WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Report

Echuca Flood Risk Management Study

Campaspe Shire Council & Murray River Council

5 March 2025

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
1	Draft	Ben Tate	Ben Tate	5 March 2025

Project Details

Project Name	Echuca Flood Risk Management Study
Client	Campaspe Shire Council & Murray River Council
Client Project Manager	John McCartney
Water Technology Project Manager	Aram Manjikian
Water Technology Project Director	Ben Tate
Authors	Aram Manjikian
Document Number	5820_R05_V01b_FRMP_VIC.docx

Acknowledgements

Campaspe Shire Council in collaboration with Murray River Council has prepared this document with financial assistance from the Victorian and NSW Governments through their respective floodplain management programs. This document does not necessarily represent the opinions of the Victorian or New South Wales Governments.

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800
Fax (03) 9558 9365
ACN 093 377 283
ABN 60 093 377 283

ACKNOWLEDGEMENT OF COUNTRY

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

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

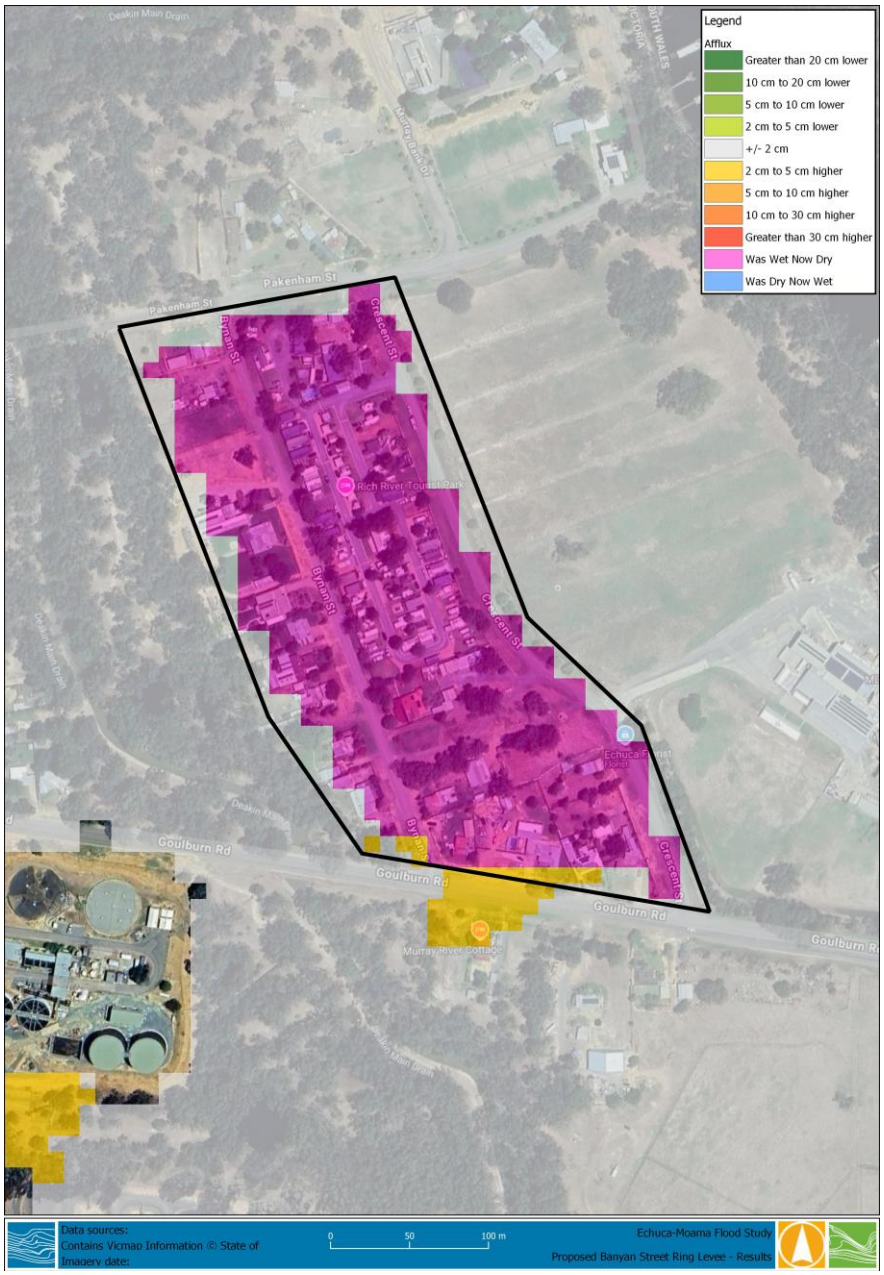
Artwork by Maurice Goolagong 2023. This piece was commissioned by Water Technology and visualises the important connections we have to water, and the cultural significance of journeys taken by traditional custodians of our land to meeting places, where communities connect with each other around waterways.

The symbolism in the artwork includes:

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

CONTENTS

LIST OF FIGURES



LIST OF TABLES

1 INTRODUCTION

The Echuca Moama Flood Study was completed and endorsed by both Campaspe Shire Council and Murray River Council in early 2024. The study updated flood information that has been gathered from recent flooding events (1993, 2011, 2016, and 2022) and improved the understanding of flooding within Echuca and Moama for various design storm events. The progression of the study has moved to flood mitigation, response and intelligence for better management of floodplain risks that will reduce the impacts of future flood events.

1.1 Objectives of the Floodplain Risk Management Study

The Floodplain Risk Management Study provides the work undertaken to:

- Gather community feedback on flood response and mitigation strategies
- Assess hydraulic impacts of potential mitigation measures for improving flooding in Echuca and Moama to reduce damages to properties,
- Determine the financial implications of measures and provide a cost-benefit ratio,
- Summarise existing emergency management arrangements, including the roles and responsibilities of stakeholders
- Using the flood study outputs, enhance existing flood intelligence for emergency response
- Review existing land use planning strategies and provide recommendations for the future

2 BACKGROUND

2.1 Study Area

The townships of Echuca and Moama are located on opposite sides of the Murray River, in Victoria and New South Wales respectively. They are positioned on the Murray River, with the Goulburn River confluence 15 km upstream, and the Campaspe River running through Echuca from the south and flowing into the Murray River on the western fringe of the township.

The towns and surrounding areas are within a complex floodplain that is characterised by a series of many levees built over several decades along the rivers and protecting urban areas and some farmland. There are two major road crossings over the Murray River, and another three crossings over the Campaspe River. With recent changes to road infrastructure, and permanent and temporary levees constructed, past historical flood impacts may not be a good guide to future flood impacts, necessitating the need for new updated information.

The two townships have a combined population of 22,500 people, and have a good spread of age cohorts according to the recent 2021 census. With both Echuca and Moama experiencing steady growth, the Campaspe Shire Council (CSC) and Murray River Council (MRC) require high quality flood information to support future town planning decisions. The last flood study for Echuca-Moama was completed in 1997. Since the previous study was completed, hydrology and hydraulic flood mapping practices have advanced significantly. Since the last study there have also been significant flood mitigation levee works constructed, including the Moama town levee.

The study area for the flood risk management plan focusses on the townships of Echuca and Moama as shown in Figure 2-1. The flood study area extended further downstream for 120 km and includes the areas of Torrumbarry, Koondrook and Barham as well as the Koondrook-Perricoota and Gunbower Forests. The study area extends upstream on the Murray River to Barmah, on the Goulburn River to Shepparton, and on the Campaspe River to Rochester. It is noted that the models were extended a long way upstream to make use of reliable streamflow gauge locations, but the focus for detailed flood mapping was really the Echuca and Moama areas.

The modelling was completed in two parts, the upstream section of the study area through to the Torrumbarry area, with a second downstream model used to investigate the effectiveness of the Torrumbarry levees. This report focuses on the upstream modelling and how it relates to flooding in the Echuca and Moama areas. The downstream Torrumbarry area is considered in a separate report.

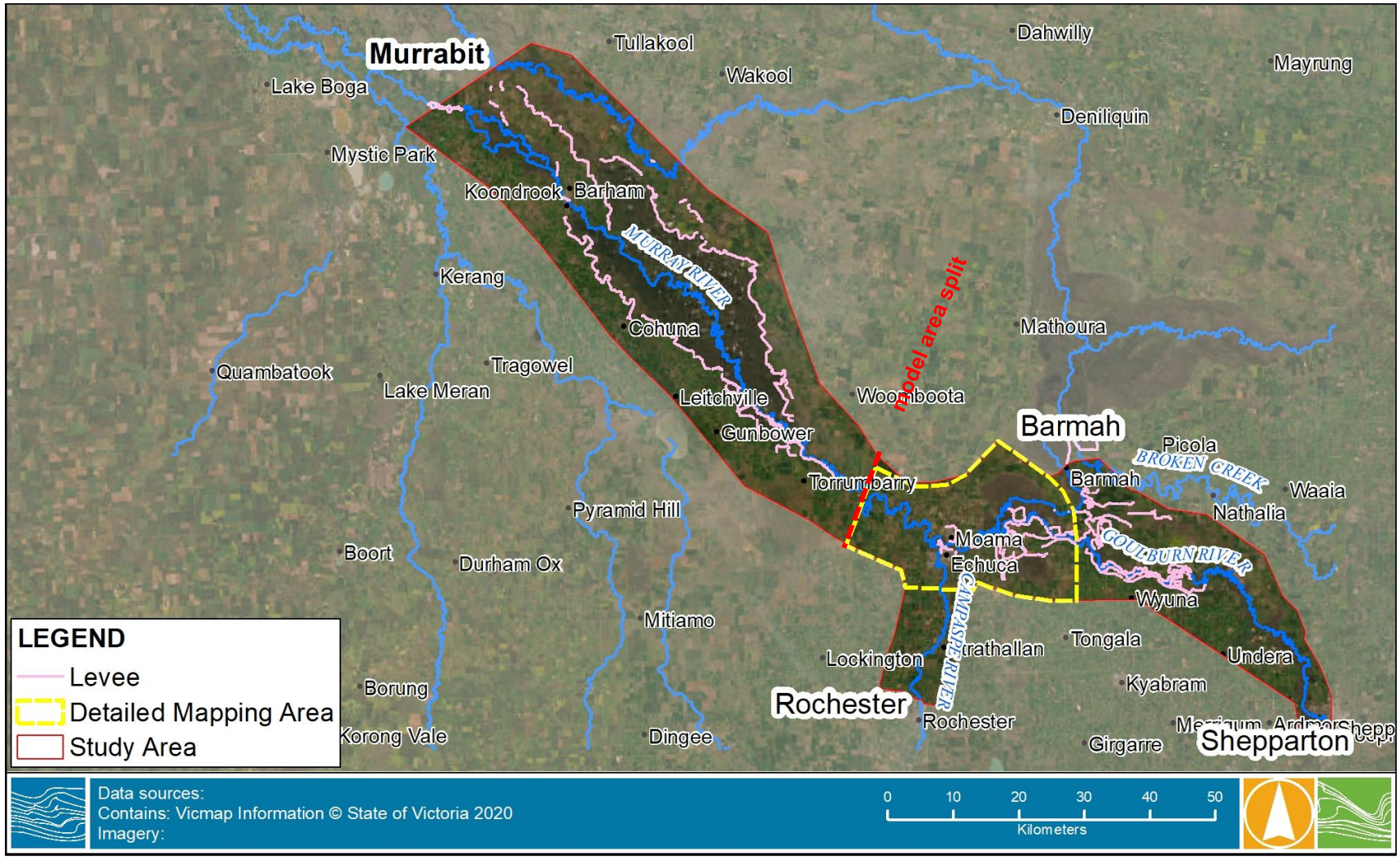


Figure 2-1 Study Area

2.2 History of Flooding

The location of the Echuca and Moama townships sit partially within the Kanyapella Basin and are impacted by the influence of three major waterways; Murray River, Goulburn River, and Campaspe River. The townships have been impacted by many flood events in their history, which has led to various works over a long period of time, both government funded public works like the Moama and Echuca town levees and many private levees.

Table 2-1 lists the significant past flood events in recorded history, with the respective water level reached at the Echuca Wharf gauge on the Murray River.

Table 2-1 Top ten historic events and water levels at Echuca Wharf gauge

Flood Event Date	Historic water level recorded at the Echuca Wharf gauge		
	Relative gauge level (m)	Gauge level (m AHD) *Gauge Zero = 84.605 m AHD*	Rank
Nov 1870	11.60	96.2	1
1867	10.75	95.35	2
Oct 2022	10.39	94.99	3
1916	10.20	94.80	4
Oct 1993	10.17	94.77	5
Nov 1975	10.15	94.75	6
1956	9.98	94.58	7
1917	9.95	94.55	8
May 1974	9.92	94.52	9
1939	9.89	94.49	10
Other more recent events for context			
Oct 2016	8.82	93.41	32
Jan 2011	8.25	92.85	44

2.3 Flood Behaviour

Flooding in the Echuca and Moama area is the result of complex interactions of flows in the Murray, Goulburn and the Campaspe Rivers. The Barmah Choke and Bama Sand Hills provide a significant constriction to the peak flow capacity of the Murray River, with Murray River flows stored within the Barmah Forest and forced north into the Edward River. When flows exceed the capacity of the Murray and Goulburn River channels downstream of the Bama Sand Hills, flood flows spill into the Kanyapella Basin, which forms a very large floodplain storage upstream of the townships, as shown in Figure 2-2. The flood flows that spill into the basin, travel across the floodplain and re-enter the Murray River close to the Moama and Echuca townships.

This summary is a basic description of how the estimated 1% AEP flood event may unfold, but it must be noted that every flood is different, and is influenced by factors like rainfall patterns, catchment wetness, temporary works on the floodplain, etc.

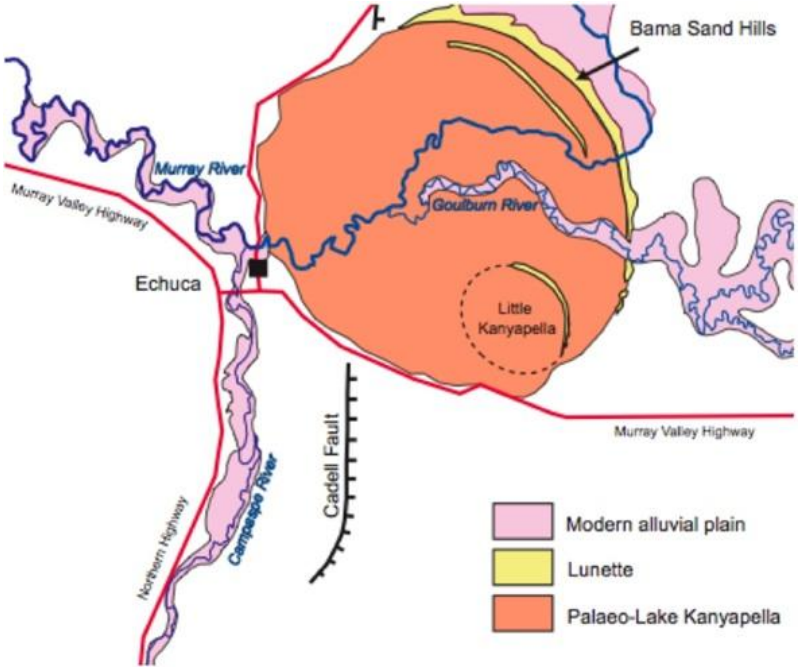


Figure 2-2 Kanyapella Basin Extent (Source: modified after Rutherfurd and Kenyon (2005); Barberias (1983))

If the Murray River upstream of Barmah Forest is flooding, then early inundation will begin in the forest area of the northern Kanyapella Basin, with water leaving the Murray and filling the lowest areas of the forest.

As the Goulburn River peak passes through Shepparton, a significant flow leaves the river and enters the Deep Creek floodplain to the north via the Loch Garry Regulator and via overtopping of the lower Goulburn River levees and other escape points through the levee. As the Goulburn River peak flows pass downstream, water then begins to fill the northern part of the Kanyapella Basin from the Murray River, slowly encroaching on the eastern parts of Moama. At this point Goulburn River flows on the northern Deep Creek floodplain, may enter the Murray River upstream of the Bama Sandhills, and may push back upstream along the Murray River.

After prolonged flooding in large rare events, water continues to spill from the rivers and gradually fills the Kanyapella basin, with water inundating a northern section of Old Deniliquin Road via Webb Road and Gregory Road in New South Wales, then flowing under the railway line at the Black Bridge and inundating the floodplain to the east of the railway line. Floodwaters from the Murray River inundate low lying areas in east-Moama directly from the river. Likewise, floodwater also backs up from the Murray River along the Deakin Main Drain and the Bay of Biscay floodway in the southern part of the Kanyapella basin in Victoria.

The properties in the low-lying areas of Echuca along Goulburn Road are inundated as the river level continues to climb.

The flow that passes under the Black Bridge north of Moama slowly heads south, flowing under a small railway bridge culvert and flowing back to the Murray River through east-Moama.

Levees on the south side of the Goulburn and Murray Rivers are likely to be overtopped or breached in large rare flood events, which rapidly increases the filling of the southern Kanyapella Basin by floodwaters. The Kanyapella Basin continues to fill with flood water spreading through the Echuca Village areas with rising flood levels.

It can take weeks to months from the onset of flooding to the peak of flooding in Echuca-Moama. After the peak the inundation will slowly drain back to the river over a period of several months.

In large flood events on the Campaspe River, flows break away from the river at Rochester into the Nanneella Depression, which flows through to the Deakin Main Drain. Another breakaway from the Campaspe River to the north of the intersection of McKenzie Rd and Echuca-Nanneella Rd also flows through to the Deakin Main Drain.

The Campaspe River extends across the floodplain on both sides of the river, and slowly flows north toward Echuca. The floodplain flows are slower than the river flows, and reach Echuca 1 to 2 days later. In the October 2022 event it was this floodplain flow which caused the highest levels in the area of newer development along the Northern Highway in Echuca West.

2.4 Summary of Echuca-Moama Flood Study (2024)

The Campaspe Shire Council (CSC) and Murray River Council (MRC) required high quality flood information to support future town planning decisions. CSC and MRC were allocated funding by their respective State Governments to conduct flood studies to update flood information for Echuca and Moama respectively focussing on the urban and growth areas affected by riverine flooding. The North Central Catchment Management Authority (NCCMA) was also allocated funding for a flood study of the Torrumbarry section of the Murray River to establish the value of levee banks in that area. In November 2017 both councils and the NCCMA resolved to undertake a joint flood study involving the Murray River from Barmah to downstream of Torrumbarry together with the lower reaches of the Goulburn and Campaspe Rivers.

The flood study took a considerable effort to complete. It considered the complex hydrology of the three contributing major rivers and developed a current best practice approach to determining flood levels and modelling flood behaviour through the study area.

The flood information developed as part of the study was used heavily in the flood response for the October 2022 flood event, and the information was also made available to community members so they could understand their flood risk. Very good feedback was received regarding the accuracy of the flood mapping compared to the October 2022 flood and its usefulness in preparing for the event. It was observed however that improvements could be made to the model, particularly in regard to the accuracy of the levee crests along the lower Goulburn River. The information gathered during and after the October 2022 flood helped to improve the accuracy of the model.

The hydrology and hydraulics were calibrated to a range of historic floods including the October 1993, January 2011, October 2016 and the October 2022 events, providing confidence that the model is capable of performing over a range of different magnitude events.

The modelling has developed updated design flood information for Echuca and Moama, superseding the previous flood study completed in 1997. The data available and the modelling methods have progressed significantly since the previous flood study. Owing to the different type of modelling approach, with modern two-dimensional hydraulic models, compared to the older one-dimensional models, the flood study has been able to better understand how flood flows leave the rivers, inundate the floodplains, interact with levees, raised roads, channel banks, culverts and bridges, and return again to the river.

The results of the flood modelling and mapping presented preliminary analysis of the impacts of flooding through Echuca and Moama, along with investigations made into the model sensitivity to climate change, waterway structure blockages and model parameters, and what may occur should levees breach. Flood hazard maps were produced, and preliminary flood function maps were drafted.

Both Councils have considered the Flood Study Report and adopted the study in the first half of 2024, which allowed the next phase of the project, being the Flood Risk Management Study and Plan, to commence.

2.5 Previous Studies

A number of flood related studies have been conducted on the Murray, Goulburn and Campaspe Rivers and their distributary creeks in the past and are summarised below. A number of these studies have excellent descriptions of the flood behaviour in the Goulburn, Murray and Campaspe River floodplains and were highly valuable resources for this study.

- Torrumbarry System Flooding (1973)
- Murray River Flood Plain Management Study (GHD 1986)
- Echuca Flood Mitigation Proposal (1987)
- Echuca Flood Mitigation Scheme (SKM 1996)
- Moama-Echuca Flood Study (SKM 1997)
- Moama Floodplain Management Study (SKM 2001)
- Lower Goulburn Floodplain Rehabilitation Scheme (Water Technology 2005)
- Echuca South-East Rural Flood Study (Water Technology 2015)
- Goulburn River Constraints Levee Risk Assessment and Risk Mitigation Strategy (Water Technology, 2016)
- Echuca South-East Riverine Flood Study (Water Technology 2016)
- Goulburn River Environmental Flow Mapping (Water Technology 2016)
- Shepparton-Mooroopna Flood Mapping and Intelligence Study (Water Technology 2017)
- Torrumbarry Gunbower FRMS (GHD 2006)
- Rochester Flood Management Plan (Water Technology 2013)
- NCCMA and GBCMA Rural Levee Assessments (Water Technology 2013)
- Gunbower Model Calibration and Extension (Water Technology 2013)
- Barmah Township Flood Mitigation Functional Design (Water Technology 2013
- North Central CMA Levee Breach Risk Assessment and Strategy (Water Technology 2014)
- Gunbower Koondrook Perricootta Forest Modelling (Water Technology 2017)
- Barmah Millewa Forest Modelling (Water Technology 2017)
- Echuca West PSP (Water Technology 2018)

An extensive Moama-Echuca flood study was completed by SKM in 1997, being the last study that considered management of flood risk for the two towns.

3 COMMUNITY CONSULTATION

Obtaining insight and feedback regarding community concerns and suggestions for management of flood risks is an important step in developing appropriate and effective measures for reducing flood risk. Successful implementation of flood mitigation infrastructure relies on community acceptance. Both the Shire of Campaspe and Murray River Council provided various opportunities for the community and agencies to attend sessions and submit ideas and observations to help guide the assessment of potential mitigation options.

3.1 Drop In Sessions

Drop-in sessions were held over two days in late January 2024 in both Moama and Echuca. The sessions allowed community members and representatives of groups and agencies to meet in person with Council staff members and the consultants undertaking the flood study. The sessions were comprised of the following:

- The study team presented the flood mapping to the community to interactively discuss the observed 2022 flooding and the potential for larger rarer floods throughout Moama and Echuca.
- The community and key stakeholders talked about issues that were faced in the 2022 flood.
- Together as a group key locations of significant flood risk were identified.
- The community and key stakeholders provided suggestions for flood mitigation options, and they were sketched up on an interactive online flood map.
- Initial high level discussions about potential planning controls and their impacts on land use.

Due to the multiple areas of Echuca that had varying degrees of flood impacts and mechanisms, multiple sessions were provided for specific areas of Echuca to ensure all inputs from the community was provided, so that focussed solutions could be discussed in detail.

3.1.1 Echuca Emergency Response Agencies

One of the sessions held was specifically for government agencies who play a role in flood emergency management. This session was an opportunity to understand key issues for each agency and hear of the lessons learned from the recent 2022 event. Some comments from attendees at this session included:

- Kerferd St was the location where sandbags were distributed. One end on Sutton St was used to dispatch large quantities out to major infrastructure areas. Other end at Mitchell St was a residential depot for people to collect sandbags for their private properties. Rough estimate of 250,000 sandbags were distributed from the Kerferd St location. There were issues noted relating to the management of distributing such large quantities of sandbags.
- Emergency response warnings panicked some residents and a lot of sandbags went out to locations that probably didn't need them. Wording of emergency warnings should be better worded and more focussed on problem areas so that efficient use of sandbags can be achieved and less panic in the community.
- Focus at the outset of response was to utilise existing infrastructure rather than people sandbagging their own properties.
- There should be better protection systems rather than only relying on levees and sandbags.
- Interconnection of separate drainage systems can provide more capacity.
- ICC warnings were based on worst case scenario of levees failing, which unnecessarily shutdown services and supplies, and evacuations that didn't have to occur.

- Need to utilise the volunteers better and know who can do what. Recommendation to register volunteers and keep a record of their skills. Also need to collate and manage how information about procedures and priorities of mitigation actions, so that it isn't as haphazard.
- Information transfer between ICC and local crews weren't getting through always. This needs to be improved.
- When Ogilvie Avenue is overtopped, Echuca is split in two. It is critical that Ogilvie Avenue is kept open and protected. Recommendation to look at levee options to keep at least one lane of traffic open.
- Local drainage around Apex Park should be improved to prevent local properties from getting flooded. This is caused by local stormwater, not riverine flooding.
- Temporary sandbag levee behind commercial buildings starting from Beechworth Bakery should be replaced with a permanent levee.
- A lot of areas had stormwater pumping occurring during the event. Better isolation valves should be put in place to effectively pump without backwater impacts.
- Earth levee built along Watson Street, and sandbags placed around NRMA caravan park by community.
- Optus tower at Sturt St was on the wet side of the temporary levee, which is critical infrastructure. Future response planning should protect this tower. Adjacent Sturt St drain should have an isolation valve added on.
- Homes along Moama St/Goulburn Rd that can't be protected with a levee could be looked at being acquired by a buyback scheme.
- Pump station at north end of Mitchell St had significant issues with stormwater. 3 additional temporary pumps had to be brought in to manage flows. Recommendation is to upgrade the permanent pump station. There are multiple outlets to the river within 500 m either side of the pump station that could all be connected to the pump station so that the multiple stormwater networks can be managed from one outlet. Litter in the stormwater system was blocking some flow and pumps were losing prime for the pumps. Litter traps need to be invested in.
- Temporary pump was placed at the end of Bowen St on the dry side of the temporary earthen levee. Recommended that a permanent pump station is installed.
- A lot of the isolation valves on the end of stormwater outlets were usually on the wrong side of temporary levees, or pit RL's were too low.
- Isolation valves in the water treatment plant are inaccessible in an emergency. There should be better access provided in emergencies.
- Levee south of the water treatment plant should be upgraded.
- Houses in Rutley Crescent got inundated that were a fair distance from the river, and flow came in from opposite side to the river. These properties have never been affected before. Need to investigate the reasons why.

3.1.2 Echuca East and Echuca Village Community – Online Session

The publicly advertised online community session was provided for community members, predominantly from Echuca East and Echuca Village to join who were unable to attend in person to discuss the outcomes of the flood study, provide observations and flood information regarding historical flood events, and contribute to discussions regarding potential mitigation options. Notes from this session were taken, including:

- Permanent Levee in the Pakenham St/Bowen St/Moama St area. Potential partial permanent levee, say 1m, then top up with sandbags.

- Stormwater drain along Bowen St was recommended by engineering department at the end of 2022 to be updated. But the Council denied that recommendation in 2023. The drain was built over 80 years ago, so it should be updated.
- Why were decisions left too late, and if planning was done earlier than it seemed, then communication should be better to the residents so that they have time to plan as well.
- A levee along Campaspe Esplanade that goes all the way to past Warren St in the north.

3.1.3 Echuca East and Echuca Village Community

The publicly advertised community session was provided for residents from Echuca East and Echuca Village areas to discuss the outcomes of the flood study, provide observations and flood information regarding historical flood events, and contribute to discussions regarding potential mitigation options. Notes from this session were taken, including:

- Maintenance of the levee on east side of Echuca Village. Crest and banks have worn away about 18 inches down and for a couple of hundred metres length in multiple locations. Bank had to be topped up with sandbags, which would have otherwise overtopped.
- Permanent levee to allow all properties to be protected in Echuca East and not build a temporary levee along Pakenham St/Bowen St. Murray Adventure River Trail already funded and can be used to pay for levee as well.
- Maintenance of stormwater drains and pumps need to be improved as some areas were flooded in 2022 due to blockages rather than the flooding from the Murray.
- Put a control on Deakin Drain to prevent backwater.
- Communication that went out should be improved. SMS messaging should be more targeted to people in affected areas, rather than all the town.
- Put floor levels on rates notices so residents know if they are at risk when compared to estimated flood levels. Also, the residents can use the floor level on the rates notice to prove they need sandbags and resources are not wasted on areas that are likely to be well above.
- Council needs better understanding of the operation of valves and better maintenance and operation rules that are clear to use during a flood emergency.
- Get laws put in to allow property owners to protect their property.
- SES needs to treat the community better. There was a lack of respect shown during the 2022 floods.
- Have members of Council trained at the National Emergency Training Centre.
- Allow residents to provide their emails to be on a database for information with regular updates on the study progress, like a monthly newsletter.
- Include in the plan that a temporary levee can be built if a flood occurs between now and when permanent levees are built.
- Information sheets on how to build sandbag levees. More education on how to access information already available on SES website.
- Sewage was pumped over temporary levee into flooded properties. This shouldn't happen in the future.

3.1.4 Echuca West Community

The publicly advertised community session was provided for residents from Echuca Central and Echuca West areas to discuss the outcomes of the flood study, provide observations and flood information regarding historical flood events, and contribute to discussions regarding potential mitigation options. Notes from this session were taken, including:

- Three stormwater outlets from Rutley Crescent to the Campaspe River should have valves on them to prevent backwater from entering the residential areas.
- Warnings for Echuca on Campaspe River come very late from BoM, when it is nearly too late.
- Reinstate gauge on Campaspe at Echuca gauge to be permanent rather than only during large flow events.
- Bypass channel from Campaspe upstream of Warren Street between Riverland Close and Anstruther Street and divert around the west side of the cemetery to connect to Campaspe River upstream of the Murray River junction.
- Stormwater drainage under Warren Street is not well designed, so water is pooling upstream of the road.
- Changes to planning overlays should be made to prevent further development.
- Stormwater network in the CBD area is undersized and should be increased.

3.2 Written submissions

Council invited members of the community to provide written submissions for potential mitigation measures to be considered by the project team. During the invitation for comment period eight submissions were made for Echuca, and were considered for modelling and annual average damages assessment.

Table 3-1 Written submissions for mitigation measures

Item	Location	Issues / Suggestions
1	12 & 14 Hicks Crescent flooded in 2022	Sandbags rationed to 25 – difficult to get sufficient, Temporary barriers for Hicks Cresc supported.
2	Pakenham/Moama Streets	Build up dirt sections of Moama and Pakenham Streets so temporary levee can be installed on them, Extend the town levee from the intersection of Sutton St/Pakenham St and Goulburn Rd along the boundary of Bunyule Forest behind the houses of Pakenham St (East) then turn and run along behind the Moama St houses up to the Water Plant (preferred option)
3A, 3B	Echuca and cemetery hill, Pakenham-Moama St	Warning system so people can return home in time to prepare, Debris build-up on the new footbridge exacerbating flooding. Water pushed back to Warren St and around the 'other way', Install a 1 metre high levee around perimeter of the cemetery hill Construct part height levees in Pakenham / Moama St with temp levees on top, Provide guides to SES re levee construction for future floods.
4	Stormwater Outlets Rutley Crescent Echuca area	3 Outlets to Campaspe River near Rutley Crescent require outlet valves but not pumps. Other outlets also need review
5	Echuca East	In 1993 sandbag levee was laid along Goulburn Rd – report requires correction, Construct a levee around houses west of Deakin Main Drain as little impact on flood levels elsewhere.
6	Echuca	Look to the Dutch and how they manage water – in particular the Delft Institute https://www.un-ihe.org/what-we-do Drainage issue with Murray St – not flood related Flood mitigation systems including drains and valves must be maintained. Need for a centralised organisation to manage. Insurance – need for flood risk map reflecting past works (12 Murray St) – Murray St is much lower risk of flooding. Maps need updating to reflect current risk and insurance firms be encouraged to use these maps. Supports community flood wardens and use of internet to keep people informed. Wardens have role in monitoring levees, periodic inspections and sharing information in their local area.
7	Echuca Village	Request for consideration of rezoning a property on the edge of town to residential in light of recent flood study.
8	Hicks Crescent and Martin Street	2022 flood event caused damage to rear of properties along the floodplain edge and there was insufficient warning for the area. Mitigation measures recommended to be investigated: ▪ The building of a levee bank along the western side of properties on the floodplain edge, or; ▪ The installation of temporary portable barriers when a flood is imminent
9	Haverfield Street	Request for levee to protect houses on west side between McKinlay St and Tyler St.

3.3 Feedback

The feedback from agencies and the community that was gathered from the drop-in sessions and written submissions provided an insight into the community thought regarding the floodplain risk and emergency response.

The main recommendations for floodplain risk management from the feedback are listed in Table 3-2.

Table 3-2 Community feedback

Respondent	Source	Comments
Campaspe Shire	Drop-In Session	▪ Recommendation to look at a levee along Campaspe Esplanade south of Ogilvie Avenue
VIC SES	Drop-In Sessions	▪ Temporary sandbag levee behind commercial buildings ▪ Better management and access of stormwater pumping systems. ▪ Earth levee built along Watson Street and around NRMA caravan park. ▪ Upgrade to levee south of the water treatment plant
Community	Drop-In Sessions	▪ Permanent Levee in the Pakenham St/Bowen St/Moama St area. ▪ A levee along Campaspe Esplanade that goes all the way past Warren St ▪ A control on Deakin Drain to prevent backwater Additional stormwater control valves to prevent backwater in areas such as Rutley Crescent ▪ Bypass channel from Campaspe upstream of Warren St Protection of Bynan St properties and individual properties within Echuca Village
Community	Written Submissions	▪ Improved warning systems Install a 1 metre high levee around perimeter of the cemetery hill ▪ Construct a levee around houses west of Deakin Main Drain ▪ The building of a levee bank along the western side of properties in the Hicks Crescent and Martin Street areas
Community	Written Submission	▪ Install levee on west side of 4 houses in Haverfield St between McKinlay St and Tyler St

4 CURRENT CONDITIONS FLOOD DAMAGE ASSESSMENT

4.1 Overview

The base case of current flood damage needs to be determined in order to assess the benefits of mitigation measures. The current number of properties affected by the existing design flood events determined by the Flood Study are first identified and included in a spreadsheet tool developed by the Department of Planning and Environment (NSW) that calculates the potential financial costs of damages to each property due to flooding. The assessment assigns dollar values to each property impacted by flooding, dependant on the depth of flooding above or below floor, the size of the property, the land use zoning of the property, and other such factors.

The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding and how to respond
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such as failure of services (sewerage), flood borne debris, sedimentation;
- The types of asset and infrastructure affected.

Floor levels of properties were determined through various means, including:

- Available floor level survey.
- Google street view estimates of height above level relative to ground level added to LiDAR ground levels
- Addition of 0.3 m to LiDAR ground levels if Google street view was obscured.

4.2 Current conditions

The flooding during various design flood events for the Echuca area are shown in Figure 4-1. Within the flood extents there are increasing numbers of properties that are affected by flooding, and changes to the extent of contribution to annual average damages as the severity of flooding increases. The numbers of affected properties are summarised in Table 4-1.

The main areas of Echuca that are currently affected by large riverine flood events include:

- Majority of the Echuca Village area
- Properties south of Pakenham Street and west of Moama Street
- Properties either side of Deakin Drain
- Properties along the Campaspe River between Ogilvie Avenue and Warren Street
- Properties on the west side of the Echuca CBD.

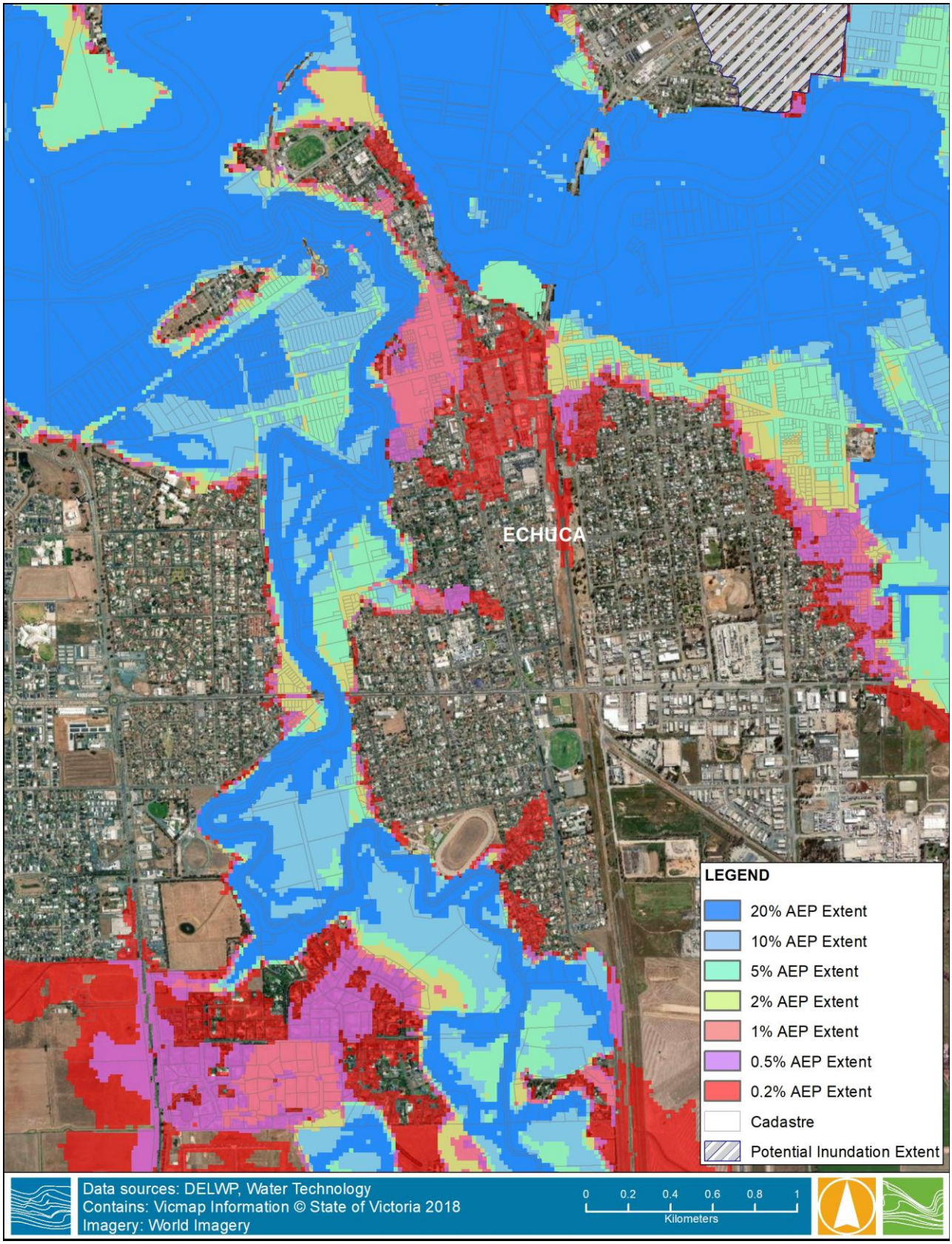


Figure 4-1 Design Modelling Flood Extents

4.3 Average Annual Damage Summary

The Department of Planning and Environment's standard spreadsheet tool for determining flood damages was used for both the New South Wales and Victorian communities.

The results of the Base Case existing conditions flood damages assessment are shown in Table 4-1 based on the current design mapping from the Echuca – Moama Flood Study.

Table 4-1 Estimated Base Case Flood Damages for the Echuca Study Area

Event	Number of Properties Affected	Number Flooded Above Floor Level	Total Damages Estimated Per Event
20% AEP	5	2	$619,825
10% AEP	29	9	$2,001,013
5% AEP	262	91	$19,282,756
2% AEP	755	513	$93,635,203
1% AEP	975	694	$137,945,626
0.5% AEP	1,309	919	$195,246,890
0.2% AEP	2,272	1,525	$337,866,302
Extreme Event	9,362	9,286	$3,008,397,313
Average Annual Damages (AAD)		**$8,976,012**	

4.4 Non-Economic Flood Damages

Non-economic flood damages are difficult to estimate in monetary terms, however they are a consideration that should be made when assessing the value of flood mitigation measures on a community. Additional damages that are incurred by residents affected by flooding include:

- Stress, mental health issues and strain on relationships.
- Injury and in extreme cases, loss of life
- Loss of sentimental items and pets
- Exacerbation of medical conditions and illness
- Increased level of fear from repeat flooding events in the future
- It is difficult to put a monetary value on these types of damages as they are likely to vary dramatically between each flood and depend on a range of factors. However, the flood damages spreadsheet does make an allowance for this damages as a percentage of the easier to quantify economic damage elements.
- The flood study has provided improved and detailed information about flood behaviour, timing and extent of flood prone areas, which can be used to raise community awareness, which is known to contribute toward increasing community resilience to flooding.

5 POTENTIAL FLOOD MITIGATION

5.1 Suggested Structural Mitigation Options

The proposed structural mitigation options investigated for the Echuca township from community and stakeholder feedback are:

- Ring levee around Bynan Street properties
- Pakenham Street – Moama Street to Goulburn Road permanent levee
- Moama Street Levee upgrade south of water treatment plant
- Individual property protection in Echuca Village
- Upgrades to Echuca CBD levees
- Levee around NRMA Victoria Park Caravan Park
- Access provisions for cemetery hill area out to Warren Street
- Diversion bypass channel from Campaspe River to the west of the cemetery
- Temporary levees along McKenzie Street and Eyre Street
- Temporary levees along Campaspe Esplanade
- Permanent levees and flood gates on Campaspe River north of Ogilvie Avenue
- Permanent levee along rear of properties in the Martin Street and Hicks Crescent area
- Upgraded drainage basin embankment/levee at Fehring Lane drainage reserve
- Levee on west side of Haverfield St properties between McKinlay and Tyler St
- Upgrade to the existing Watson Street levee top up to provide sufficient freeboard

5.2 Mitigation Option Prefeasibility Assessment

Prior to completing the hydraulic modelling and cost benefit analysis, the proposed structural mitigation measures listed in Section 5.1 underwent a pre-feasibility assessment that refined the options that would have the best chance of being an effective measure.

The following assessment criteria was considered in the pre-feasibility assessment:

- High level cost considerations
- Constructability and disruption
- Maintenance requirements
- Flood risk reduction benefits in both frequent and rare flood events
- Modelling complexity
- Potential adverse flood impacts

Each of the criteria are rated as Poor, Fair or Good to determine an overall rating. Any options that rated as Poor overall were not progressed to the modelling and economic assessment stage for the cost benefit analysis.

The proposed structural mitigation options were graded against the pre-feasibility assessment criteria as presented in Table 5-1.

Table 5-1 Mitigation Prefeasibility Assessment

Mitigation Option	Costs	Constructability and Disruption	Maintenance	Flood Risk Reduction Benefits	Adverse Impacts
Ring levee around Bynan Street properties	Fair	Poor	Fair	Good	Good
Pakenham Street permanent levee	Poor	Poor	Fair	Good	Good
Moama Street Levee upgrade south of water treatment plant	Fair	Good	Fair	Fair	Good
Individual property protection in Echuca Village	Good	Good	Good	Fair	Fair
Upgrades to Echuca CBD levees	Fair	Fair	Fair	Good	Good
Levee around NRMA Victoria Park Caravan Park	Fair	Good	Fair	Good	Good
Access provisions for cemetery hill area out to Warren Street	Poor	Fair	Good	Good	Fair
Diversion bypass channel from Campaspe River to the west of Warren St	Poor	Poor	Fair	Good	Poor
Temporary levees along McKenzie Street and Eyre Street	Fair	Good	Fair	Fair	Good
Temporary levees along Campaspe Esplanade	Fair	Good	Fair	Good	Good
Permanent levees and flood gates on Campaspe River north of Ogilvie Avenue	Poor	Poor	Poor	Good	Poor
Permanent levee along rear of properties in the Martin Street and Hicks Crescent area	Fair	Good	Fair	Fair	Good
Upgraded drainage basin embankment/levee at Fehring Lane drainage reserve	Good	Good	Good	Good	Good
Levee on west side of Haverfield Street properties between McKinlay and Tyler Streets	Good	Good	Good	Good	Good
Upgrade to the existing Watson Street levee	Good	Good	Good	Good	Good

The proposed diversion bypass for the Campaspe River was not taken through to the next stage of the cost benefit analysis. The preliminary modelling showed unacceptable levels of increased flooding and hazard to large numbers of properties. It was also clear that the significant lengths of levees and infrastructure would be a cost that would far outweigh the benefits of the areas being protected. The preliminary modelling results are shown in highlighting the significant increase in flooding.

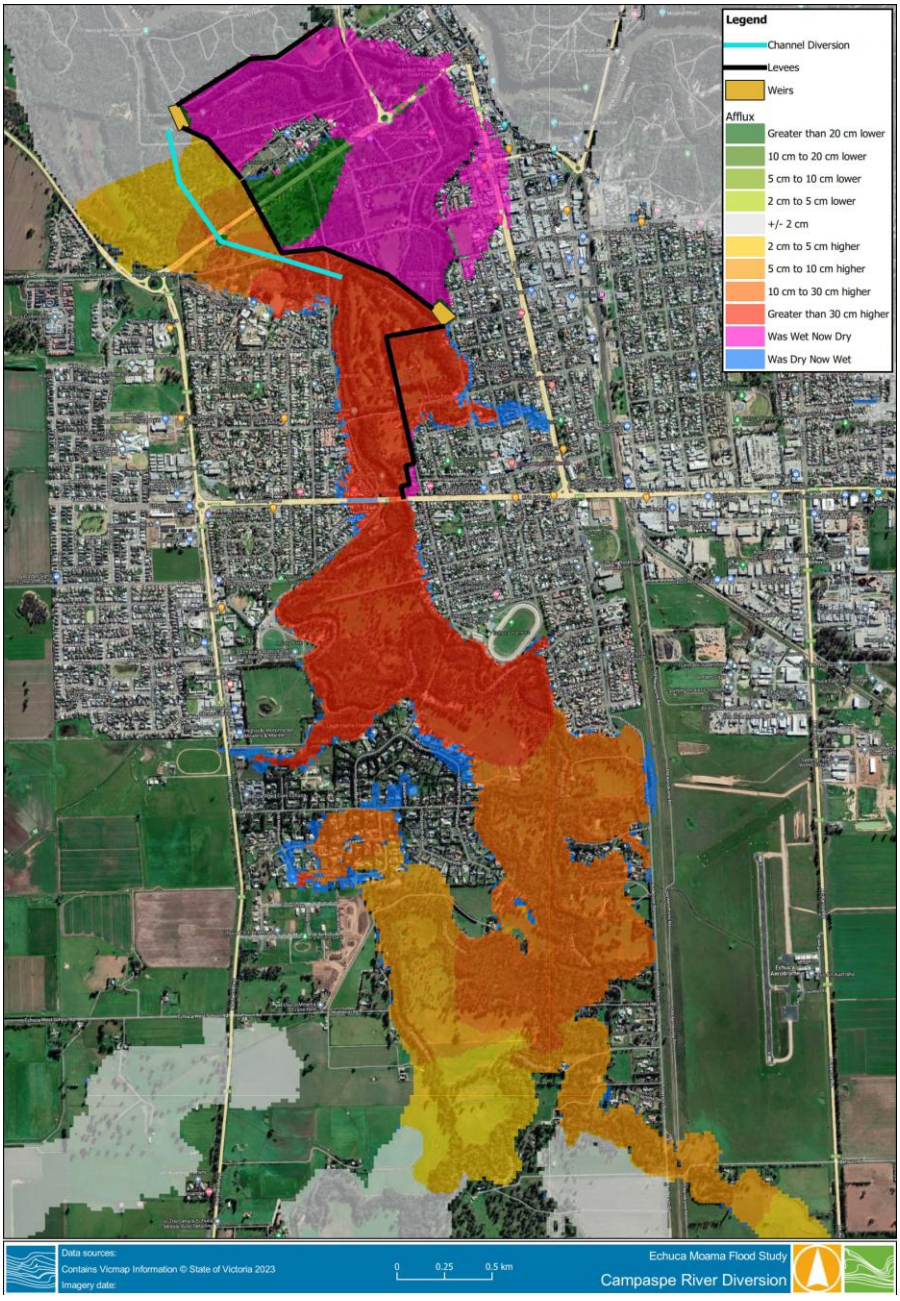


Figure 5-1 Preliminary modelling of proposed diversion bypass channel from Campaspe River to the west of the cemetery

5.3 Options Recommended for Modelling

In modelling several of the levee options, the model focussed only on the alignment and preventing overtopping and outflanking of the levee. The descriptions below are only concepts, and it is recommended that they be carefully reviewed at a functional and detailed design phase. This further design would optimise the levee construction type, allowing for constraints to be dealt with and opportunities realised at a local level. For instance, it may not be feasible in some cases to use demountable levees if the depth of flooding is to high for off the shelf products.

Several concept mitigation options are described below and are further investigated in subsequent sections, describing any changes to flood behaviour, and likely costs and benefits due to the works.

5.3.1 Ring levee around properties along Bynan Street

The ring levee proposed for the Bynan Street area in Echuca East was modelled as a single continuous bund encompassing all of the properties on the east side of the Deakin Drain. The simplistic approach was made for modelling purposes only as it was conservative which was likely to cause the largest external impact expected.

In practice the final arrangement of protection measures for the properties could be a mix of individual property protections such as raised garden beds, and sections of traditional levee bunding earthworks across multiple properties.

If levees are constructed on private properties, it does complicate maintenance arrangements. If the levee is a private levee, then responsibility for maintenance would rest with the landowner. If the levee was constructed on private land but Council were to be responsible for maintaining it, they would most likely seek an easement to allow access for maintenance.

If levee protection was provided, these properties would remain isolated as road access across the Deakin Main Drain would be cut in a rare flood event.

Figure 5-2 Bynan Street Modelled Ring Levee

5.3.2 Levees along Pakenham St and Moama Street

The levee proposed for the Pakenham and Moama Street areas was modelled as a new bund along parts of Pakenham Street, Levee Track and private/crown land behind some properties. The Moama St section of the works looks to extend and top up the levee along the east side of the road south of the water treatment plant.

The Pakenham Street and Moama Street section, north of Goulburn Road, would involve raising of approximately 200 m of road, and an earthen bund along the rear of properties on the north side of Pakenham Street.

The remaining areas of the levee will be temporary demountable assets placed on top of the permanent sections of levee during a riverine flood event for the extents shown in Figure 5-3. The lengths of temporary demountable levees are significantly long. The length of the demountable temporary levees may be cost prohibitive, and the functional design phase should consider if costs can be optimised by increasing the length of permanent levees and reducing the length of temporary levees.

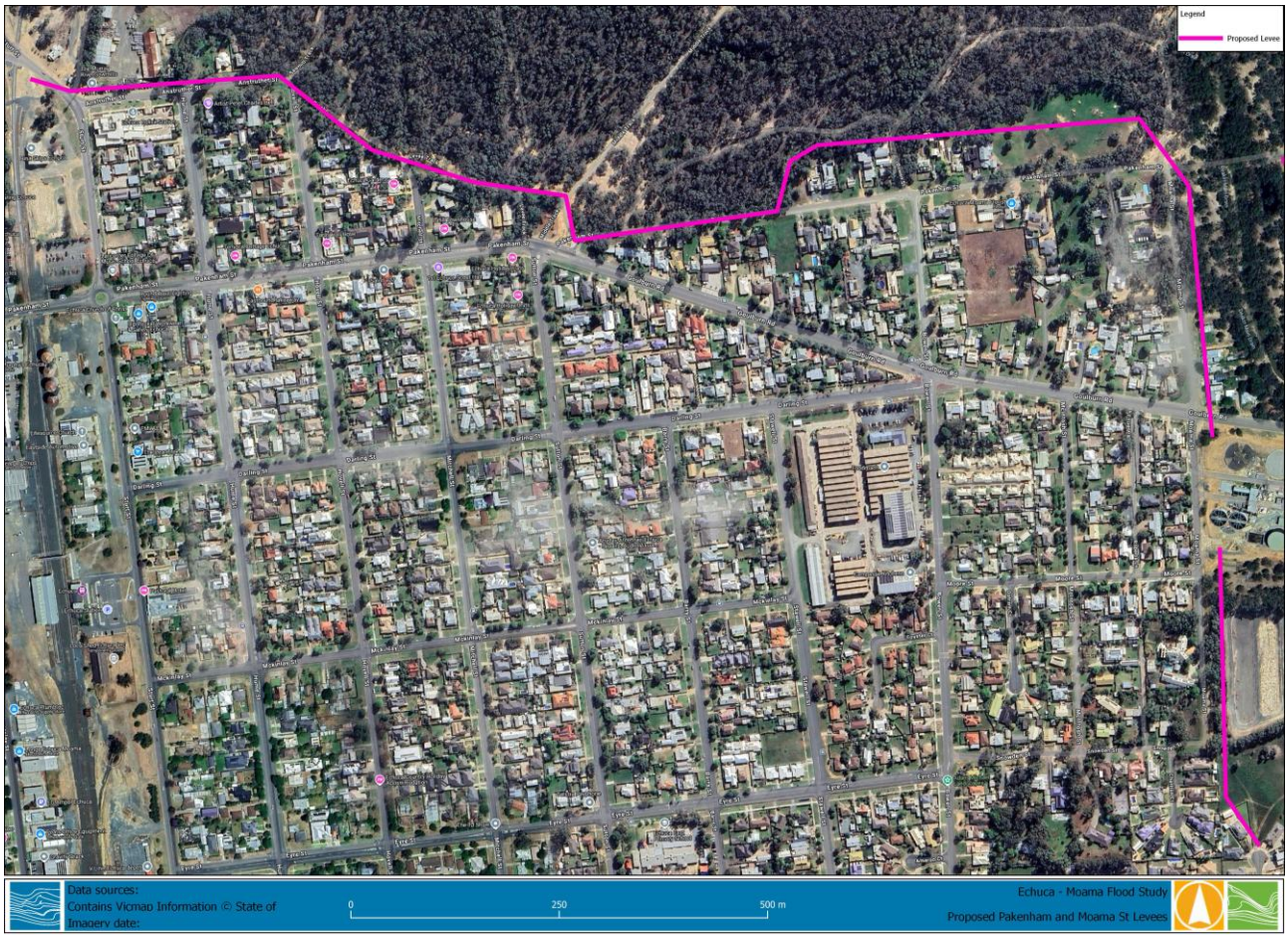


Figure 5-3 Pakenham St and Moama St Modelled Levees

5.3.3 Levee around NRMA Victoria Park Caravan Park

The levee proposed for the area around the Victoria Park Caravan Park was modelled as a continuous bund along the perimeter of the park on three sides connecting to Watson Street and Crofton Street. Recent discussions regarding the alignment have included a potential to connect the levee directly to the abutments of the Cobb Highway bridge to reduce the total length of the levee.

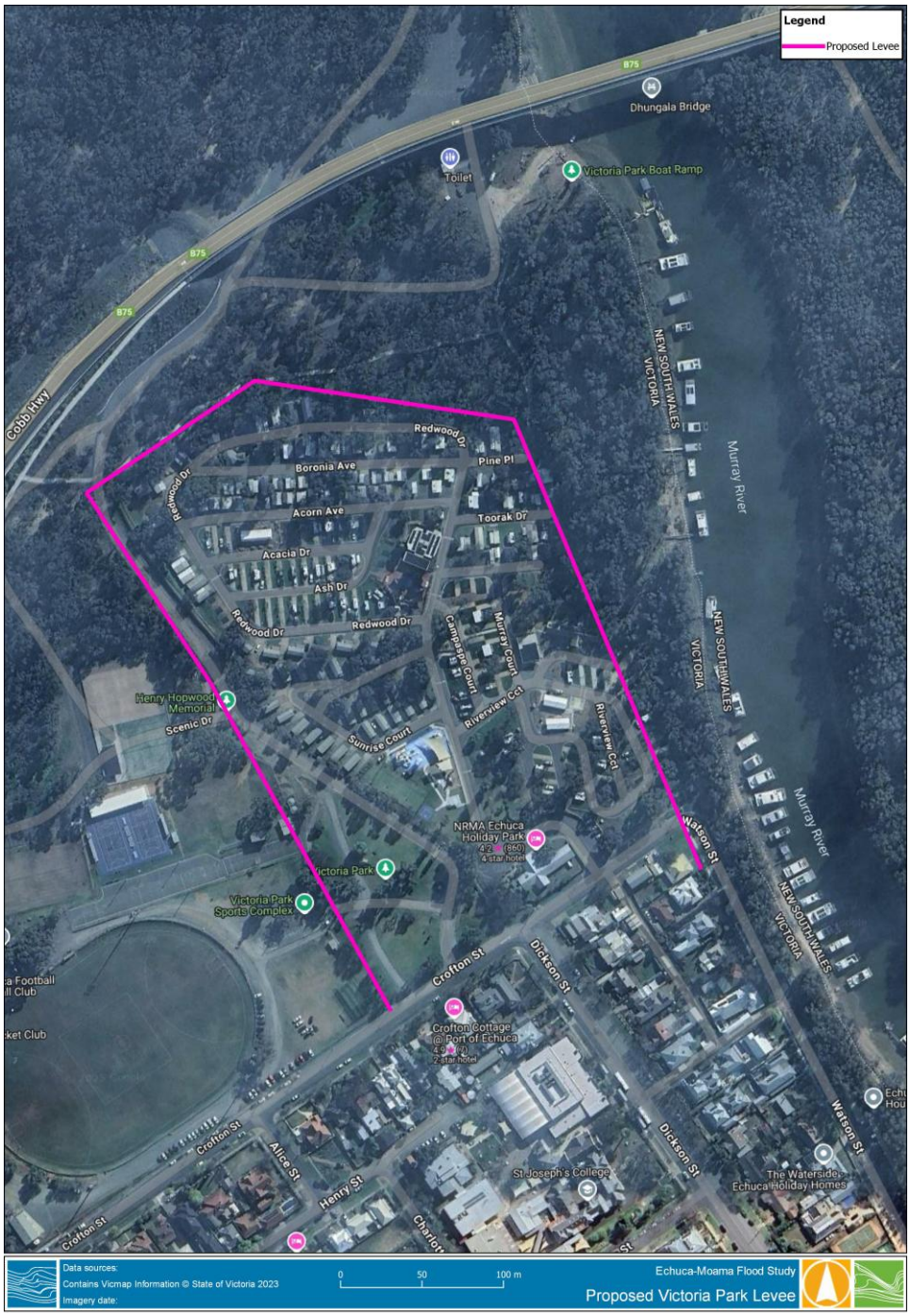


Figure 5-4 Victoria Park Caravan Park Modelled Levee

5.3.4 Upgrades to Echuca Levees

The existing levees along the rear of properties through the Echuca CBD and the primary school oval was modelled along the current alignments and proposed alignments to allow a continuous bund along the East side of the Campaspe River.

Figure 5-5 Echuca CBD Modelled Levees

5.3.5 Access provisions for Cemetery Hill area out to Warren Street

The levee proposed for the area around north-eastern end of the cemetery hill was modelled as a continuous levee along the Warren Street service road and median strip then partway up Homan Street, a section of Campaspe Esplanade and through the Campaspe River reserve area. The levees along the Warren Street service road and median strip, as well as along the section of Campaspe Esplanade would be temporary/demountable levees. The area through the reserve could either be permanent earthen levees or temporary demountable levees.

This option aims to allow access for the Cemetery Hill area to the new bridge crossing, where access can be achieved through to Echuca via the old bridge crossing.

Figure 5-6 Warren St Access Modelled Levees

5.3.6 Temporary levees along McKenzie Street, Eyre Street and Campaspe Esplanade

The levee proposed for the area was modelled as a continuous levee along McKenzie and Eyre Streets. The levee proposed for the area was modelled as two separate levees along Campaspe Esplanade, either side of Ogilvie Avenue. The levees along the streets are proposed to be temporary/demountable.

Figure 5-7 Mckenzie St, Eyre St and Campaspe Esplanade Modelled Temporary Levees

5.3.7 Permanent levee along rear of properties in the Martin Street and Hicks Crescent area

The levee proposed for the area around Martin Street and Hicks Crescent was modelled as a continuous bund along the rear of properties on the edge of the Campaspe River floodplain. It is proposed that the levee will be a permanent earthen bund starting from Ogilvie Avenue to the north and connecting to the end of Simmie Street to the south.

Figure 5-8 Martin Street Modelled Levee

5.3.8 Upgraded drainage basin embankment/levee at Fehring Lane drainage reserve

The levee proposed for the Fehring Lane area was modelled as an increased height bund along the embankment of a stormwater management detention basin built on the edge of the Campaspe River floodplain It is proposed that the top of the embankment is raised to the required level to prevent riverine flooding entering the drainage reserve.

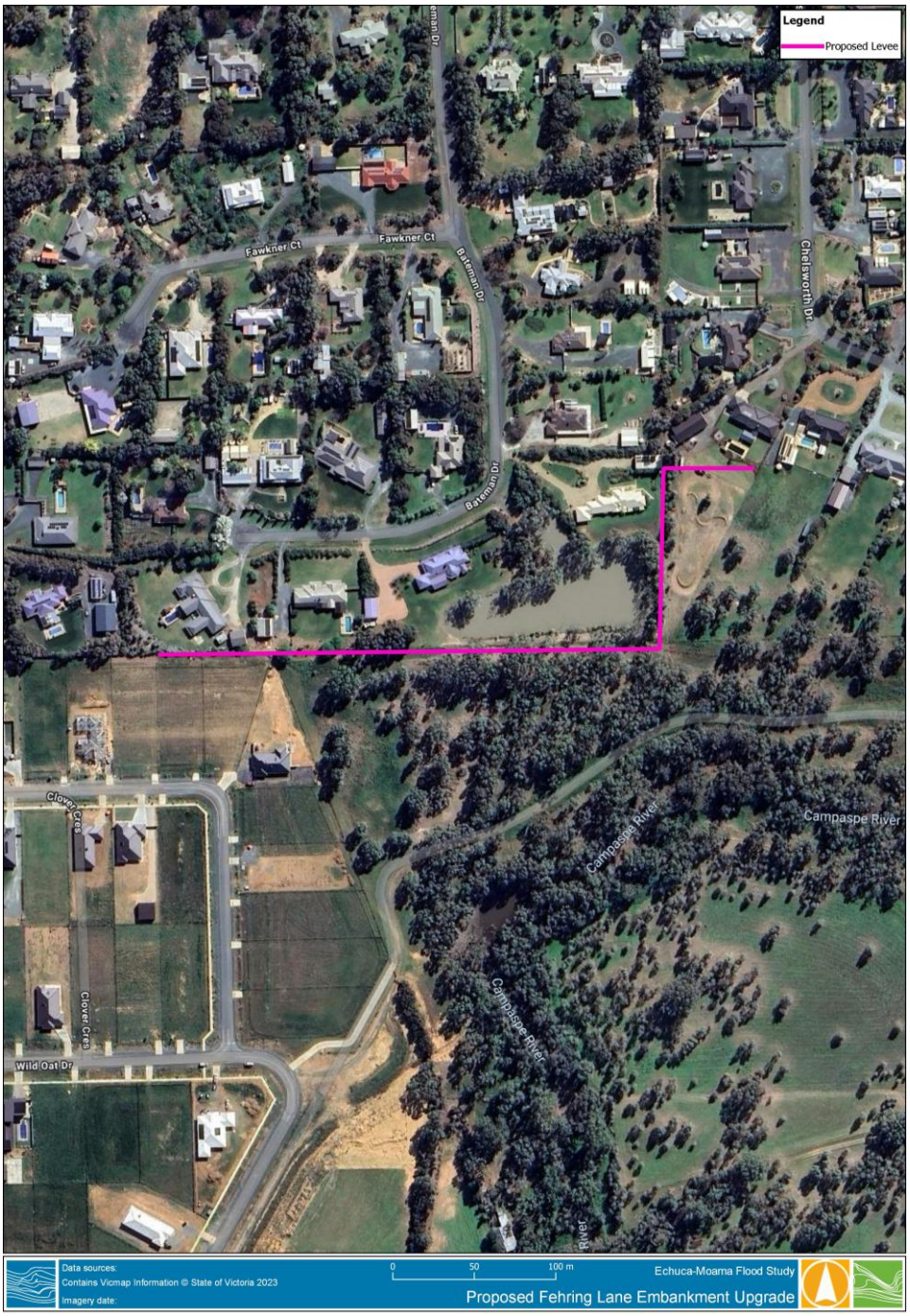


Figure 5-9 Fehring Lane Drainage Reserve Modelled Levee

5.3.9 Permanent Levee along Haverfield Street

The levee proposed for the area along Haverfield Street was modelled as a continuous levee along Haverfield Street and wraps around the rear of some properties. The sections around properties will be formed with permanent earthworks while avoiding the existing trees and the section along the street can be constructed within the road reserve. Some sections may tie into naturally high ground and not require further raising.

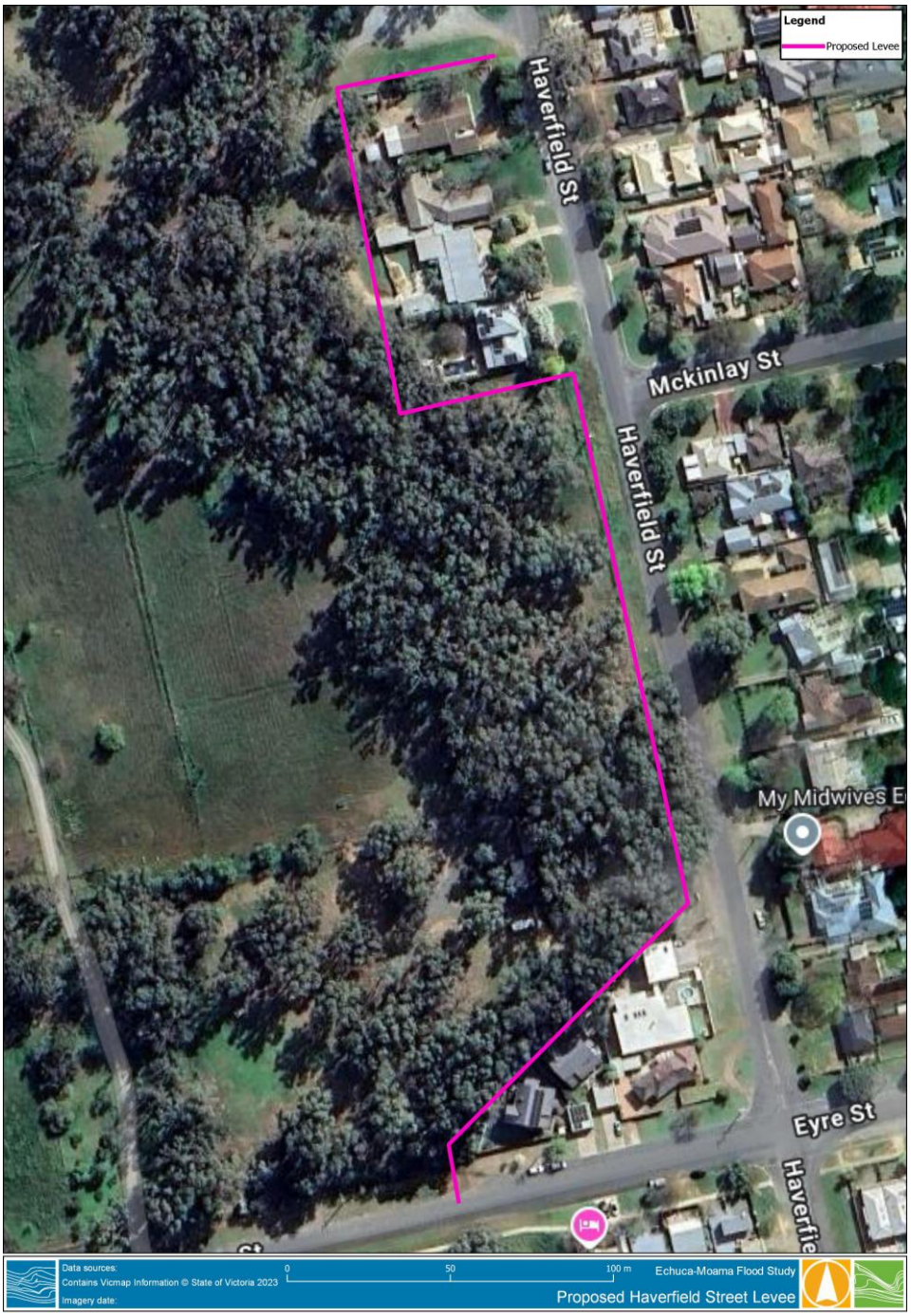


Figure 5-10 Haverfield Street Levee

5.3.10 Levee Upgrade along Watson Street

The existing levee along the east side of Watson Street does not have sufficient freeboard to protect a properties during a 1% AEP event. The levee was included in the design events modelled as part of the Echuca Moama flood study, and it was assumed that the levee did not breach before flood levels overtopped its crest level. The results of the flood study modelling indicated that the standard freeboard required of an urban levee was not afforded, and therefore an upgrade of the levee crest should be considered.

If a levee does not provide the required freeboard, the damages assessment should consider the scenario that the levee is breached and areas behind the levee are inundated. The proposed improvement works for the existing levee is to increase the height of the levee crest to provide the appropriate 600 mm freeboard above the 1% AEP flood level along the whole length of the levee.

5.4 Model Results

The proposed mitigation measures were tested within the hydraulic model developed as part of the Echuca Moama Flood Study to determine both positive and negative impacts that may arise from the construction of the proposed works.

5.4.1 Ring levee around properties along Bynan Street

The levee is proposed to be designed to have a design crest equal to the 1% AEP flood level plus the appropriate level of freeboard. The level of freeboard would see the crest level above the flood level of rarer events, although the risk of levee breaches would be increased as the freeboard is reduced in larger, rarer events.

The hydraulic model from the Echuca-Moama Flood Study was updated to incorporate the proposed levee, with the results shown in Figure 5-11. The results indicate that the entire area within the ring levee would be protected from flooding as intended. The final protection arrangement that is progressed will determine how access to Bynan Street will be provided over or through the proposed levee.

The results indicates that in the 1% AEP event there is limited afflux caused only directly south of the area along Goulburn Road at less than 50 mm increase. This limited impact is because removing the relatively small amount of storage compared to the broader Murray River floodplain has very little impacts on flood levels.

The modelled representation of the ring levee was coarse and conservative in the absence of design and final arrangement of the protection, which may take on a different form and alignment. Therefore, with further refinement of the final levee arrangement and more detailed modelling there will likely be no adverse flood impacts on private property that would prevent the implementation of this flood protection measure.

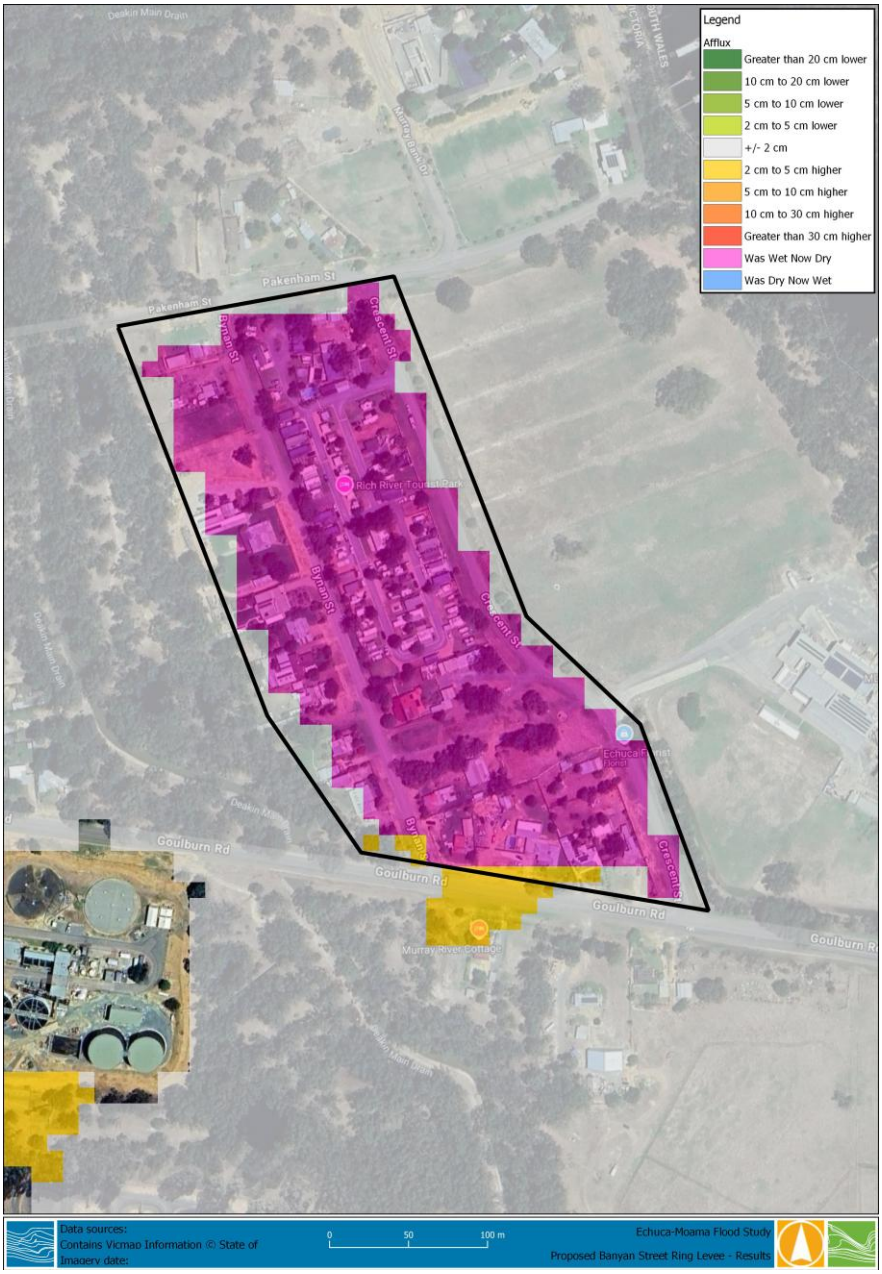


Figure 5-11 Bynan Street Ring Levee Modelling Results

5.4.2 Raising of Pakenham St and Moama Street levels

The levee is proposed to be designed to have the temporary levees placed on the permanent levee sections with appropriate level of freeboard above the 1% AEP flood level. The level of freeboard would see the crest level above the flood level of rarer events, although the risk of levee breaches would be increased as the freeboard is reduced in larger rarer events.

The proposed levee was built into the Echuca-Moama flood model and run for various design events. The results in Figure 5-12 indicate that all the residential properties previously subject to inundation would be protected from flooding as intended, with negligible adverse impacts on neighbouring land.

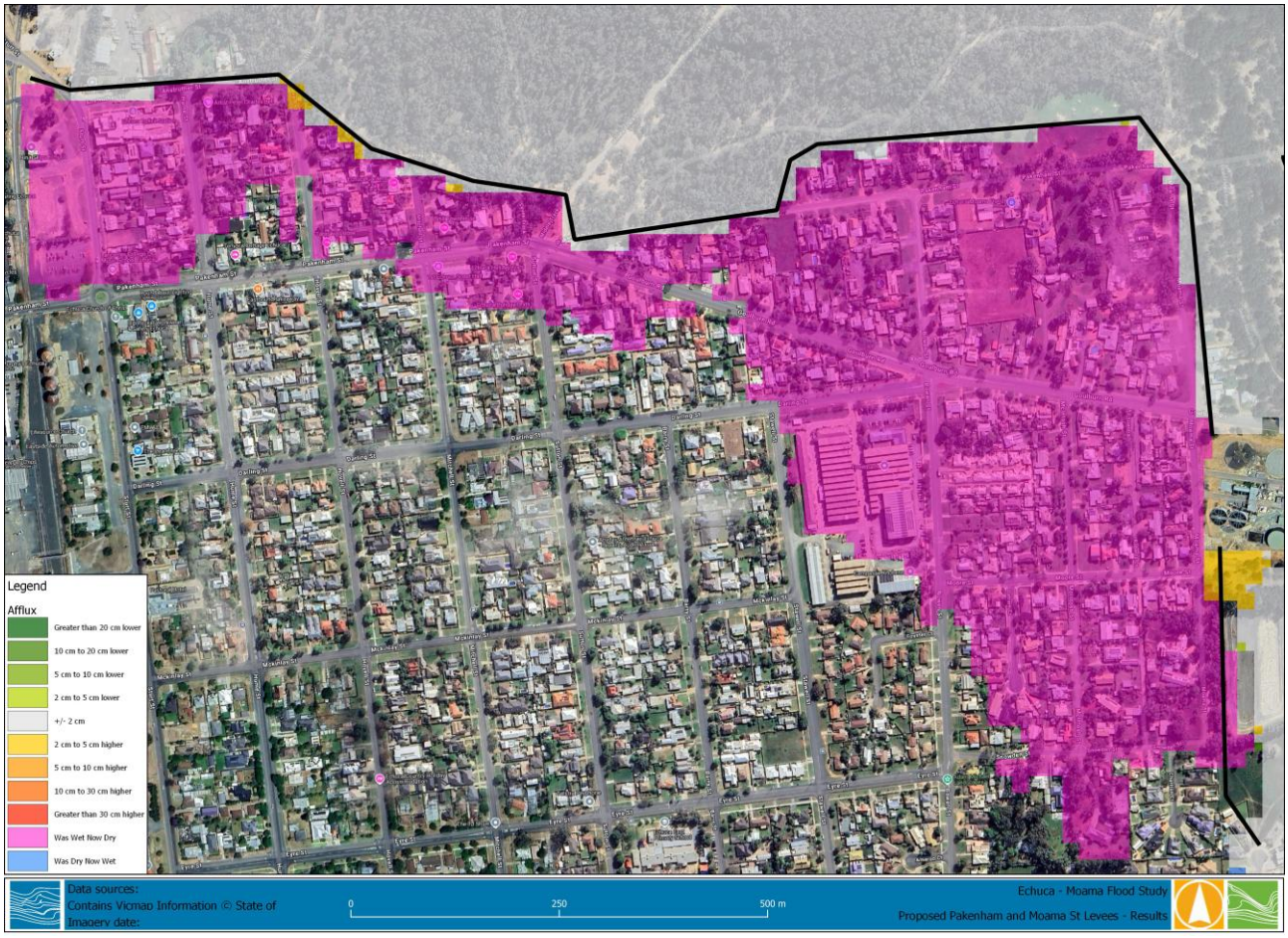


Figure 5-12 Pakenham Street and Moama Street Levee Results

5.4.3 Levee around NRMA Victoria Park Caravan Park

The levee is proposed to be designed to have a design crest equal to the 1% AEP flood level plus the appropriate level of freeboard. The level of freeboard would see the crest level above the flood level of rarer events, although the risk of levee breaches would be increased as the freeboard is reduced in larger, rarer events.

The hydraulic model from the Echuca-Moama Flood Study was updated to incorporate the proposed levee, with the results shown in Figure 5-13. The results indicate that all the caravan spaces and permanent cabins previously subject to inundation would be protected from flooding as intended.

The results indicates that in the 1% AEP event there is no afflux caused in any private properties upstream of the levee. Therefore, there is no adverse flood impacts on private property that would prevent the implementation of this flood protection measure.

Figure 5-13 Victoria Park Levee Results

5.4.4 Upgrades to Echuca CBD Levees

The levees are proposed to be topped up to have a design crest equal to the 1% AEP flood level plus the appropriate level of freeboard. The level of freeboard would see the crest level above the flood level of rarer events, although the risk of levee breaches would be increased as the freeboard is reduced in larger, rarer events.

The hydraulic model from the Echuca-Moama Flood Study was updated to incorporate the proposed levee, with the results shown in Figure 5-14. The results indicate that all the commercial properties previously subject to inundation would be protected from flooding as intended.

The results indicates that in the 1% AEP event there is no afflux caused in any private properties upstream of the levee. Therefore, there is no adverse flood impacts on private property that would prevent the implementation of this flood protection measure.

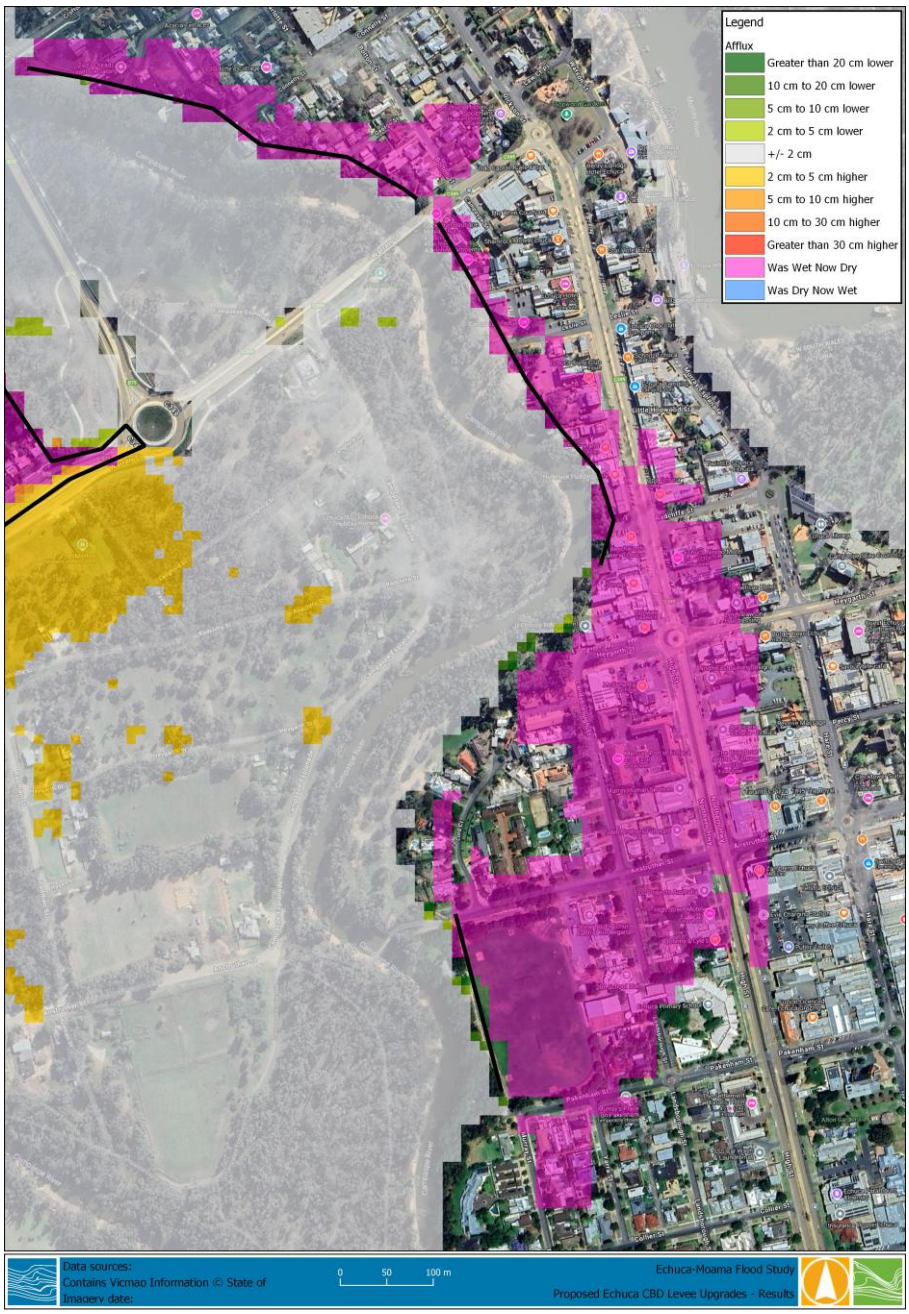


Figure 5-14 Echuca CBD Levee Upgrade Results

5.4.5 Access Provisions and Temporary Levees for Cemetery Hill Area

The temporary levees are proposed to be placed on the median strip of Warren Street bitumen and along the edge of the service road, Homan Street, a section of Campaspe Esplanade and through the Campaspe River reserve area, specified to have a design crest equal to the 1% AEP flood level plus the appropriate level of freeboard. The level of freeboard would see the crest level above the flood level of rarer events, although the risk of levee breaches would be increased as the freeboard is reduced in larger, rarer events.

The hydraulic model from the Echuca-Moama Flood Study was updated to incorporate the proposed levees, with the results shown in Figure 5-15. The results indicate that all the residential properties previously subject to inundation would be protected from flooding as intended. The emergency access for all properties within the cemetery hill area can now be provided, even for properties not affected by flooding that were previously isolated.

Closing Warren St with a temporary levee would need to be carefully managed and left until the road was soon to be closed due to overtopping, as the road would be heavily used by those preparing for the flood.

The results indicates that in the 1% AEP event there is limited afflux caused only directly south of the area along Warren Street at less than 25 mm increase. This limited impact is because removing the relatively small amount of storage compared to the broader Campaspe River floodplain has very little impacts on flood levels. The existing private properties in this increased afflux area are already inundated between 1.5 m to 2 m of floodwater during the existing 1% AEP event, which places the area at the highest flood hazard category of H6, so the comparatively fractional increase will be negligible. Therefore, there is no adverse flood impacts on private property that would prevent the implementation of this flood protection measure.

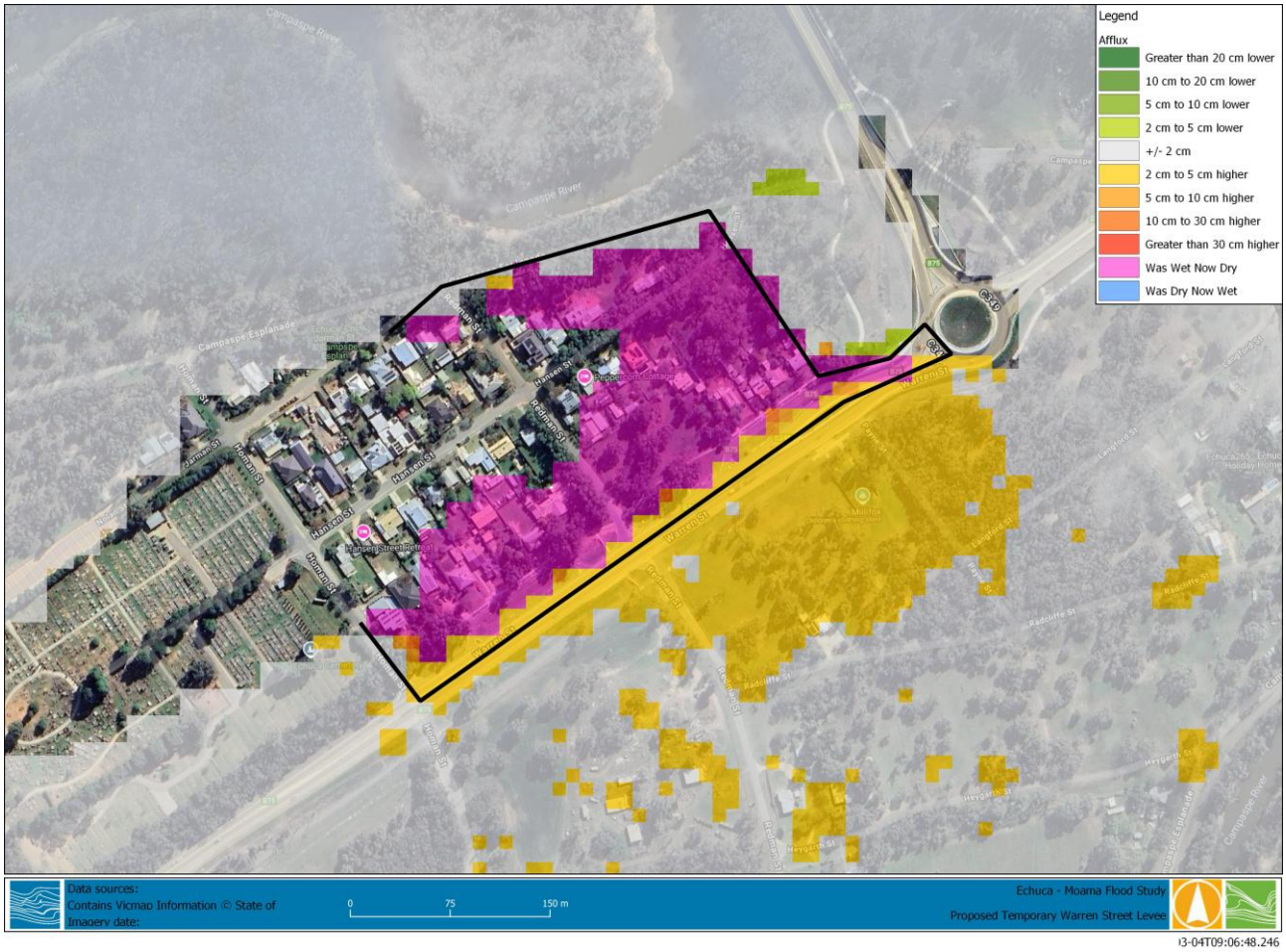


Figure 5-15 Warren Street Temporary Levee Results

5.4.6 Temporary Levees along McKenzie Street, Campaspe Esplanade and Eyre Street

The temporary levees are proposed to be placed on the bitumen along the edge of the road on the floodplain side and specified to have a design crest equal to the 1% AEP flood level plus the appropriate level of freeboard. The level of freeboard would see the crest level above the flood level of rarer events, although the risk of levee breaches would be increased as the freeboard is reduced in larger, rarer events.

The hydraulic model from the Echuca-Moama Flood Study was updated to incorporate the proposed levees, with the results shown in Figure 5-16. The results indicate that all the residential properties previously subject to inundation would be protected from flooding as intended.

The results indicate that in the 1% AEP event there is limited afflux caused between Campaspe Esplanade and Mckenzie Street at less than 25 mm increase. This limited impact is because removing the relatively small amount of storage compared to the broader Campaspe River floodplain has very little impacts on flood levels. The existing private properties in this increased afflux area are already inundated by over 1 m of floodwater during the existing 1% AEP event, which places the area at the highest flood hazard category of H6, so the comparatively fractional increase will be negligible. Therefore, there is no adverse flood impacts on private property that would prevent the implementation of this flood protection measure.

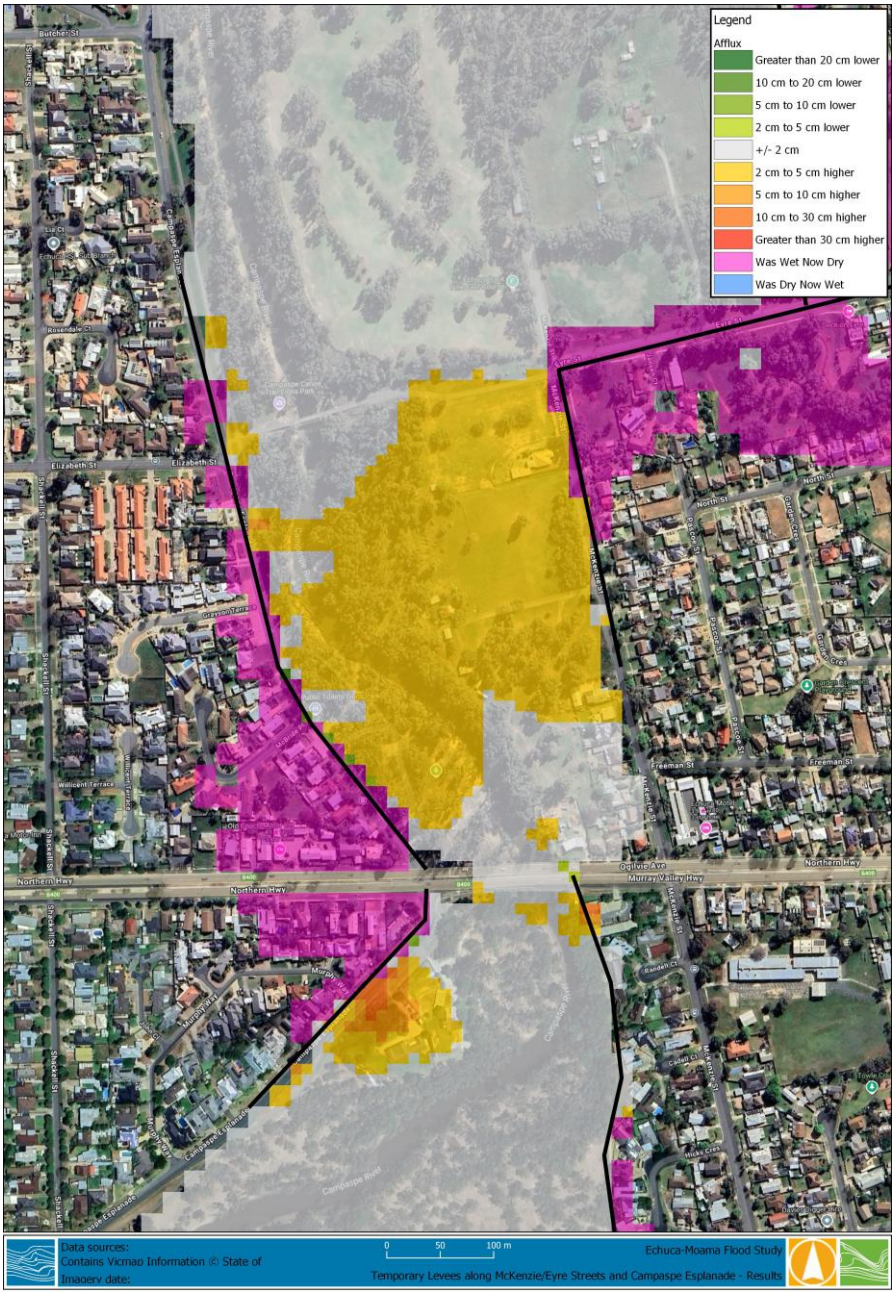


Figure 5-16 Mckenzie and Eyre Streets, Campaspe Esplanade Levee Results

5.4.7 Permanent Levee along rear of properties in the Martin St and Hicks Cres area

The levee is proposed to be designed to have a permanent earthen levees placed along the rear of the properties adjacent to the Campaspe River floodplain edge with appropriate level of freeboard above the 1% AEP flood level. The level of freeboard would see the crest level above the flood level of rarer events, although the risk of levee breaches would be increased as the freeboard is reduced in larger, rarer events.

The hydraulic model from the Echuca-Moama Flood Study was updated to incorporate the proposed levee, with the results shown in Figure 5-17. The results indicate that all the residential properties previously subject to inundation would be protected from flooding as intended.

The results indicates that in the 1% AEP event there is no afflux caused in any private properties upstream of the levee. Therefore, there is no adverse flood impacts on private property that would prevent the implementation of this flood protection measure.

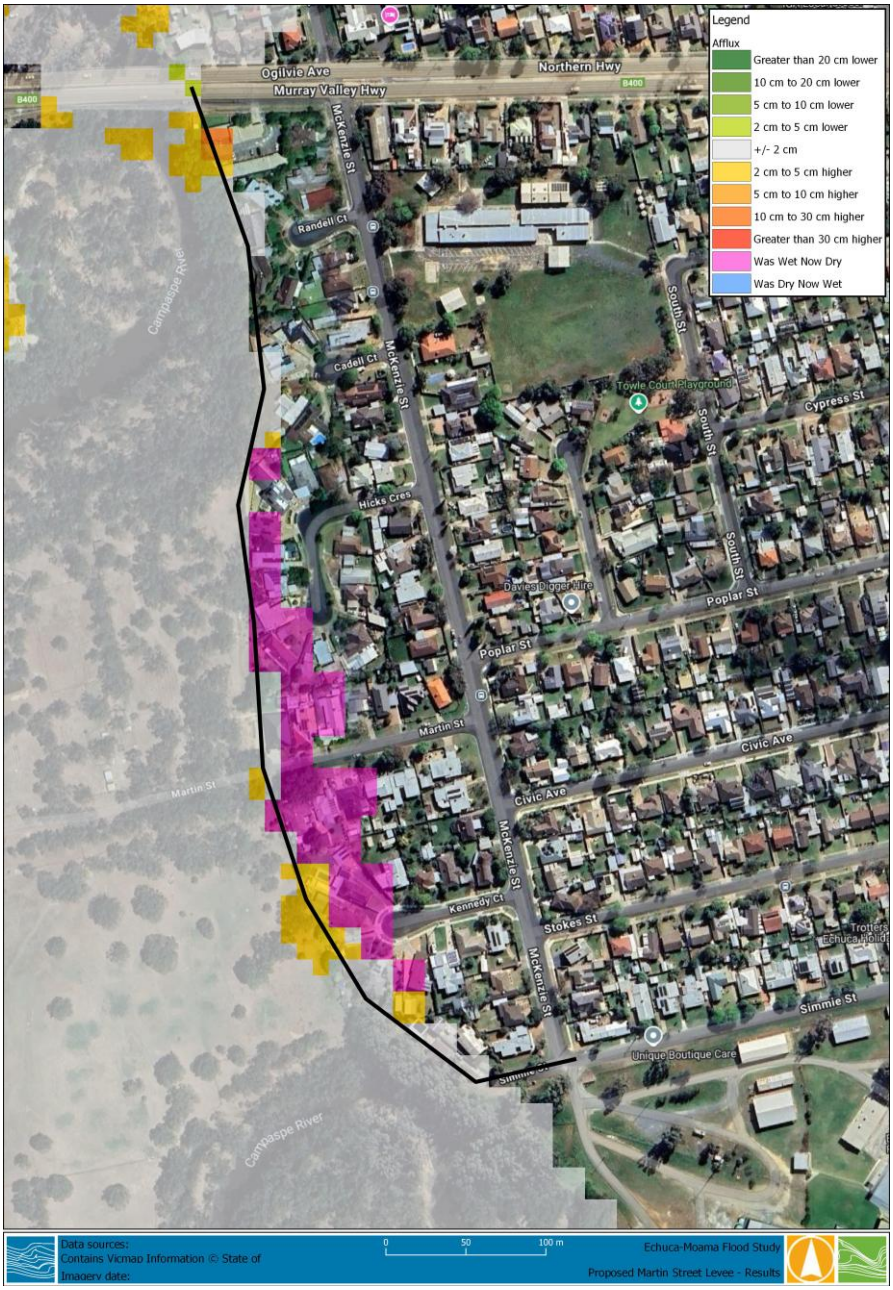


Figure 5-17 Martin Street Levee Results

5.4.8 Upgraded drainage basin embankment/levee at Fehring Lane Drainage Reserve

The levee is proposed to be designed to increase the height of the existing embankment and extending new sections at the eastern end with appropriate level of freeboard above the 1% AEP flood level. The level of freeboard would see the crest level above the flood level of rarer events, although the risk of levee breaches would be increased as the freeboard is reduced in larger, rarer events.

The hydraulic model from the Echuca-Moama Flood Study was updated to incorporate the proposed levee, with the results shown in Figure 5-18. The results indicate that all the residential properties previously subject to inundation would be protected from flooding as intended.

The results indicates that in the 1% AEP event there is no afflux caused in any private properties upstream of the levee. Therefore, there is no adverse flood impacts on private property that would prevent the implementation of this flood protection measure.

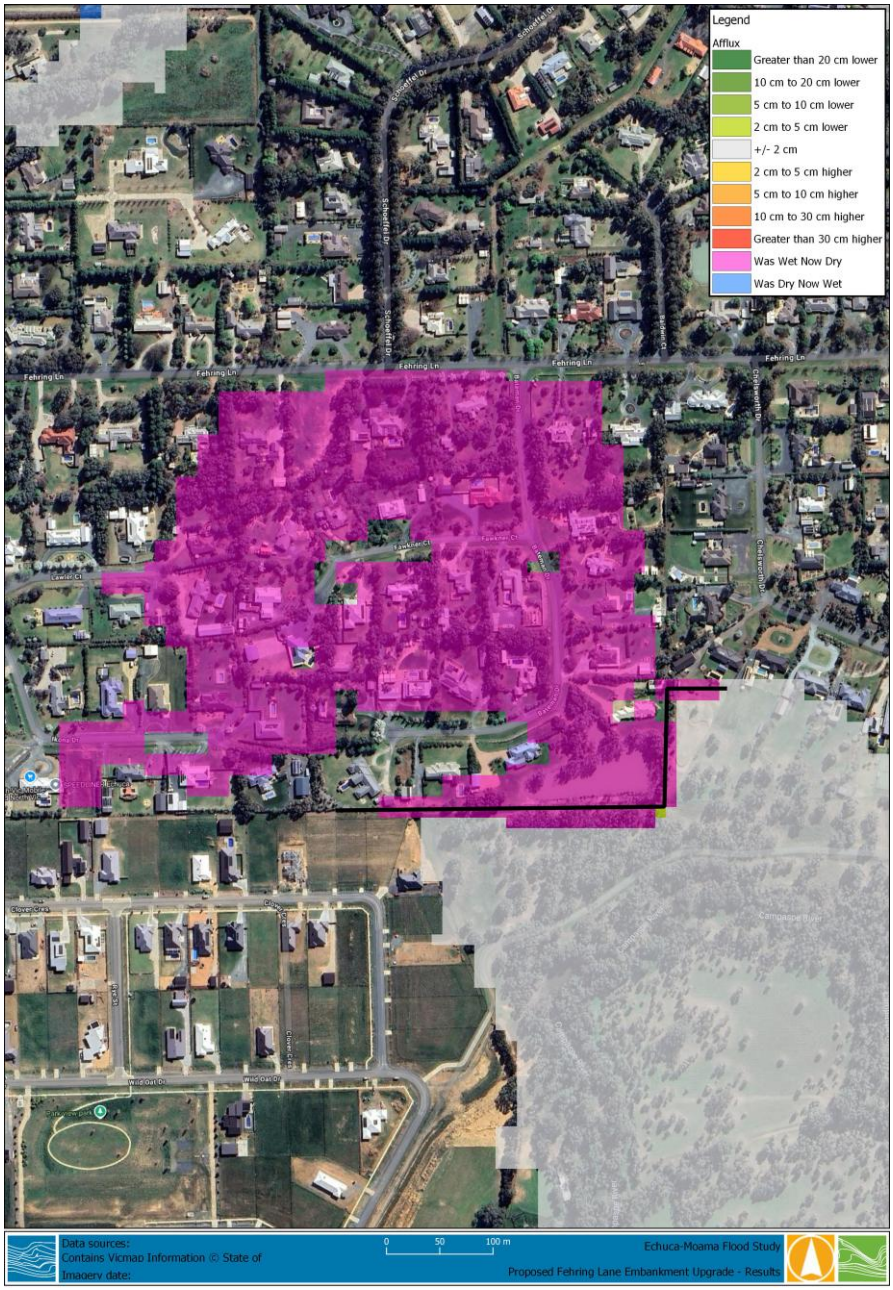


Figure 5-18 Fehring Lane Upgraded Drainage Reserve Embankment Results

5.4.9 Permanent Levee along Haverfield Street

The levee is proposed to be designed to have a permanent earthen levee placed along the rear of the properties adjacent to the Campaspe River floodplain edge and along the road reserve with appropriate level of freeboard above the 1% AEP flood level. At the back of the houses at the southern end there is a lack of space, and the levee may need to take the form of a concrete retaining wall along the back fence of the properties. The level of freeboard would see the crest level above the flood level of rarer events, although the risk of levee breaches would be increased as the freeboard is reduced in larger, rarer events.

The hydraulic model from the Echuca-Moama Flood Study was updated to incorporate the proposed levee, with the results shown in Figure 5-19. The results indicate that all the residential properties previously subject to inundation would be protected from flooding as intended.

The results indicates that in the 1% AEP event there is no afflux caused in any private properties upstream of the levee. Therefore, there is no adverse flood impacts on private property that would prevent the implementation of this flood protection measure.

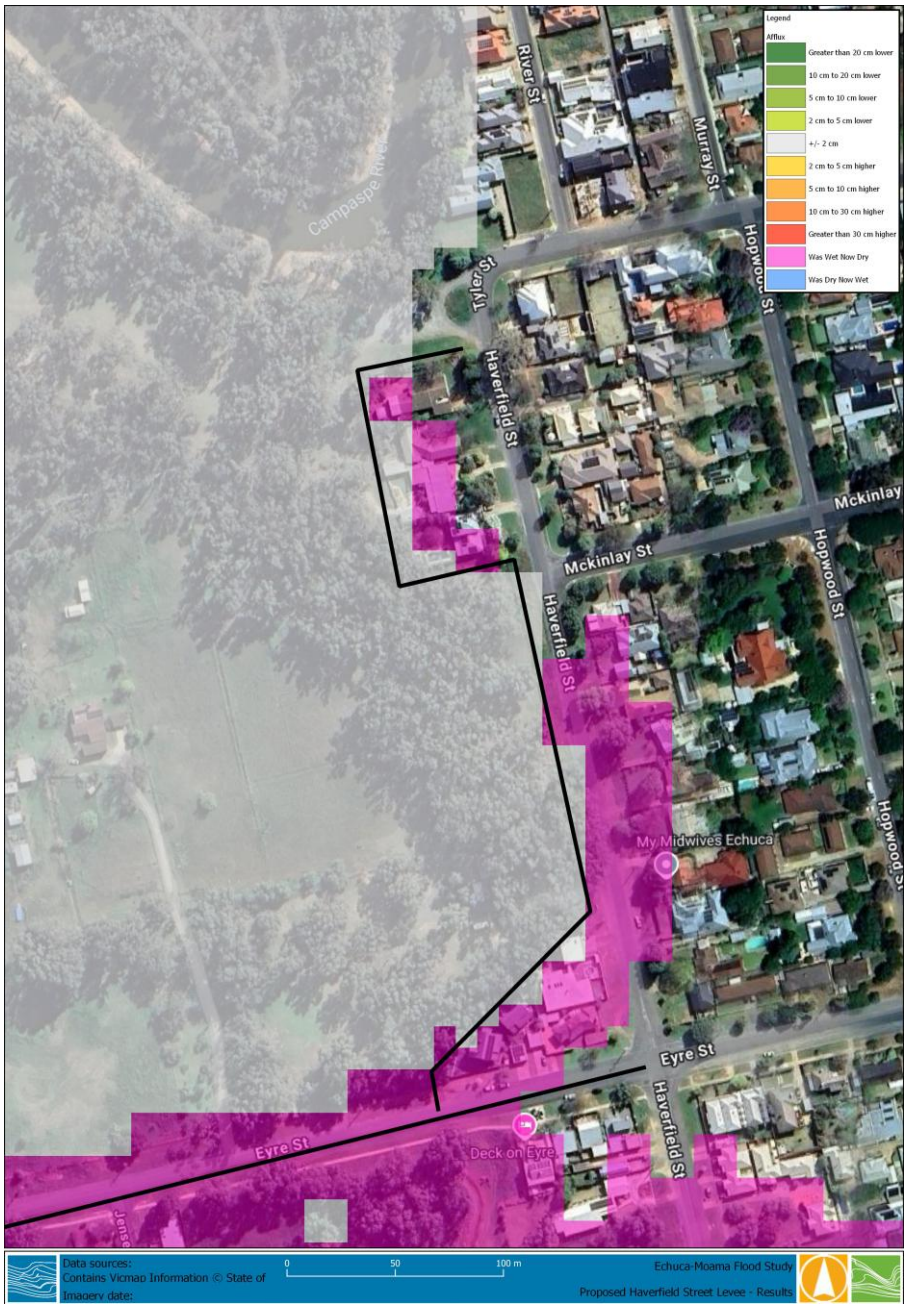


Figure 5-19 Haverfield Street Levee Results

5.5 Cost Benefit Analysis

The cost effectiveness of flood protection options in reducing flood liability is determined using the cost benefit analysis (CBA) approach as one of the key factors in determining whether flood mitigation works should proceed.

5.5.1 Overview

The NSW Flood Damage CBA Tool was utilised to calculate residential and commercial flood damages for the study area. It provides a means for consistent and comparable assessment of damages across NSW. The tool has built in multiple damage curves for property damage, below floor level and above floor level, relocation costs and mental health costs.

5.5.2 Mitigation Option Costs

The mitigation measures that were considered for the Echuca region are a construction of a new earthen levee, and upgrade of an existing levee. The assumptions and costs estimated for the levees in the cost benefit analysis (CBA) were derived from the NSW Levee Handbook that has been developed by the NSW Public Works, which is currently in draft form. It was considered by the Project Reference Group that these costs and assumptions would be appropriate for use in Echuca as well.

The assumptions for costs from the handbook include consideration of:

- Different costs for new levees and remediation of existing levees.
- Cost estimates based on a database of previous similar works
- Cost scaling for various types of works
- Project Management costs
- Engineering design costs

The cost values used in determining the overall costs were as follows:

- $1,500 per metre for a new levee
- $500 per metre for remediation of existing levee
- Cost scaling
  - 1 x for earth levee
  - 5 x for concrete levee
- Project management estimated as 12% of construction cost
- Engineering design estimated as 8% of construction cost
- An additional contingency of 30% was added to cover potential cost increases and unforeseen issues arising during construction that would require additional out of scope items to be addressed.

The costs for temporary levee installation was selected from a quote provided by a supplier to be incorporated in the CBA. The rate per metre provided by the supplier was $760 and the following considerations were also added to the costs:

- $10,000 per annum for storage and maintenance costs
- 8% multiplier for associated handling and base preparation during deployment

The lengths of levees used in determining the overall cost for each mitigation option are listed in Table 5-2.

Table 5-2 Levee Lengths

Proposed Levee Locations	Length
Bynan St	1,225 m
Pakenham and Moama Streets	▪ Permanent Levee – 747 m ▪ Temporary Levee – 1,685 m
Victoria Park	950 m
Echuca CBD Upgrades	1,175 m (total)
Warren Street	790 m
Mckenzie and Eyre Streets	620
Campaspe Esplanade	877
Martin Street and Hicks Crescent	745
Fehring Lane	470
Haverfield Street	490
Watson Street Upgrade	410

5.5.3 Cost Benefit Analysis Results

The benefit-cost analysis for each of the options are provided in the tables below. The number of properties listed as flooded above floor levels protected (column 3) is also included in the number of properties protected in total (column 2).

Table 5-3 Bynan Street Ring Levee CBA Analysis Results

Event	Number of Properties Protected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	3	1	$61,674
5% AEP	23	17	$4,176,623
2% AEP	23	22	$6,341,677
1% AEP	23	22	$6,921,372
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$8,611,873**	
Present Value of Costs		**$2,955,823**	
Present Value of Benefits		**$5,583,401**	
Net Present Value		**$2,627,578**	
Benefit Cost Ratio		**1.89**	

Table 5-4 Pakenham Street and Moama Street Levee CBA Analysis Results

Event	Number of Properties Affected	Number Flooded Above Floor Level	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	N/A	N/A	$0
5% AEP	132	28	$6,398,136
2% AEP	250	101	$25,115,237
1% AEP	275	139	$35,842,478
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$7,756,914**	
Present Value of Costs		**$4,511,895**	
Present Value of Benefits		**$16,194,216**	
Net Present Value		**$11,682,321**	
Benefit Cost Ratio		**3.59**	

Table 5-5 NRMA Victoria Park Caravan Park Levee CBA Analysis Results

Event	Number of Properties Protected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	N/A	N/A	$0
5% AEP	N/A	N/A	$0
2% AEP	249	245	$26,101,694
1% AEP	265	264	$31,112,745
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$7,897,847**	
Present Value of Costs			**$2,296,019**
Present Value of Benefits			**$13,130,909**
Net Present Value			**$10,834,890**
Benefit Cost Ratio			**5.72**

Table 5-6 Upgrades to Echuca CBD Levees CBA Analysis Results

Event	Number of Properties Protected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	N/A	N/A	$0
5% AEP	4	1	$125,199
2% AEP	17	6	$812,713
1% AEP	109	67	$9,993,288
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$8,737,264**	
Present Value of Costs			**$1,028,235**
Present Value of Benefits			**$1,543,549**
Net Present Value			**$515,314**
Benefit Cost Ratio			**1.50**

Table 5-7 Warren Street Temporary Levees CBA Analysis Results

Event	Number of Properties Affected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	N/A	N/A	$0
5% AEP	1	N/A	$19,450
2% AEP	4	2	$272,108
1% AEP	5	2	$540,079
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$8,826,318**	
Present Value of Costs			**$1,184,670**
Present Value of Benefits			**$256,328**
Net Present Value			**-$928,342**
Benefit Cost Ratio			**0.22**

Table 5-8 Temporary levees along McKenzie Street and Eyre Street CBA Analysis Results

Event	Number of Properties Protected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	N/A	N/A	$0
5% AEP	N/A	N/A	$0
2% AEP	8	2	$331,930
1% AEP	17	9	$2,063,922
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$8,799,338**	

Present Value of Costs	**$966,495**
Present Value of Benefits	**$633,239**
Net Present Value	**-$333,255**
Benefit Cost Ratio	**0.66**

Table 5-9 Temporary levees along Campaspe Esplanade CBA Analysis Results

Event	Number of Properties Protected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	N/A	N/A	$0
5% AEP	N/A	N/A	$0
2% AEP	35	18	$2,957,696
1% AEP	43	30	$6,960,705
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$8,679,633**	
Present Value of Costs			**$1,442,369**
Present Value of Benefits			**$2,425,989**
Net Present Value			**$983,620**
Benefit Cost Ratio			**1.68**

Table 5-10 Martin Street and Hicks Crescent Levee CBA Analysis Results

Event	Number of Properties Protected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	N/A	N/A	$0
5% AEP	2	N/A	$1,568
2% AEP	4	2	$343,064
1% AEP	11	7	$1,204,490
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$9,109,205**	
Present Value of Costs			**$1,800,562**
Present Value of Benefits			**$569,956**
Net Present Value			**-$1,230,607**
Benefit Cost Ratio			**0.32**

Table 5-11 Fehring Lane Drainage Reserve Levee CBA Analysis Results

Event	Number of Properties Protected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	5	2	$0
10% AEP	29	9	$0
5% AEP	262	91	$0
2% AEP	755	513	$0
1% AEP	24	9	$1,400,408
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$8,806,558**	
Present Value of Costs			**$402,725**
Present Value of Benefits			**$478,864**
Net Present Value			**$76,139**
Benefit Cost Ratio			**1.19**

Table 5-12 Haverfield Street Levee CBA Analysis Results

Event	Number of Properties Protected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	N/A	N/A	$0
5% AEP	1	N/A	$7,842
2% AEP	6	2	$298,736
1% AEP	9	6	$1,402,262
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$8,819,022**	
Present Value of Costs			**$1,184,263**
Present Value of Benefits			**$365,143**
Net Present Value			**-$819,120**
Benefit Cost Ratio			**0.31**

Table 5-13 Watson Street Levee Upgrade CBA Analysis Results

Event	Number of Properties Protected	Number Flooded Above Floor Level Protected	Total Benefits
20% AEP	N/A	N/A	$0
10% AEP	N/A	N/A	$0
5% AEP	N/A	N/A	$0
2% AEP	20	12	$2,945,924
1% AEP	42	15	$3,310,244
0.5% AEP	N/A	N/A	$0
0.2% AEP	N/A	N/A	$0
Extreme Event	N/A	N/A	$0
Average Annual Damages (AAD)		**$8,837,059**	
Present Value of Costs			**$351,314**
Present Value of Benefits			**$1,589,485**
Net Present Value			**$1,238,171**
Benefit Cost Ratio			**4.52**

5.6 Complete Structural Mitigation Concept Plan for Echuca

The complete package of works assessed would provide benefits across Echuca and the Council is likely to implement all of the measures presented in Section 5.3. Although individually some of the proposed measures are below a cost benefit ratio of 1, when combined the ratio for all of Echuca is weighted toward benefits with a value of 2.09.

Table 5-14 Combined Structural Mitigation CBA Analysis Results

Present Value of Costs	**$18,056,446**
Present Value of Benefits	**$42,771,079**
Net Present Value	**$24,714,633**
Benefit Cost Ratio	**2.37**

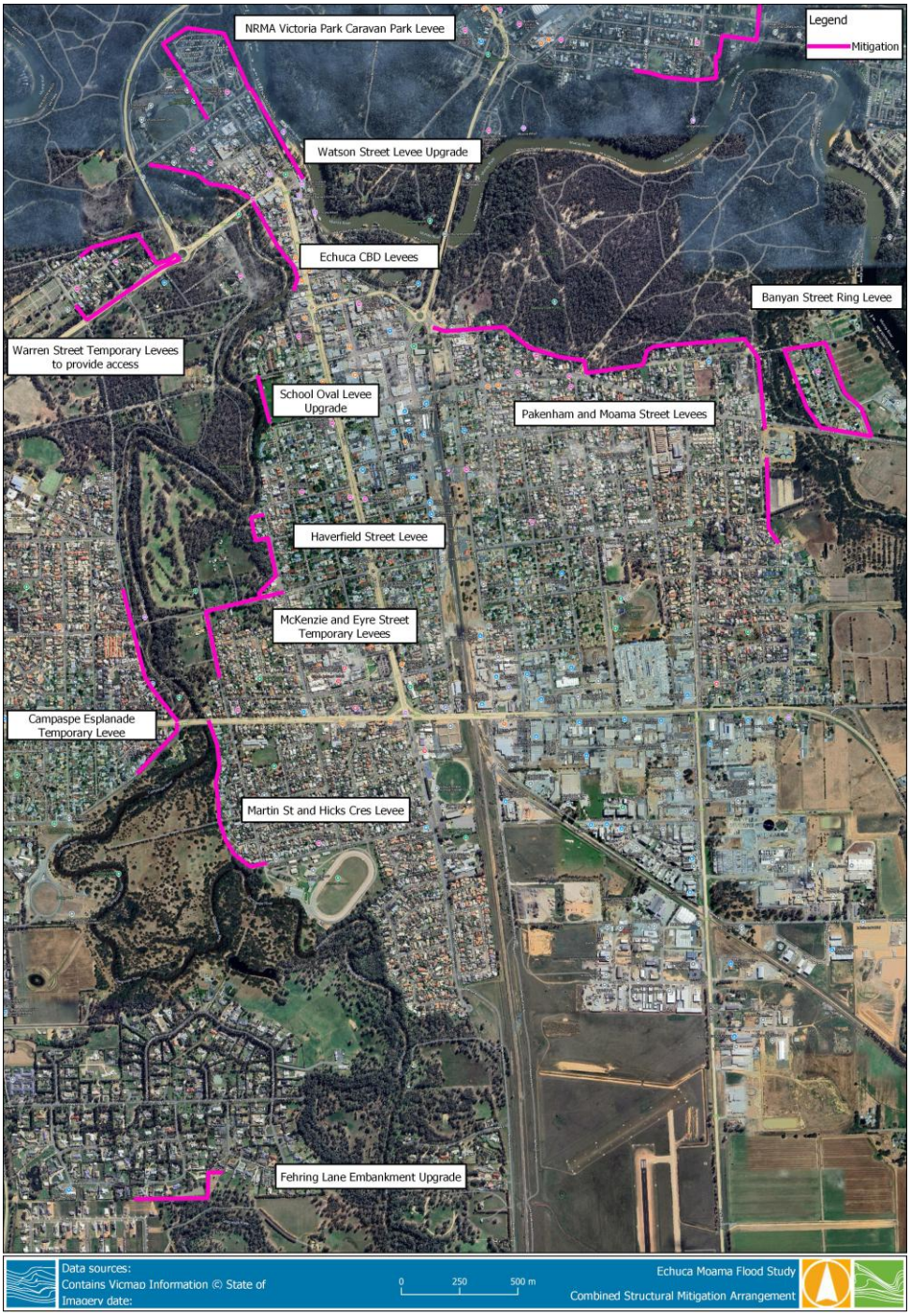


Figure 5-20 Combined Structural Mitigation Asset Layout

6 NON-STRUCTURAL FLOOD MITIGATION MEASURES

The reduction of flood risk involves much more than just structural flood mitigation measures. Effective land use planning, education, flood warning, emergency response planning and coordination between all stakeholders can contribute to reducing flood risk.

6.1 Flood Preparedness

Flood preparedness is key to reducing the impact of flooding on property and increase the safety of people living on the floodplain. The Murray/Goulburn Rivers have a long lead time to inundation at Echuca, which provides opportunities to put in place effective temporary measures, action flood response plans and evacuate the community if required in a timely manner to reduce financial, social and emotional damages. The Campaspe River has a shorter lead time from rainfall to inundation at Echuca compared to the Murray/Goulburn Rivers, but there is still ample time to prepare.

6.1.1 Roles and Responsibilities

The roles and responsibilities in flood planning and emergency response is documented in the State Emergency Management Plan (SEMP). It is acknowledged however when it comes to flood planning and mitigation, that there are many cases where there is shared responsibility.

For flood mitigation, Table 8 of the SEMP sets out that CMAs and DEECA are responsible for the legislative policy framework, Councils and DTP are responsible for the land use planning (with CMA as a referral authority), Councils are responsible for the flood mitigation infrastructure in urban areas, property owners are responsible for their own property modifications, CMAs are responsible for works on waterways and vegetation management on waterways, and the Bureau are responsible for riverine flood warnings.

When it comes to responding to a flood emergency, Tables 9 and 10 in the SEMP clearly sets out that VICSES are the control agency in responding to flood, with many lead supporting agencies also involved.

6.1.2 Monitoring and warning systems

There is typically a warning time of multiple weeks before the Murray River peaks at Echuca due to upstream rainfall. Flooding at Echuca is influenced strongly by Goulburn River flows, which may take around a week for river levels to peak following heavy rain in the Goulburn catchment. This means that residents are generally given sufficient time to receive a warning, prepare for an evacuation and to safely evacuate, including relocating possessions to minimise damage.

Emergency messages and news about flooding are shared in Victoria through several methods, including:

- VicEmergency: A Statewide system that sends alerts to mobile phones in areas at risk. Emergency services use this system to warn about events like floods and fires.
- State Emergency Service website.
- Local ABC radio provides updates on emergency situations.
- TV news media
- Social media
- Council website and social media including Facebook
- Door knocking and community meetings during an emergency event

Whilst there is a trend for more and more news being shared via digital media, elderly and infirm communities typically rely on other traditional forms of communication such as word of mouth, door knocking, emergency

broadcasts on radio etc. Additionally, a communication strategy needs to be conscious of reaching a diverse community, considering the need for multiple languages.

Flood warning can significantly reduce damages and risk to life and studies have shown that flood warning systems generally have high benefit/cost ratio if sufficient warning time is provided. Flood warning and the implementation of evacuation procedures by the SES are widely used throughout VIC to reduce flood damages and protect lives.

The Bureau of Meteorology (Bureau) is responsible for flood warnings on major river systems which the SES disseminates to the local community. Adequate warning gives residents time to move goods and personal items above the reach of floodwaters and to evacuate from the immediate area to designated evacuation points or flood free ground.

The Bureau have State based forecasting teams, with the Murray River forecasting completed by the NSW team. Typically, a flood warning is not issued until the Bureau have confidence in the prediction and have seen upstream gauges peak. The Bureau provides a quantitative flood warning service for the Murray River at the Echuca Wharf gauge, and they have a target warning lead time of 24 hours prior to flood levels reaching the peak and will issue warnings for any event expected to reach or exceed the minor flood class level of 93.5 m AHD. This can create some discomfort at a local community level, with pressure put on local VIC and NSW SES and Councils to fill the information void and make early predictions. These early predictions are often made within Incident Control Centres (ICC), and in the 2022 event it was made in the Epsom ICC in VIC. Given the cross-river relationship between the two Councils, information from both States was shared during the 2022 event, and it is recommended that this continues. A strong Council presence is recommended at the respective ICCs so that latest information from the emergency response team can be fed back into Council.

In discussions with the Bureau, there are currently two different approaches to forecasting flood levels at the Murray River at Echuca Wharf gauge. The Bureau have a large Murray River URBS rainfall-runoff model, but this needs improvement and has trouble representing some of the “hydraulic” features of this complicated section of the Murray River floodplain. The Bureau also relies on a set of lookup tables that have used historic data to correlate levels at Echuca Wharf with gauge flows/levels upstream, along with travel times between gauges.

The current approaches to forecasting levels at Echuca Wharf are in need of improvement. With a better understanding of the flooding behaviour for a large range of events now available through the Echuca-Moama Flood Study, it is recommended that this information be used to improve the flood forecasting capability of the Murray River URBS model. In particular, the flood modelling results can be used to develop improved floodplain storage relationship, for the lower Goulburn River floodplain.

In the interim, the inflows for the historic and design modelling for the Echuca-Moama Flood Study can be used to guide emergency response. The Bureau will provide a quantitative flood forecast at Shepparton, and this can then be used to correlate with the Echuca-Moama flood model inflows for the Goulburn River.

6.2 Land Use Planning

Land use planning is an effective measure to prevent intensification of flood risk, directing appropriate use and development of land in flood prone areas, commensurate with the level of flood risk.

The Victoria Planning Provisions are enacted under the Planning and Environment Act (1987), and they are supported by State and regional strategies. Local planning schemes set out the policies and provisions for how land is to be used and developed. Along with state-wide provisions there are several zones and overlays within planning schemes which relate to controlling and guiding development in flood prone areas.

The following three controls are the most common flood related controls used in planning schemes to control riverine flooding.

The **Urban Floodway Zone (UFZ)** identifies waterways, major flood paths, drainage depressions and high hazard areas within urban areas which have the greatest risk and frequency of being affected by flooding. It is to ensure that any development maintains the free passage and temporary storage of floodwater, minimises flood damage and is compatible with flood hazard, local drainage conditions and the minimisation of soil erosion, sedimentation and silting. The UFZ is typically a zoning used to discourage development within the highest hazard areas of the floodplain.

The **Land Subject to Inundation Overlay (LSIO)** identifies land in a flood storage or flood fringe area affected by the 1% AEP flood or any other area determined by the floodplain management authority. It is to ensure that development maintains the free passage and temporary storage of floodwaters, minimises flood damage, is compatible with the flood hazard and local drainage conditions and development will not cause any significant rise in flood level or flow velocity.

The **Floodway Overlay (FO)** identifies waterways, major flood paths, drainage depressions and high hazard areas which have the greatest risk and frequency of being affected by flooding. To ensure that any development maintains the free passage and temporary storage of floodwater, minimises flood damage and is compatible with flood hazard, local drainage conditions and the minimisation of soil erosion, sedimentation and silting.

6.2.1 Current Planning Controls

Large areas of UFZ are currently in place in Echuca, along the Campaspe River, along the Murray River and the Deakin Main Drain. This zoning sends a strong signal that further development in these areas is unlikely to be supported. There are also large areas of LSIO and FO.

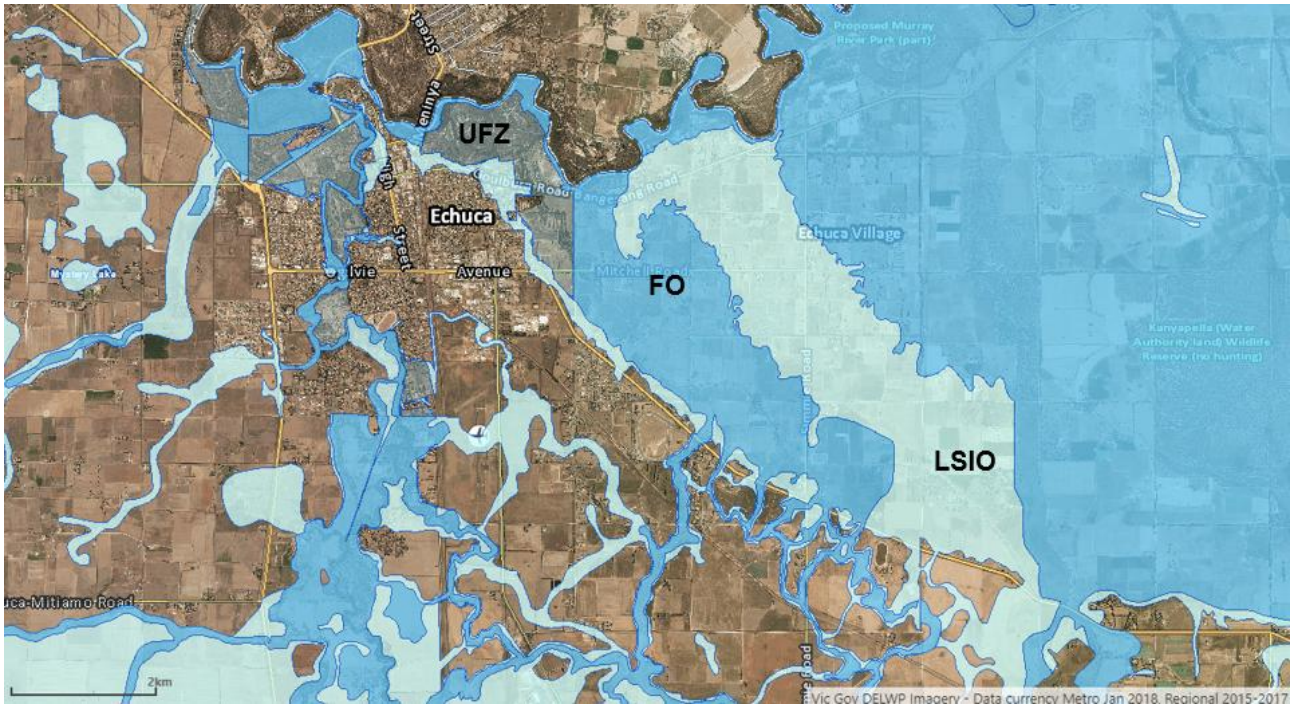


Figure 6-1 Current Zones and Overlays

As well as these three planning controls, decisions on land use in the Echuca Village area have previously been guided by the Echuca Village Restructure Plan (1999), which is an incorporated document in the Campaspe Planning Scheme. The plan applies to the areas of Echuca Village, Glanville and Boileau. The plan permits 1 dwelling per 16 ha on land with natural ground levels above 95.0 m AHD, within the current LSIO

area and 1 dwelling per 2ha in the Glanville/Boileau area. The plan also sets out some rules regarding floor levels for extensions to existing dwellings.

6.2.2 Recommended Updates to the Planning Controls

It is recommended that the Echuca Village Restructure Plan be reviewed along with the current flood planning controls. The UFZ, LSIO and FO planning controls should be updated using the latest flood mapping from the Echuca-Moama Flood Study (2024). The Echuca Village area is subject to deep flooding and long periods of isolation in events which overtop the Goulburn and Murray River levees. It is suggested that LSIO and FO controls are appropriate to guide development in the Echuca Village area, and the Echuca Village Restructure Plan may no longer be required. However, we must note strongly that if the Echuca Village Restructure Plan was removed, this is in no way an endorsement for further intensification of development in these areas, it would only be removed to be replaced by a FO planning control. Access to these areas during the 1% AEP design flood will not meet safety criteria, meaning development applications are unlikely to be supported by the flood authority.

The 1% AEP is the design flood standard for Victoria, however there is clear direction that climate change must be considered. In the Echuca-Moama Flood Study (2024), the study considered the 0.5% AEP flood extent under current conditions to be representative of the 1% AEP flood under climate change conditions. This followed an extensive investigation into the impacts of climate change (RCP 4.5 to 2090) on the Goulburn River (HARC, 2018).

It is recommended that for the development of the planning scheme overlays, that the 0.5% AEP flood modelling is used. To determine Floodway Overlay, the North Central CMA and Goulburn Broken CMA typically use the following definition.

- Floodway Overlay (FO) areas
  - Depth > 0.5 m in the 0.5% AEP event, or
  - Velocity > 1.5 m/s in the 0.5% AEP event, or
  - Depth x Velocity > 0.4 m2/s in the 0.5% AEP event
- Land Subject to Inundation Overlay (LSIO) areas
  - Remaining area of flood prone land in the 0.5% AEP event

It was found that the velocity and the depth x velocity categories added very little to the area of FO, with the depth > 0.5 m forming the basis of the majority of the FO area.

It is also recommended to update the LSIO and FO mapping and schedules of the Campaspe Planning Scheme via a planning scheme amendment process.

It is recommended that the current UFZ be maintained, as these areas are within the highest hazard areas of the floodplain. Some minor amendments to the UFZ may be required to address mapping anomalies, which were made many years ago prior to detailed floodplain LiDAR being available. The UFZ boundaries could be realigned to tie in with the proposed FO areas, such that FO and the realigned current UFZ areas operate together to control development in the highest hazard areas.

The proposed updated LSIO and FO are shown in Figure 6-2. The final mapping deliverables will infill small islands of LSIO within the FO and vice versa.

In addition, the proposed updated overlays will be clipped to the Bama sandhills, upstream of the Koondrook-Perricoota breakout into NSW, and at a location in southern Echuca to be determined. The location in southern Echuca will be determined based on the results of a currently ongoing project which is updating the flood mapping for Rochester and the rest of the Campaspe River. Note, that the intent is that the existing UFZ areas

would be realigned to the FO boundary and those areas would be clipped out of the proposed updated FO. It is also noted that there are some areas of current LSIO and FO in the planning scheme that apply to areas not impacted by riverine inundation from the Murray, Goulburn and Campaspe Rivers, these areas should be retained in any update to the planning controls.

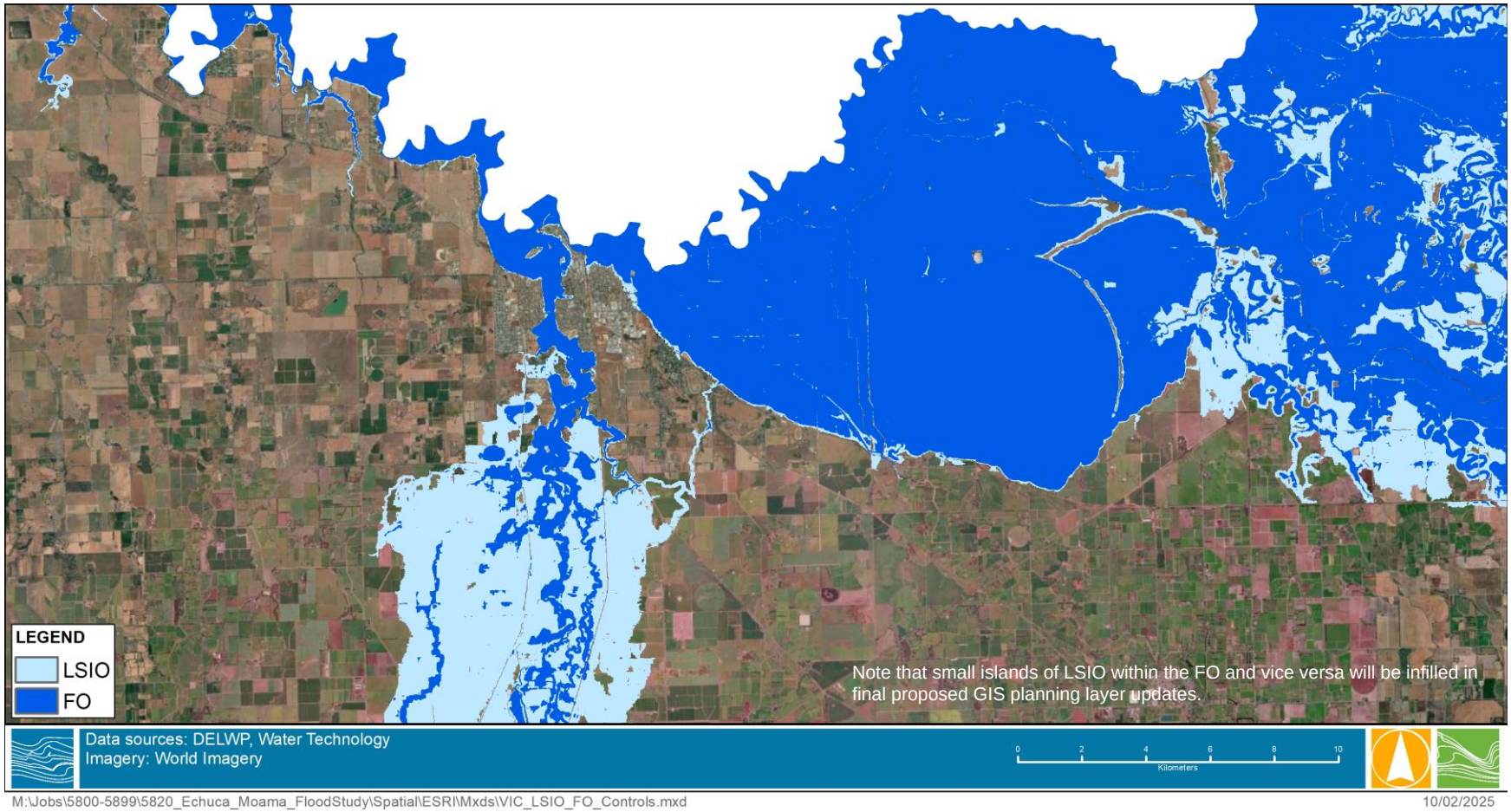


Figure 6-2 Proposed area to be updated with LSIO and FO Planning Controls

6.3 Stormwater Drainage

Stormwater drainage networks within town that cross under levees and discharge to the Campaspe and Murray Rivers are at risk of providing an avenue for riverine floodwaters to affect areas that would otherwise be protected from elevated flood levels. One way valves prevent this back flooding from the river. However, when the river is high, this can impact the ability to drain stormwater, causing stormwater flooding inside protected areas. Stormwater flooding of this nature was observed during the 2022 floods.

Several areas of the stormwater network in Echuca are fitted with sumps with either permanent pumps or space for temporary pumps, to pump stormwater over levees when the river is in flood.

Stormwater drainage capacities, condition and potential upgrades were not the focus of this riverine flood mapping study and flood risk management study.

6.3.1 Existing Infrastructure

Due to the closure of several penstocks and stormwater pipes/pits under levees in Echuca, several pumps are required during a flood event to effectively manage internal flooding during rainfall events. Pumps are typically installed in stormwater pits or sumps, and discharge over levees during rainfall events. Council has several pumps available to assist in Echuca, with a mix of permanent pump stations and locations where temporary pumps are placed in stormwater pits.

Figure 6-3 Echuca Pump Locations along the Murray River

Figure 6-4 Echuca Pump Locations Along the Campaspe River

6.3.2 Proposed Infrastructure

In the recent 2022 flood event there were a couple of areas where stormwater drainage was submerged by riverine flooding along the Campaspe River. The 2022 event was an extreme event for the Campaspe River, it was greater than a 1% AEP event, which is traditionally the event that is used to provide flood protection measures.

It is recommended that the following locations are considered for protection with flood valves to prevent riverine water backing up the stormwater system:

- Rutley Crescent area
- Murray Street area

As the catchment areas draining to these points are quite small, it is suggested that permanent pump stations are not required, but provision may be required for temporary pumping for a short period of time in the situation where the river flood levels are high and the stormwater cannot drain. Locations for proposed valves are shown in Figure 6-5.

The 2022 event also highlighted locations subject to Murray River flooding where existing drainage outlet infrastructure performed inadequately (Mitchell St pump capacity and blockages), flood gates had not been installed on the drainage outlets (Sturt Street) and / or the pump wells came close to overtopping from the Murray River (Mitchell St). This indicates all pump wells require review to ensure their adequacy. It is recommended a review of all drainage outlets be undertaken to ensure:

- Locations are clear of temporary levee locations and accessible at flood times,
- Pump wells are not at risk of overtopping,
- The arrangement of connecting pipework and pits is clearly documented,
- Flood gates are installed on all outlets and operational, and
- Adequate storm storage is available without placing protected buildings at risk.

New levees will impound storm flows and require drainage outlet infrastructure to prevent risk of internal flooding. Cost estimates for new and upgraded levees in this report provide for basic outlet structures and portable pumps. A full assessment of internal drainage and how best to manage discharges to the rivers during flood periods is beyond the scope of this study. A further study is recommended to investigate how best to manage these discharges

Figure 6-5 Proposed flood valve locations

6.3.3 Roles and Responsibilities

The operation of the valves and pumps during a flood emergency are set out in the Echuca Flood Mitigation Scheme Operating Manual, which is a Shire of Campaspe document.

Council staff members should be in constant communication with each other regarding all their responsibilities which cover the following:

- Manage and update asset maintenance schedules
- Organise rectification works if needed

- Organise maintenance crews/external contractors and obtain resources needed for maintenance and rectification purposes
- Continually monitor the effectiveness of stormwater pumping during flood events and identify whether additional locations are required to better manage stormwater in affected areas.

It is noted that during the 2022 event, several issues were found when trying to operate stormwater drainage valves and pumps. Feedback was that some valves did not operate through lack of maintenance. It is recommended that Council performs a condition inspection and audit of its drainage assets.

6.3.4 Inspections and timing

Performance of flood valves and pumps to manage stormwater behind levees is crucial in reducing the increased risks during a flood event. Inspections and testing of stormwater assets should form part of Council maintenance program and it is recommended to follow the below schedule in Table 6-1.

Table 6-1 Inspections and timing

Activity	Timing
Storage of portable temporary pumps to be in secured and covered housing	N/A
Portable pumps to be regularly serviced.	Annually and after each use
Automated flood gates and pump switches to be tested for alarms and correct operation	Quarterly
Manual flood gates and valves, operated and lubricated if needed, to prevent corrosion and seizing.	Quarterly
Pressure test all pumps and service if necessary	Quarterly
Portable pump distribution drill to replicate emergency response to ensure efficient and appropriate response	Annually
Permanent pump outfalls to be checked clear of debris	Quarterly and after each flood event
Pump wells and manholes to be checked and clear of any debris	Quarterly and after each flood event

6.4 Landowner Rights to Protect Properties

To reduce the risk of flooding to rural homes in areas that are not protected to an appropriate standard, landholders in rural areas can seek advice from the Catchment Management Authority and Council regarding the construction of protection measures around their dwelling or rural shedding and its immediate curtilages.

Modelling during this study has shown that adverse impacts of small ring levees in the Echuca Village area are typically negligible, because the storage volume of the areas protected is miniscule compared to the overall volume of the Kanyapella Basin floodplain. Regardless, these structures should continue to require a planning permit which is referred to the Catchment Management Authority for advice.

It is recommended that private protection measures follow the standard approvals process and are designed and constructed well prior to a flood event. But there will always be individuals who wish to construct ring

levees of earth or sandbags immediately prior to a flood event to protect their assets. In rural areas there is typically no issue if these structures are contained to the immediate area around the critical asset. But in cases where significantly long levee systems are constructed, there is a risk that this may adversely impact neighbouring properties, and the construction of these large protection measures can lead to disagreements with neighbouring landholders.

Any private levee structures constructed during a flood emergency will need to be removed following the event.

7 EMERGENCY FLOOD RESPONSE PLAN

This section has summarised useful information that can be used during an emergency to help guide the response effort. We discuss triggers to help translate a flood forecast to a mapped flood event from the flood study, consequences of flooding and recommended actions.

This has been further summarised in a standalone Flood Intelligence Card.

7.1 Flood Classification Levels

The Bureau of Meteorology (Bureau) provides a quantitative flood forecasting and warning service for the Murray River at Echuca Wharf gauge location. The Service Level Specification states that a warning will be provided if it is expected that the water level will reach above the minor flood level (93.5 m AHD), with a minimum lead warning time of 24 hours prior to the expected peak. Flood Warnings will refer to the flood classifications, which are currently set at:

- Minor – 93.5 m AHD
- Moderate – 93.9 m AHD
- Major 94.4 m AHD

The Bureau classifies minor, moderate and major floods using the following definitions.

Minor Flooding: This type of flooding leads to inconveniences, such as the closure of minor roads and the submergence of low-level bridges. The lower threshold for this category is marked by the initial flood level at which landholders and community members start to experience significant impacts, prompting the Bureau of Meteorology to issue a public flood warning.

The inundation observed in the design mapping for the 20% AEP (the lowest design event modelled), suggests that the current minor flood level of 93.5 m AHD is reasonable and matches the definition.

Moderate Flooding: This level of flooding inundates low-lying regions, necessitating the evacuation of some homes and the removal of livestock. Key traffic routes may also be affected by flooding.

The current moderate flood classification appears reasonable when considering that the area inundated will be slightly larger than the 20% AEP event, where a small number of buildings and large areas of rural floodplain and low lying urban floodplain is inundated. Only minor impacts on the road network are likely, with some rural roads like Old Deniliquin Road in NSW inundated.

Major Flooding: This severe flooding results in widespread inundation of rural areas, isolating properties, villages, and towns, and causing significant flooding in urban areas.

The current major flood classification is equivalent to the 10% AEP event. At this level lower sections of Warren Street in Echuca are potentially overtopped. With this being a major transport route, this classification seems reasonable.

Table 7-1 below shows the flood classification levels at the Echuca Wharf gauge along with design events and their corresponding inflows to the model area from the Campaspe River at Rochester, Goulburn River at Shepparton and Murray River at Barmah.

Table 7-1 Inflows in relation to Echuca Wharf Gauge Level

Design event at Echuca Wharf	Murray River at Echuca Wharf (m AHD)	Goulburn River at Shepparton (ML/d)	Murray River at Barmah (ML/d)	Campaspe River at Rochester (ML/d)
MINOR	93.50			
20% AEP	93.75	70,000	27,216	15,898
MODERATE	93.90			
10% AEP	94.40	97,800	31,104	22,464
MAJOR	94.40			
5% AEP	94.88	128,200	38,292	33,178
2% AEP	95.30	173,800	38,292	49,939
1% AEP	95.48	213,200	38,292	62,122
0.5% AEP	95.70	237,366	38,292	74,390
0.2% AEP	96.10	305,047	38,292	89,730

7.2 Timing

The below table provides an estimate of flood peak travel times between key gauge locations in the study area. The travel times in this floodplain can be complicated because of the three river systems, which can contribute flows independently or concurrently depending on where the rainfall is located within the region.

Table 7-2 Historical Peak Travel Times

From	To	Location with respect to Echuca Wharf @ Murray River	Timing	Description of flood hydrograph
Murray River at Barmah (409215)	Murray River at Echuca Wharf (409200)	Around 45 km upstream on the Murray River to the north east	4 to 6 hours	Large Murray River floods are typically long duration 3 to 6 months in duration. Peak gauge levels at Barmah historically can occur after the peak at the Echuca Wharf gauge, with the Echuca Wharf peak level driven by Goulburn River floods and to a lesser extent Campaspe River floods. The flows from the Murray River alone typically do not lead to significant flooding at Echuca and Moama.
Campaspe River at Rochester Peak (1580011)	Campaspe River at Echuca Peak (406265)	Around 30 km upstream on the Campaspe River to the south	1 to 1.5 days	The travel time from Rochester to Echuca for the two latest large floods in 2011 and 2022 both show a travel time of around 1.5 days. In the September 2010 event the travel time was a little shorter at around 20 hours.
Goulburn River at Shepparton Peak (405204)	Murray River at Echuca Wharf (409200)	80 to 90 km upstream on the Goulburn River to the south-east.	7 to 12 days	The lower Goulburn River has a lot of volume in the floodplain, with large floods overtopping the levees and filling the floodplain storage. An analysis of past events has shown that travel times along the Goulburn River can vary by a large amount depending on the magnitude and volume of the event hydrograph. Previous estimates of travel time in the MFEP were much lower at 4-5 days. Recent experience has shown that the travel time between peaks can be much longer.

7.3 Consequences and Actions

Peak flood depth surfaces for the 20% AEP up to the extreme flood were assessed against surveyed and estimated floor levels for Echuca. A summary of the analysis is shown below in Table 7-3 and related to gauge levels at Echuca Wharf gauge.

The Municipal Flood Emergency Plan Appendix C flood intelligence card was updated to incorporate the information gathered regarding properties and roads inundated. This has been included as a standalone word document for SES and Council to review and use to update their current version of the MFEP. Details of building locations inundated above and below floor, and names of roads inundated in various events has been provided in a standalone spreadsheet. The consequence information has not been repeated in detail here in this section, but is summarised below.

Table 7-3 Property Consequences in Echuca

Modelled Flood Level at Gauge (mAHD)	Event	Inundated Above Floor Level	Inundated Above Ground Level
93.75	20% AEP	2	5
94.40	10% AEP	9	29
94.88	5% AEP	91	262
95.30	2% AEP	513	755
95.48	1% AEP	694	975
95.74	0.5% AEP	919	1309
96.10	0.2% AEP	1525	2272
97.20	PMF	9286	9362

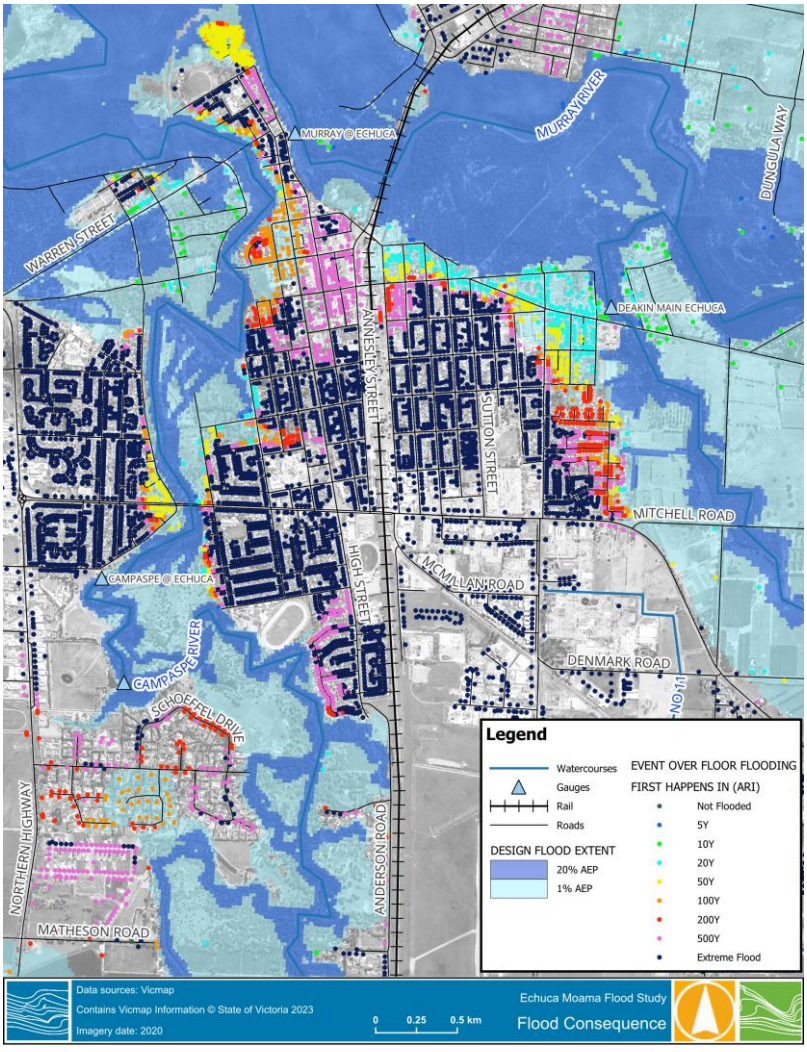


Figure 7-1 Property Consequences

Table 7-4 Roads Inundated

Event	Number of Roads	Total length of Roads Inundated – Unique Event (km)	Total length of Roads Inundated – Cumulative (km)
20% AEP	32	117.5	117.5
10% AEP	40	11.4	128.9
5% AEP	63	24.9	153.9
2% AEP	79	10.6	164.6
1% AEP	85	5.9	170.4
0.5% AEP	101	8.1	178.5
0.2% AEP	121	10.1	188.7
PMF	137	47.9	236.5

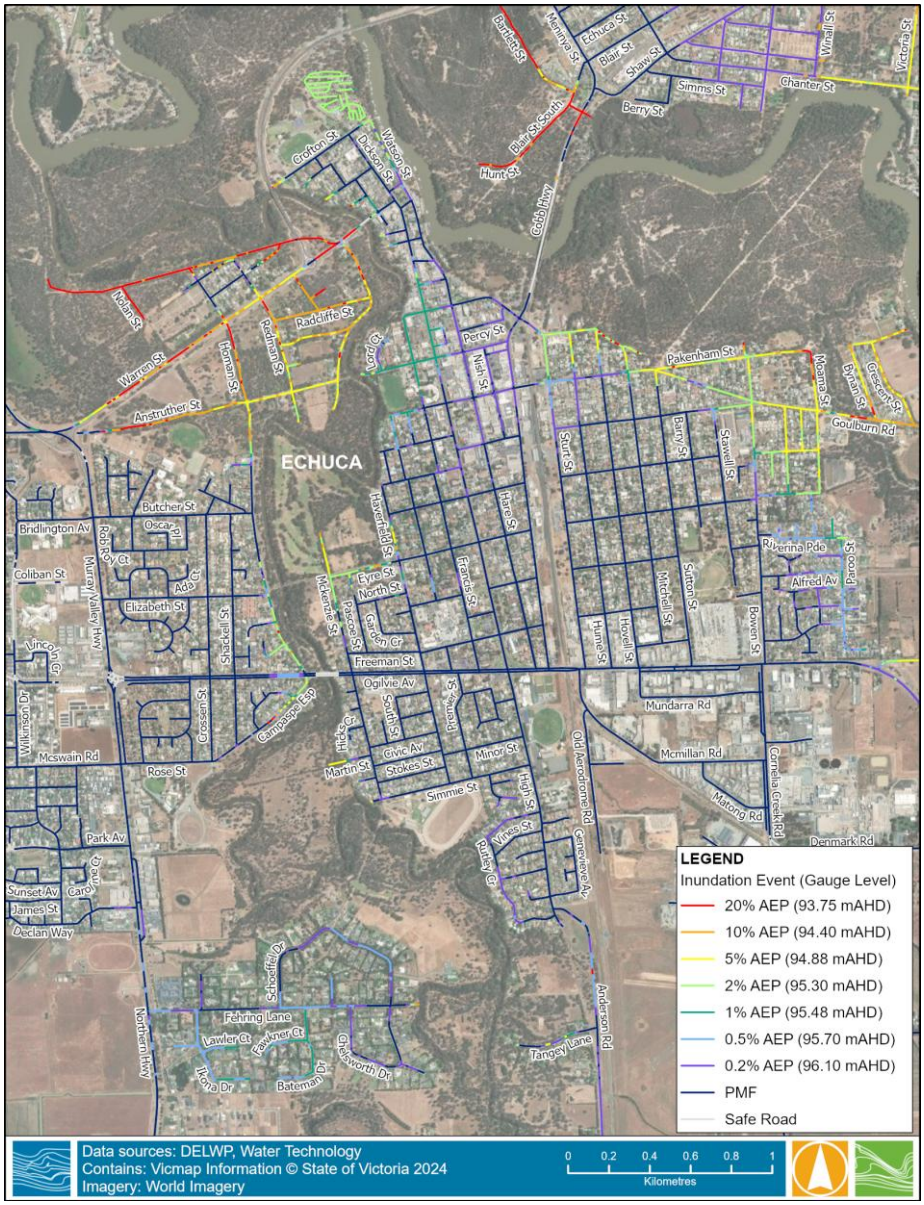


Figure 7-2 Roads Inundated - Echuca

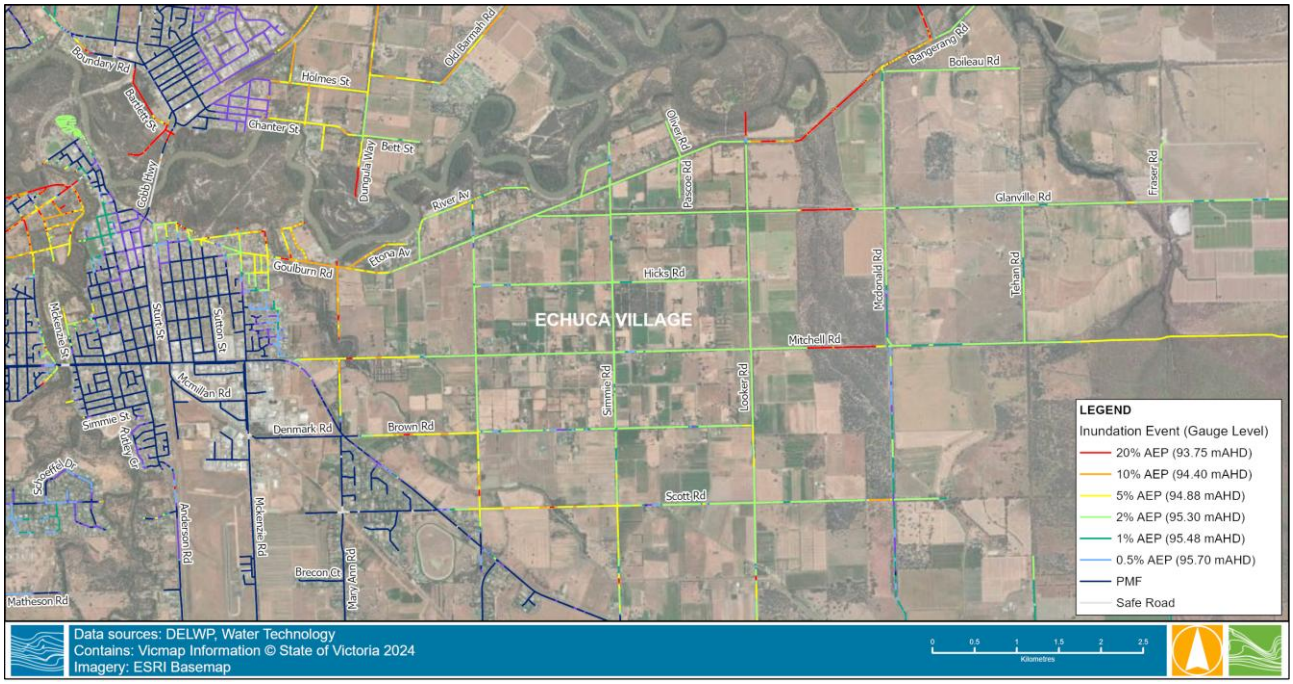


Figure 7-3 Roads Inundated – Echuca Village

8 RECOMMENDATIONS

The Floodplain Risk Management Study for Echuca and Moama was developed as a collaborative effort between Councils and authorities in both Victoria and New South Wales. It is strongly recommended that this cross-border relationship continue to be strengthened, and that the management of flood risk continues to be carried out in partnership on the shared floodplain of the Murray River. This shared responsibility means that when developing flood mitigation, the impact on the other side of the floodplain must be considered. Equally, it is recommended that intelligence in a flood emergency situation be shared, so that both communities are receiving the same messaging. Further opportunities may also exist to pool resources for the benefit of the two communities during a flood event.

The flood risk management study has investigated several flood mitigation concepts across Echuca. It is strongly recommended that the total flood mitigation concept plan presented in Section 5.6 be further investigated with a functional and detailed design. It is likely that the concepts can be optimised, striking a balance between permanent and temporary structures, and where possible preferencing structures with low maintenance requirements. In addition to the proposed flood mitigation levees, it is also recommended that Council review the condition and adequacy of their stormwater drainage system, including pumps, and valves/gates to prevent back flooding from the rivers.

It is recommended that private landholders with dwellings below the design flood level and outside of the township, in areas where levee solutions have not been proposed, investigate their own private levees to protect their dwelling. These private levees should be confined to the immediate vicinity of the dwelling itself and any high value storage areas. Large levees protecting vast tracts of agricultural land is discouraged as this leads to potential for adverse impacts on neighbouring land, which ultimately ends in disputes.

It is recommended that the flood forecasting for the Murray River at Echuca Wharf gauge be investigated for improvement. It is suggested that the hydraulic flood modelling relationships developed between inflows and the resulting flows and levels at Echuca Wharf may be of use, and that some of the hydraulic behaviour and floodplain storage information can be used to improve the Bureau's URBS model of the Goulburn, Murray and Campaspe Rivers.

A flood intelligence card for Echuca has been updated, along with information regarding the likely timing between gauges and correlations of upstream tributary gauge flows with Murray River at Echuca Wharf gauge levels. The Municipal Flood Emergency Plan should be updated with this new information.

It is recommended that the planning controls be reviewed and that the mapping for the LSIO, FO and UFZ within the study area be updated, along with a review of the Echuca Village Structure Plan which is an incorporated document of the Campaspe Planning Scheme.

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800

Sydney

Suite 3, Level 1, 20 Wentworth Street
Parramatta NSW 2150
Telephone (02) 9354 0300

Brisbane

Level 5, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460

Adelaide

1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000

Perth

Level 1, 21 Adelaide Street
Fremantle WA 6160
Telephone (08) 6555 0105

New Zealand

7/3 Empire Street
Cambridge New Zealand 3434
Telephone +64 27 777 0989

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Geelong

51 Little Fyans Street
Geelong VIC 3220
Telephone (03) 8526 0800

Wimmera

597 Joel South Road
Stawell VIC 3380
Telephone 0438 510 240

Gold Coast

Suite 37, Level 4, 194 Varsity Parade
Varsity Lakes QLD 4227
Telephone (07) 5676 7602

watertech.com.au