



Flood Warning Assessment Report

Newstead Flood Study and Mitigation Strategy(M1751-2023)

Mount Alexander Shire Council

5 December 2025



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ACKNOWLEDGEMENT OF COUNTRY

The Board and employees of Water Technology acknowledge and respect the Aboriginal and Torres Strait Islander Peoples as the Traditional Custodians of Country throughout Australia. We specifically acknowledge the Traditional Custodians of the land on which our offices reside and where we undertake our work. In particular, we recognise the Dja Dja Wurrung People as the Traditional Custodians of the waters and lands on which this project is based.

We respect the knowledge, skills and lived experiences of Aboriginal and Torres Strait Islander Peoples, who we continue to learn from and collaborate with. We also extend our respect to all First Nations Peoples, their cultures and to their Elders, past and present. In particular, we recognise the Dja Dja Wurrung People as the Traditional Custodians of the waters and lands on which this project is based.



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

The symbolism in the artwork includes:

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



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GLOSSARY

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 likely be relatively small magnitude. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would likely be of extreme magnitude.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
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	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life 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.
Incident Control Centre (ICC)	A facility established by VicSES to manage and coordinate a response to an emergency incident.
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.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Probable Maximum Flood	The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area.
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 to undertake modelling using hydrological modelling inputs.



1 INTRODUCTION

1.1 Overview

Water Technology was commissioned by Mount Alexander Shire Council (MASC) to undertake the Newstead Flood Study and Mitigation Strategy. The project is funded by the Disaster Ready Fund and the Victorian Government. The investigation covers the study area presented in Figure 1-1.

Newstead is a small township in Victoria, located 15 km west of Castlemaine on the banks of the Loddon River. Located within MASC and the North Central Catchment Management Authority (NCCMA) management area, Newstead was established in the mid-19th century as a river crossing point and today hosts a population of approximately 800 people.

The Loddon River catchment upstream of Cairn Curran Reservoir was included in a RORB hydrology model prepared as part of the Cairn Curran Dam Hydrology report¹ prepared by SKM. This model was refined for the catchment upstream of Guildford during the NCCMA Rapid Flood Risk Assessment². The SKM model was calibrated to three events from 2010 and 2011. Given the age of the SKM model and that the Guildford model only covers part of the catchment upstream of Newstead, a new hydrology model was produced for the current study. However, parameters adopted for the previous models were considered for model validation. This study will produce flood intelligence information for use in emergency management, assess the current flood impact/exposure in terms of annual average damages caused by flooding in Newstead, investigate structural and non-structural mitigation options and make recommendations for establishing a flood warning system for the town.

This report is one of a series documenting the outcomes for the Newstead Flood Study. Each reporting stage is shown below:

R01 – Data Review and Validation Report – Final version published 20 August 2024

R02 – Hydrology Report – Final version published 31 October 2024

R03 - Draft Hydraulic Modelling Report – Final version published 13 December 2024

R04 – Final Hydraulic Modelling Report – Final version published 3 April 2025

R05 - Design Modelling and Mapping Outputs – Final version published 3 April 2025

R06 – Municipal Flood Emergency Plan (MFEP) Documentation – Draft published 8 May 2025

R07 – Flood Damage and Structural Mitigation Options – TBC

R08 – Final Project Report – TBC

R09 - Flood Warning Assessment Report – This report

This report provides an assessment of the flood warning components currently in place for Newstead, with recommendations for further improvement to the flood warning system

¹ SKM, 2012 Cairn Curran Dam: Flood Hydrology Update

² HARC, 2020 Guildford Rapid Flood Risk Assessment - North Central CMA Region, prepared for North Central CMA



1.2 Objectives and outputs

The Newstead Flood Study and Mitigation Strategy outputs are required to meet several floodplain management objectives as highlighted in the project brief prepared by MASC. The objectives of the investigation are described below:

- Undertake hydrologic and hydraulic modelling to determine flood levels and flood extents for the full range of flood events up to and including the Probable Maximum Flood (PMF).
- Calibrate models to historic flood events including the October 2022 flood event.
- Investigate modelling of climate change scenarios.
- Assess the feasibility of a range of potential mitigation options including understanding of the level of protection provided by the existing levee and information to inform necessary upgrades to this levee.
- Analyse the feasibility of establishing effective flood warning, accounting for time available between rainfall and the township flooding, in the context of a total flood warning system.
- Update flood intelligence to be incorporated into the Municipal Flood Emergency Plan.
- Provide recommendations to update the Planning Scheme and ensure it is informed by the best available flood information.

1.3 Study area

The main flood risk in Newstead is posed by the Loddon River, a levee was constructed in the 1920's that is still protecting the eastern portion of the township from Loddon River flooding. However, a number of smaller catchments generate runoff towards Newstead directly or indirectly, resulting in complex hydrologic and hydraulic conditions to address in planning and emergency response. These catchments include Mia Mia Creek, Muckleford Creek, Larni Barramal Yaluk, Green Gully and Green Gully Creek as shown in Figure 1-1. Additionally, there are several tributaries joining the Loddon River near Newstead further impacting river levels.

Newstead most recently experienced flooding in October 2022, causing flooding to parts of the township located on the western side of the Loddon River. Flooding in Newstead has historically caused levee breaches which were mitigated by sandbagging during the flood event. Flooding of the Loddon River also leads to the town being isolated when major traffic routes are cut off. The Loddon River at Newstead has been subject to considerable physical and ecological modifications due to extensive historic mining activities and other anthropogenic influences since European settlement. In recent years, bank erosion has been an issue for landholders adjacent to the Loddon River.

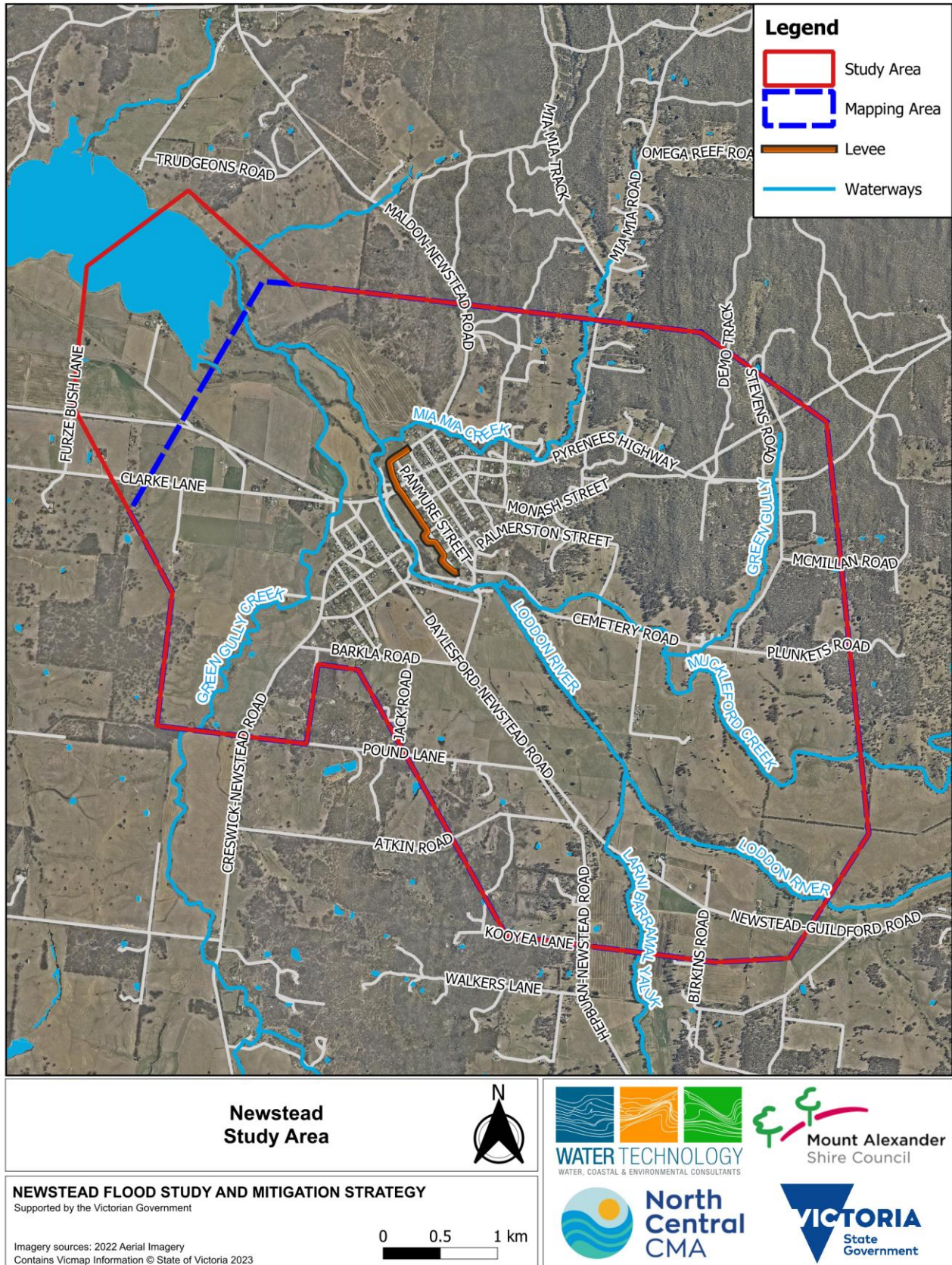


Figure 1-1 Newstead study area



1.4 Flood warning improvement deliverables

The tender brief sets out the following flood warning assessments to be delivered as part of the Newstead Flood Study and Mitigation Strategy:

- Estimates of effective flood warning time for flood magnitudes likely to result in damage to the township.
- Assessment of the capacity of the community and emergency services (including CFA and SES) to implement effective actions within the estimated flood warning times.
- Identification of potential gauge sites for flood warning, and development of theoretical relationships between appropriate measures and flooding in the township for future implementation of permanent or mobile gauging systems.

2 BACKGROUND: TOTAL FLOOD WARNING SYSTEM

Water Technology is currently undertaking the Loddon Total Flood Warning System Review³, which includes an assessment of flood risk, flood history, flood warning lead times and the existing flood warning systems for a number of communities, including Newstead, located in the Loddon River catchment. This study has also sought to identify possible total flood warning system (TFWS) component gaps and TFWS improvements for each community. This report builds on the work undertaken as part of both the Loddon Total Flood Warning System Review and previous reporting from the Newstead Flood Study and Mitigation Strategy (the current study).

The Australian Government has provided guidance to assess and design robust flood warning systems. It introduced the concept of the 'total flood warning system' to describe the full range of elements that must be developed if flood warning services are to be provided effectively.

Guidelines for the assessment and development of a TFWS are provided by the Australian Government in its document: Application of the Total Warning System to Flood⁴. A schematic of the components of the TFWS promoted by this document is provided in Figure 2-1.

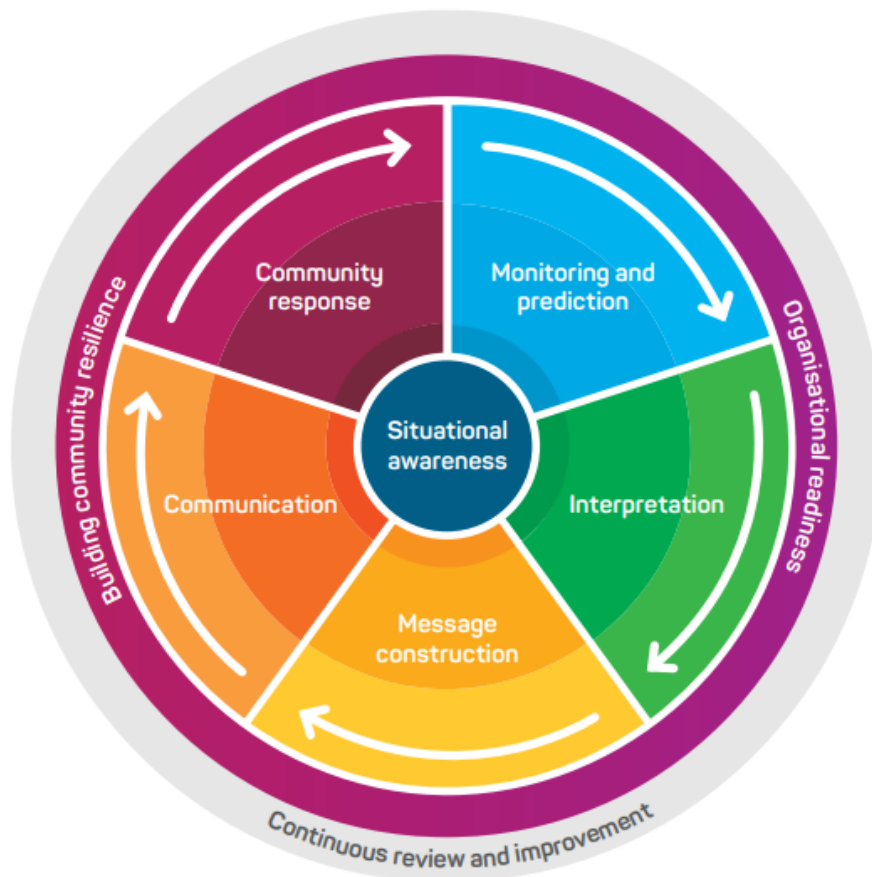


Figure 2-1 Australian Components of the Total Flood Warning System⁴

³ Water Technology, 2025 *Loddon Total Flood Warning System Review*, report prepared for the North Central Catchment Management Authority

⁴ AIDR, 2022 *Application of the Total Warning System to Flood*. Australian Institute for Disaster Resilience



The information produced by a flood investigation generally relates to the “monitoring and prediction” and “interpretation” elements. Flood mapping, damages and intelligence produced by the study will be valuable in interpreting incoming data. Some of the elements of the study (for example the “Flood/No Flood” tool produced in the Municipal Flood Emergency Plan) can aid with prediction.

Emergency message construction, communication, and community response are outside the scope of a flood investigation however would generally be completed from within an Incident Control Centre (if one has been set up) and the applicable Incident Management Team controlling the incident. Formal flood warning messages in Victoria fall within the remit of the Bureau of Meteorology and fall within two classes: Flood Watches and Flood Warnings.

Flood Watches are general warnings covering a large area and are not specific to particular waterways or townships. They can be delivered well before flooding is expected to arise and are often based on forecast rainfalls.

Flood Warnings, on the other hand, are specific to a location and will predict how high the water will peak at that location. Flood Warnings are often related to Flood Class Levels (see Section 5).

Review of available information should take place after any flood event, or any other discovery of new flood information as appropriate. Historic events should be added to the available information, particularly the MFEP, as they occur.

Monitoring, in the context of flooding, generally refers to monitoring rainfall and stream levels but may include other aspects such as storage levels and catchment conditions to name a few. Locations to monitor will depend on the available data sources and the catchment of interest.

The following sections will discuss the current and potential monitoring capability for the Loddon River and tributaries upstream of Newstead, flood travel times and flood class levels at Newstead to assist in future data collection and prediction.



3 CURRENT FLOOD WARNING SYSTEM

A TFWS assessment framework⁵ was used to review the existing flood warning system for Newstead and identify potential improvements in the system. This framework builds on that promoted by the Australian Government and the Australian Institute for Disaster Resilience^{6,7} and is similar to that outlined in the Application of the Total Warning System to Flood Handbook⁴. The framework involves 12 components of the TFWS:

- Understanding flood risk
- Emergency management planning
- Community flood engagement and education
- Data collection
- Prediction
- Interpretation
- Warning message construction
- Warning message communication
- Response
- Review
- Community participation
- Integration of the TFWS components

Figure 3-1 provides a schematic representation of the TFWS assessment framework used in the Loddon Total Flood Warning System Review³.

⁵ Molino, S., Dufty, N., Crapper, G. & Karwaj, A., 2011 *Are warnings working? Achievements and challenges in getting communities to respond*, paper presented to the Floodplain Management Association Conference, Tamworth NSW, February 2011

⁶ *Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia* (AIDR 2017).

⁷ *Public Information and Warnings* (AIDR 2021).

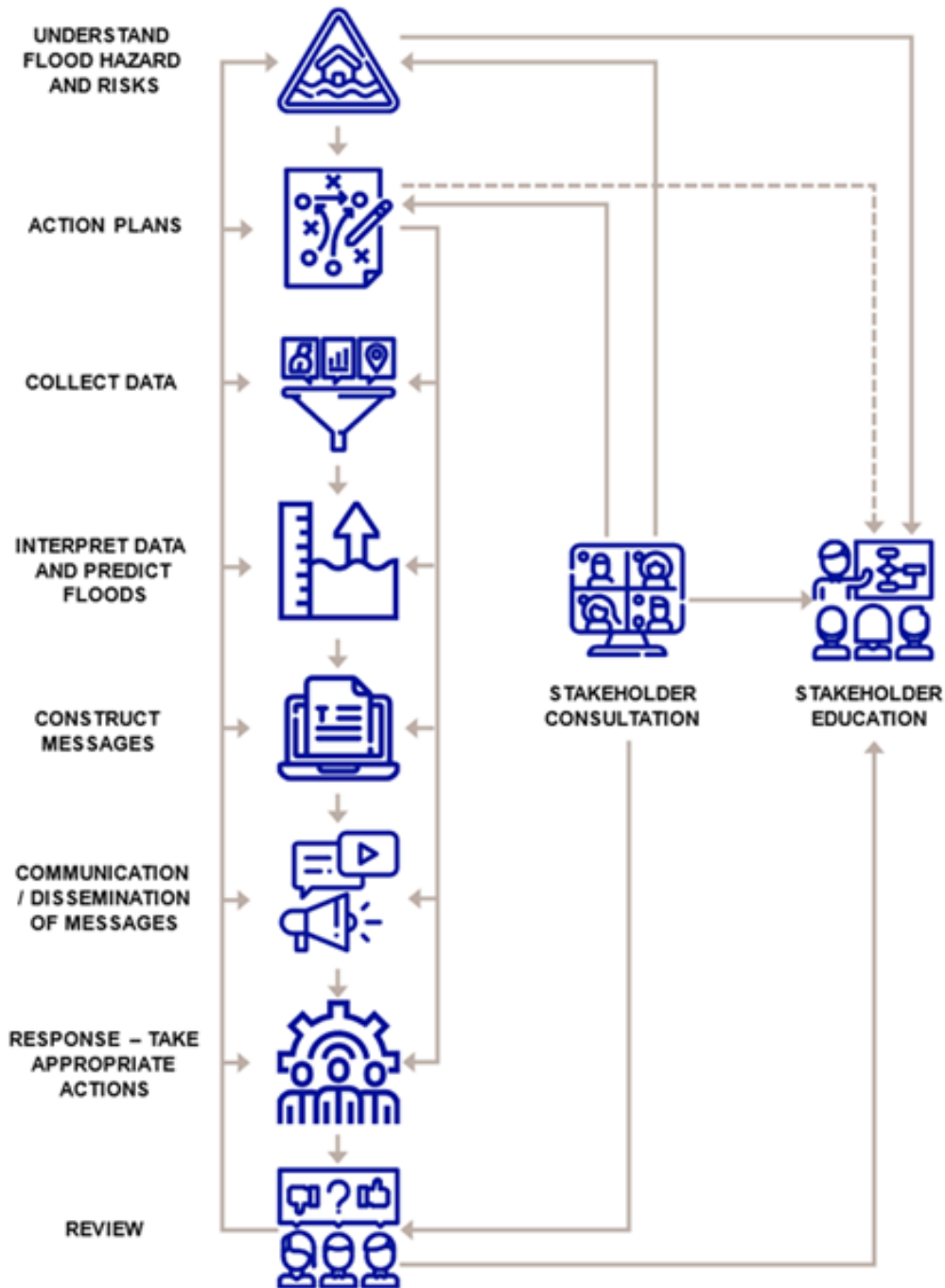


Figure 3-1 TFWS assessment framework⁵

An assessment of the existing flood warning system in Newstead in relation to the 12 TFWS components is provided in Table 3-1. Further refinement of the assessment was provided through community and stakeholder engagement.



Table 3-1 Assessment of the existing flood warning system for Newstead

TFWS Component	Assessment of the existing flood warning system
Understanding flood risk	The current study has provided details of flood impacts for different events (R04 – Final Hydraulic Modelling Report) and possible flood risk mitigation options (R07 – Flood Damage and Structural Mitigation Options). Recent flood experience enables the local community to understand flood risk and have realistic flood perceptions. Levee overtopping is a significant concern to the local community. Impacts of flash flooding from overland flows should also be considered in the TFWS. There are newcomers to the town that may be unaware of flood risk.
Emergency management planning	The Municipal Flood Emergency Planning Committee (MFEP) is currently reviewing the Mount Alexander Shire Council Municipal Flood Emergency Plan (MFEP). It was last updated July 2019. In relation to flood warning, the MFEP should include the flood intelligence products produced as part of the current study (R06 – Municipal Flood Emergency Plan Documentation) as well as the updated MFEP template. The MFEP also includes details about flood warning arrangements (e.g. roles of emergency agencies). Evacuation routes and appropriate emergency relief centres should be checked and are understood to be under review as part of the ongoing work that Mount Alexander Shire is undertaking through regular MEMPC committee meetings.
Community flood engagement and education	The Newstead Local Flood Guide (LFG) provides public information about the flood risk, flood levels, flood warnings, emergency kits and an emergency plan - https://dev.ses.vic.gov.au/plan-and-stay-safe/flood-guides/mount-alexander-shire-council. The LFG is being updated based on the flood study.
Data collection	There are several telemetered rainfall gauges within the catchment upstream of Newstead. The closest rain gauges that record sub-daily rainfalls and report to the BoM's website are outside of the catchment and include the Ballarat Airport AWS (6 minute recording, displayed at 1-hour intervals on BoM and approximately 10 minutes on Flood Zoom), Redesdale and Bendigo Airport. Four active streamflow gauges are located within the Upper Loddon Catchment with water level and streamflow data available to the present date at: ■ Loddon River at Vaughan ■ Loddon River at Newstead ■ Larni Barramal Yaluk at Yandoit ■ Muckleford Creek at Muckleford The streamflow gauges located upstream of Newstead may be useful in predicting flooding at Newstead however it is noted that they are located relatively close to Newstead and that there are a number of ungauged catchments which contribute to flooding in Newstead, including Mia Mia Creek and Green Gully Creek. The Bureau of Meteorology (BoM) does not provide a quantitative level of service at the Newstead gauge. Any warning information is likely to be general in nature.



TFWS Component	Assessment of the existing flood warning system
	A Flood Watch or Warning for Newstead is predicted from information at the streamflow gauges listed above. The warning times from rainfall to flooding will be affected by the predicted rainfall totals, catchment conditions, and the amount of time rain takes to fall. The information provided in a Flood Watch or Warning may be very general in nature. Newstead would benefit from a specific warning product. GMW track around 65% of inflows into Cairn Curran and then look at how much the dam has risen each hour to decide on releases. Lack of rain gauges in the upstream catchment hinders the prediction service. Given the proximity of the existing streamflow gauges to Newstead and subsequently, the limited travel time from the upstream gauges, and the presence of ungauged catchments upstream of Newstead, predicting the likely magnitude of flooding in Newstead is reliant on the real time rainfall gauge network and rainfall forecasts. In some events, warning times may be too short for monitoring of streamflow to be of any use as a means of issuing early flood warning. This is further assessed in Section 4.
Prediction	Newstead could benefit from a predictive service. GMW is able to provide predicted inflow and outflow from Cairn Curran (downstream of Newstead) but cannot precisely predict what flow will occur at Newstead. Based on previous significant flood events, the flood peak at Newstead is occurring well after 6-hours from the onset of rainfall within the catchment. Modelled flood peaks can manifest around 10 to 20 hours from the start of intense rainfall, with the majority of events peaking between 12 hours and 3 days from the start of the rainfall burst, This is discussed further in Section 4 and Section 6.
Interpretation	Interaction with the town levee is a key impact that has been assessed as part of the design modelling (R04 – Final Hydraulic Modelling Report) and flood intelligence assessment (R06 – Municipal Flood Emergency Plan Documentation). A river level gauge exists in town that flood emergency mapping has been linked to for interpretation in an Incident Control Centre (ICC) and with local emergency managers. The current flood class levels at the Loddon River at Newstead Gauge are as follows: ■ Minor Flood Level 3.00m ■ Moderate Flood Level 4.50m ■ Major Flood Level 5.60m Compared to the design modelling levels from the current study, the flood class levels are low, this is further discussed in Section 5.



TFWS Component	Assessment of the existing flood warning system
Warning message construction	Generic messaging is currently limited to flood watch, regional flood warnings and severe weather warnings for the Loddon catchment. Riverine flooding warnings presently issued on advice of BoM, VICSES reviews and adds consequence information (MFEP), polygons catchment/sub-catchment based. The establishment of Newstead as a forecast location quantitative prediction appears worth pursuing.
Warning message communication	Warning group in ICC can tailor area within the message, however this is not overly specific without input from G-MW on expected flows into Cairn Curran.
Response	Newstead becomes isolated which can hinder response efforts. The levee being close to overtopped/overtopping in 2011 and 2022 has led to trauma within the community. Feedback from the community indicates the Current warnings are not specific enough - community finds that really confronting, increasing anxiety. There is an older population (mean age 51 years ⁸). Only 5.5% of community require assistance in a flood and there are high levels of volunteerism (27.3%) indicating strong social connectedness. There are relatively few renters (9.2%) in town demonstrating low transience. No land uses with vulnerable people at risk (i.e. aged care, hospitals, pre-schools, caravan parks, schools etc.)
Review	There was no evidence that the existing flood warning system for Newstead was being reviewed regularly (e.g. through a system monitoring and evaluation process).
Community participation	High level of volunteerism shows the potential for community participation in emergency management including flood warning. There is an active CFA Brigade in the town https://newsteadcfa.org/ and the closest SES unit is based in Castlemaine.
Integration of the TFWS components	There was no strong evidence (e.g. in the MFEP) found that the linkages across the components of the TFWS were well understood for the study area.

⁸ Australian Bureau of Statistics, Census Data 2021, <https://abs.gov.au/census/find-census-data/quickstats/2021/SAL21936>



4 FLOOD PEAK TRAVEL TIME

4.1 Overview

Definitive information on the time it takes for flooding to develop (i.e. to arrive at a location) following the onset of heavy rain and the time it takes for the flood peak to be reached is highly variable. The magnitude and timing of a flood is dependent on several factors including the attributes of the rainfall/storm event and antecedent catchment conditions. The flood peak travel time assessment from R06 – Municipal Flood Emergency Plan (MFEP) Documentation is repeated below in more detail.

4.2 Historic events

4.2.1 Gauged flows

Flood peak timing for all gauges within the Upper Loddon River catchment was assessed against existing gauge data to identify the time from the onset of heavy rainfall to develop an understanding of lag times from rainfall to gauge rise and catchment travel times.

Table 4-1 shows the typical travel time along the Loddon River and its tributaries, based on the flood events in 2022, 2016, 2011 and 2010. Figure 4-1 shows the location of the streamflow gauges. The rainfall temporal pattern and storm duration or the combination of both can impact the magnitude of flooding at Newstead. The table highlights that reliance on upstream gauges provides limited warning time, and that more warning time can be provided by monitoring rainfall gauges within the catchment.

Table 4-1 Timing of peak flow at Newstead

From	To	Typical travel time
Start of rainfall (catchment)	Start of Loddon River rising in Newstead	11 hours to 4 days
Start of Loddon River rising in Newstead	Peak Loddon River flow at Newstead	11 to 54 hours
Peak Loddon River flow at Vaughan	Peak Loddon River flow at Newstead	3.5 to 4.75 hours
Peak Muckleford Creek flow at Muckleford	Peak Loddon River flow at Newstead	2 to 5 hours
Peak Larni Barramal Yaluk flow at Yandoit	Peak Loddon River flow at Newstead	0 to 6 hours
End of heavy rainfall (catchment)	Peak Loddon River flow at Newstead	0 to 7 hours

Recorded rainfall and streamflow during the 2022, 2016, 2011 and 2010 event are shown in Figure 4-2 to Figure 4-5, showing rainfall totals recorded at the Bendigo Airport, Redesdale and Ballarat Aerodrome sub-daily rainfall stations and streamflow at each existing streamflow gauge location. The estimated lag time between the onset of heavy rain in the upper catchment to a rise at the Newstead streamflow gauge was between 11 hours and 4 days. The Newstead gauge peaked between 0 to 7 hours after the end of the rainfall. The flood peak travel time between the Vaughan and Newstead gauges was between 3.5 and 4.75 hours.

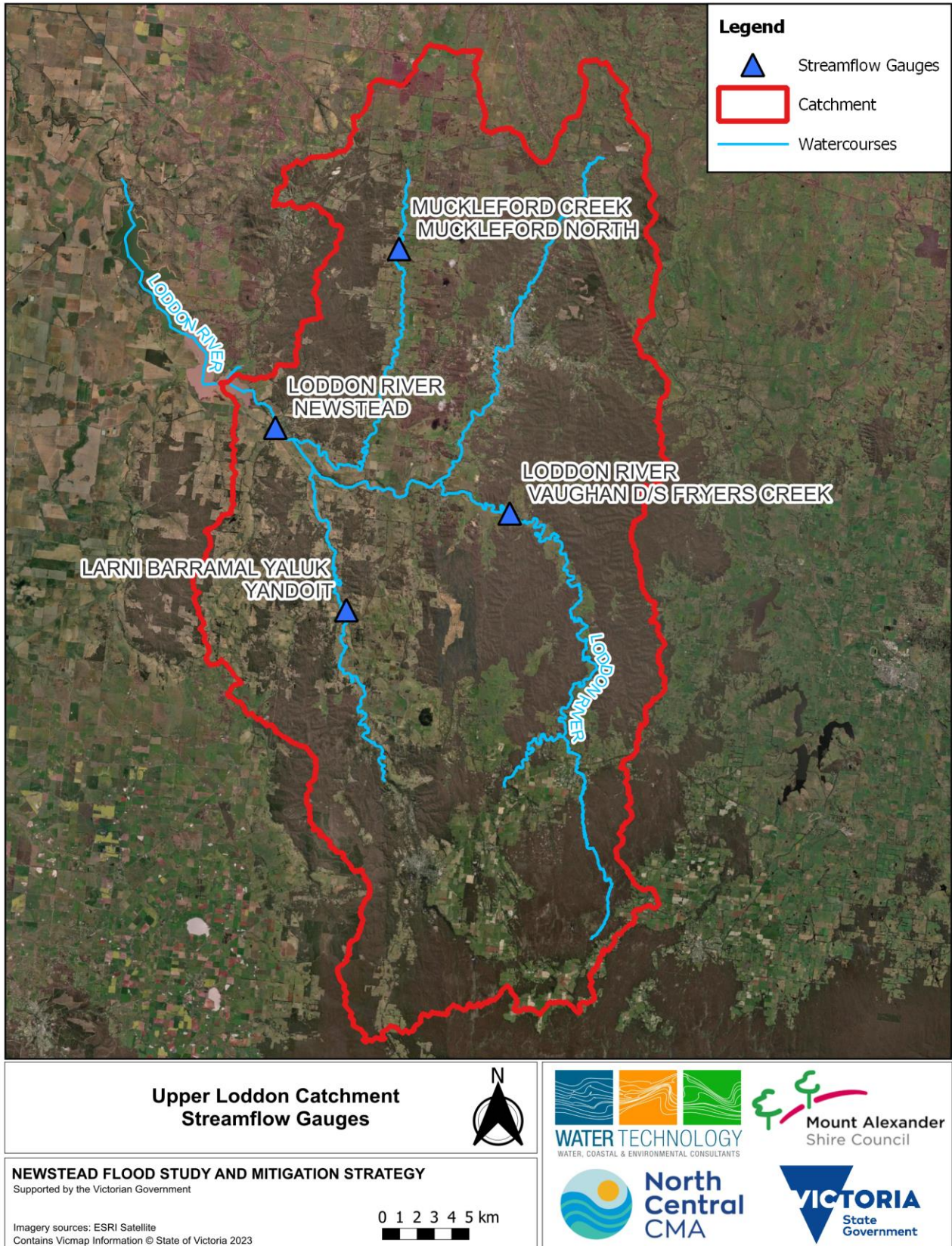


Figure 4-1 Streamflow gauge locations

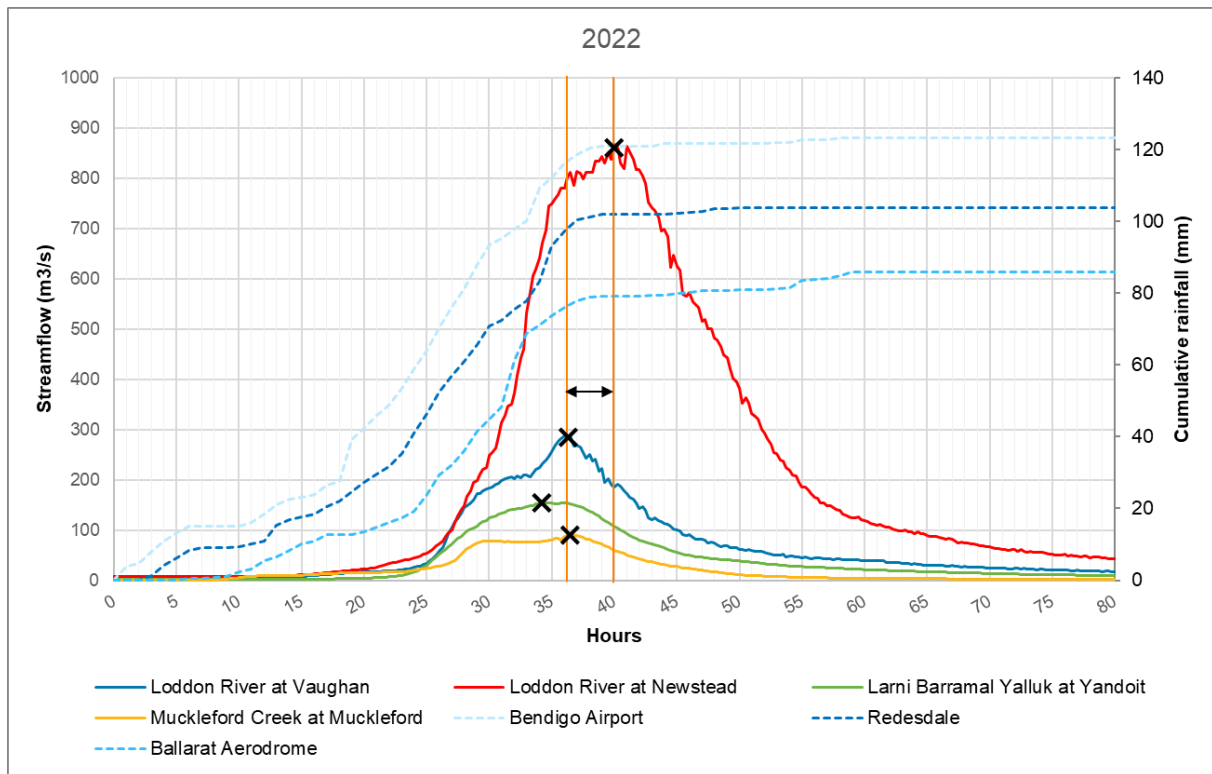


Figure 4-2 Gauged travel time between gauging stations during October 2022

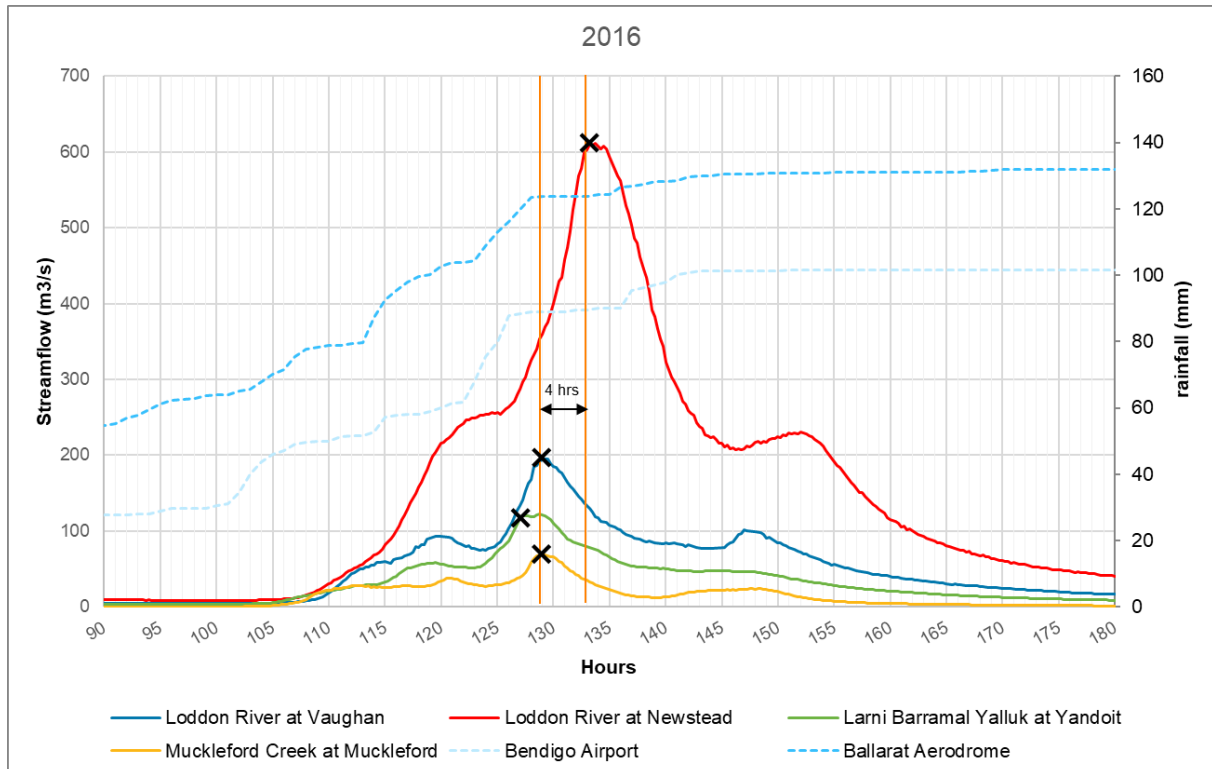


Figure 4-3 Gauged travel time between gauging stations during September 2016

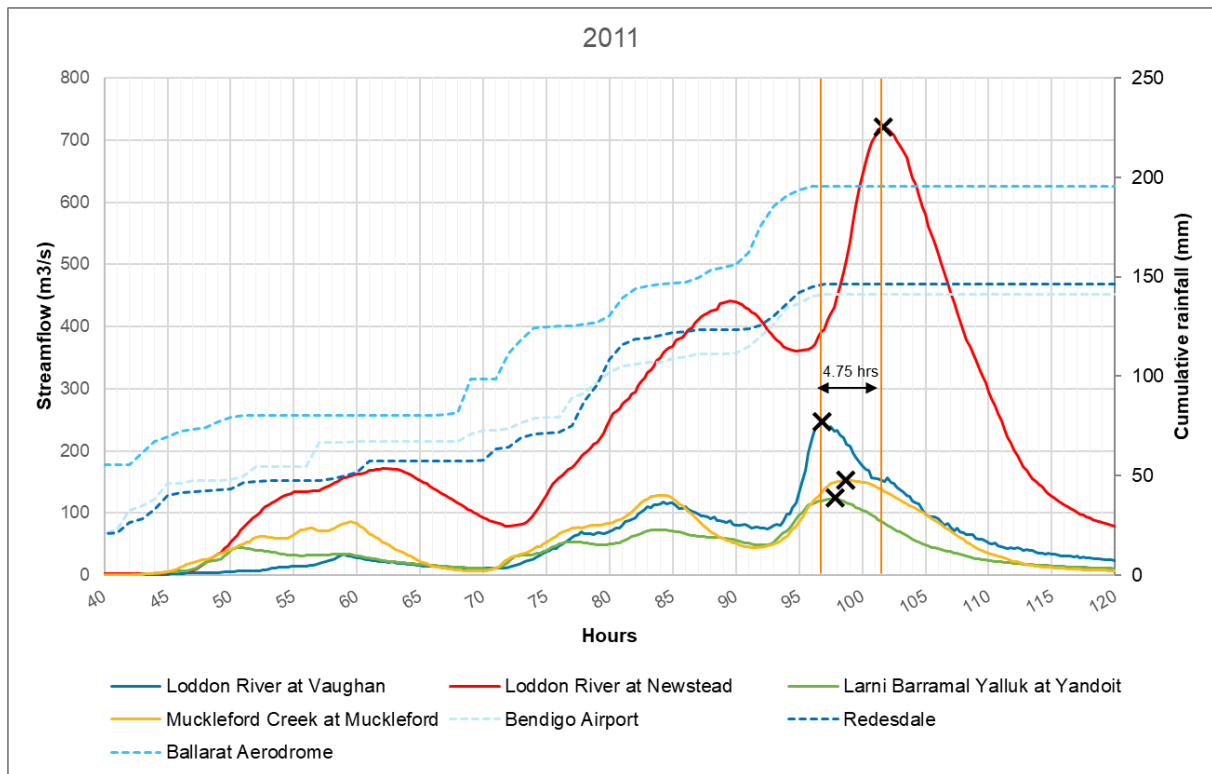


Figure 4-4 Gauged travel time between gauging stations during January 2011

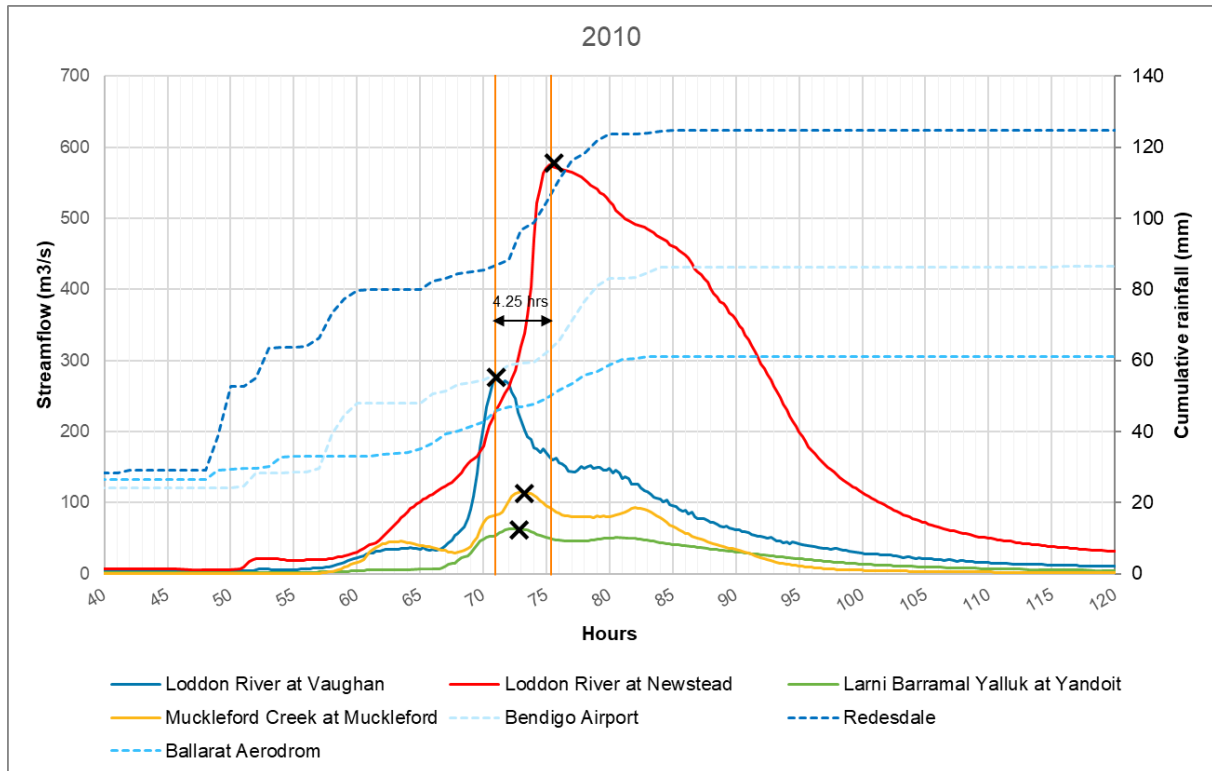


Figure 4-5 Gauged travel time between gauging stations during November 2010



4.2.2 Modelled flows

The flood peak timing analysis was repeated using the hydrology model results to enable assessment of potential additional gauge locations. Artificial gauge stations were added at three locations (see Figure 4-6):

- Loddon River at Vaughan Springs Road – to assess the benefit of a streamflow gauge further upstream in the Loddon River catchment
- Campbells Creek at Castlemaine – to assess the benefit of a streamflow gauge on a major ungauged catchment contributing to Loddon River flooding
- Green Gully Creek at Sandon – to assess the benefit of a streamflow gauge within an ungauged catchment that causes flood impacts in Newstead
- Mia Mia Creek at Mia Mia Track – to assess the benefit of a streamflow gauge within an ungauged catchment that causes flood impacts in Newstead

Recorded rainfalls at the sub-daily rainfall stations and modelled streamflows at each potential streamflow gauge location are shown in Figure 4-7 to Figure 4-10 for the 2022, 2016, 2011 and 2010 events. The plots also include modelled flows at existing stations on the Loddon River for comparison. Table 4-2 shows an overview of the modelled flood peak travel times.

Table 4-2 Timing of modelled flows at potential gauging stations

From	To	Typical travel time
Peak Loddon River flow at Vaughan Springs Rd	Peak Loddon River flow at Newstead	2 to 6 hours
Peak Loddon River flow at Vaughan	Peak Loddon River flow at Newstead	1 to 5 hours
Peak Campbells Creek flow at Castlemaine	Peak Loddon River flow at Newstead	2 to 5 hours
Peak Mia Mia Creek flow at Mia Mia Track	Peak Mia Mia Creek flow at Newstead	0 to 2 hours
Peak Green Gully Creek flow at Sandon	Peak Green Gully Creek flow at Newstead	2 to 6 hours (2016 - 24 hours, outlier)

The results show that an additional gauge upstream of Vaughan only provides up to two hours of additional warning time, with the Loddon River at Newstead flood peak occurring within 2 to 6 hours of the peak at Vaughan Springs Road. Additionally, the placement of a gauge far upstream means many of the tributaries contributing to flooding at Newstead are not accounted for by this gauge meaning a gauge at this location would not be a reliable indicator of flooding at Newstead.

Similar travel times are shown at the remaining proposed gauge sites, indicating none of them would provide much value in predicting a flood event at Newstead.

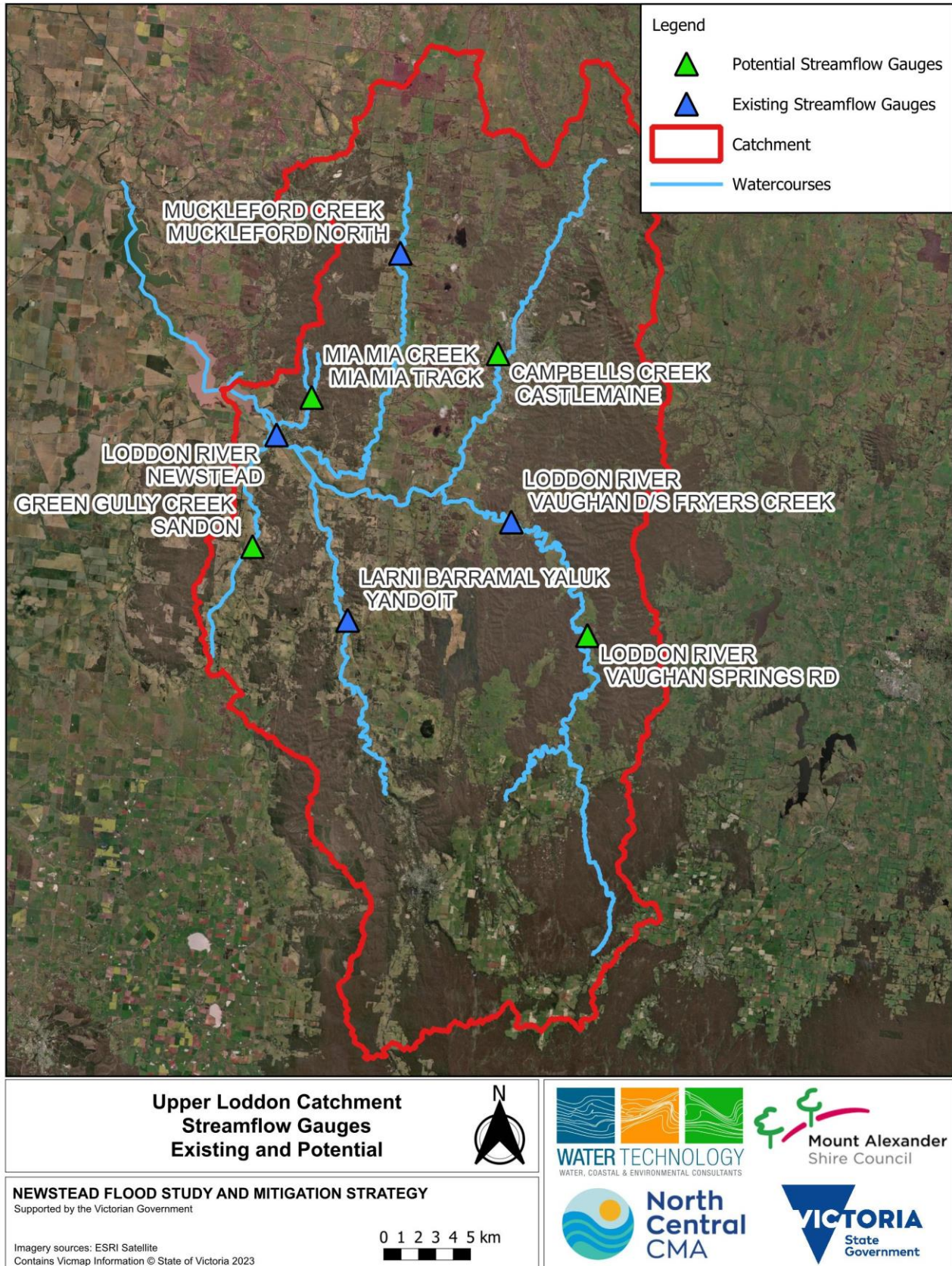


Figure 4-6 Potential streamflow gauge locations

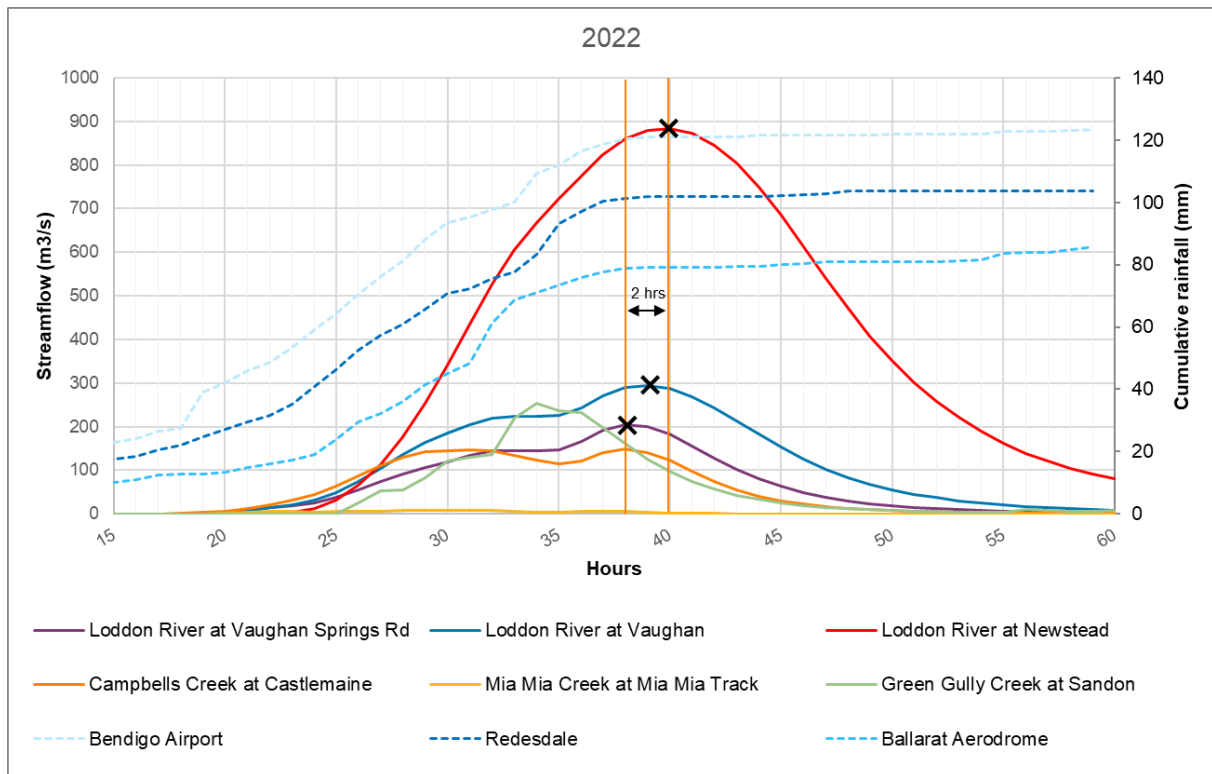


Figure 4-7 Modelled travel time between gauging stations during October 2022

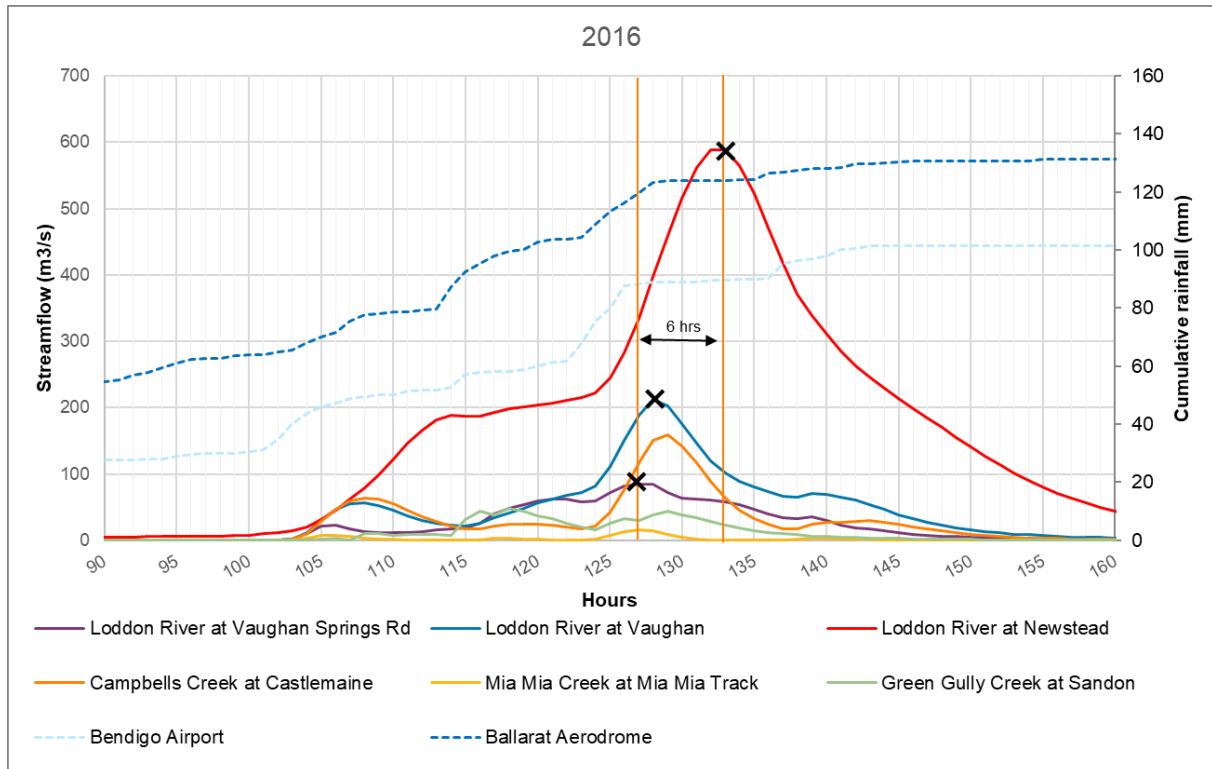


Figure 4-8 Modelled travel time between gauging stations during September 2016

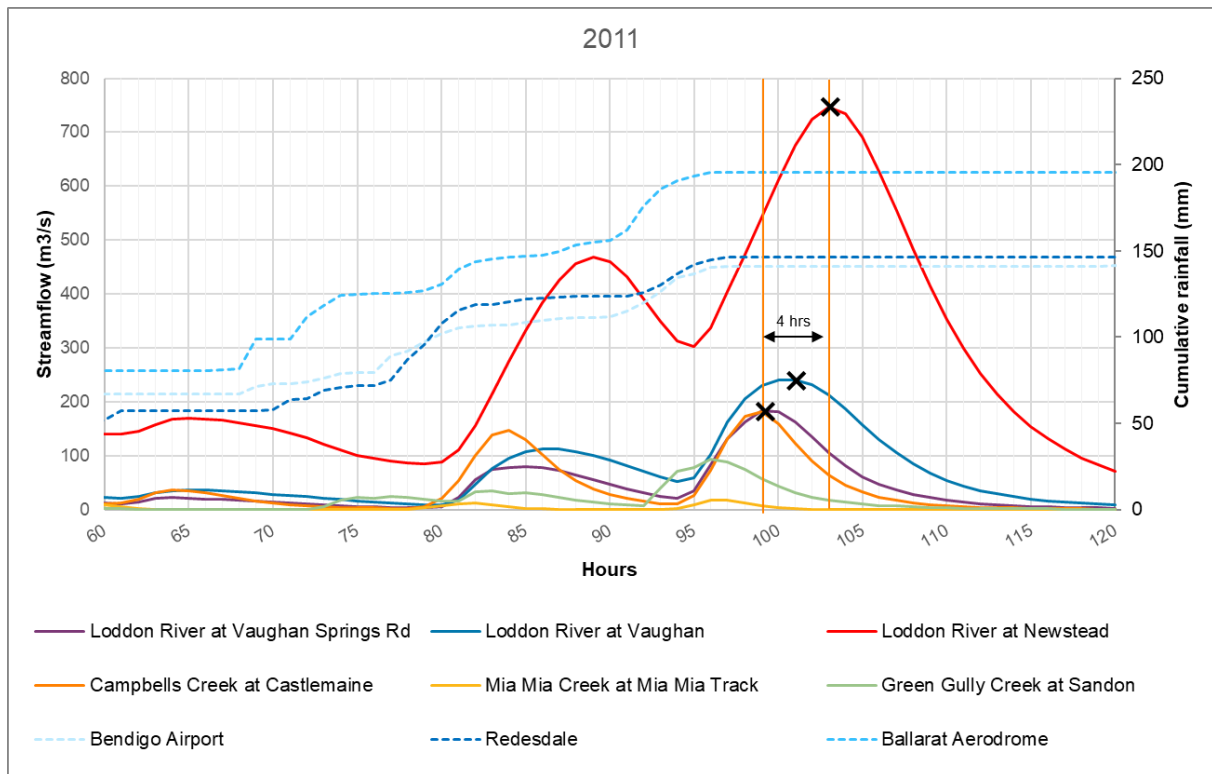


Figure 4-9 Modelled travel time between gauging stations during January 2011

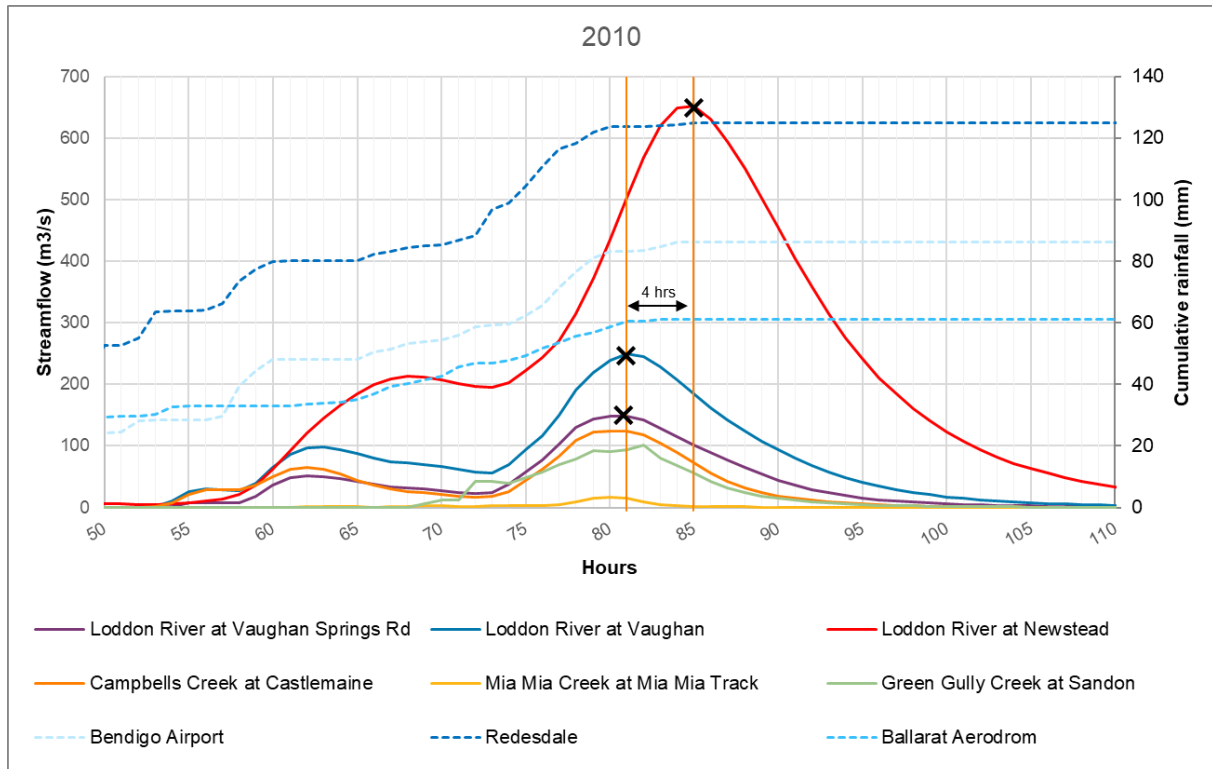


Figure 4-10 Modelled travel time between gauging stations during November 2010

4.3 Design flood peak travel times

Additional to analysing historic events, the calibrated hydrology model developed as part of this study was utilised to estimate typical flood peak travel times for a range of storms. The modelled hydrographs at the Loddon River at Newstead gauge for the 1% AEP and 10% AEP rainfall events are shown in Figure 4-11 and Figure 4-12. The graphs show all modelled AEP events for durations between 12 hours and 168 hours for all ten temporal patterns. A total of 100 hydrographs were produced for each AEP. Also shown on the graphs is the critical duration and median temporal pattern peak flow at this location, selected in accordance with the recommendations of ARR.

The graphs show a significant range in peak flows and timing produced by rainfall depths of a specified AEP when that rain falls over different durations and temporal patterns within the duration. This illustrates the difficulty in accurately predicting flood peaks and timing from rainfall alone.

The graphs show that the modelled flood peaks can manifest around **10 to 20 hours** from the start of intense rainfall, with the majority of events peaking between 12 hours and 3 days from the start of the rainfall burst. Some events peak beyond 3 days from the start of rainfall, however these become rarer and may contain “embedded bursts” where rainfall intensity within an event increases for a short period of time.

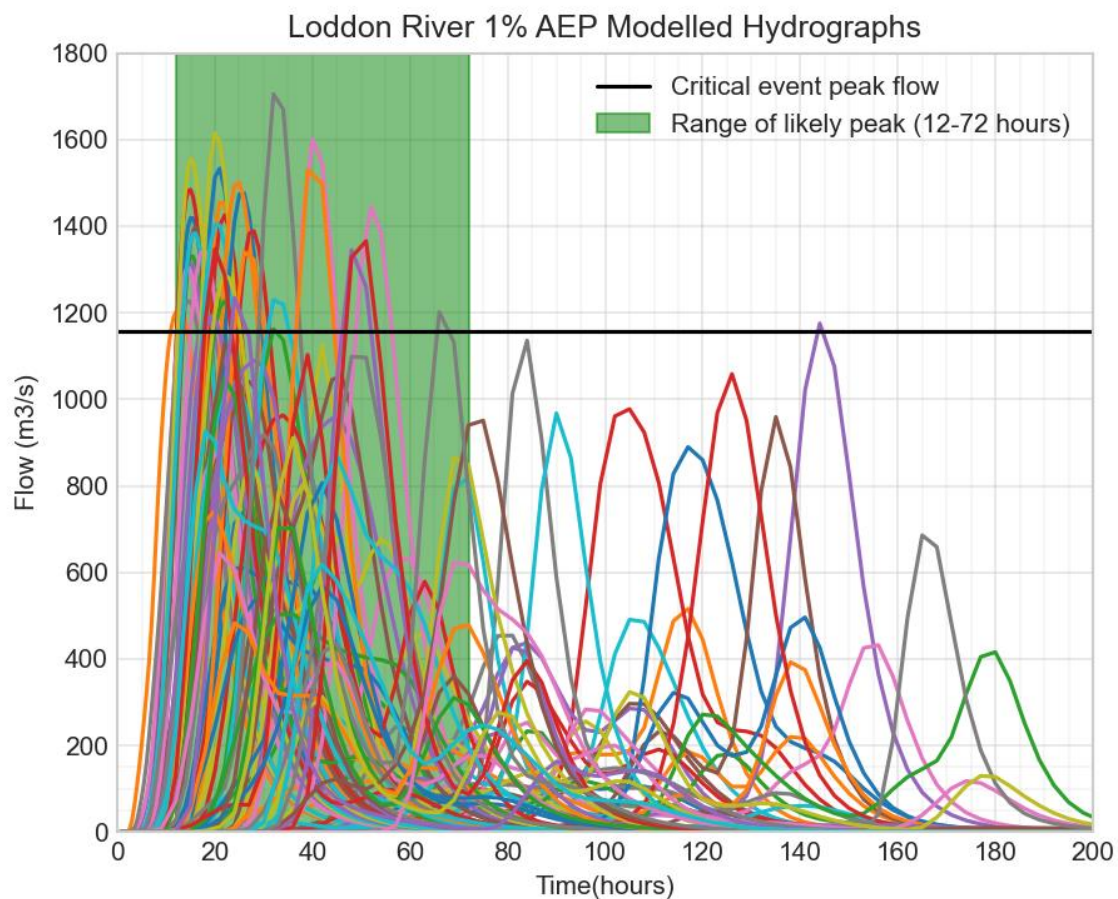


Figure 4-11 1% AEP hydrograph for all modelled rainfall events at Newstead

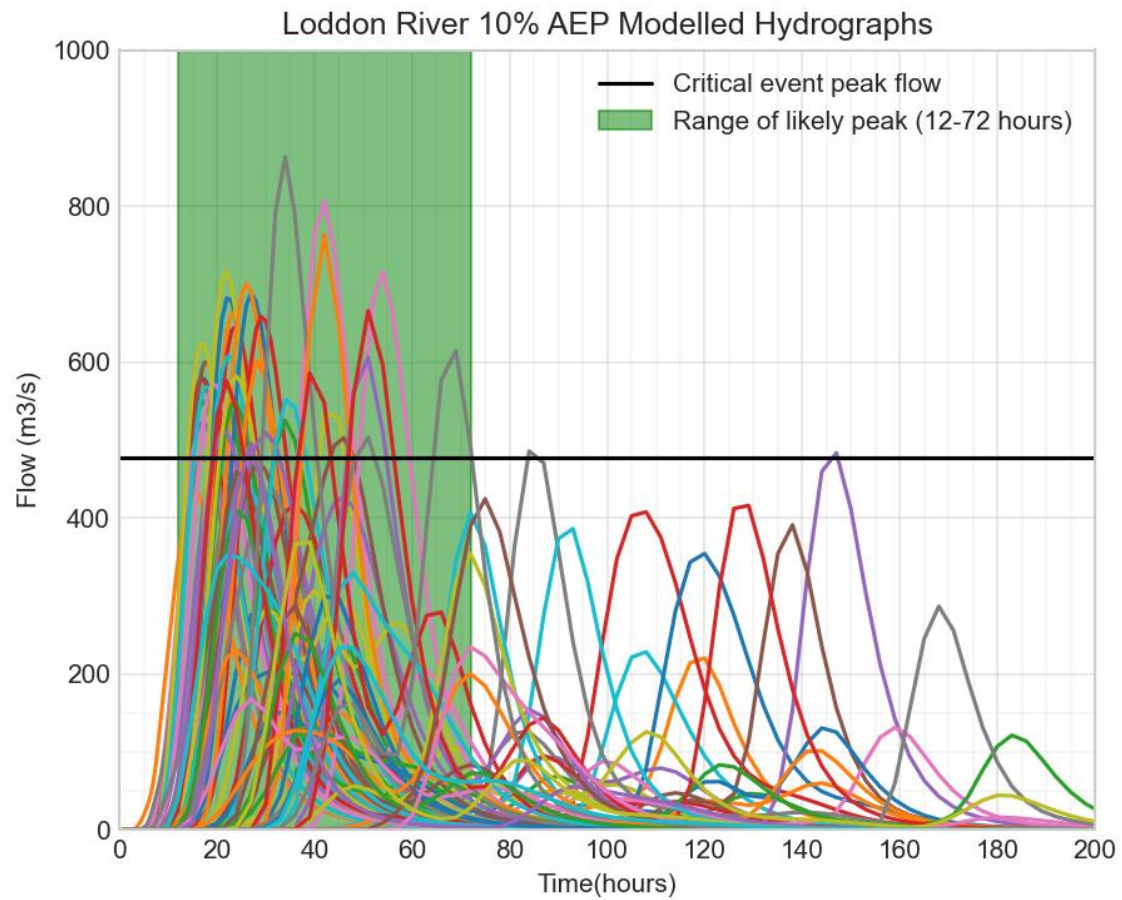


Figure 4-12 10% AEP hydrograph for all modelled rainfall events at Newstead



5 FLOOD CLASS LEVELS

Defined Flood Class Levels (FCLs) are available for the Loddon River at Newstead gauge and are detailed in Table 5-1.

Table 5-1 Current Flood Class Levels for Newstead

Flood Class	Gauge level at Loddon River at Newstead gauge (m)	Flood Level at Loddon River at Newstead gauge (mAHD)	Description
Minor	3.0	210.937	The minor flood level is well below the 20% AEP level at Newstead (5.49 m). Minor out of bank flooding from the Loddon River is observed upstream of Punt Road. Mia Mia Creek floods onto farmland north of Newstead and shallow outbreaks are observed along Green Gully Creek.
Moderate	4.5	212.437	The moderate flood level is also well below the 20% AEP level at Newstead (5.49 m). Out of bank flooding is observed along the Loddon River and Green Gully Creek in most of the study area, with the Pyrenees Highway overtopped by Green Gully Creek.
Major	5.6	213.537	The major flood level is in between the 20% and 10% AEP level at Newstead (5.49 m and 5.80 m respectively). Widespread out of bank flooding is expected along all waterways entering Newstead, with impacts to the Pyrenees Highway and Hepburn-Newstead Road as well as some residential streets.

The Bureau of Meteorology's definitions of FCLs are presented below:⁹

Minor flooding

If the water level reaches the minor flood level, it causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas flooding may affect some backyards and buildings below floor level as well as bicycle and pedestrian paths. In rural areas removal of livestock and equipment may be required.

Moderate flooding

If the water level reaches the moderate flood level, the area of inundation is larger. Main traffic routes may be affected. Some buildings may be affected above floor level. Evacuation may be required. In rural areas removal of livestock is necessary.

Major flooding

If the water level reaches the major flood level large areas are inundated. Many buildings may be affected above floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation may be required. Utility services may be affected.

⁹ <http://www.bom.gov.au/australia/flood/knowledge-centre/about-warning-service.shtml>



Based on the Bureau of Meteorology definitions, the existing flood class levels at Newstead appear to be slightly low. Table 5-2 details proposed flood class levels based on the design modelling undertaken for the current project.

Table 5-2 Proposed Flood Class Levels for Newstead

Flood Class	Level at Loddon River at Newstead gauge (m)	Level at Loddon River at Newstead gauge (mAHD)	Description
Minor	4.5	212.437	Propose to adopt the current moderate flood level as the minor flood level. Out of bank flooding is observed along the Loddon River and Green Gully Creek in most of the study area, causing inconvenience with the Pyrenees Highway overtopped by Green Gully Creek but at a shallow level.
Moderate	5.5	213.427	Propose to adopt the 20 % AEP flood level (5.49m gauge height) as the moderate flood level. Widespread out of bank flooding is expected along all waterways entering Newstead, with road closures on the Pyrenees Highway and Hepburn-Newstead Road as well as some residential streets. No property is flooded above floor, but 1 property is flooded below floor with over 30 parcels inundated away from the main building.
Major	5.8	213.737	Propose to adopt the 10% AEP flood level as the major flood level. Widespread out of bank flooding is expected along all waterways entering Newstead, with road closures on the Pyrenees Highway, Hepburn-Newstead Road and Daylesford-Newstead Road as well as some residential streets. The water level is still below the Newstead levee crest. No property is flooded above floor, but 3 properties are flooded below floor with over 30 parcels inundated away from the main building, and areas of Newstead are isolated.



6 FLOOD WARNING IMPROVEMENTS

6.1 Existing capability

Currently, there is no formal flood warning system in place that is specific to Newstead. As described in Table 3-1, the flood warning system at Newstead consists of generic messaging limited to flood watch, regional flood warnings and severe weather warnings for the Loddon catchment. Additionally, there are several ungauged catchments and the streamflow gauges upstream of Newstead are located too close to provide sufficient warning time alone. Currently, official flood warning capability for the catchment and township is limited to the issue of a Flood Watch for the Loddon River. Note a flood watch is not necessarily guaranteed to be issued prior to flooding.

There are no sub-daily rainfall gauges within the Upper Loddon catchment upstream of Newstead, therefore rainfall estimates in the catchment upstream of Newstead are not well captured. Currently estimates of rainfall within the catchment relies on rainfall gauges outside of the catchment.

6.2 Ideal (Potential) capability

The Loddon Total Flood Warning System Review³ has identified possible improvements to the flood warning system specifically for Newstead, see Table 6-1.

Table 6-1 Possible improvements to the flood warning system at Newstead

TFWS Component	Potential Actions	Rationale
Understanding flood risk	Share mapping and findings of the current study with the Newstead community including newcomers.	Newstead Flood Study and Mitigation Strategy will provide details of flood impacts for different events and possible flood risk mitigation options. Levee overtopping is a concern to the local community. There are newcomers to the town that may be unaware of flood risk.
Emergency management planning	Update the Mount Alexander Shire Council MFEP in the light of the Newstead Flood Study and Mitigation Strategy, specifically R06 – Municipal Flood Emergency Plan (MFEP) Documentation and de-briefs from recent flood events.	The Municipal Flood Emergency Planning Committee (MFEPC) is currently reviewing the Mount Alexander Shire Council Municipal Flood Emergency Plan (MFEP). It was last updated July 2019.
Community flood engagement and education	Update the Newstead Local Flood Guide (LFG) in line with the MFEP update.	The Newstead Local Flood Guide (LFG) provides public information about the flood risk, flood levels, flood warnings, emergency kits and an emergency plan - The LFG needs to be updated based on the flood study.
Community flood engagement and education	Install a gauge board with historic flood levels near the Newstead levee to provide a robust reference for communications during emergencies	Levee overtopping is critical to emergency response including sandbagging and possible evacuation.



TFWS Component	Potential Actions	Rationale
Data collection	Install telemetered stream gauges in Mia Mia Creek and Green Gully Creek catchments. Section 4.2.2 details an assessment of potential new gauging sites, this is further discussed below.	Four active streamflow gauges are located within the Upper Loddon Catchment with water level and streamflow data available to the present date. The streamflow gauges located upstream of Newstead may be useful in predicting flooding at Newstead, however it is noted that they are located relatively close to Newstead and that there are a number of ungauged catchments which contribute to flooding in Newstead, including Mia Mia Creek and Green Gully Creek.
Prediction	Explore the possibility of a quantitative level of flood warning service at Newstead with BoM	Currently, the information provided in a Flood Watch or Warning may be very general in nature. The assessment of the onset of flooding/flood peak timing from the beginning of rainfall within this report suggests sufficient warning time meet the BoM requirements for a quantitative level of service. G-MW currently predict inflows into Cairn Curran Reservoir.
Interpretation	Use the Flood/No Flood tool provided in R06 – Municipal Flood Emergency Plan (MFEP) Documentation to assist in flood decision-making along with the Flood Intelligence Cards to assist emergency decision-making and to develop warning advice to the Newstead community.	Given the proximity of the streamflow gauges to Newstead and subsequently, the limited travel time from the upstream gauges, and the presence of ungauged catchments upstream of Newstead, predicting the likely magnitude of flooding in Newstead is reliant on the real time rainfall gauge network and rainfall forecasts. In some events, warning times may be too short for monitoring of streamflow to be of any use as a means of issuing early flood warning.

6.3 Additional monitoring infrastructure

Flood data monitoring for the catchments upstream of Newstead would benefit from the placement of a sub-daily rainfall gauge in the upper catchment. There are no existing gauges in the upper catchment. The nearby gauges at Ballarat, Bendigo and Redesale may not reflect rainfall in the catchment nor in the immediate vicinity of the township.

A sub-daily rain gauge within the Upper Loddon catchment would therefore improve the monitoring capability for the township and broader catchment. A rain gauge within Newstead itself would provide the additional benefit of allowing for monitoring of flash flooding conditions within the township, which is known to have caused issues recently, based on feedback received during community consultation sessions for this project.

Analysis presented in Section 4 indicates that the benefit from providing additional streamflow gauges in the Upper Loddon, Campbells Creek, Mia Mia Creek and Green Gully Creek is relatively limited for predicting



flooding at Newstead, however may provide additional benefits at locations such as Castlemaine and Campbells Creek for establishing a quantitative flood history.

In summary,

- Discussions on the ability for BoM to provide a quantitative level of service at Newstead should be undertaken. Involvement with G-MW on their current prediction of flow into Cairn Curran may aid in the discussions.
- A rainfall gauge in the Upper Loddon catchment would improve monitoring capabilities in Newstead. The gauge would play a direct role in warning of impending floods.
- An additional streamflow gauge within the Campbells Creek, Mia Mia Creek or Green Gully Creek catchments would provide some (but limited) benefit to estimating flows at Newstead/Cairn Curran but may provide other benefits including improved flow estimation for Cairn Curran inflows or benefits for other towns.



7 SUMMARY AND RECOMMENDATIONS

The Newstead Flood Study and Mitigation Strategy has produced detailed flood modelling of the Loddon River and other tributaries for the catchment upstream of Newstead. Flood modelling has underpinned the basis of this investigation with the mapping produced to be used for flood emergency planning and response alongside flood intelligence, statutory and strategic planning in the town.

A summary of the flood warning findings has identified:

Preferred monitoring capability and infrastructure to support a Total Flood Warning System for Newstead has been discussed, with a sub-daily rain gauge recommended in the Upper Loddon catchment would provide Newstead with improved monitoring for flood conditions in the town. This may allow for a quantitative level of flood warning service to be discussed with both G-MW, who currently predict inflows into Cairn Curran Reservoir and the Bureau.

Updated Flood Class Levels have been proposed based off the Bureau of Meteorology's definitions and flood mapping completed for Newstead. The Flood Class Levels utilise the existing stream gauge in Newstead, which could be accompanied by a gauge board for manual reading. It is noted that insufficient lead time for a flood would mean that the implementation of flood class levels and a qualitative warning system would not be achievable.

A number of Flood Warning recommendations from the Newstead Flood Study have been separated into the agencies responsible for their fulfilment. This report should be read in conjunction with the Loddon Total Flood Warning System Review³ report to understand the broader Loddon River flood warning context.

The flood warning recommendations include:

- Review the information within the Flood Intelligence and Flood Warning Report to undertake an update of the Mount Alexander Shire Council MFEP.
- Undertake a review of the current response, maintenance and operations documentation with Council staff.
- Upload the Victoria Flood Database mapping data and the excel spreadsheet of property inundation to FloodZoom.
- In conjunction with the NCCMA
 - Discuss with the BoM requirements for a quantitative level of service at Newstead. This should also involve G-MW who currently predict inflows into Cairn Curran Reservoir.
 - Investigate opportunities to install telemetered rainfall gauges within the catchment and to a lesser extent, stream gauges at Castlemaine/Campbells Creek and the Mia Mia Creek and Green Gully Creek catchments.
 - Investigate opportunities install a level gauge with historic flood levels near the Newstead levee to provide a robust reference for communications during emergencies.
 - Discuss with BoM to review the current Flood Class Levels at Newstead.
- In conjunction with VicSES
 - Continue to engage the community through regular flood awareness programs such as the VICSES FloodSafe program.
 - Update the Newstead Local Flood Guide.

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