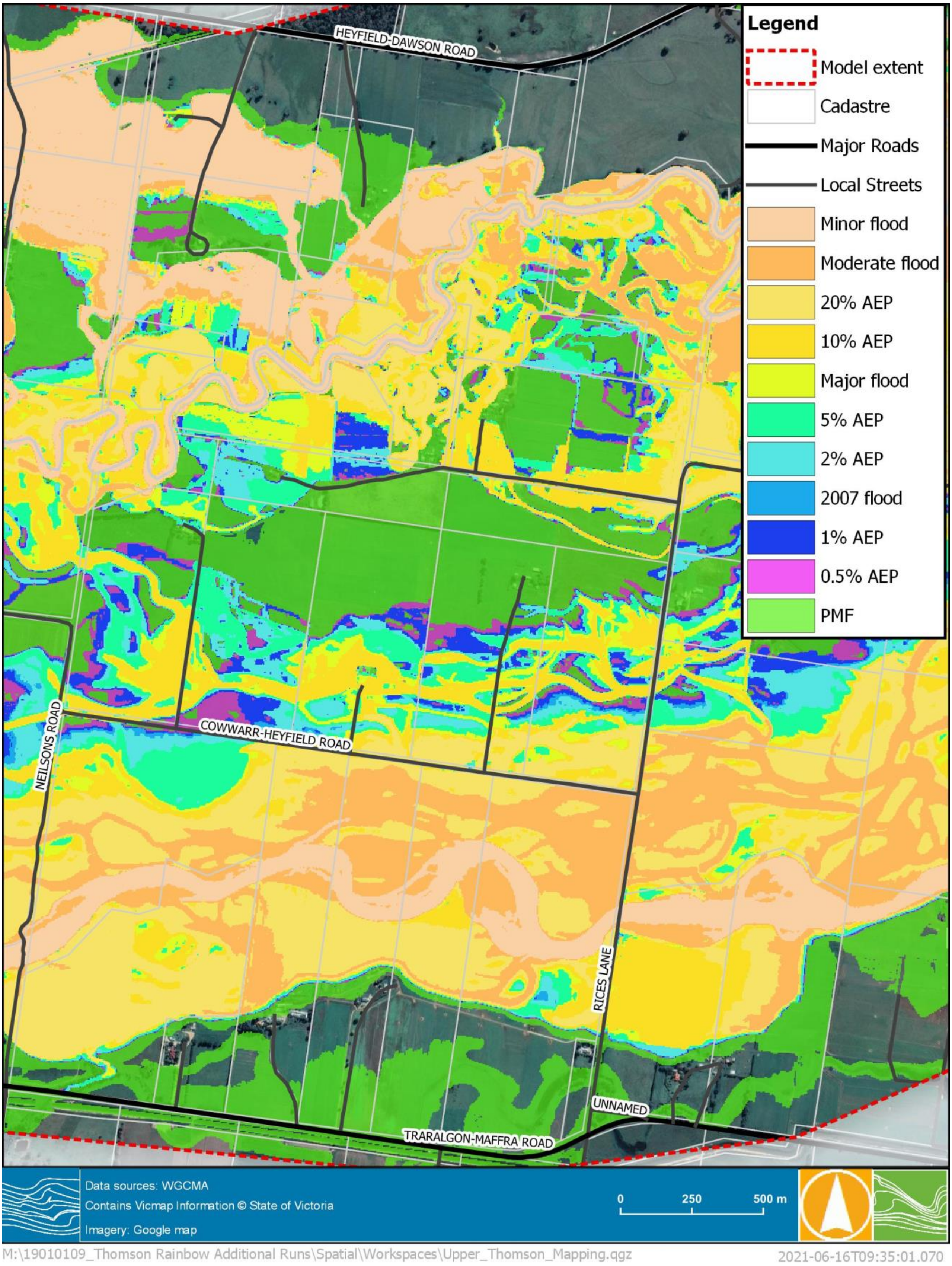

FIGURE 6-4 ROADS IMAPCTED IN DESIGN MODELLING EXTENTS – MIDDLE REGION

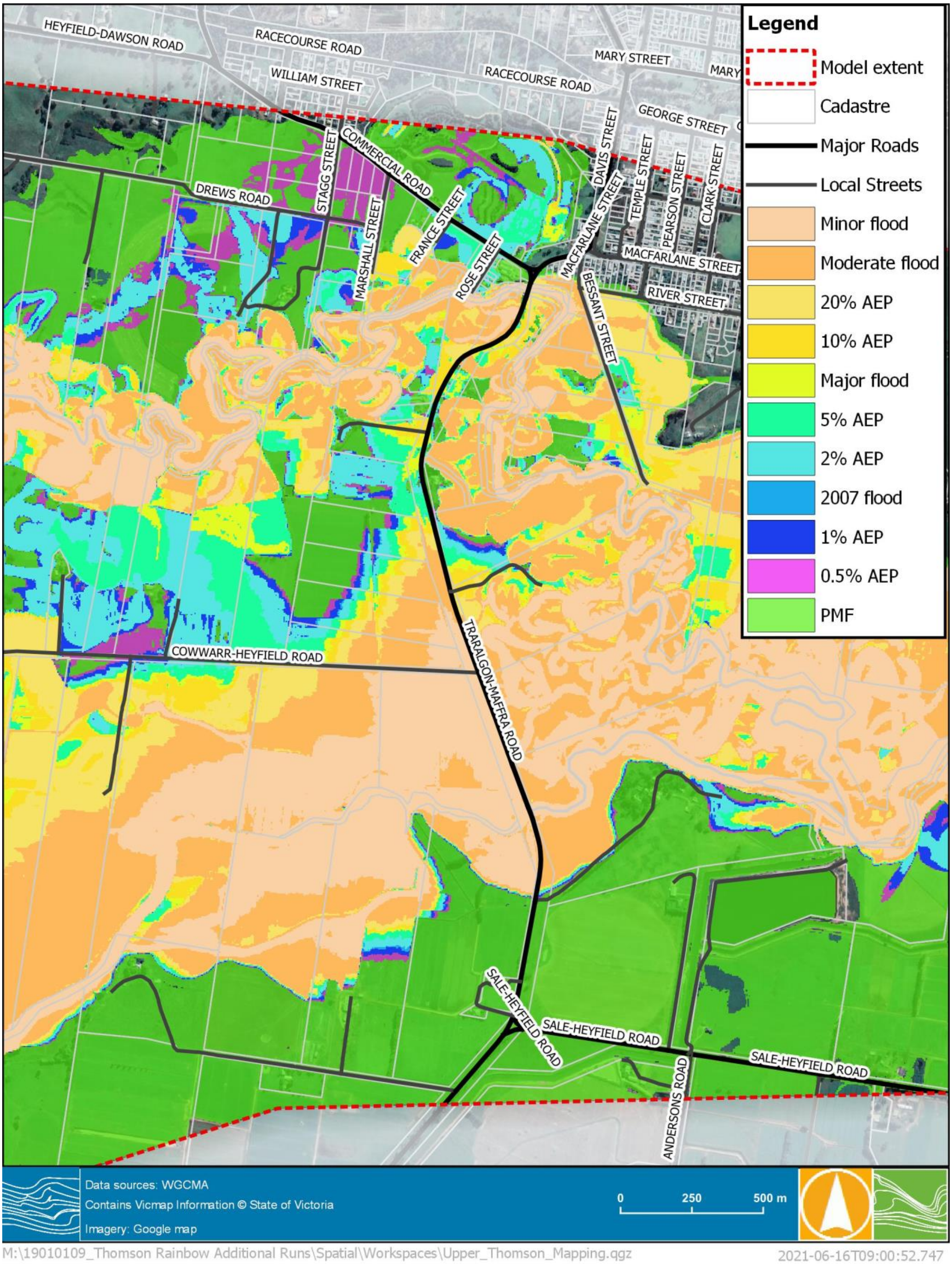

FIGURE 6-5 ROADS IMAPCTED IN DESIGN MODELLING EXTENTS – LOWER REGION

7 RECOMMENDATIONS

Recommendations made during the Upper Thomson River Flood Study have been separated into the agencies responsible for their fulfilment, these are as follows:

BOM

- Utilise the model results to improve flood warning information for the Thomson River and Rainbow Creek.

Wellington Shire Council

- Review and consider endorsement of the flood study and consider a planning scheme amendment to update the flood related planning overlays – LSIO and FO.
- Consider a review of existing roadside water level boards along impacted roads.
- Review the information provided by this project and consider an update to the Wellington Municipal Flood Emergency Plan (MFEP) in discussion with VicSES.
- Actively promote the use of the VIC Emergency website and App to the community to improve flood preparedness and awareness.

West Gippsland CMA

- Review and consider endorsement of the flood study and use the flood mapping data to inform floodplain risk management decisions.
- Upload the Victoria Flood Database mapping data to FloodZoom.

Victoria State Emergency Service with assistance from Wellington Shire Council:

- Continue to engage the community through regular flood awareness programs.
- Update the relevant Local Flood Guides.
- Aid Wellington Shire Council in updating MFEP.
- Review the updated MFEP (when available) and discuss with Council the changes proposed prior to adopting the revised document.

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Melbourne

Brisbane

Adelaide

Perth

Geelong

Gippsland

Wangaratta

Wimmera