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Extraordinary Council Meeting

Tuesday, 29 April 2025

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Flood Study Report

Echuca-Moama Flood Study

Campaspe Shire Council / Murray River Council

18 June 2024

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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Front Cover Image: Echuca Wharf, May 2018 Source: Water Technology

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Acknowledgements

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EXECUTIVE SUMMARY

The townships of Echuca and Moama are situated on opposite sides of the Murray River floodplain. The Campaspe and Goulburn Rivers flow into the Murray River in close proximity to the towns.

The Campaspe Shire Council (CSC) and Murray River Council (MRC) require 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.

This flood study has taken a considerable effort to complete. It has 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.

Design hydrology was also updated to account for the additional years of record and the addition of the October 2022 event, which is the third largest flood on record at the Murray River at Echuca Wharf gauge. Encouragingly, the addition of this extra data has not changed the 1% (1 in 100) AEP flood level by much from the previous estimate of 95.45 m AHD, which is now estimated to be 95.5 m AHD.

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 at 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. This flood behaviour through East Moama is quite nuanced, and the modelling developed in this current flood study is far better placed to represent it appropriately than in the previous flood study.

This report presents the results of the flood modelling and mapping and has presented some preliminary analysis of the impacts of flooding through Echuca and Moama, along with some investigation 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. It is noted that these flood function maps will be further investigated and finalised in the early stages of the Flood Risk Management Study and Plan phase of this project. This next phase has now begun as both Councils have considered the Flood Study Report and adopted the study. The meeting minutes of each Council where the adoption is evidenced has been provided in Appendix H.

1 INTRODUCTION

Echuca and Moama are located at the confluence of three major river systems, the Murray, Goulburn and Campaspe Rivers. The townships have a long history of flooding, with good streamflow gauge records dating back to the late 1800's, and indigenous knowledge and stories of flooding going back well into the past.

The previous flood study (SKM, 1997) did a good job of developing flood levels and documenting flooding behaviour, but with the availability of new data and technology, and updated design flood estimation techniques, a new flood study was needed. Development pressure on the areas surrounding the major townships, in areas known to be flood prone, was another reason why this flood study was needed.

1.1 Project Objectives

The project is delivered in two parts as shown below, developing flood information that can be used by authorities and community for land use planning, flood risk management, emergency response, community education and insurance.

■ Update existing flood level, depth, velocity, hazard and extent information for a range of riverine flooding events across the study area (not including stormwater). ■ Identify flooding risks and consequences including the extent of impact to properties within the townships and satellite development areas. ■ Community consultation to present the findings of the flood study and obtain feedback from the community.	***Flood Study***
■ Estimate flood damage costs for the townships and satellite development areas. Identify and assess (at high level) mitigation works that may be considered to alleviate identified flooding impacts. ■ Undertake broad consultation and gain input into the preparation of the Flood Study and following Flood Risk Management Study and Plan. ■ Review existing flood management and warning systems ■ Develop revised flood related development controls to be applied across the study area to guide future development.	***Flood Risk Management Study and Plan***

1.2 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 long 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 changes to road infrastructure, and permanent and temporary levees, historical impacts due to flooding may have changed over time.

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.

Whilst the townships of Echuca and Moama are the focus of the study, and the modelling effort has focussed on the detailed flood mapping area shown in Figure 1-1, the study area extends 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. Care should be taken when interpreting flood levels outside of the detailed flood mapping area.

The modelling area was split upstream of the Torrumbarry Weir, to allow for a more detailed model of the Echuca and Moama area, with a separate model to investigate the levees in the Torrumbarry area. This report focuses on the Echuca and Moama modelling and mapping area. The downstream Torrumbarry area will be included in a separate report.

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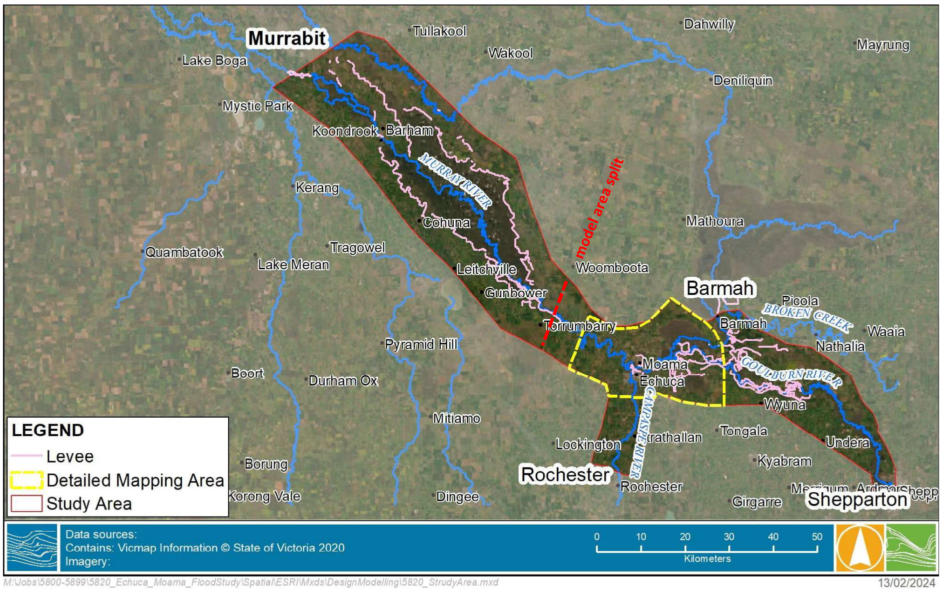

FIGURE 1-1 STUDY AREA

1.3 Geomorphological History

The study area is an interesting location from a geological and geomorphological perspective. The uplift of the Cadell Fault between 45-65,000 years ago halted the original path of the Murray River at Mathoura, forcing water to flow north or south. The original river channel was left stranded and is today known as Green Gully. The northern flow path is now known as the Edward River and the southern flow path the current day Murray River. The Cadell Fault uplift blocked both the Murray and Goulburn Rivers, forming the Barmah Forest and the Kanyapella Basin. Eventually the river broke through the sand dunes of the Kanyapella Basin and the Goulburn and Murray Rivers found their current courses.

The Wakool River branches off the Edward River downstream of Deniliquin and makes its way into the original course of the Murray River (Green Gully) north of Koondrook. The lower Goulburn and Campaspe Rivers are both perched above the floodplain and in large flood flows, water breaks out of the banks, and in the lower Goulburn River, breaches levees and inundates the floodplain.

This geomorphological history is important to understand from a flood risk perspective, as it controls the distribution of flood water. The geological uplift created a choke which restricts the peak flow from the Murray River downstream of Barmah to approximately 35,000 ML/d (Moama Floodplain Management Study, 2001). Downstream of Barmah, the peak flows are then dominated by the Goulburn and Campaspe Rivers. However, with Echuca and Moama located immediately downstream of the Kanyapella Basin, the floodplain functions as a natural retarding basin, and flood volume (not just peak flow) becomes critical to driving the peak flood levels. The floodplain narrows as it passes between the two towns, controlling the water levels upstream. Before reaching Torrumbarry, the floodplain again expands as flood water breaks out on the Victorian side around Richardsons Lagoon (and is contained by levees), and spills into Gunbower Forest, attenuating the flow before returning to the Murray River at Barham. A large percentage of the Murray River flood flows head north through the Koondrook-Perricootta Forest to the Wakool River, so that the flood flows on the Murray River at Barham are vastly reduced.

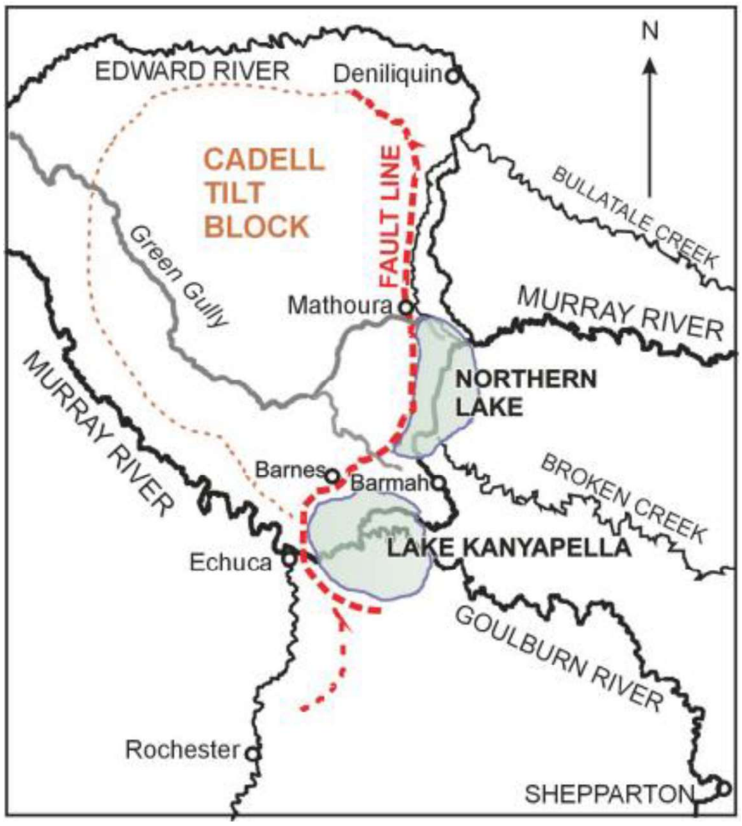

FIGURE 1-2 CADELL FAULT (SOURCE: WWW.ENVIROSTORIES.COM.AU/)

1.4 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. The hydraulic modelling used a MIKE11 1D hydraulic model. The previous investigation provided valuable and extensive background information and description of flooding for the current study. This study has been reviewed and drawn upon as necessary to provide background, context and verification of the current study approach and outcomes.

The Moama-Echuca Flood Study by SKM (1997) needed to be updated because hydraulic flood mapping techniques and hydrology have made great strides since the earlier work. Major works such as the flood mitigation levees around the Moama township and the new bridge crossing also needed to be incorporated into the new flood model to better understand today's flood risk.

2 HYDRAULIC MODELLING FRAMEWORK

2.1 Overview of the Modelling Approach

The modelling approach adopted a detailed two-dimensional hydraulic model with linked one-dimensional hydraulic structures to provide an accurate understanding of flood behaviour. The study not only models the Echuca-Moama area, but the broader upstream and downstream floodplain to improve the understanding of the flood risk over the wider regional area, to provide better linkages to flood warning gauges and to understand the level of protection offered by a series of levees throughout the floodplain. Given the size of this area to model, the model was split into two: the Echuca-Moama model from the upstream boundaries at Barmah, Shepparton and Rochester to Torrumbarry, and the Torrumbarry model from Torrumbarry to Gonn Crossing at Murrabit as shown in Figure 2-1.

This report includes just the Echuca-Moama model area upstream of Torrumbarry.

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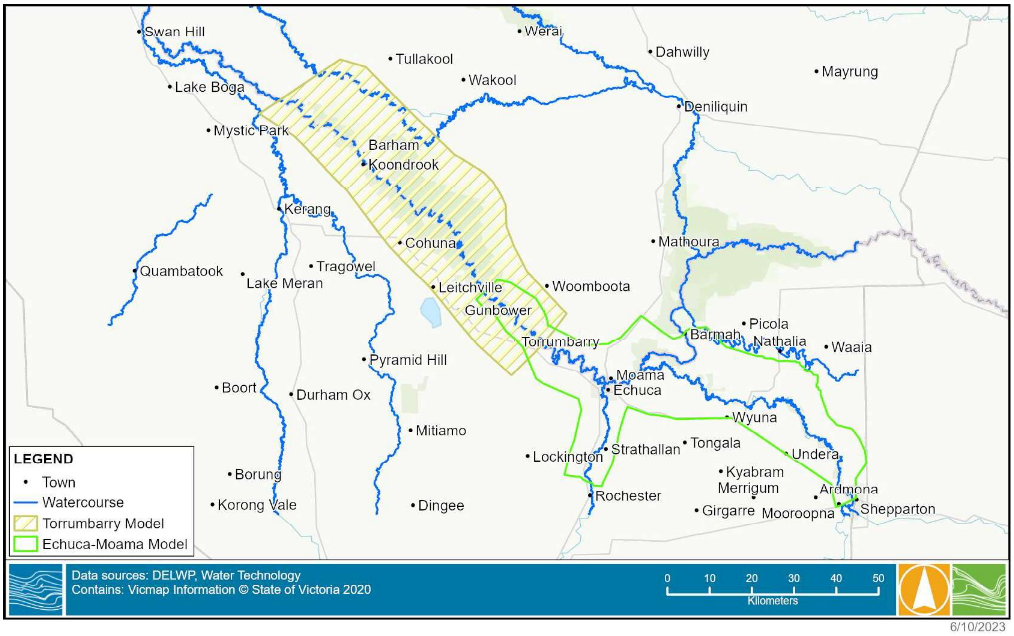

FIGURE 2-1 ECHUCA-MOAMA MODEL & TORRUMBARRY MODEL AREA

2.2 Hydraulic Model Limitations

There are numerous contributing factors to the ultimate output uncertainty in a complex hydraulic modelling exercise such as that undertaken for this study. Some of the uncertainties relate to the data inputs, whilst others are dependent on the numerical modelling processes itself. Sources of output uncertainty related to the input data for the hydraulic modelling include:

- Topographic data
- Definition of hydraulic controls/structures
- Inaccurate boundary conditions
- Limitations of the grid resolution to define flow features
- Observed and estimated design flows for model input
- Observed flows and water levels for model calibration

Sources of uncertainty related to the hydraulic modelling process include (Syme, 2001):

- Model numerical and computational schemes
- Floating point accuracy of computing resources
- Model schematisation and set-up
- Model parameters such as computational time-steps, surface-friction and other energy-loss parameters.

The hydraulic model development process can only address uncertainties arising from model schematisation and set-up, model parameters and definition of hydraulic controls/structures. The remaining aspects are constrained by the available data sources and software attributes.

There is a wide variation in the magnitude of the impact associated with each source of uncertainty. In order to identify the most significant sources of uncertainty it is possible to consider items as either first or second order magnitude, where second order items have a much smaller impact on model uncertainty compared to first order items and can generally be treated with minor consideration. A list of the main sources of the modelling uncertainty and their approximate magnitudes is provided in Table 2-1.

Due to the complexity of the relationships between the input data and modelling outputs, there is no direct correlation between input and output data uncertainty, and the error bounds on the data inputs are generally not cumulative. However, there are inferred relationships between model inputs and output uncertainty that are typically developed through hydraulic modelling project experience.

TABLE 2-1 COMPARISONS OF SOURCES OF UNCERTAINTY

Scenario/Data/Process	Order of Uncertainty	Approximate Impact on Results
Topographic data	First	Change in floodplain levels/depths ± 0.1 m. LiDAR validation survey was gathered and the survey demonstrated that the LiDAR datasets used in the modelling were appropriate for use and within the reported levels of accuracy. There was no need for any shift in LiDAR datum. Channel representation based on LiDAR can often cause underestimation of channel conveyance. Without more detailed survey, this has to be accepted as a model uncertainty. Recent bathymetry data of the Murray River along with cross-section survey from State Rivers and Water Supply Commission plans from the late 1970s and early 1980s, were used to create a bathymetric DEM of the rivers.
Definition of hydraulic controls/structures	First	Change in floodplain levels/depths of around 0.2 m. The majority of the hydraulic structures in this model are bridges or culverts which can have a significant impact on the local water surface level but unlikely to have a large impact on the flood extents and levels across the broader study area.
Hydrology	First	One of the largest influences on flood levels. The quality of gauged streamflow data was variable with some gauges having poor quality, extrapolated data for much of the historic flood events. This varies somewhat between the gauges but overall, the reliability can be considered to be of a moderate level. This is discussed further in this report. Design flood estimation for this study has used the flood frequency analysis technique, design quantile estimates are one of the higher sources of uncertainty for any design flood modelling.
Observed water levels for model calibration	First	Depends on available data, generally ± 0.2 m for observed flood levels. Some of the observed water levels from the historic events were pegged from debris lines which may overestimate the actual peak water level. For many of the surveyed levels the method of identification of water level is unknown and the reported reliability varies from low to high in the Victorian Flood Database (VFD) dataset.
Model schematisation and set-up (location of boundaries, grid resolution, structures)	First	Difficult to quantify. The main reason why the inflow boundaries were extended back upstream to Barmah, Shepparton and Rochester was so that appropriate inflow boundaries could be set and based on streamflow gauge data.
Model parameters such as computational time-steps, roughness and other energy-loss parameters	First	Difficult to quantify. Reduced through calibration to four historic events.
Model numerical and computational schemes	Second	minor

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Scenario/Data/Process	Order of Uncertainty	Approximate Impact on Results
Floating point accuracy of computing resources	**Second**	**Minor**

2.3 Model Calibration

The model calibration consisted of initially modelling three historic events:

- **October 1993** – A Goulburn River dominated flood, registered 94.77 m AHD at the Echuca Wharf gauge.
- **January 2011** – A Campaspe River dominated flood close to a 1% AEP event on the Campaspe River, but well below a minor flood on the Murray River registering just 92.84 m AHD at the Echuca Wharf gauge.
- **October 2016** – A Murray River flood just below the minor flood level which is approximately a 20% AEP event, registering 93.42 m AHD at the Echuca Wharf gauge.
- **October 2022 -** A Campaspe River flood close to a 0.2% AEP event, combined with a Goulburn River flood between a 1-2% AEP event, registered 94.99 m AHD at the Echuca Wharf gauge resulting in a flood on the Murray River at Echuca Wharf of close to a 5% AEP event on the Murray River at Echuca Wharf.

The Torrumbarry model will use the 1975 event as a calibration event because there are many surveyed flood levels available in the Torrumbarry area for that event. The calibration events represent a broad range of flood magnitudes, with different tributary contributions.

2.4 Design Modelling

The design flood modelling and mapping was completed for the 20%, 10%, 5%, 2%, 1%, 0.2% and 0.5% Annual Exceedance Probability (AEP) events plus an extreme flood event.

The design hydrology approach for this study was developed by WMA Water. The first component of this approach included a flood frequency analysis of the water level record at the Murray River at Echuca Wharf gauge. Typical concurrent flow correlations between the three main tributary inflows on the Goulburn River at Shepparton, the Campaspe River at Rochester, and the Murray River at Barmah were then developed. A historic flood event from October 1992 was selected that possessed the characteristics of the typical concurrent flow correlations as the basis of the hydrograph shapes and timing of peaks. The selection of the event is described in Appendix D. Using the historic donor hydrograph shape and timing, the flow correlation relationship was trained to produce the required design water level at the Murray River at Echuca Wharf gauge. Through iteration it was found that the flood frequency levels on the Murray River at Echuca Wharf could be reproduced using the equivalent peak design inflow on the Campaspe River at Rochester, the maximum peak flow able to pass down the Murray River through the choke, along with a flow equal to or greater than the equivalent design peak flow at Shepparton on the Goulburn River.

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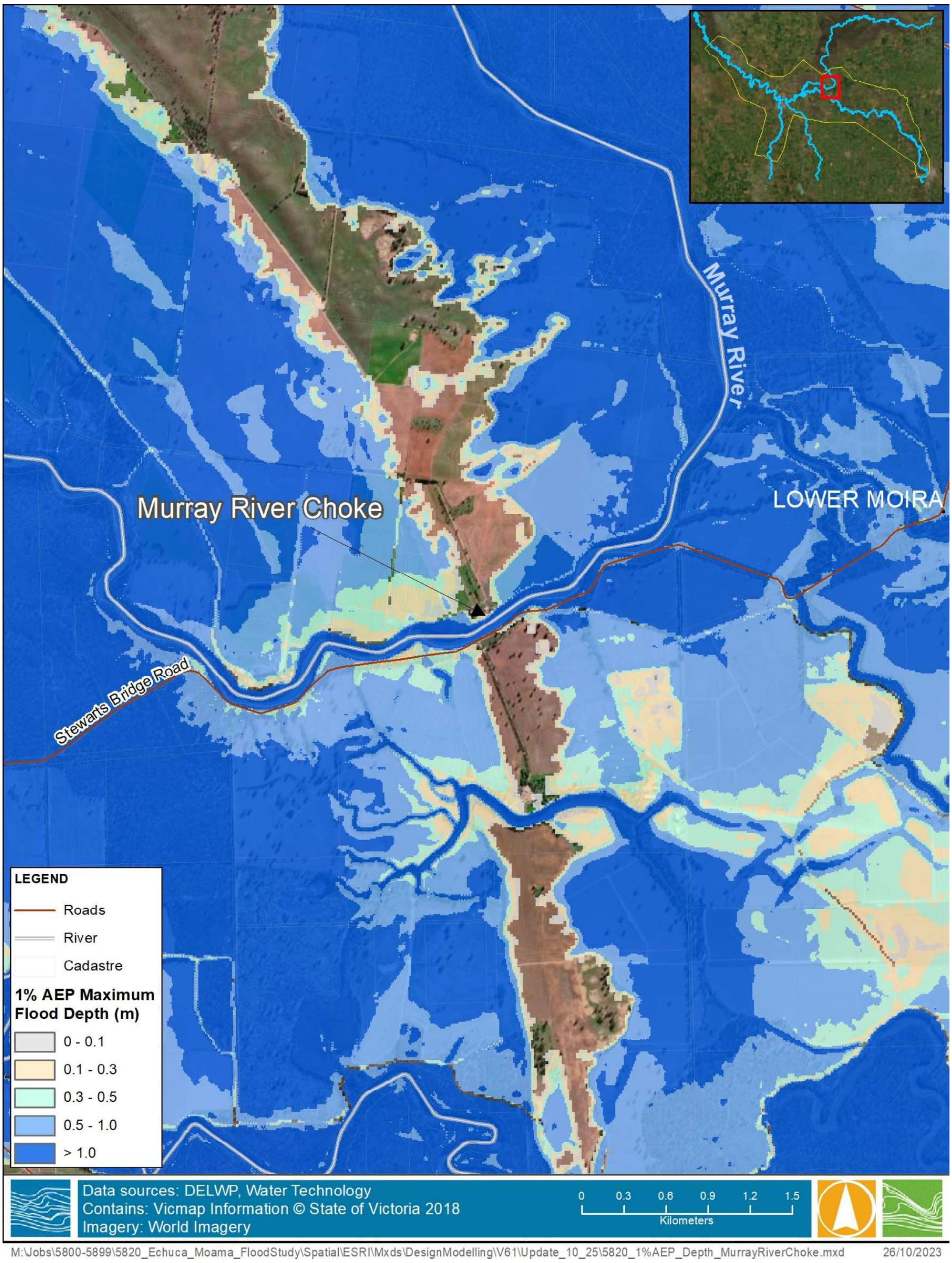

FIGURE 2-2 LOCATION OF MURRAY RIVER CHOKE EAST OF THE KANYAPELLA BASIN

2.5 Hydraulic Modelling Software

TUFLOW modelling software was used for this study. TUFLOW is a one and two-dimensional flood and tide simulation software package that simulates the complex hydrodynamics of floods and tides using the full one-dimensional St Venant equations and the full two-dimensional free- surface shallow water equations. TUFLOW is the most widely used flood modelling software in Australia.

The 2020 TUFLOW HPC release provided a significant update on modelling techniques available. Features of the software include Quadtree mesh refinement and Sub-Grid Sampling (SGS). The TUFLOW HPC software with the inclusion of Quadtree mesh refinement and sub-grid sampling allows significant improvements in model run time compared with other software schemes, allowing for higher model resolution and still achieving reasonable model run times.

The latest TUFLOW HPC version at the time of calibration for the 1993, 2011 and 2016 events, which was the 2020-10-AA version was used to run the model and was run in Single Precision.

The updated calibration for the October 2022 event utilised an updated TUFLOW HPC version, 2023-03-AB, at the time the calibration commenced and was run in single precision. This version was also utilised for the design event modelling. Sensitivity testing between the two versions indicated no impacts are caused by the different models. The same SGS calculation method was utilised in both versions, rather than the alternative method that is the default setting in the 2023-03-AB build version so that results were similar.

2.6 Hydraulic Model Schematisation

The model was developed as a 2D TUFLOW model with 1D linked structures and major bridges modelled using layered flow constrictions. The TUFLOW HPC software initially included a more detailed Quadtree mesh in the east-Moama area, along with sub-grid sampling of the waterway bathymetry. The Quad-tree area was removed in the October 2022 calibration as it was found to be slowing the model down, and with improvements to the definition of levee breaklines etc, it was no longer needed to represent the flow behaviour accurately. The October 2022 calibration setup was largely used for design modelling and sensitivity testing between the two versions indicated no significant changes in the results were observed.

For the hydraulic analysis of complex overland flow paths an integrated 1D/2D model such as TUFLOW provides several key advantages when compared to the likes of the 1D only model from the previous Moama-Echuca Flood Study (SKM 1997). A 2D approach can:

- better facilitate the identification of the potential overland flow paths and flood problem areas,
- dynamically model the interaction between hydraulic structures such as culverts and complex overland flow paths,
- better represent the available flood storage within the 2D model geometry, and
- better represents flow paths that are not parallel with the defined river branch of a 1D model.

Importantly, a 2D hydraulic model can better define the spatial variations in flood behaviour across the study area. Information such as flow velocity, flood levels and hydraulic hazard can be readily mapped across the model extent. This information can then be easily integrated into a GIS based environment enabling the outcomes to be readily incorporated into Council's planning activities. The model developed for the present study provides a flexible modelling platform to properly assess the impacts of any management strategies within the floodplain (as part of the ongoing floodplain management process). In TUFLOW the ground topography is represented as a uniformly-spaced grid with a ground elevation and a Manning's "n" roughness value assigned to each grid cell. The grid cell size is determined as a balance between the model definition required and the computer run time (which is largely determined by the total number of grid cells).

2.6.1 Hydraulic Model Extent

The Echuca-Moama model domain is illustrated in Figure 2-3. The Echuca-Moama model extends along the Murray River from the Barmah streamflow gauge to near Torrumbarry, on the Goulburn River from Shepparton to the Murray River, and on the Campaspe River from the streamflow gauge at the Waranga Western Channel syphon at Rochester to the Murray River. The downstream boundary location of the Echuca-Moama model on the Murray River was taken near Torrumbarry to avoid any boundary impact at Echuca. The mapping from this model was clipped to a point upstream of Torrumbarry where the impact of the boundary is negligible. The total reach of the Murray River included in the Echuca-Moama model is approximately 140 km, the Goulburn River is approximately 155 km and the Campaspe River is approximately 55 km. The model needed to extend to the upstream gauges to allow robust design hydrology to be completed for the inflow boundaries. Having the boundaries at these upstream gauges also provides benefits from a flood intelligence and flood warning perspective. One limitation with this approach, particularly along the Goulburn River, is that levee breaches along the lower Goulburn River can impact the flood behaviour and resulting hydrograph experienced at Echuca-Moama.

2.6.2 Hydraulic Model Resolution

The Sub-Grid Sampling technique was applied in the Echuca-Moama model. Sub-grid sampling (SGS) involves the extraction of sub-grid scale topographic characteristics at the resolution of the underlying LiDAR (1m resolution) into conveyance tables that describe the variation within each cell. This provides a much richer description of the hydraulic behaviour of the cell compared to a traditional grid that has a single topographic elevation. This is particularly useful for models with coarse grid resolution.

The Goulburn River, Murray River and Campaspe River DEM was modelled using SGS at a 1 metre sampling resolution, with the rest of the modelling area having a 20 m grid resolution. Using the SGS within the channel bathymetry DEM ensures that the capacity of the channel is well represented in 2D, avoiding the saw tooth nature of a coarse grid around bends in the river.

The area east of the Moama township was originally modelled using the Quadtree modelling technique at 5 metre grid resolution to more accurately depict the rural roads and levees. This was originally used to allow better modelling of the 1993 event where private rural levees, channel banks, and some roads played an important role in directing floodplain flows. These features become less important in larger flood events where they are overtopped. Figure 2-3 shows the initial quadtree area and the three river DEM where SGS 1 metre resolution was used.

The initial inclusion of the quadtree extent meant that the model runtime was taking up to 7 days for the design runs. During the October 2022 calibration further testing and refinement of the models levee breaklines found that the Quadtree area was no longer required, and when removed the model run time was greatly improved. A comparison of levels in the area showed negligible variation between the two approaches, and it was decided that the benefit in removing the quadtree component to gain efficiency in modelling was valid. This same model setup was used in the final design modelling.

2.6.3 Topography

A detailed representation of the ground surface was required to appropriately capture the topographic detail within the hydraulic model. The topography of the floodplain across the study area is incredibly complex and has been shaped by past geological events as described in Section 1.3. A number of LiDAR (aerial laser survey) and bathymetric survey files were used to develop the hydraulic model topography grids. The floodplain topography is shown in Figure 2-4, and in more detail around Echuca-Moama in Figure 2-5.

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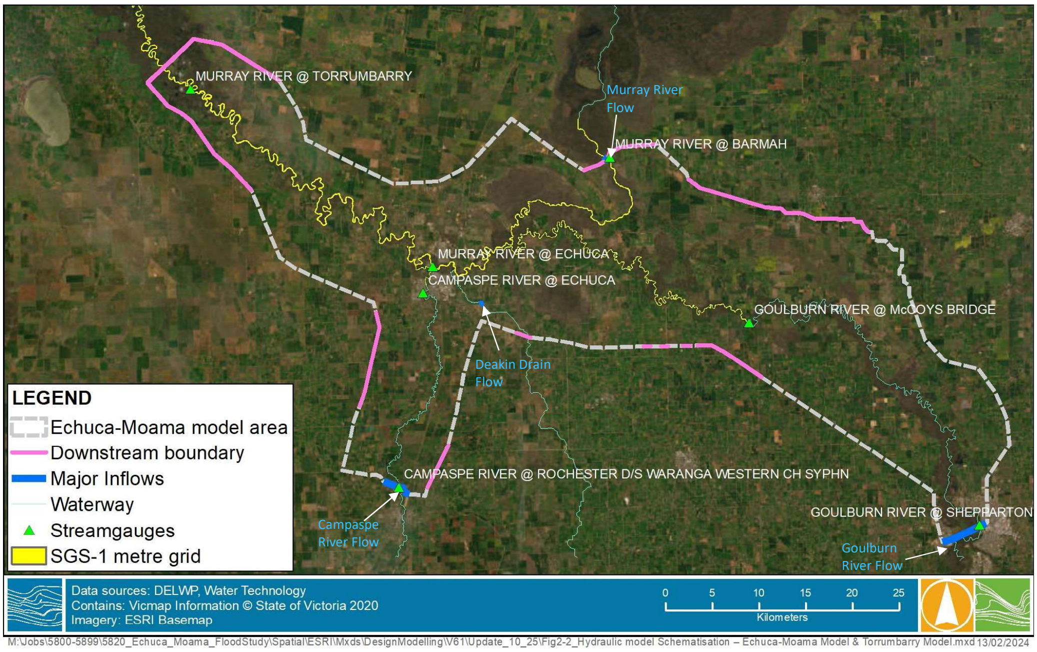

FIGURE 2-3 HYDRAULIC MODEL SCHEMATISATION – ECHUCA-MOAMA MODEL

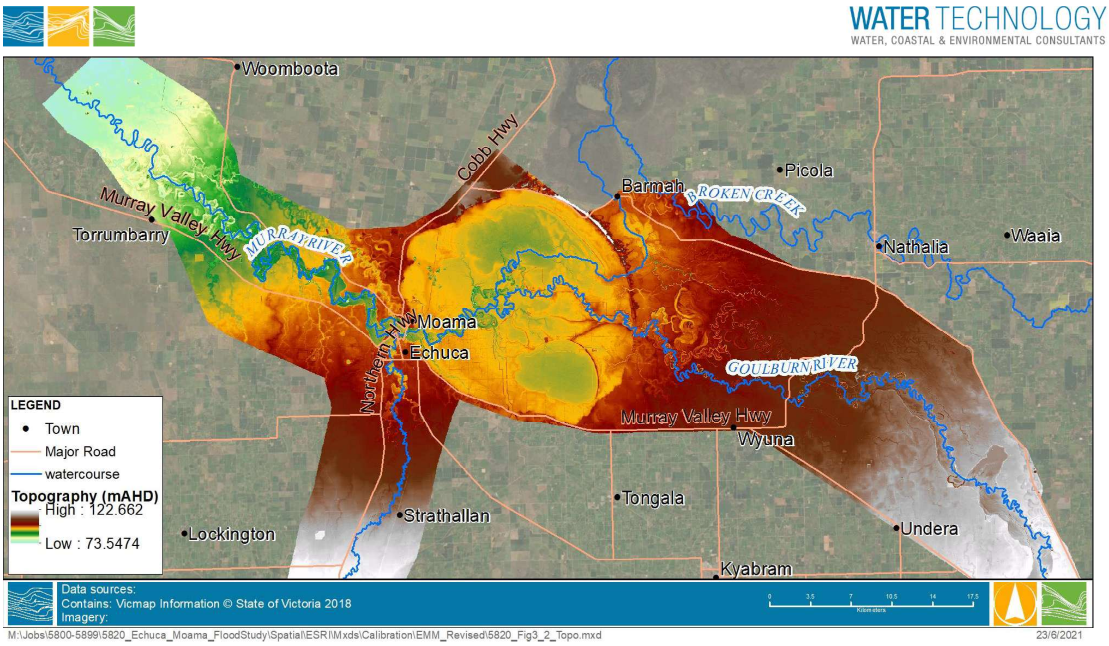

FIGURE 2-4 TOPOGRAPHY OF THE STUDY AREA

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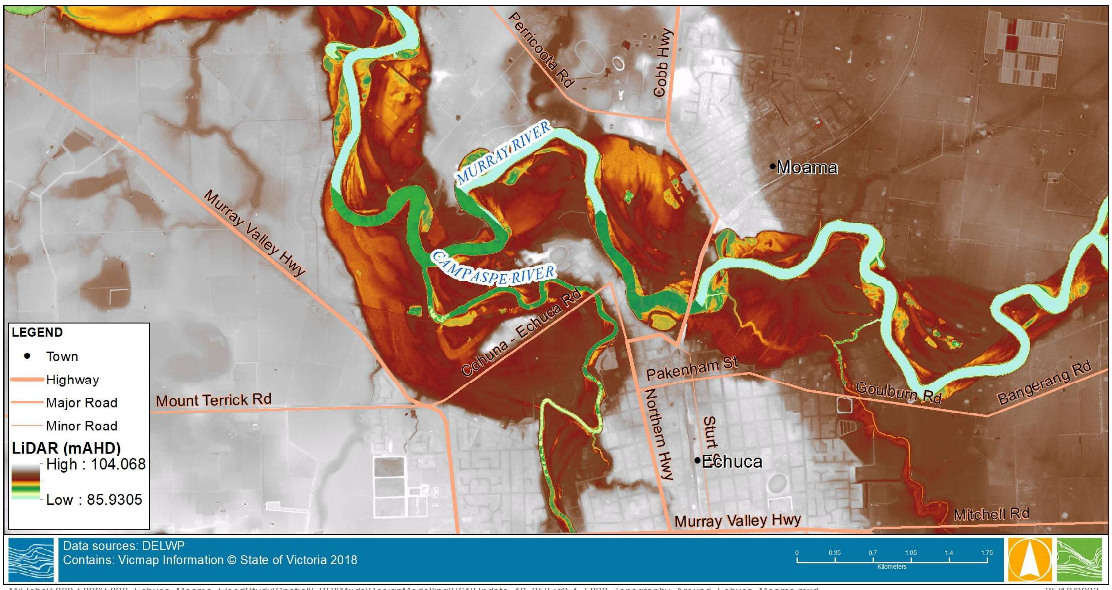

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FIGURE 2-5 TOPOGRAPHY AROUND ECHUCA-MOAMA

2.6.3.1 LiDAR

There are several available LIDAR datasets of relevance to the study area which include:

TABLE 2-2 LIDAR DATASETS

Source	Year captured	Resolution	Horizontal accuracy	Vertical accuracy
Murray Darling Basin Authority (MDBA)	2001	1 metre	horizontal accuracy +/- 0.5 m	vertical accuracy +/- 0.15 m
Goulburn Broken Catchment Management Authority (GBCMA)	2007	1 metre	horizontal accuracy +/- 0.4 m	vertical accuracy +/- 0.2 m
Victorian Government (VIC) ISC	2010	1 metre	horizontal accuracy +/- 0.4 m	vertical accuracy +/- 0.2 m
VIC Floodplains Stage 1	2011	1 metre	horizontal accuracy +/- 0.3 m	vertical accuracy +/- 0.1 m
VIC Floodplains Stage 3	2011	1 metre	horizontal accuracy +/- 0.3 m	vertical accuracy +/- 0.1 m
Geoscience Australia (GA) Wakool	2015	1 metre	horizontal accuracy +/- 0.8 m	vertical accuracy of +/- 0.3 m
New South Wales Government (NSW) Echuca	2017	1 metre	horizontal accuracy +/- 0.8 m	vertical accuracy +/- 0.3 m

The extent of each of these LiDAR datasets is shown in Figure 2-6.

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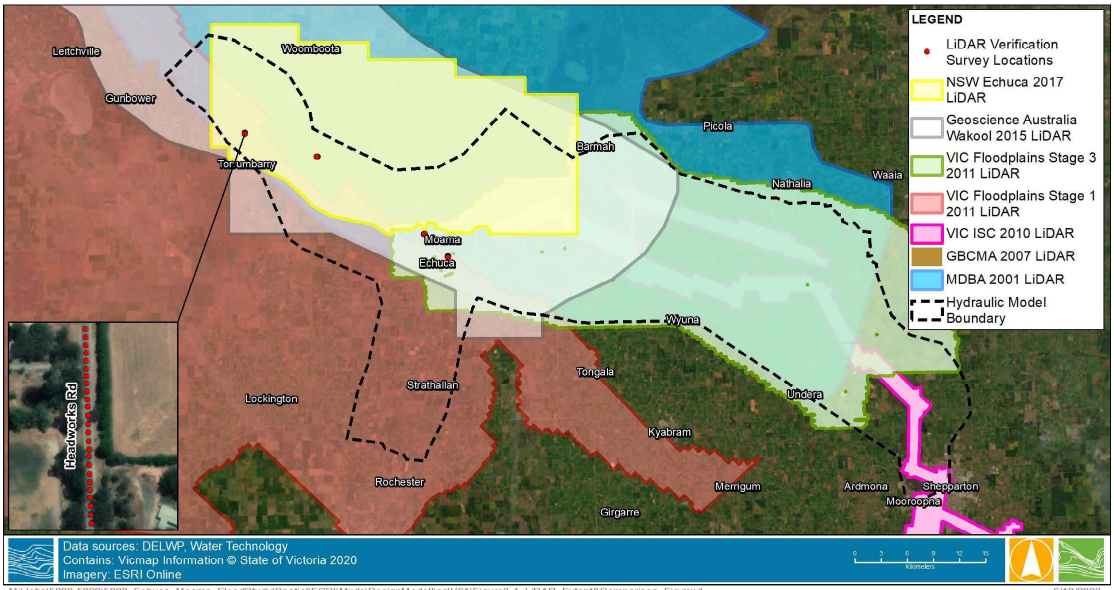

FIGURE 2-6 EXTENTS OF AVAILABLE LIDAR DATASETS AND LOCATION OF VERIFICATION SURVEY

A control survey was commissioned to verify the accuracy of the different LiDAR datasets within the hydraulic model area. The control survey consisted of five 100 m long transects spread out across the Echuca and Torrumbarry study areas along flat, sealed roads. Figure 2-6 also shows the locations for the control survey.

It should be noted that the hydraulic model boundary was not expected to extend as far upstream of the Goulburn River at the time of the control survey, so there was no survey captured for that part of the model area.

The LiDAR elevations were compared to the surveyed elevations at each survey point, and the differences were tabulated to help assess the accuracy of each LiDAR dataset and determine an order of preference for use in the hydraulic model development. The summarised results of this verification are presented in Table 2-3.

TABLE 2-3 COMPARISON OF CONTROL SURVEY MINUS LIDAR

Control Survey Minus LiDAR	Minimum Difference (m)	Maximum Difference (m)	Mean Difference (m)
MDBA LiDAR (2001)	0.000	0.240	**0.076**
VIC Floodplains Stage 1 LiDAR (2011)	0.002	0.267	**0.074**
VIC Floodplains Stage 3 LiDAR (2011)	0.004	0.240	**0.034**
GA Wakool LiDAR (2015)	0.237	0.507	**0.340**
NSW Echuca LiDAR (2017)	0.017	0.245	**0.080**

The LiDAR verification indicated that all datasets agreed reasonably well with the AHD levels of the control survey (mean difference within ±100 mm), except the GA Wakool LiDAR. The GA Wakool LiDAR was found to be too low (average of 340 mm too low compared to the control survey) and was therefore not used for the model development as it didn't provide any additional LiDAR coverage either.

Based on the above findings, it was determined that the LiDAR datasets be used in chronological order of preference (priority to most recent LiDAR) where they overlap. Given the mean differences for all the datasets fell within their reported error margins, there was no need to globally raise or lower any of the datasets.

VIC ISC 1 m LiDAR (2010), and GBCMA 1 m LiDAR (2007) datasets were used to complete the LiDAR coverage for the hydraulic model in the most upstream part of the model between Shepparton and the VIC Floodplains Stage 3 LiDAR.

2.6.3.2 Channel Bathymetry

LiDAR data of the floodplain is available, but the LiDAR does not penetrate the water surface, so the channel bathymetry has to be defined by other survey data. Murray Darling Basin Authority (MDBA) recently surveyed the bathymetry of the Murray River in January 2020 from Barmah to Lock 6. The processed bathymetry of the Murray River from Echuca Village to Wharparilla was available from the GHD (2018) Echuca-Moama Bridge model.

In addition to the LiDAR data, various cross-section surveys of the Murray, Goulburn and Campaspe Rivers were available, which Water Technology was able to source from past projects. Some of this survey data was very old, from the 1980s, but it does provide a reasonable representation of the channel bathymetry. The bathymetry data was merged with the LiDAR to provide a complete topography dataset. The preparation of a single Digital Elevation Model (DEM) for hydraulic modelling involved creating a 1 m resolution mosaic of the available LiDAR datasets and bathymetry data. This process is described below.

The coverage of the MDBA bathymetric survey, GHD bathymetry grid, and older Murray River cross sections are shown in Figure 2-7.

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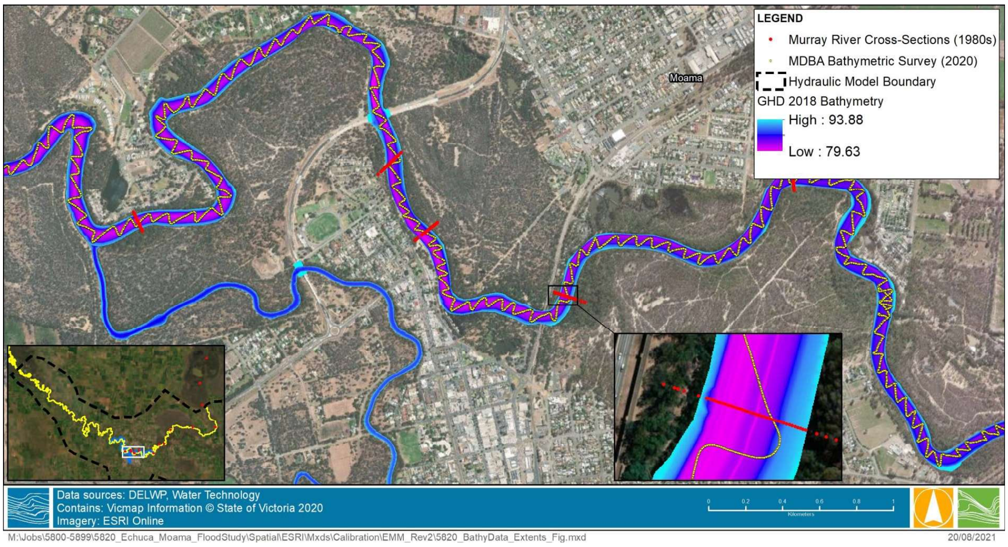

FIGURE 2-7 COVERAGE AND DETAIL OF BATHYMETRY DATA

Cross-section survey of the Murray and Goulburn River channels from the State Rivers and Water Supply Commission surveyed in the late 1970s and early 1980s was used to more accurately represent the channel capacity within the model. Several cross-sections of the lower reaches of the Campaspe River through Echuca were also gathered at the start of this study which supplemented the existing cross-sections and allowed the capacity of the Campaspe River to be more accurately represented.

The lowest point in each cross-section was determined and these points were joined to form a centre-line string representative of the stream thalweg. Interpolation of elevations between each cross-section point was used to apply elevations along each river channel alignment. The centreline was then buffered outwards to create a channel with a thirty metre wide bottom width. Index of Stream Condition (ISC) top-of-bank data from the Victorian Government was used to define the channel banks with associated elevations taken from the Floodplains LiDAR dataset. A Triangular Irregular Network (TIN) was created using the bathymetry centreline, offsets and the elevations at the top of the bank.

After several iterations, during which the centreline was adjusted to better represent the channel, a trapezoidal TIN of the channel was created (see example in Figure 2-8). Figure 2-9 shows an example cross-section comparing the MDBA LiDAR to the trapezoidal TIN stamped into the model topography. It can be seen that the capacity has been significantly increased through more accurate representation of the channel invert level.

FIGURE 2-8 COMPARISON OF DEM WITH TRAPEZOIDAL CHANNEL DEM OVERLAID IN BOTTOM IMAGE; RAW LIDAR (IN BROWN) VS. TRAPEZOIDAL STAMPED CHANNEL (IN GREEN) OF MURRAY RIVER

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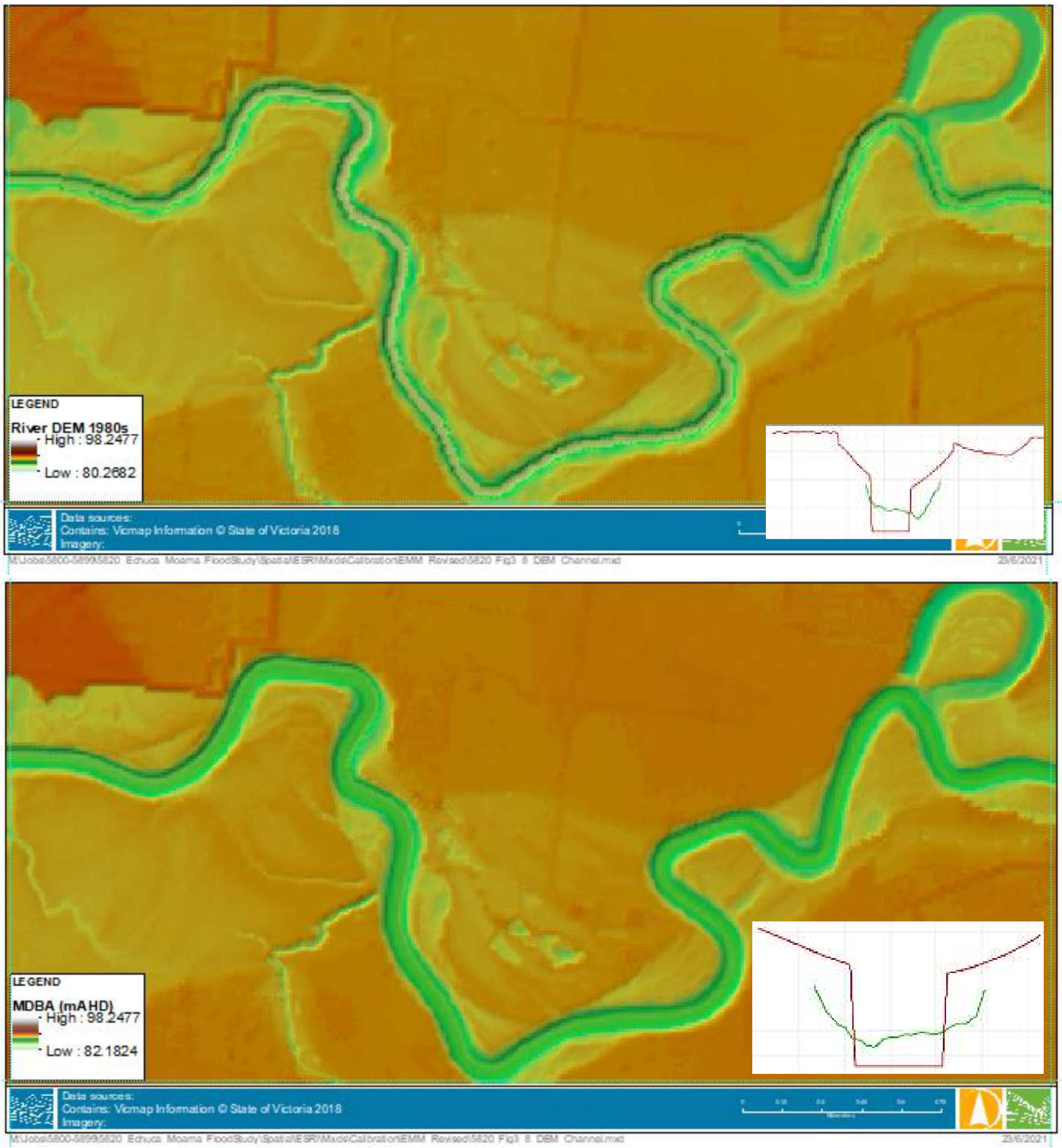

FIGURE 2-9 COMPARISON OF CHANNEL DEM INTERPOLATED USING 1980 SURVEY AND MDBA RIVER BATHYMETRY FROM GHD (2018); [INSET] COMPARISON OF STAMPED CHANNEL SECTION, 1980 SURVEY (BROWN), MDBA BATHYMETRY (GREEN)

2.6.3.3 Drone Survey

Feedback from responses to the draft flood study indicated that recent development within both Moama and Echuca was not captured in the Lidar data used in the model, which could have impacts on design flood extents, Campaspe Shire commissioned drone surveys to be undertaken for areas along Pericoota Road and Fehring Lane, as shown in Figure 2-10. Addition of the new drone survey areas improved the design flood extents for those areas.

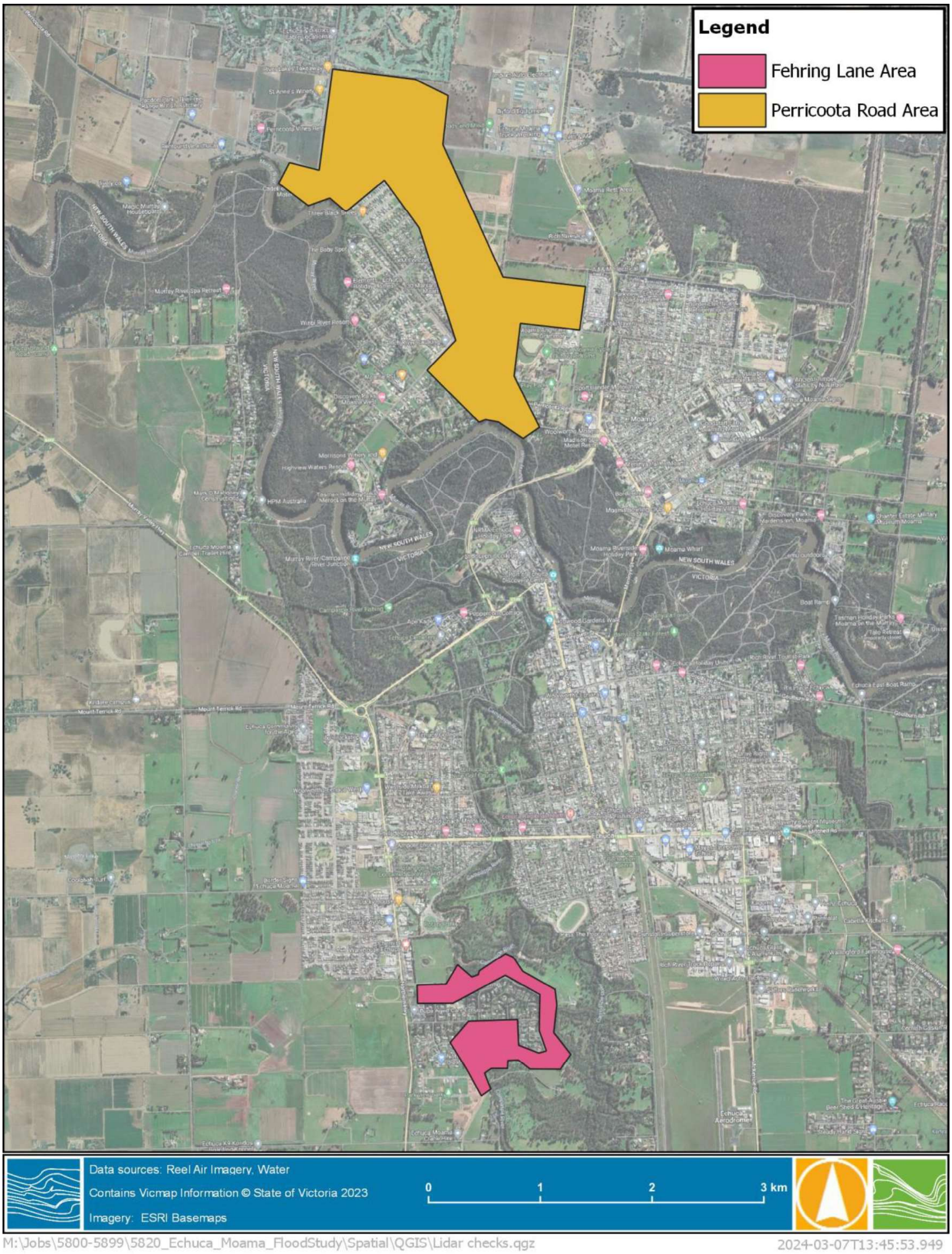

Figure 2-10 Drone Survey Areas

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2.6.4 Levees and Key Hydraulic Controls

To ensure all key hydraulic controls across the floodplain such as levees (formal and informal), road crests and railway lines were accurately represented, these structures were all included into the model using TUFLOW Z-shapes. The Z-shapes allow the crest levels to be sampled along a narrow linear feature like a levee or road from detailed LiDAR and read into the model as a series of 3D points along a polyline.

Several sources of levee data were incorporated into the model, including Council GIS and PDF datasets, and the Victorian Flood Database. These surveyed levee heights were used to ensure the levees were represented accurately in the model. Water Technology had also completed several levee audits for North Central and Goulburn Broken CMA, so used survey from these previous projects. Crest levels for all other unsurveyed hydraulic structures were extracted from the 1 m LiDAR datasets using GIS tools.

There have been a number of significant changes to the topography since the 1993 flood event with the most significant change being the construction of the Moama town levee, and in the Torrumbarry area, the construction of the Koondrook-Perricootta levees and inlet/outlet regulators. These changes were incorporated into the model DEM but were excluded from any of the historic calibration events which occurred prior to their construction.

In and around the Echuca and Moama area, there are several urban levee systems maintained by the Campaspe Shire and Murray River Councils. These levees have been constructed to various design standards with different construction methods over many years. The levees are shown in Figure 2-11.

The second bridge crossing of the Murray River also resulted in significant changes to the floodplain topography with an embankment across the floodplain, raised approach roads and several structures under Warren Street upgraded.

2.6.4.1 Echuca and Moama Urban Levees

The Echuca levees were constructed between 1989 and 1992 under the Flood Mitigation Scheme (Figure 2-11). The levees protect central areas of the town from Murray River flooding up to a 3% AEP event with 600 mm freeboard. The Scheme includes a stormwater drainage and pumping system also. Some essential water treatment infrastructure is protected to above a 1% AEP event. Levees were constructed from Collier Street to Radcliffe Street, along Crofton Street and Watson Street, from Sturt to Pakenham Street and along Moama Street. Goulburn Road west of Moama Street was also raised as part of the Scheme. Levees include earthen levees with walking tracks on top of them, crib walls, retaining walls and raised roads.

The Moama urban flood levee was constructed in 2004 (Figure 2-11) and was designed at the time to a 0.5% AEP design level with 600 mm freeboard on earthen sections and a 300 mm freeboard on the concrete retaining wall, Kiely Road, Barnes Road and Holmes Street. A short section along Chanter Street is lower than the design flood level. Prior to construction of the levee, the significantly damaging 1993 flood event severely impacted Moama, and a temporary levee was constructed during the flood. The urban levee was subsequently constructed along a slightly different alignment to the temporary 1993 levee. The Moama levee uses a concrete retaining wall along the river front from War Street to just east of Murray Street, and earthen levee through to Chanter Street, a short section of Chanter Street that is sandbagged during a flood event, then another section of earthen levee running north along what is marked in the cadastre as Winall Street through to the railway line. The earthen levee then continues along Barnes Road to the north-east of the industrial area and north through to Kiely Road. The northern most section of the levee wraps around the water treatment dams before tying into high ground on Kiely Road near the Cobb Highway. There are short sections where the levee crosses roads etc that would require sandbagging during a flood event.

For the more recent calibration and design events, the Moama urban town levee was incorporated based on surveyed plans from Council. In areas along the Moama town levee where gates are required to be closed and where sandbags are required to top up the levee along road and rail crossovers (they are known emergency response actions), these changes to the levee height were implemented in the model. The management and operation of the levee is dictated by the levee owners manual that was developed along with the design of the levee. The modelling assumes that the full extent and height of the levee is in place during the extreme flood events.

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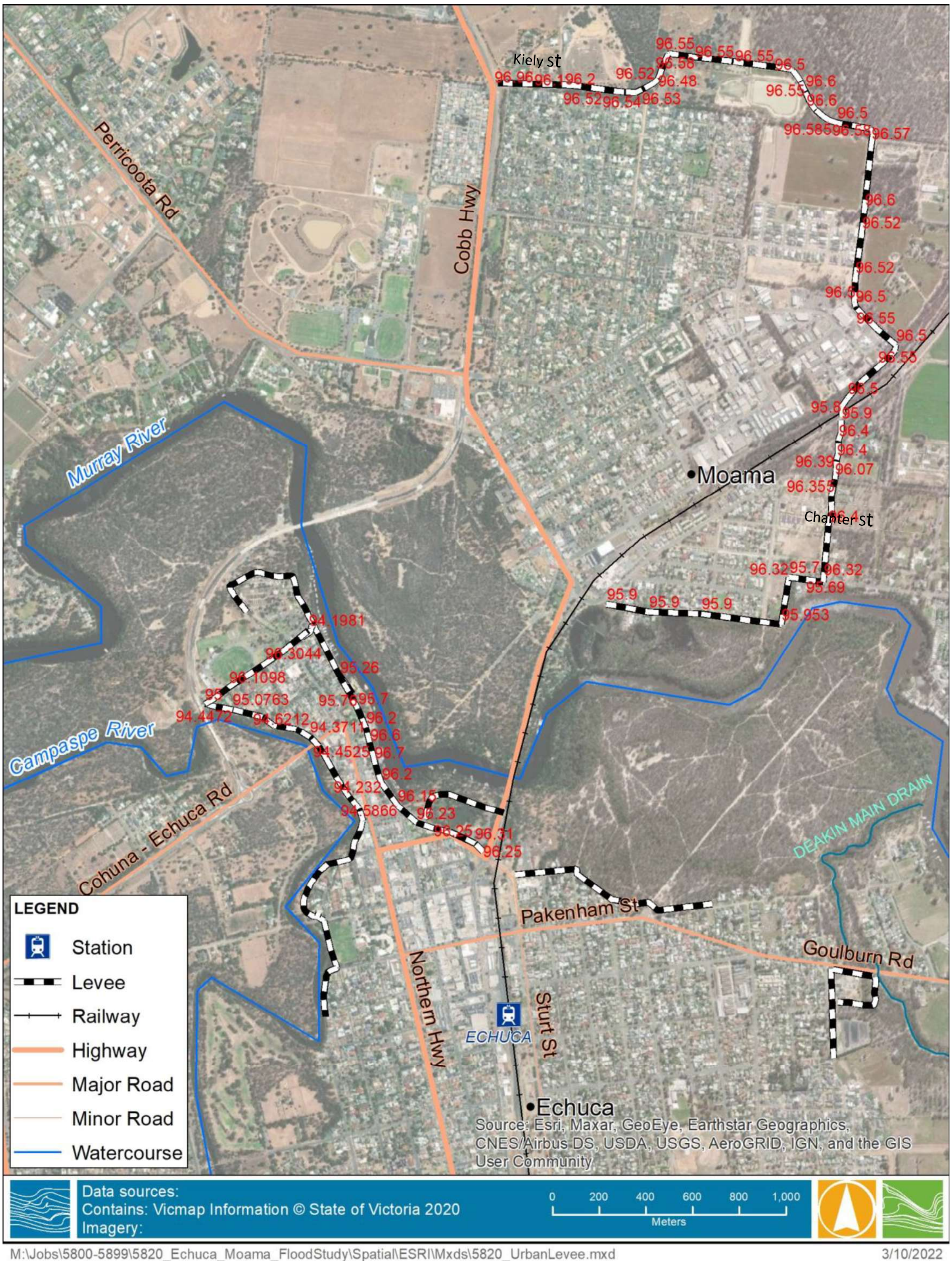

FIGURE 2-11 ECHUCA-MOAMA URBAN LEVEES

2.6.4.2 Temporary Levees

In Moama, the urban town levee was not constructed until after the 1993 flood, with a temporary levee constructed during the event. Significant effort was given to locate the temporary levee alignment around Moama town during the October 1993 flood. The most appropriate source was found to be aerial images taken around peak of October 1993 flood event. The temporary levee alignment on the aerial image is shown in Figure 2-12. Temporary sandbag levees along Pakenham Street in Echuca were also identified during initial community consultation as shown in Figure 2-13.

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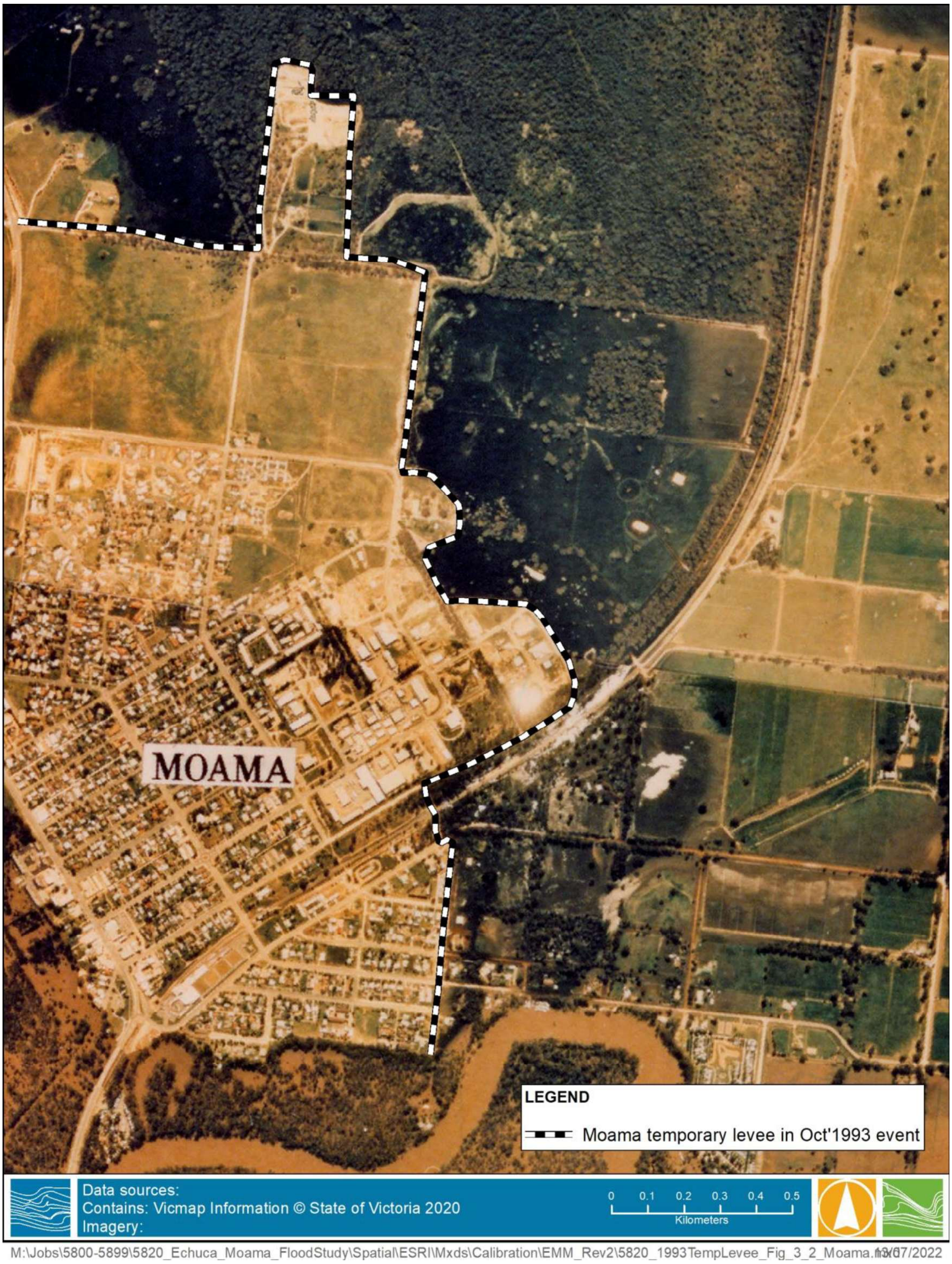

FIGURE 2-12 MOAMA TOWN TEMPORARY LEVEE IN OCTOBER 1993 FLOOD EVENT

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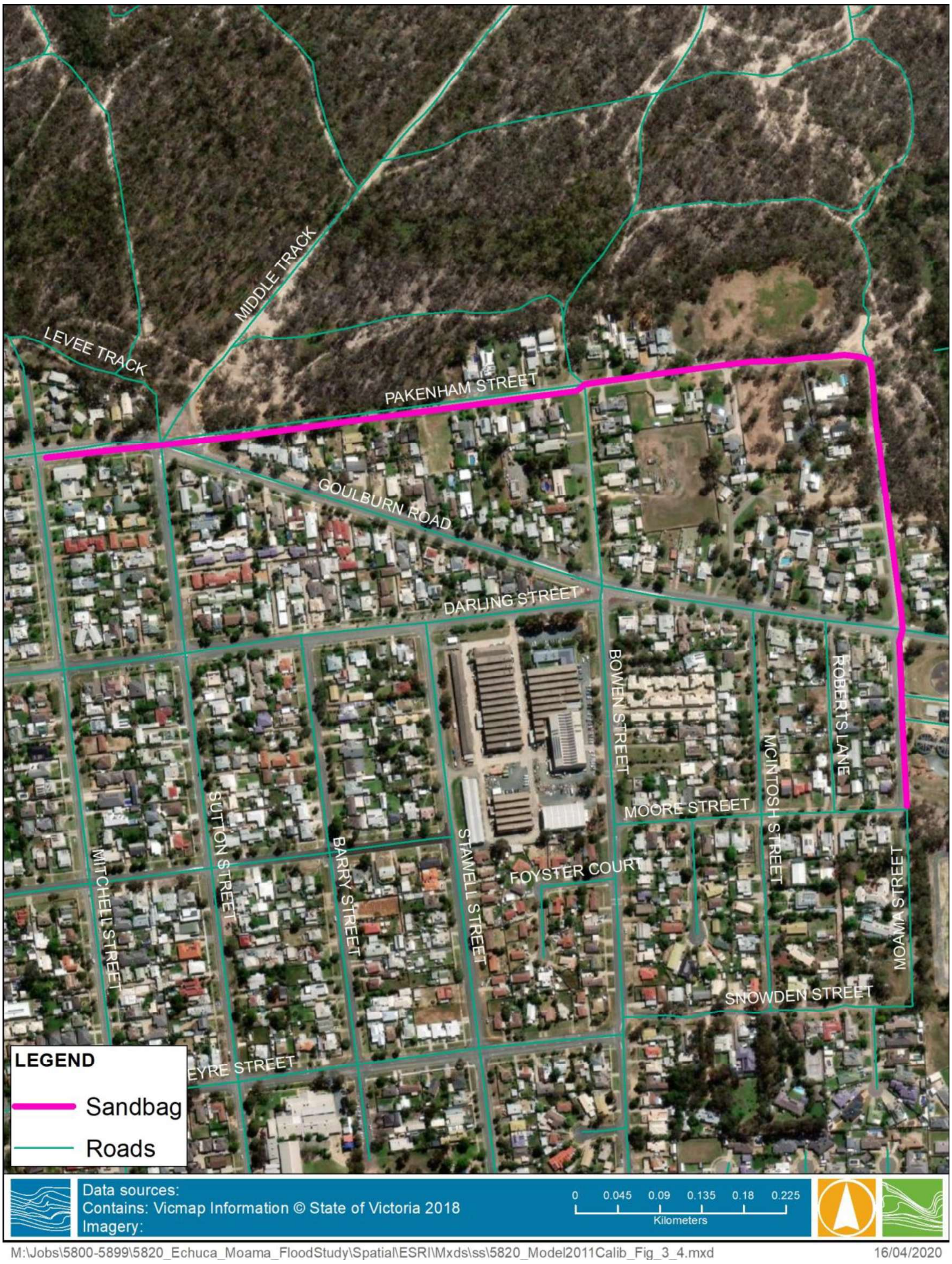

FIGURE 2-13 THE SANDBAG LEVEE ALONG PAKENHAM ST AND BROWN ST IN OCTOBER 1993 FLOOD

There was extensive temporary levee work constructed across the floodplain in the October 2022 flood event. This is further discussed during the calibration section of the report. The temporary levees were built into the flood model for calibration. Temporary levees such as these were not incorporated into the design modelling, with the exception of Chanter Street in the Moama town levee that is part of Council's flood response plan, put in place since after the 1993 event.

2.6.4.3 Rural Levee and Channel Bank

Many rural levees that protected Moama from the October 1993 flood were not well understood until feedback during the initial community engagement provided more information and later included in the model. This includes a series of earthen rural levees to the east of Moama in the Old Deniliquin Road region, as depicted in Figure 2-14. On the excerpt from SKM (1997), which is depicted in Figure 2-14, the rural levees that holding back the floodwater during the 1993 event are marked as green region.

There are many informal rural levees and irrigation channel banks that act as levees during flood events where depths are shallow. A significant amount of effort was expended developing levee crest levels from LiDAR to incorporate these informal structures into the model.

The survey conducted in October 1994 by Council served as the major source for the rural levee alignment and heights. Murray River Council had PDF copies of the survey, which is presented in Figure 2-15. These PDF files were scanned and converted to digital form for use in the model. A lot of work was spent examining various sources to determine the height and alignment of the rural levees east of Moama. The primary sources included the survey conducted in October 1994, flood images taken on October 14, 1993, Landsat imagery taken on October 25 1993, and LiDAR data.

South of Old Barmah Road, there are several irrigation channels that have high banks, that act as levees during a flood. The flood imagery from October 1993 (Appendix B) reveals that some of these banks between Old Barmah Road and Bett Street hold back flood water, keeping lots close to Bett Street dry. These channel banks were digitized and added to the model. The bank elevation was derived from adjusted 2015 LiDAR data collected by Geo-Science Australia. In Figure 2-16, the channel banks are displayed.

In the October 2022 model calibration, significant additional work was put into better representing the Goulburn River levees and several major irrigation channel banks to the south of the Goulburn River which prevent flood water from spilling on into the Kanyapella Basin. Additional rural levees were also added to the model in the east-Moama area.

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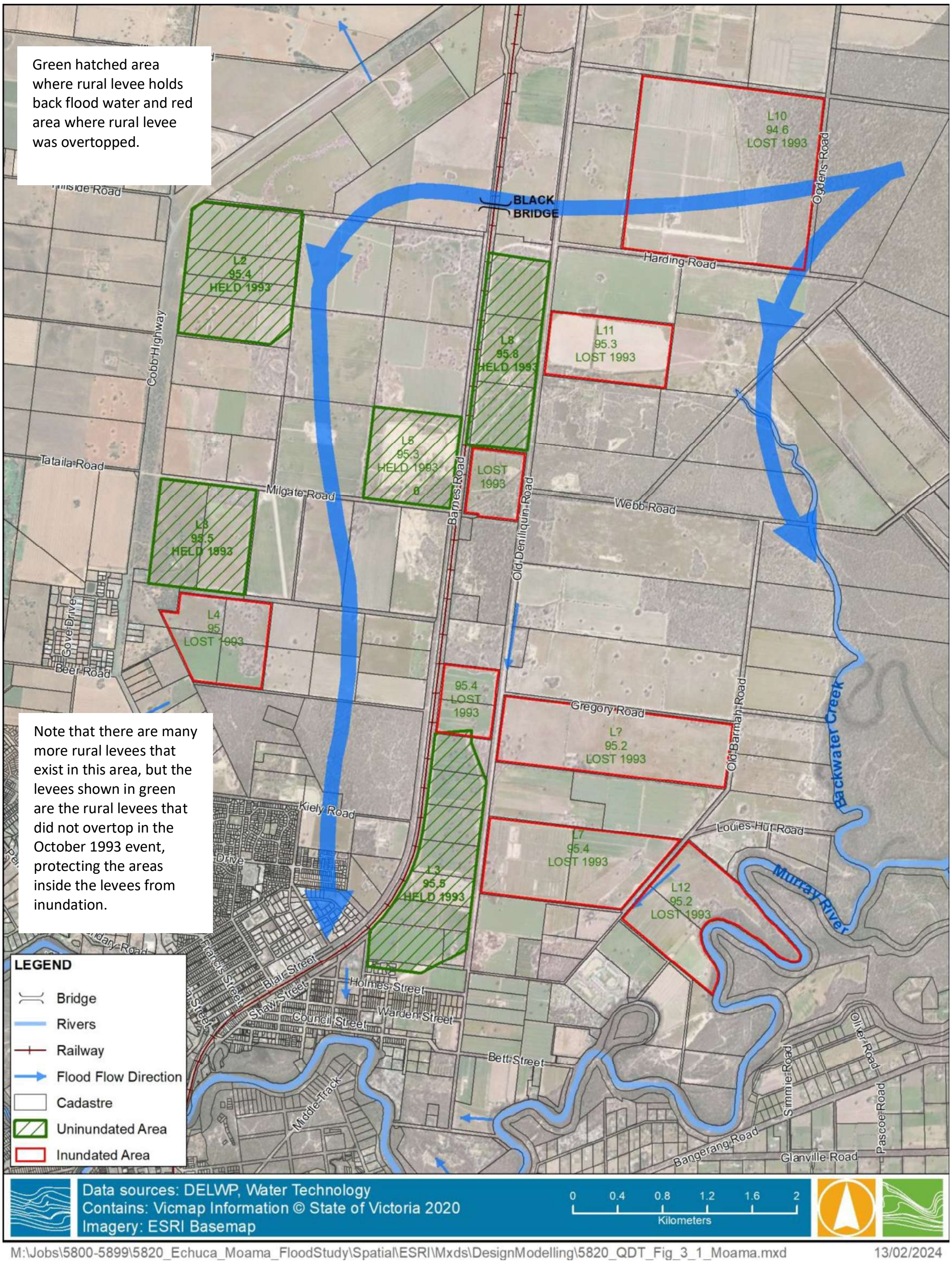

FIGURE 2-14 RURAL LEVEES HELD BACK FLOOD WATER IN 1993 EVENT (SOURCE: SKM (1997))

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FIGURE 2-15 EXAMPLE OF RURAL LEVEES (SOURCE: COUNCIL)

FIGURE 2-16 EXAMPLE OF IRRIGATION CHANNEL BANKS

In total more than 3,200 km of levees, roads and railway line were stamped into the model, with the full dataset shown in Figure 2-17.

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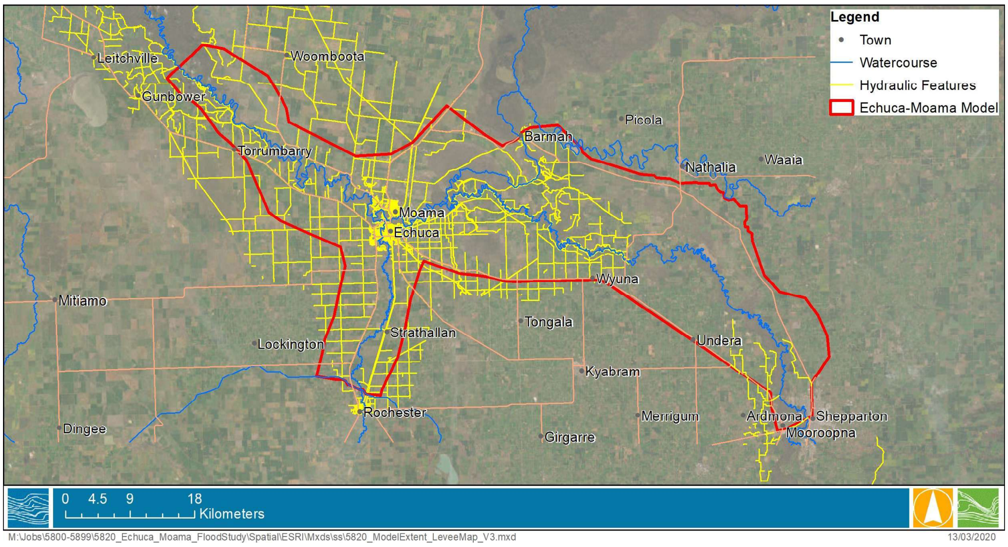

FIGURE 2-17 LOCATION OF KEY HYDRAULIC FEATURES (E.G. LEVEES, ROADS, RAILWAY, CHANNEL EMBANKMENTS) STAMPED INTO THE MODEL DEM

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2.6.4.4 Maidens Inn

As shown in the flood photography taken at the time of the peak of the 1993 flood, Figure 2-18, the Maiden Inn resort was flood-free in 1993. After discussion at the Project Reference Group meeting, it was decided to represent a low temporary sandbag around it to keep it from becoming inundated in the 1993 calibration event.

FIGURE 2-18 MAIDENS INN IN OCTOBER 1993 FLOOD (SOURCE: MURRAY RIVER COUNCIL)

2.6.5 Boundary Conditions

There are three major upstream inflow model boundaries, one minor inflow boundary, and multiple downstream water level boundaries controlling the exchange of water into and out of the Echuca-Moama hydraulic model. The main downstream boundary is located on the Murray River floodplain at the western extent of the hydraulic model. All other downstream boundaries allow flows to leave the model that would flow to external areas and prevent glass walling on the edges of the model.

These boundaries are identified in Figure 2-3.

2.6.5.1 Inflow Boundary

Four inflow boundaries were used which are listed below and also shown in Figure 2-3.

- Murray River at Barmah
- Goulburn River at Shepparton
- Campaspe River at Rochester (downstream of Waranga Western Channel Syphon)
- Deakin Main Drain

Inflow hydrographs at these points for calibration events were determined from streamflow gauge records or from previous flood studies at each of the major inflow locations, with the ungauged Deakin Main Drain inflow estimated.

The Murray River inflow for the calibration events adopted the Murray River at Barmah (409215) streamflow gauge record. For the 1993 event where streamflow data was missing, modelled data from MDBA was used. There is also missing streamflow data at the Barmah (409215) gauge at the peak of the October 2016 event, with the model inflow interpolating the missing data from the recorded hydrograph.

Rating curves for the three main inflow boundaries are presented in Figure 2-19 to Figure 2-22. The Murray River at Barmah gauge rating curve is considered reliable up to a flow of 33,000 ML/d. The Goulburn River at Shepparton gauge is considered reliable up to a flow of 163,000 ML/d. The Campaspe River at Rochester D/S of Waranga Western Channel Syphon is considered reliable up to a flow of 64,000 ML/d according to the rating curve, but the rating curve becomes very flat and there are limited points at the upper flow range. For large flows, hydrology from the Rochester Flood Management Plan (Water Technology 2013) was used to increase confidence in the flows.

The Goulburn River inflow used the Shepparton (405204) streamflow gauge record for all calibration events.

The Campaspe River inflow used the Rochester (406202) streamflow gauge data for all calibration events along with modelled flows from the Rochester Flood Management Plan (Water Technology 2013) to adjust the flows used for the October 2022 event, which is further discussed in Section 3.3.4.2.

For the Deakin Main Drain inflow, a nominal 1 m^3/s flow was applied for the calibration events. In the January 2011 and October 2022 events, a breakout from the Campaspe River at Rochester flowed through the Nanneella Depression and into the Deakin Main Drain. A second breakout from the Campaspe River to the north of the Echuca-Nanneella Road and McKenzie Road intersection flowed into the Deakin Main Drain also. This area is extremely complex and establishing accurate inflows from the Deakin Main Drain is not within the scope of this study and would have a limited impact on flood levels through Echuca and Moama anyway. A nominal 1 m^3/s flow was applied to represent general local catchment runoff during the flood events. These Deakin Main Drain flows are rough estimates only, used to show the presence of water, and are only indicative. Inundation along the Deakin Main Drain area in this study is primarily a result of water backing up into the low areas of the topography from the Murray River.

The Campaspe River flows at the Waranga Western Channel Syphon gauge used the gauge data up to the point where the rating curve was no longer reliable, and then used modelled data from the Rochester Flood Management Plan (Water Technology 2013) to complete the peak of the hydrograph.

While it is not an inflow boundary conditions, there is a rating curve at McCoys Bridge that was used in the calibration of the model, which is shown in Figure 2-22. The Goulburn River at McCoys Bridge gauge rating curve is considered reliable up to a flow of 52,000 ML/d

The rating curves for each gauge are presented below in Figure 2-19 to Figure 2-22 and flow hydrographs used as inflow boundaries for the four calibration events are presented below in Figure 2-23 to Figure 2-26.

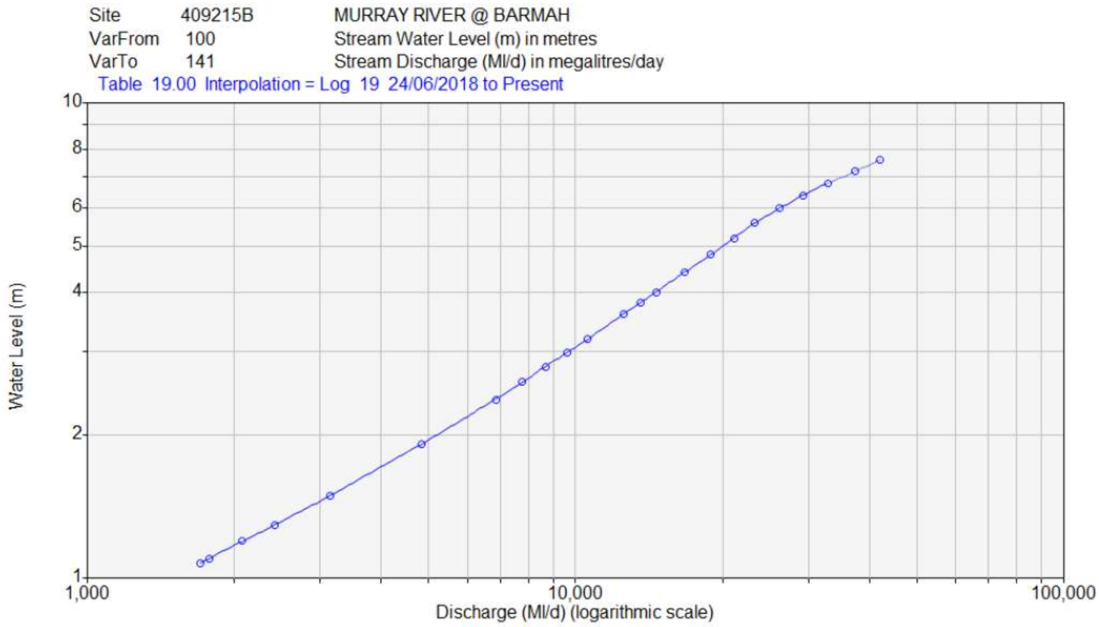

FIGURE 2-19 MURRAY RIVER AT BARMAH GAUGE (409215) RATING CURVE

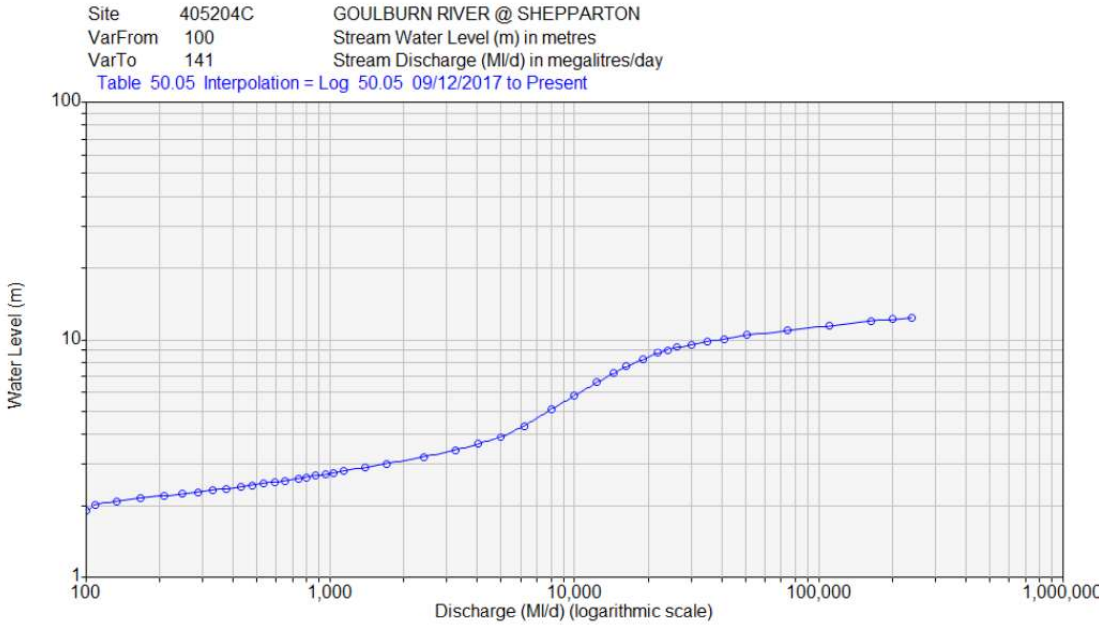

FIGURE 2-20 GOULBURN RIVER AT SHEPPARTON GAUGE (405204) RATING CURVE

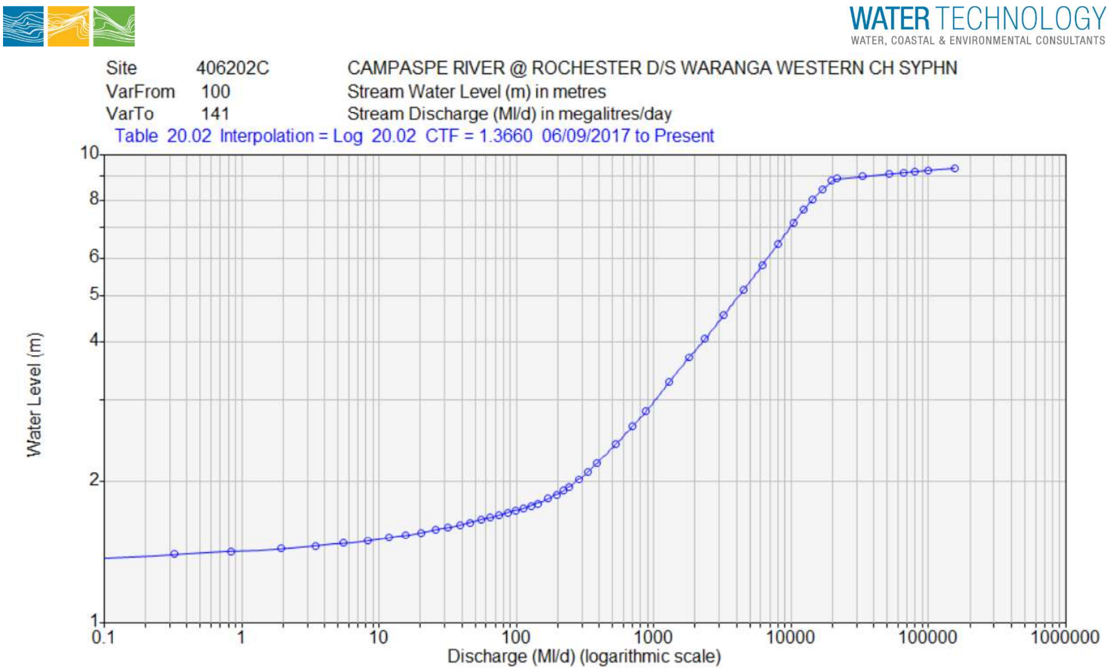

FIGURE 2-21 CAMPASPE RIVER AT ROCHESTER GAUGE (406202) RATING CURVE

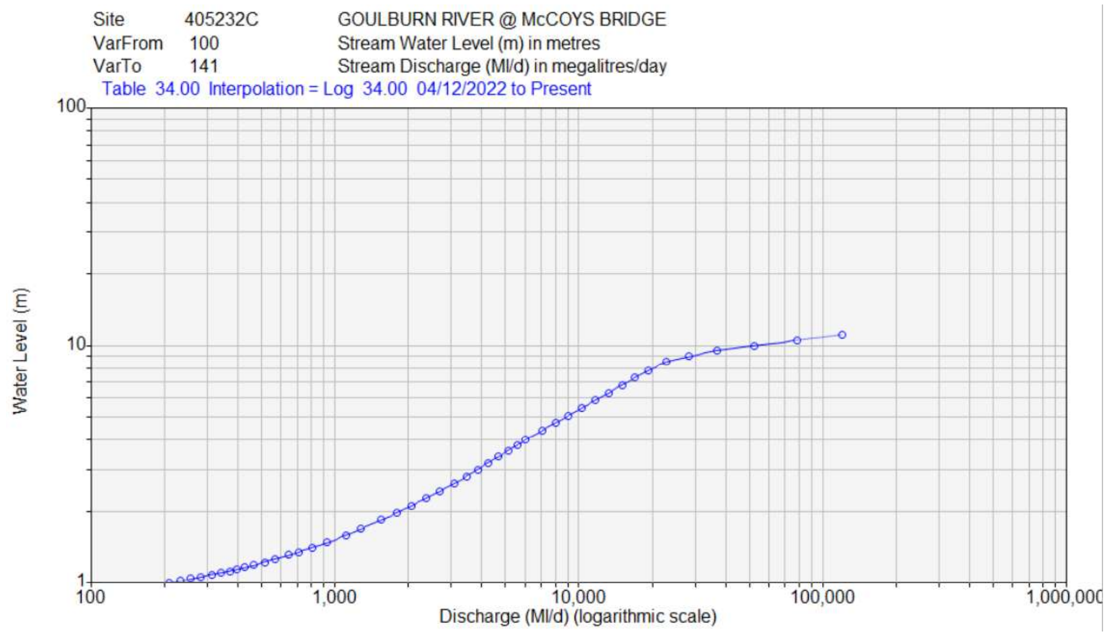

FIGURE 2-22 GOULBURN RIVER AT MCCOYS BRIDGE GAUGE (405232C) RATING CURVE

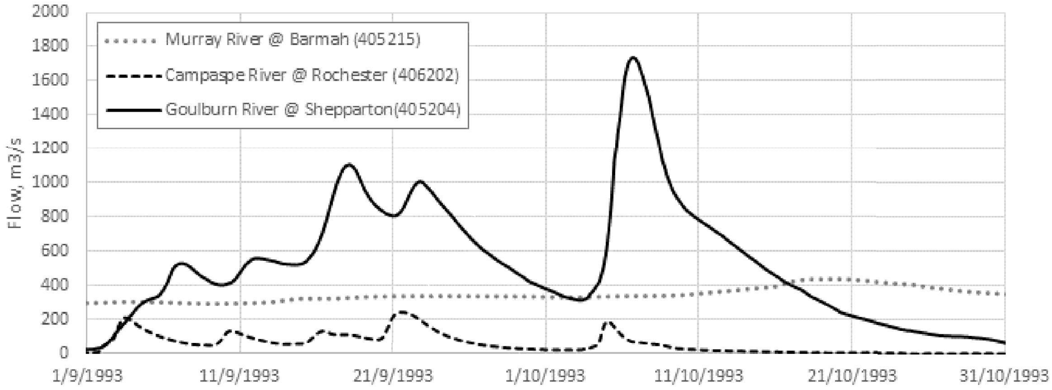

FIGURE 2-23 HYDRAULIC MODEL INFLOW BOUNDARIES – OCTOBER 1993 EVENT

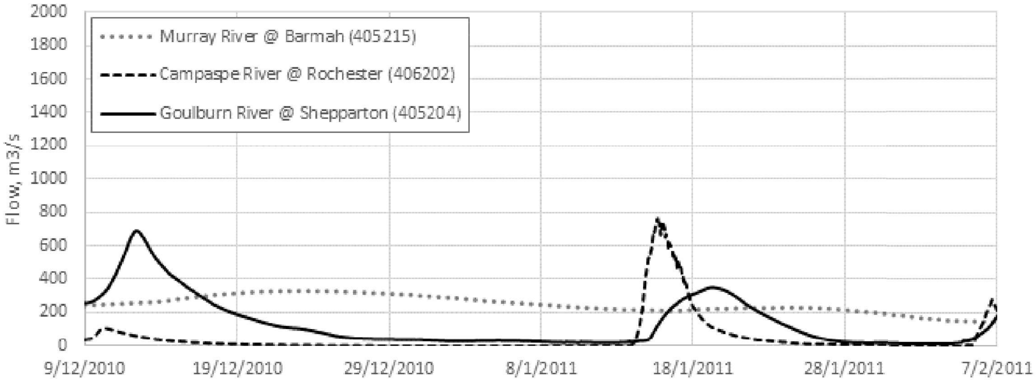

FIGURE 2-24 HYDRAULIC MODEL INFLOW BOUNDARIES – JANUARY 2011 EVENT

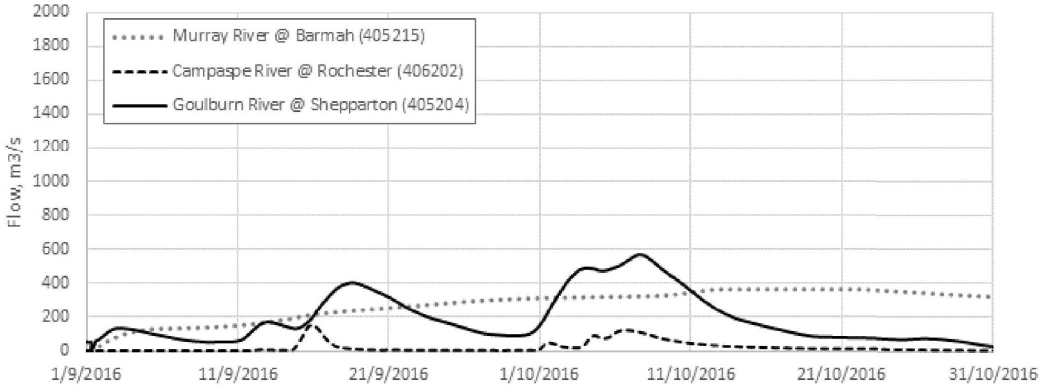

FIGURE 2-25 HYDRAULIC MODEL INFLOW BOUNDARIES – OCTOBER 2016 EVENT

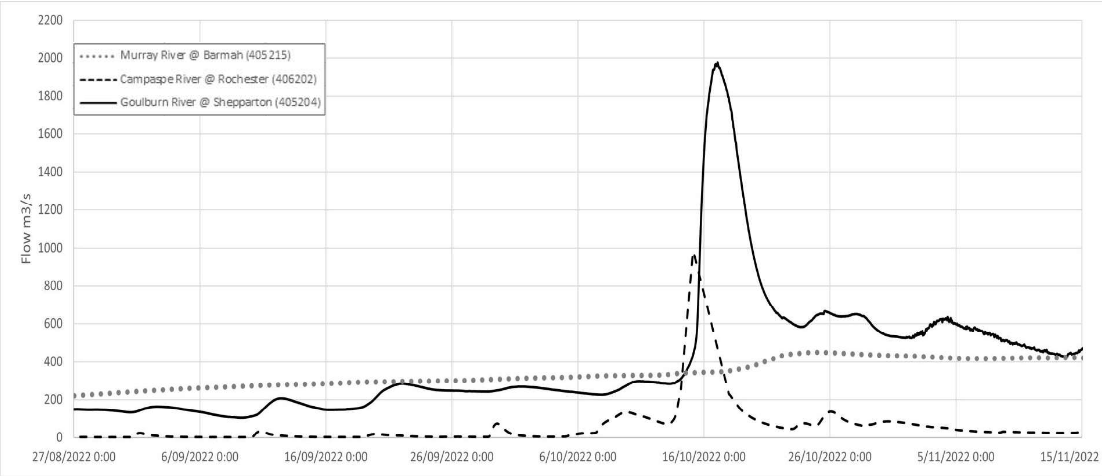

FIGURE 2-26 HYDRAULIC MODEL INFLOW BOUNDARIES – OCTOBER 2022 EVENT

2.6.5.2 Outflow Boundaries

A rating curve boundary was applied to the model downstream boundaries at locations where flow is leaving the model, whereby the model determines a water-level/discharge relationship based on the topography, roughness and specified water surface slope at that location. The water surface slope adopted was taken from an early version of the model which extended all the way to Murrabit.

2.7 Roughness

The roughness of the terrain influences the speed and height of flood waters and is represented by a Manning's "n" number. The lower the number the smoother the terrain and the faster the water travels across it, resulting in lower flood levels. For the estimation of the floodplain Manning's "n", this study assessed land-use and vegetation cover. Planning layers were initially used to allocate roughness values based on land use and were verified using aerial imagery.

The roughness as estimated using Manning's 'n' roughness coefficients were adopted from industry standard values and then adjusted during calibration of the model. A Manning's 'n' roughness of 0.05 for the bushland along the rivers and on the floodplains resulted in a good calibration fit initially at the Echuca Wharf gauge. These roughness values were incorporated into the calibration simulation by delineating the areas of bushland in higher detail shown in Figure 2-27. The roughness along the Murray River and Goulburn River was a little higher than along the Campaspe River to improve the calibration at the Echuca gauge on Campaspe River.

The latest calibration of the October 2022 event also showed that the roughness along the Goulburn River and floodplains were too low for that event, as evidenced by lower peak levels in the area upstream of the sand hills, which also affected the timing of the peak at Echuca Wharf coming through too soon in the model. Although not part of the study focus area, increasing the roughness in the floodplain upstream of the sandhills resulted in better representation of peak levels and extents matching observed levels along the Goulburn River. This change also improved the timing of the rise and fall of the water level when compared to the gauge data.

In hydraulic modelling applications, the effect of vegetation on the passage of flow along a channel or overland flow path may vary with depth and velocity of flow during a flood event. A channel or open space with dense reeds growing in it may have a high roughness at low flows when the reeds are standing tall, but at a certain point the combined depth and velocity of the flows may cause the reeds to bend over and lie down in the bed with a corresponding dramatic reduction in hydraulic roughness.

The adopted Manning's values are considered appropriate for the calibration scenarios based on the reasonable fit to the observed levels and the extent.

The adopted roughness values used in the calibration are presented in Figure 2-27, along with the adopted values summarised in Table 2-4.

TABLE 2-4 MANNING'S ROUGHNESS VALUES ADOPTED

Material/ Land Use	Manning's Roughness (n) used prior to October 2022 event	Manning's Roughness (n) used after October 2022 recalibration
Residential parcels	0.15	0.15
Industrial	0.30	0.30
Sealed Road/ Carpark	0.02	0.02
Unsealed Road	0.03	0.03
Railway Line	0.125	0.125
Waterway	0.03	0.03
Bushland	0.05	0.07
Farmland	0.04	0.04
Cropping	-	0.08

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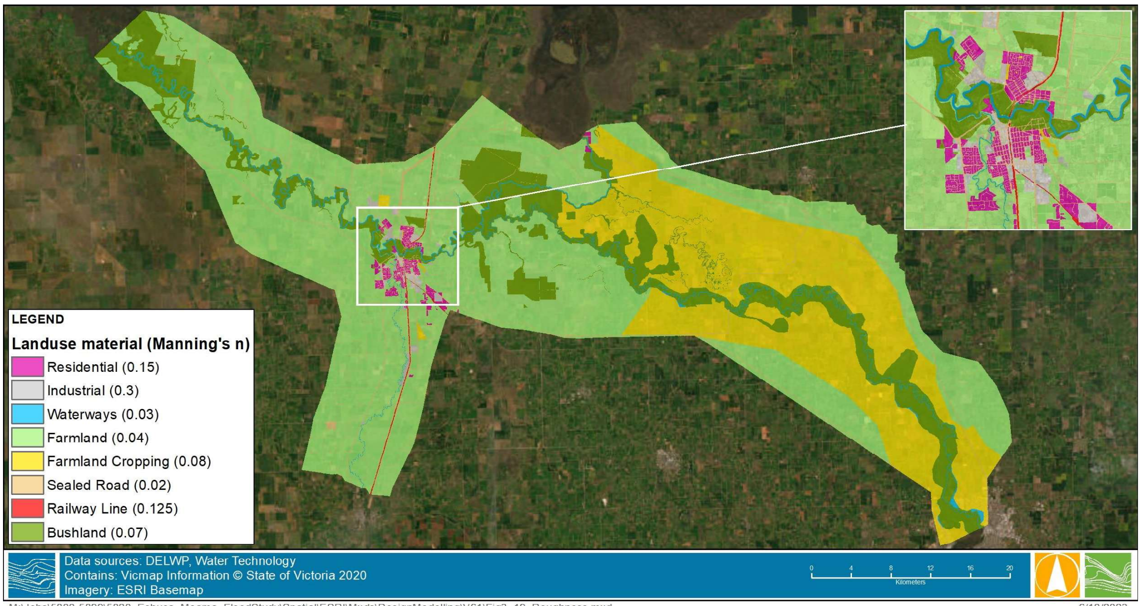

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FIGURE 2-27 MANNING'S ROUGHNESS (N) MAP USED IN HYDRAULIC MODEL

2.8 Structures

A number of key road and railway structures were explicitly included in the hydraulic model. They included bridges and culverts of varying sizes that were located along major and minor flow paths, particularly around Echuca-Moama. These structures were modelled either as 1D structures or 2D layered flow constrictions using structural data provided by VicRoads and Councils, or through on-site survey.

Large structures along the Murray and Campaspe Rivers were modelled within the 2D domain using layered flow constrictions. Where 2D structures are used there needs to be a minimum width of 4-5 grid cells through the structure and this was checked at all locations where 2D structures were used.

Hydraulic structures can play an important role in the movement of flow throughout the waterways. Where available, bridge information such as invert level and dimensions were placed in the TUFLOW model. Where this information were not available, engineering judgement and 'roughed in' measurements taken on site were used to provide the required structure details. At McCoy Bridge and Stewarts Bridge on the Goulburn River, no 2D structures was used, rather the waterway was kept open as it will have little impact on the flooding at the study area.

A summary of the structures and their locations is shown in Figure 2-28.

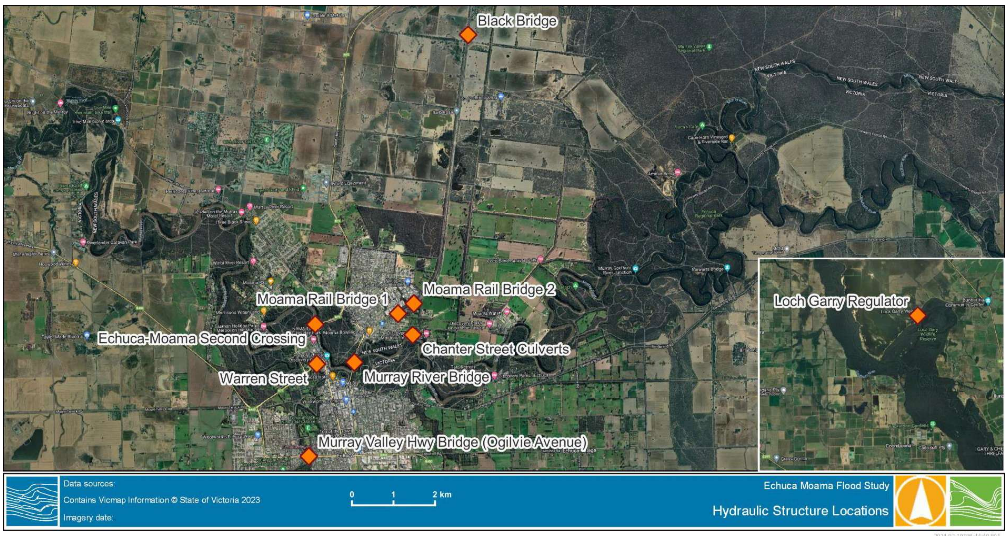

FIGURE 2-28 KEY STRUCTURES INCLUDED IN HYDRAULIC MODEL

2.8.1.1 Murray River Bridge

The existing bridge across the Murray River between Echuca and Moama includes a rail and road bridge parallel to each other. A layered flow constriction representing the waterway area under the bridge was included in the TUFLOW model. Measurements collected during the project were used to specify the structure geometry in the TUFLOW model. Photos taken during the site visit are shown in Figure 2-29. The railway bridge runs parallel to the road bridge, and piers are generally in alignment on both structures. The two bridges were modelled as a single structure in TUFLOW.

FIGURE 2-29 MURRAY RIVER BRIDGE - FLOODPLAIN CROSSING (TOP), RIVER CROSSING (BOTTOM)

2.8.1.2 Campaspe River Bridge – Murray Valley Highway

The Campaspe River bridge on the Murray Valley Highway (Ogilvie Avenue) was modelled using a layered flow constriction in TUFLOW, representing the waterway area under the bridge. A photo of the bridge from a site visit is shown in Figure 2-30. The bridge has three sets of super-t piers each 750 mm wide. The bridge deck is 1,500 mm deep. The batters on both sides of the bridge are reasonably steep. Aerial imagery was used to approximate the bridge width and batter locations.

FIGURE 2-30 CAMPASPE RIVER BRIDGE ON MURRAY VALLEY HIGHWAY

2.8.1.3 Black Bridge

The Black Bridge is located under the railway line to the north of Moama. It allows flood flows to pass under the bridge and down the eastern side of the railway line. These flows spread across the floodplain slowly, and flow to the south towards Moama. The flows eventually pass back under the railway line at a small bridge culvert described in Section 2.8.1.6 below. In the 1993 and the October 2022 events water reached to the underside of the bridge deck.

FIGURE 2-31 BLACK BRIDGE NORTH OF MOAMA

2.8.1.4 Echuca-Moama Second Bridge Crossing

Echuca and Moama until recently were connected by a single Murray River Bridge that was opened in 1878. A second bridge crossing was recently opened, connecting the Murray Valley Highway and Warren Street at

Echuca with the Cobb Highway at Perricoota Road in Moama. An overview of the project is shown in Figure 2-32 and it includes.

- Stage 1: Upgrade of the Murray Valley Highway and Warren Street intersection - completed in mid-2018
- Stage 2: Warren Street in Echuca, between the Murray Valley Highway and High Street, was fully opened to traffic on Saturday 23 November 2019. The upgrade of Warren Street involved building:
  - four new flood relief bridges, increasing the capacity of the culverts significantly.
  - a new roundabout at Campaspe Esplanade.
  - an extended right-hand turning lane into Homan Street for local residents and the Echuca Cemetery.
  - new service roads for residents.
  - a new shared walking and cycling path.
- Stage 3: Construction of new bridges over the Campaspe and Murray rivers - major works commenced in April 2020.
- Stage 4: Intersection upgrades to the Cobb Highway, Meninya Street and Perricoota Road intersection – works on this stage began during March 2020 (to be delivered by Transport for NSW).

The model setup for the second bridge crossing, was adopted from the GHD (2018) Echuca-Moama Bridge model, which was based on modelling originally completed by Water Technology as part of the tendering process for the design project. The major bridges were modelled as a layered flow constriction in TUFLOW. This approach applies a form loss per unit length in the direction of flow. Therefore, the mapped results show flows passing through the structure, but inundation does not reach the deck level.

FIGURE 2-32 WARREN STREET UPGRADE: ECHUCA-MOAMA BRIDGE PROJECT OVERVIEW

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Warren Street Prior to Upgrade

The previous Warren St bridge over the Campaspe River was constructed in 1964-65. The Warren Street bridge prior to the upgrade project was modelled using a layered flow constriction. The bridge drawing is shown in Figure 2-33. The bridge has four sets of piers each 300 mm wide. The bridge deck is 600 mm deep.

The four older flood relief culverts along Warren Street were also included in the calibration models as 1D structures.

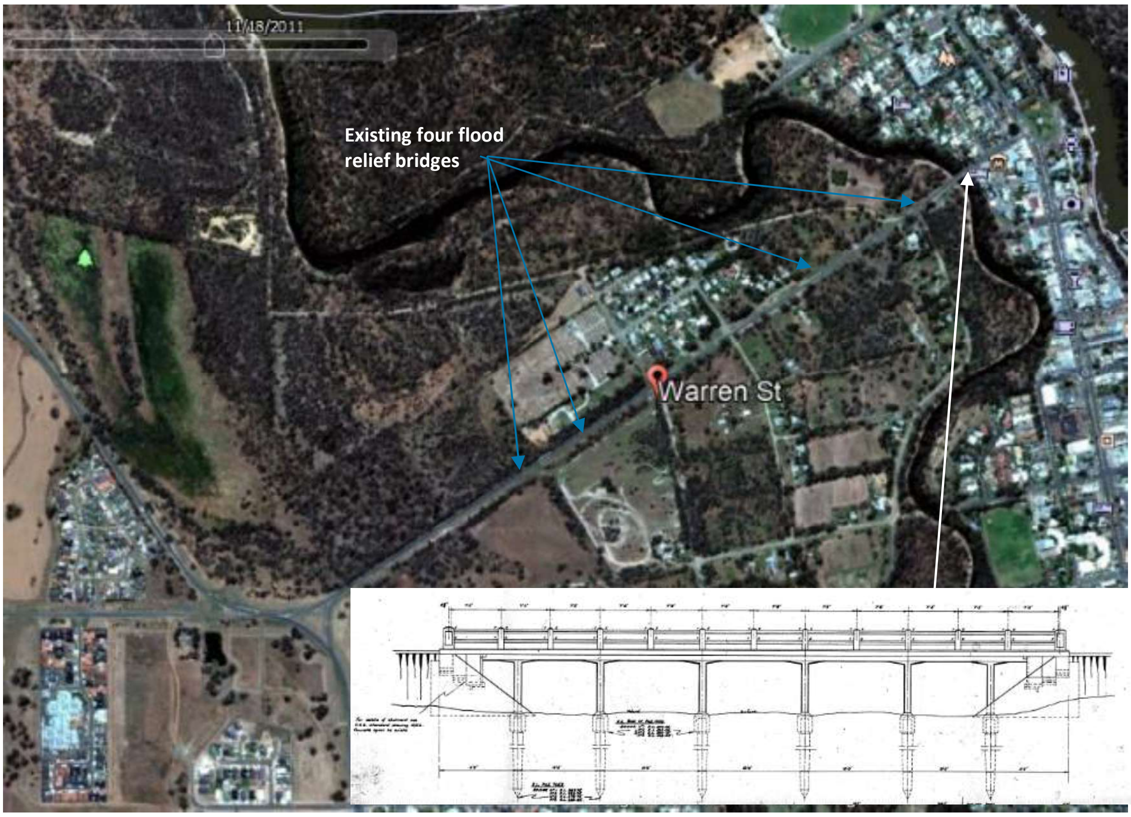

FIGURE 2-33 WARREN STREET BRIDGE ON CAMPASPE RIVER (BEFORE UPGRADE)

2.8.1.5 Loch Garry Regulator

The Loch Garry regulator on the Goulburn River downstream of Shepparton is operated to allow water to spill out on to the floodplain and reduce the pressure on the lower Goulburn River levees in a flood event. Loch Garry was constructed in the 1920's as a concrete structure with 48 bays, each approximately 2.2 metres wide, which contains slots that enable bars to be inserted or removed as required. The current operating rules for operation of the regulator require that 24 hours after the Shepparton gauge exceeds 10.36 m (110.49 m AHD), 23 bars are removed and for every additional 0.031 m rise in the river level at the Shepparton gauge, 23 more bars are removed. If the river continues to rise, all bars are to be removed 24 hours after the river reaches 10.96 m at Shepparton. The structure was represented in TUFLOW as a variable z-shape.

During the October 2022 event the opening of Loch Garry was not complete because the river rose too quickly and it became a safety hazard and could not be operated manually. The structure was also represented with variable z shapes to only open partly compared to the standard operating rules for operation, which was reported to be half the level of full opening. It is understood that the operating rules of the structure is to be reviewed.

FIGURE 2-34 LOCH GARRY FLOOD CONTROL STRUCTURE

2.8.1.6 Moama Railway Bridges

On the Moama railway line, there are two bridges, one inside the new Moama town levee and the other outside the levee. Figure 2-35 show the photos of two bridges, with an inset figure indicating where each bridge is located. Below are the current bridge measurements as provided by Council.

- Bridge 1 is inside new Moama levee. It has concrete pylons and concrete top beams. It has 9 cells with openings that are each roughly 800 mm high by 2000 mm wide (Figure 2-35).
- Bridge 2 is outside of the new levee and has old concrete pylons with wooden beams. It is 7 cells with openings that are each roughly 750 mm high by 2500 mm wide (Figure 2-35).

The bridges were incorporated as TUFLOW culvert structures in the model.

FIGURE 2-35 RAILWAY BRIDGE 1 INSIDE LEVEE (LEFT); RAILWAY BRIDGE 2 OUTSIDE LEVEE (RIGHT) (COURTESY: CAMPASPE SHIRE COUNCIL)

2.8.1.7 Chanter Street Culverts

A series of culverts under Chanter Street helps flood flows and overland stormwater drain from the Moama East area through to the Murray River, which were constructed after the 1993 flood event. The culverts are located on Chanter Street near River Captains Cottage, west of Moama Street. There are 8 cells of culverts and each cell is 900 mm high and 1800 mm wide. A photo of the culvert arrangement is shown in Figure 2-36.

The culverts were incorporated into the model as a TUFLOW culvert structure.

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FIGURE 2-36 CHANTER STREET BRIDG

3 HYDRAULIC MODEL CALIBRATION AND VERIFICATION

3.1 Calibration Approach

This Section discusses the refinement of the hydraulic model parameters through calibration against observed flood levels, water level and stream flow data, and outlines the validation of adopted model parameters.

The calibration process consisted of systematic comparison of observed and modelled flow/levels and available flood extents. The model parameters were adjusted to minimise the differences between the modelled and observed data. Further validation occurred through comparing the model results against other available data including flood imagery and comparison against anecdotal accounts from community members.

The historical flood events used to calibrate/validate the models were chosen on the basis of available observed flood information. The following Sections detail the selection of events and available data for the calibration/validation.

The calibration of the model centred on the determination of floodplain and river channel hydraulic roughness values (Manning's 'n' values) and river channel capacity to achieve a reasonable agreement between observed and modelled flood levels. Initial Manning's 'n' values were assigned to various land uses based on previous modelling experience, and where necessary to achieve a reasonable agreement, these initial Manning's 'n' values were refined.

Form losses and constriction losses were used to describe the bridge losses. A single flow constriction was used to model the bridge piers and estimate the bridge afflux along the river. The method is a replication of applying losses as described in publications that are considered industry standards, such as "Hydraulics for Bridge and Waterways" (Bradley 1978). The publication can be found online at http://www.fhwa.dot.gov/engineering/hydraulics/pubs/hds1.pdf. By adjusting the form loss value in the model and roughly matching to the estimated value from Figure 4 of Bradley's 1978 publication, the decrease in the modelled water level across the bridges was calibrated against the observed flood levels. Figure 4 from Bradley (1978) is provided in Appendix C.

The most recent calibration of the October 2022 flood event improved the models representation of several levees and irrigation channel banks along the Goulburn River, and made some adjustments to Mannings roughness to better reflect the travel time of flood flows in the October 2022 event.

3.2 Available Observed Flood Data and Calibration/Validation Event Selection

The purpose of the model calibration and validation was to ensure that the general flood behaviour during large flood events was accurately represented. The selection of calibration and validation events reflected a range of different types of flood events but was limited to those where adequate observed flood data was available.

The largest flood event with a reasonable amount of historic observed information at the time of the initial model calibration was October 1993. A total of 93 observed flood marks were available for the October 1993 event, of which 69 are from the VFD database and 24 are from the Murray River Council archive.

The more recent but smaller January 2011 and October 2016 events were also selected. The January 2011 event was the largest flood in living memory on the Campaspe River (prior to the October 2022 event) whilst the October 2016 event was a minor flood but still resulted in flooding of rural areas particularly through the downstream areas of the study area.

In October 2022 the flood study was approaching completion when a major flood event occurred. The October 2022 event exceeded flood heights of January 2011 on the Campaspe River, and was slightly above the 1993 flood levels on the Murray River at the Echuca Wharf gauge. It was decided by the Echuca Moama Torrumbarry Flood Study Reference Group that the hydraulic model should include the October 2022 flood event as an additional calibration event. This was justified, as there was some uncertainty regarding the flood extents from the 1993 event, and it was apparent that the model was over estimating flooding in the Kanyapella Basin compared to that observed in the October 2022 event.

The October 1993 and January 2011 events have a reasonable amount of observed flood information including surveyed flood levels. The October 2016 event has less data available but does have flood imagery along the entire study area reach which was provided by North Central CMA. The October 2022 event had a significant amount of information available from multiple authorities, as well as credible anecdotal information from the community given how recently the event had taken place.

Table 3-1 displays the recorded gauge levels at Echuca and associated approximate AEP for the model calibration/validation events, and general nature of available observed flood information. The estimated flood AEP is based on preliminary hydrological analysis at the Echuca Wharf Gauge and is largely in line with previous hydrological analysis. AEP estimates from other studies on the Goulburn River and Campaspe River are also included.

TABLE 3-1 SUMMARY OF HYDRAULIC MODEL CALIBRATION/VALIDATION EVENTS

Event	Peak level (m AHD) and approximate AEP		Available flood information
	Level	Approximate AEP (%)	
October 2022	94.99	5%-2% AEP at the Murray River at Echuca Wharf gauge 2-1% AEP at the Goulburn River at Shepparton gauge 0.5 – 0.2% AEP at the Campaspe River at Rochester gauge	Surveyed flood marks: 291 Flood Imagery Aerial photos Satellite imagery Observed flood extent Gauged flows and levels
October 1993	94.77	10% AEP at the Murray River at Echuca Wharf gauge 5-2% AEP at the Goulburn River at Shepparton gauge 20% AEP at the Campaspe River at Rochester gauge	Surveyed flood marks: 93 Observed flood extent Gauged flows and levels Flood Imagery Aerial photo Numerous photos

Event	Peak level (m AHD) and approximate AEP		Available flood information
	Level	Approximate AEP (%)	
January 2011	92.85	<20% AEP at the Murray River at Echuca Wharf gauge <20% AEP at the Goulburn River at Shepparton gauge 1% AEP at the Campaspe River at Rochester gauge	Surveyed flood marks: 109 Observed flood extent Gauged flows and levels
October 2016	93.41	<20% AEP at the Murray River at Echuca Wharf gauge <20% AEP at the Goulburn River at Shepparton gauge <20% AEP at the Campaspe River at Rochester gauge	Flood Imagery Observed flood extent Gauged flows and levels

*Note that for minor events less than 20% AEP, the AEP has not been provided in this table.

3.3 Calibration and Validation Results

3.3.1 October 1993 Event

The October 1993 flood peaked at 150,000 ML/d at the Goulburn River at Shepparton gauge on the 6th of October. It was preceded 3 weeks earlier by a smaller flood peak at around 95,000 ML/d. Consequently, when heavy rain fell in northeast Victoria on the 3rd of October, much of the floodplain was wet and water was already ponding within floodplain storages. The 1993 flood was the highest flood on record in the Broken River which flows into the Goulburn River at Shepparton. The flood at the Goulburn River at Shepparton gauge was estimated to have a probability of around 1 in 27 year Average Recurrence Interval (ARI). The lower Goulburn River levees were breached in several locations. Combined with relatively high flows in the Murray River, the Goulburn River inflows saw the Murray River at Echuca Wharf gauge reach a flood level of 94.77 m AHD, which places it in the top 10 historic flood levels recorded since the 1860s, but a long way short of the largest ever recorded flood level of 96.19 m AHD in the 1870 flood.

A significant effort was made to establish the alignment of the temporary Moama levee during the 1993 flood event. The best match we consider is the 14th October 1993 flood imagery and we aligned the levee based on this imagery (Figure 2-12). The levee crest elevation was assumed to be 300 mm above the available 1993 flood marks around that area.

3.3.1.1 Gauge Comparison

Modelled water levels were compared to gauged data at Echuca Wharf and at McCoys Bridge for the 1993 event. The results are summarised below in Table 3-2.

During calibration, the three calibration events were modelled in tandem, and the roughness value in the river and the adjacent floodplain was altered to achieve the best calibration across the three events. The model result almost matches the peak recorded level at Echuca Wharf, only 5 cm lower. At the McCoys Bridge gauge on the Goulburn River the modelled peak water level is lower by 14 cm.

TABLE 3-2 COMPARISON OF PEAK WATER LEVEL FOR THE OCTOBER 1993 FLOOD EVENT

Gauge	Gauged Peak Water Level (m)	Modelled Peak Water Level (m)
Murray River at Echuca Wharf (409200)	94.77	94.72
Goulburn River @ McCoy Bridge (405232)	102.45	102.31
Campaspe River @ Echuca (406265)	N/A	94.55

The comparison of gauged water level at the Echuca Wharf gauge on the Murray River to the modelled water level is shown in Figure 3-1. The gauged water level and flow hydrograph was compared at McCoys Bridge gauge on the Goulburn River and shown in Figure 3-2. The comparison shows that the timing and peak values are matching quite well to the recorded data except for the McCoys Bridge gauged flow, with the model underestimating the peak flow at McCoys Bridge. The reliability of the gauge rating table at the McCoys Bridge gauge is questionable for the 1993 flood event, as the water level is well into the extrapolated zone of the rating table. This is illustrated in Figure 3-2 showing the limit of the reliable section of the rating curve on the gauge hydrograph.

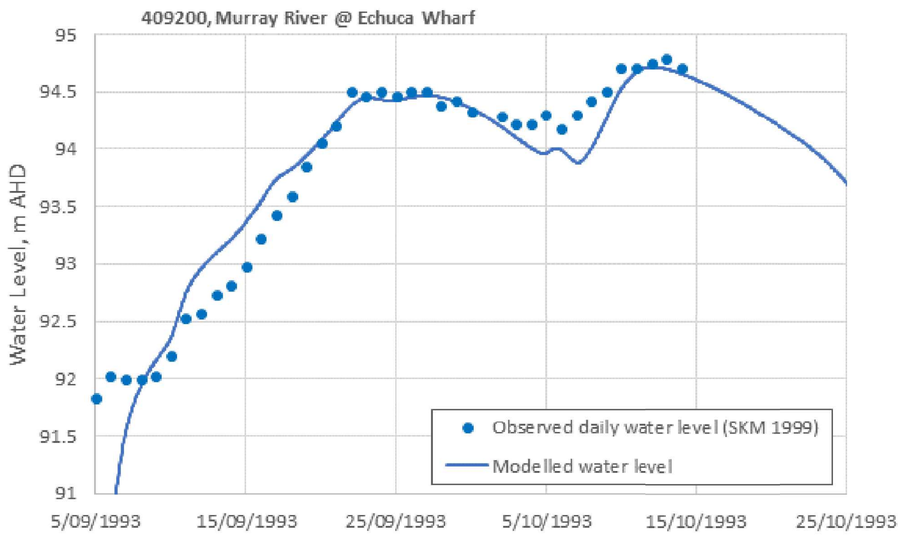

FIGURE 3-1 COMPARISON AT MURRAY RIVER @ ECHUCA WHARF (405200) – OCTOBER 1993 EVENT

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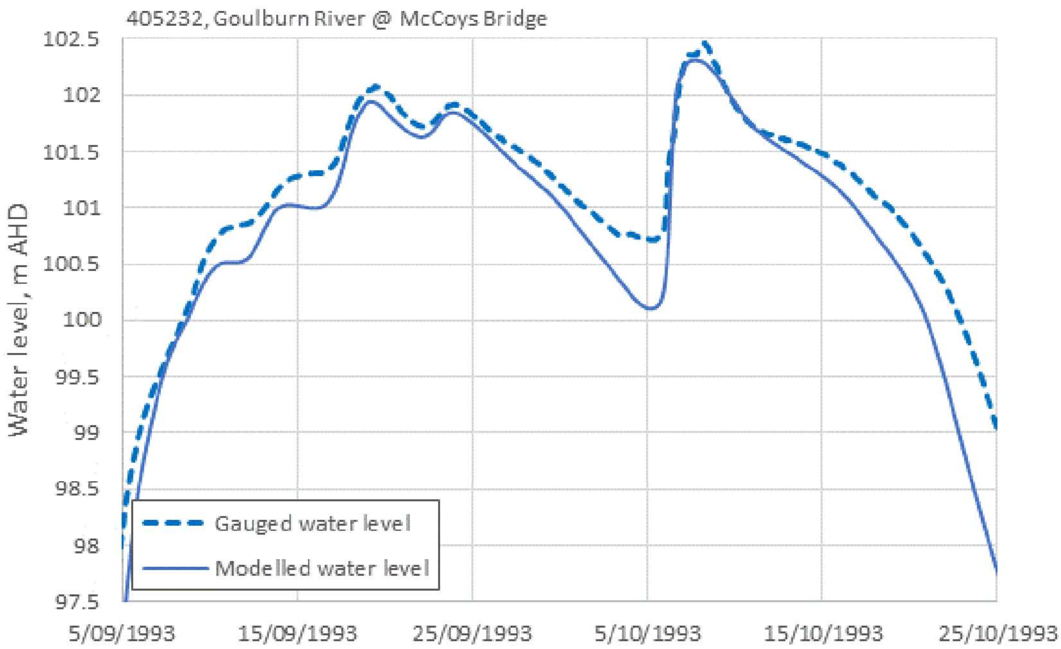

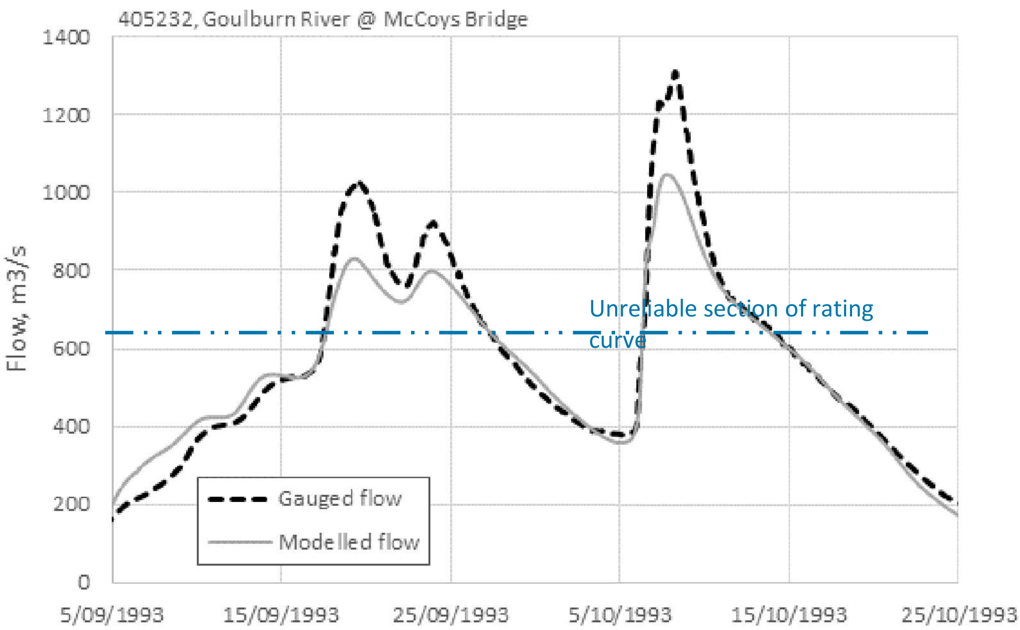

FIGURE 3-2 COMPARISON AT GOULBURN RIVER @ MCCOYS BRIDGE GAUGE (405232) – OCT 1993 EVENT

3.3.1.2 Surveyed Flood Marks

The October 1993 event was calibrated using 93 available surveyed flood marks along the Goulburn and Murray River floodplains.

It is important to note that the quality and reliability of the surveyed data points was found to vary considerably based on the "Reliability" attribute in the Victoria Flood Database (VFD) dataset. Flood level survey is very useful in the calibration of hydraulic models but needs to be used with judgement and consideration of the potential sources of error inherent in the data.

Out of 93 observations, 28 of the surveyed flood marks for the 1993 event within the model extent are located immediately upstream of the Echuca-Moama township. The rest of the points are located further upstream close to Barmah on the Murray River and McCoys Bridge on the Goulburn River.

The modelled results were compared with the surveyed flood levels recorded at these points and the difference was calculated as modelled minus recorded height. Across the study area, approximately 76% of modelled water levels were within +/- 0.2 m of the recorded heights About 89% of modelled points were within +/- 0.3 m of the recorded heights. Figure 3-3 shows the distribution of the difference in height between the modelled and recorded flood heights, and Figure 3-4 shows the differences on a map. Overall, the calibration to the historic flood levels is considered to be very good.

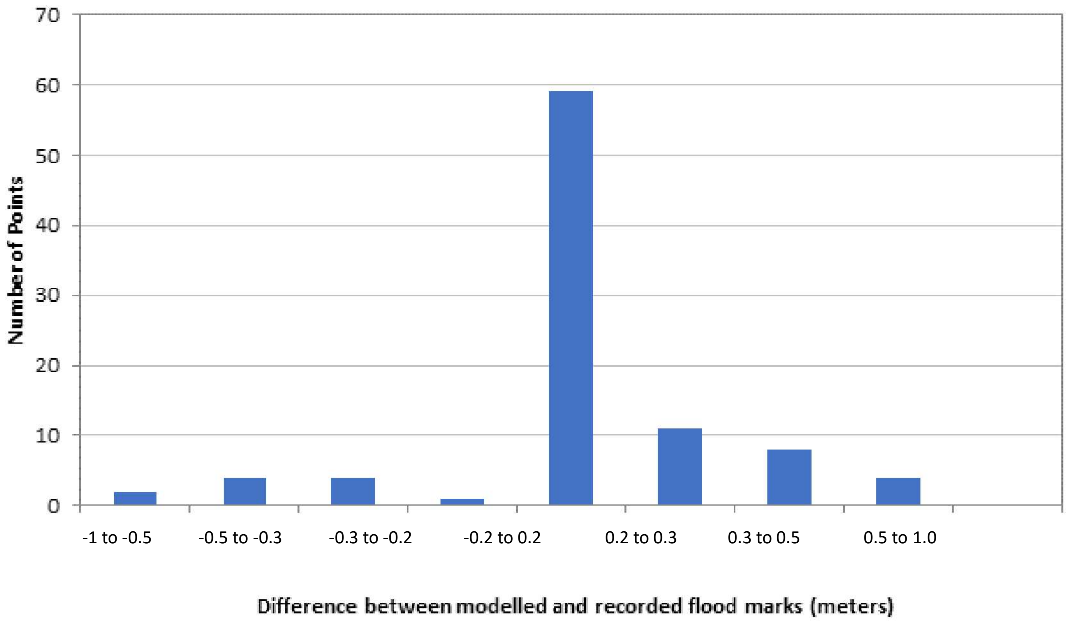

FIGURE 3-3 MODELLED AND HISTORIC FLOOD MARKS DIFFERENCE – OCTOBER 1993 EVENT

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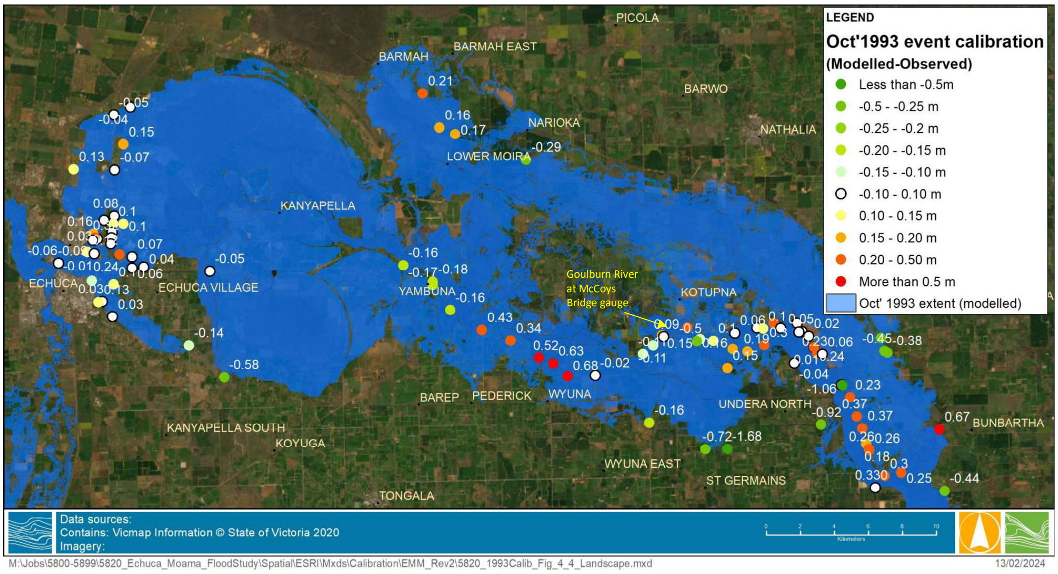

FIGURE 3-4 COMPARISON OF MODEL RESULTS TO FLOOD MARKS, OCTOBER 1993

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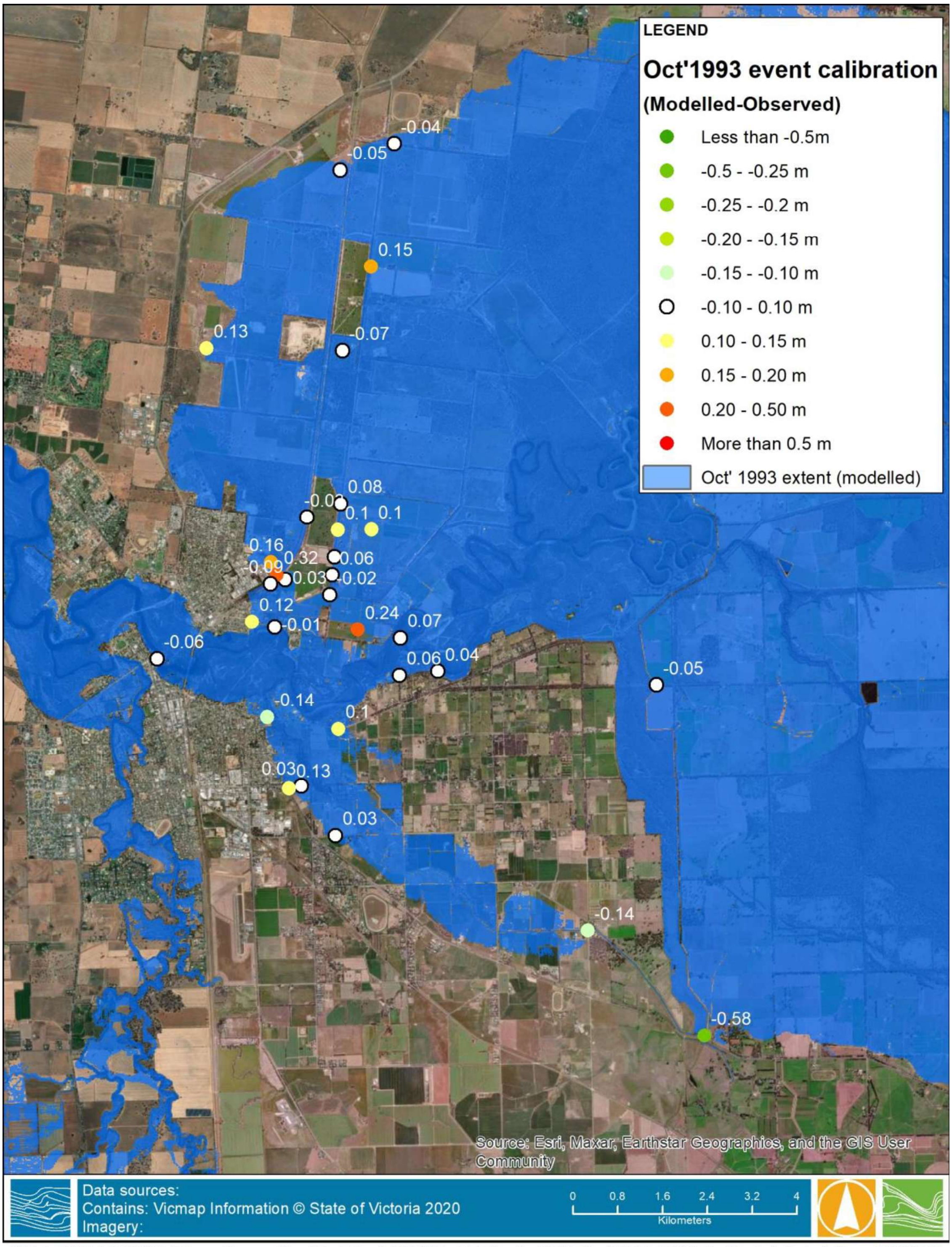

FIGURE 3-5 COMPARISON OF MODEL RESULTS TO FLOOD MARKS (ECHUCA-MOAMA), OCTOBER 1993

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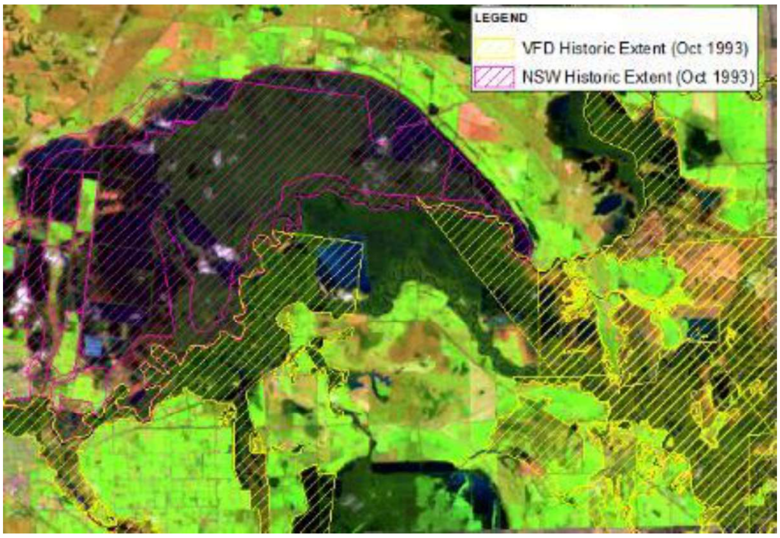
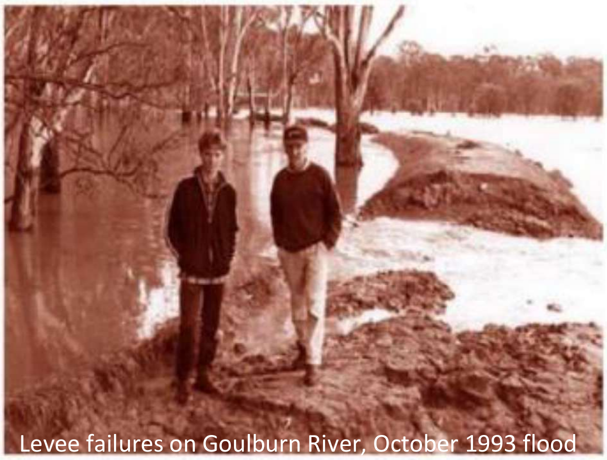
3.3.1.3 Flooding Extents

The model extent was compared to the Victoria Flood Database (VFD) and NSW Government historic digitised flood extents (DPC extent) Figure 3-6 and Figure 3-7. The digitised flood extents may not represent the peak flooding, potentially being based on aerial imagery from a particular point in time, or perhaps the digitisation effort just did not cover the full floodplain. Noticeably there is a large discrepancy in the modelled and digitised extents in the Kanyapella Game Reserve area to the east of Echuca Village. With the modelled levels lower than the available flood mark survey points in that area, it is clear that the discrepancy lies in the completeness of the digitised historic extent, as you would expect the area to be inundated based on the flood marks. On the left shows the historical extent overlaid on the Landsat image taken on 25th October 1993. It clearly shows the inundation on the Kanyapella Game Reserve in October 1993 flood.



There are several levees along the Goulburn River which were breached during the October 1993 flood, whereas the model did not include any levee breaches as the focus of the modelling exercise was on Echuca and Moama, not the lower Goulburn River. It is understood that levees were breached or damaged in 45 separate locations on the south bank downstream of Coomboona and eight separate locations on the north bank upstream of McCoys Bridge. Levees were also breached at Madowla Park and downstream of McCoys Bridge and Hancocks Creek outlet (HydroTechnology, 1995). On the right shows a photo of one such levee failure on the Goulburn River during the October 1993 flood.


Levee failures on Goulburn River, October 1993 flood

Without representing these levee breaches there is a degree of uncertainty in the model results along the Goulburn River. However the good match with gauged data at McCoys Bridge gauge, surveyed flood marks and a general good fit with the flood extents, provide some confidence that the model is fit for purpose. Further, the modelling of the Goulburn River is not intended for detailed planning purposes, rather it is to allow a good inflow boundary at the Goulburn River gauge.

The flood extents were uploaded onto an ArcGIS Online map and were open to the public. Throughout the calibration phase many comments were received regarding the 1993 event, and this information was used to further validate our modelling. This feedback highlighted several temporary flood protection works (sandbag levees) that were built during the event, and which were subsequently incorporated into the 1993 model calibration. There was also much discussion around the eastern side of Moama, particularly with regard to the rural earthen levees. The final model calibration represented the crest levels of the levees accurately, showing the levees which were not breached during the event to be holding back flood waters, and replicating flood depths observed during the event.

Figure 3-8 to Figure 3-10 provide modelled flood depth maps of zoomed in areas across Echuca and Moama. From feedback from community and Council and comparison to historic aerial flood photos supplied by Council, the flood extents match the observed inundation quite well.

After the October 2022 flood and comparison of what was observed versus what the model predicted, it became clear that the crest levels of some sections of the lower Goulburn levees were not represented as accurately as they needed to be in the model, and needed updating. This further explains why the flood model was predicting widespread inundation as compared to historic digitised extents. Given that the October 2022 event was similar but slightly higher than 1993 event, the decision was made to place further effort into calibrating the October 2022 flood event prior to completing the design modelling.

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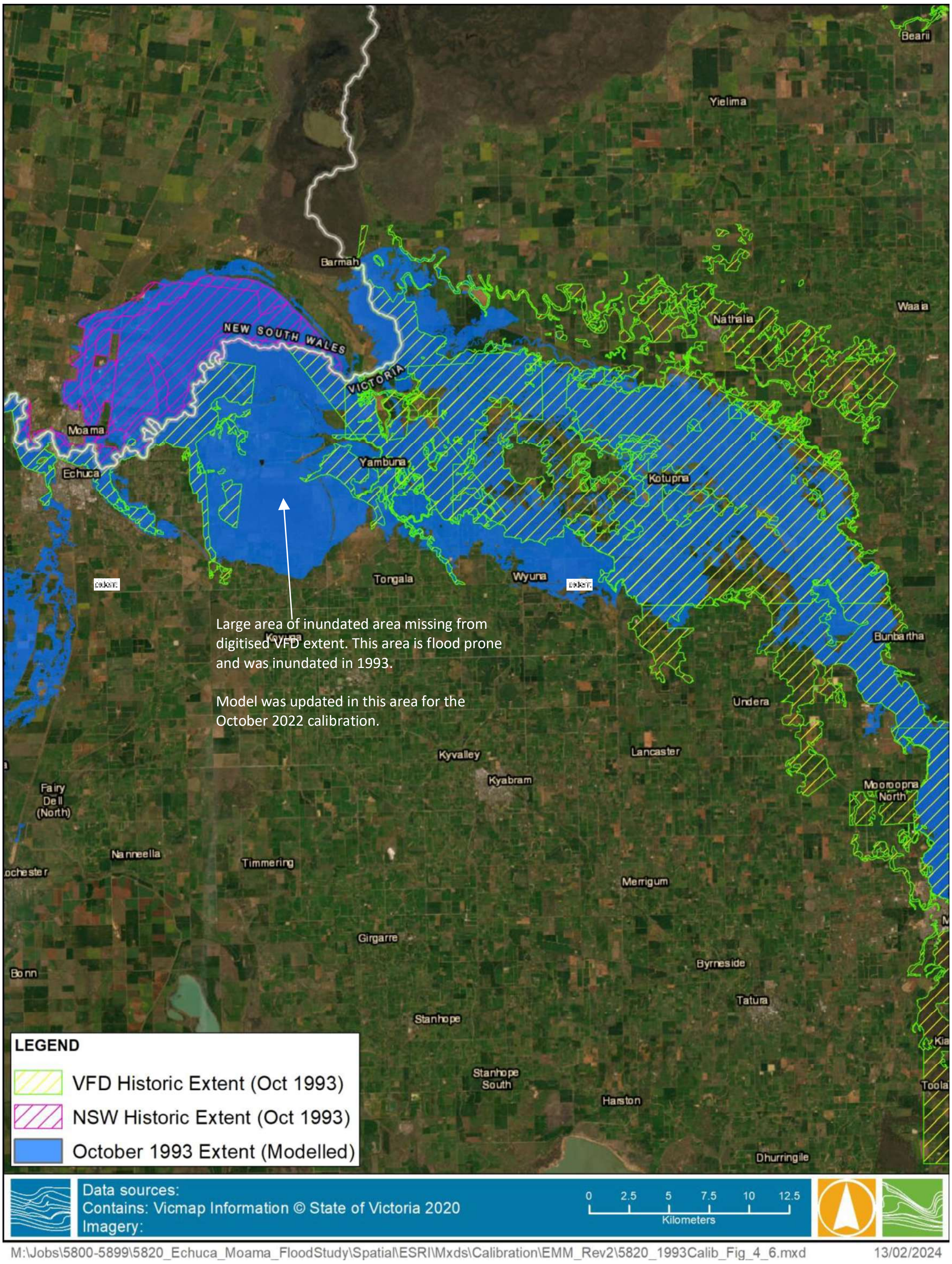

FIGURE 3-6 COMPARISON OF MODEL RESULTS TO VIC/NSW DIGITISED FLOOD EXTENTS, OCTOBER 1993

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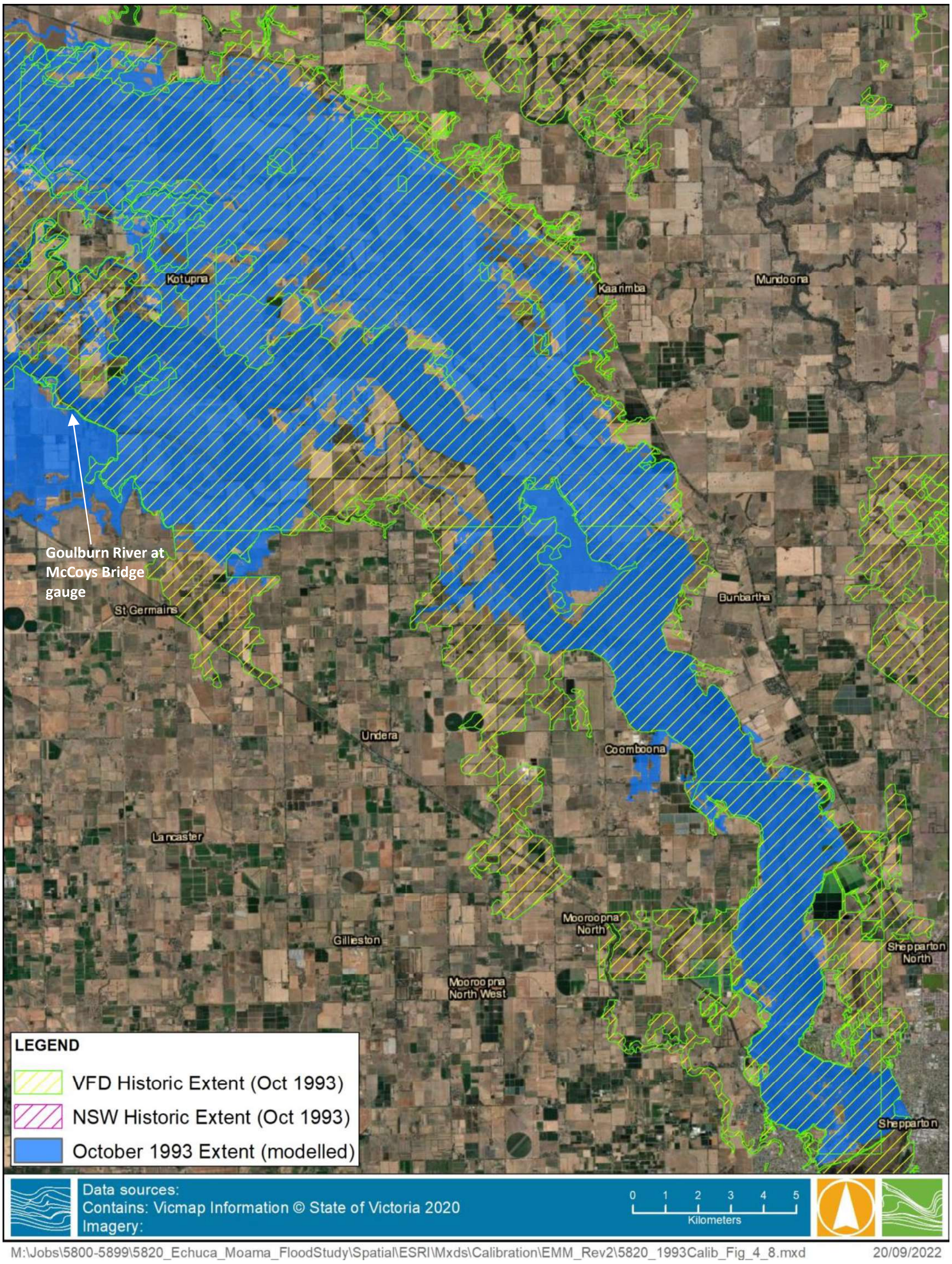
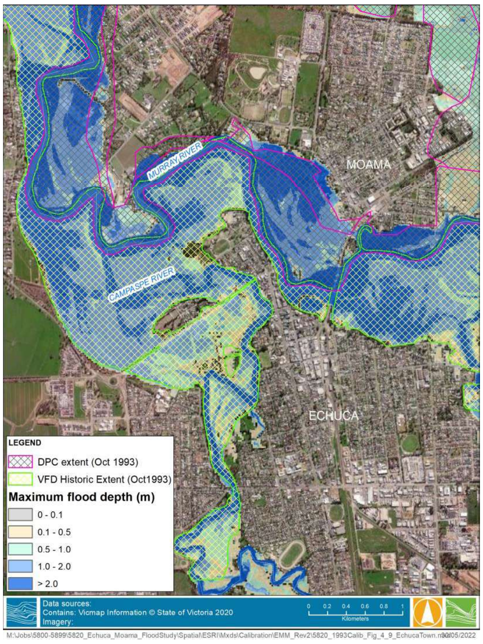


FIGURE 3-7 COMPARISON OF MODEL RESULTS TO VFD EXTENTS, OCTOBER 1993 (SHEPPARTON-KOTUPNA)



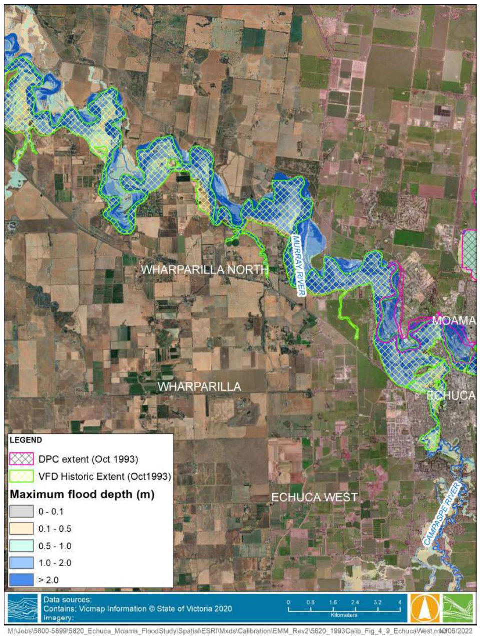


FIGURE 3-8 MODELLED FLOOD DEPTH, OCTOBER 1993 – LEFT: ECHUCA TOWN; RIGHT: DOWNSTREAM OF ECHUCA-MOAMA AREA

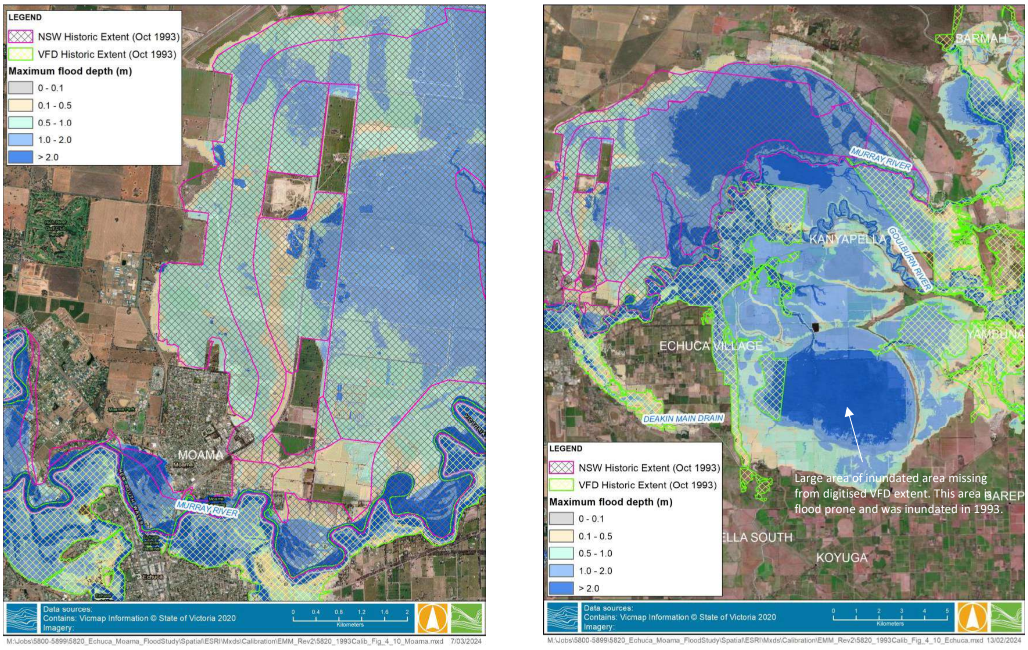


FIGURE 3-9 MODELLED FLOOD DEPTH, OCTOBER 1993 – LEFT: MOAMA AREA; RIGHT: ECHUCA VILLAGE / KANYAPELLA AREA

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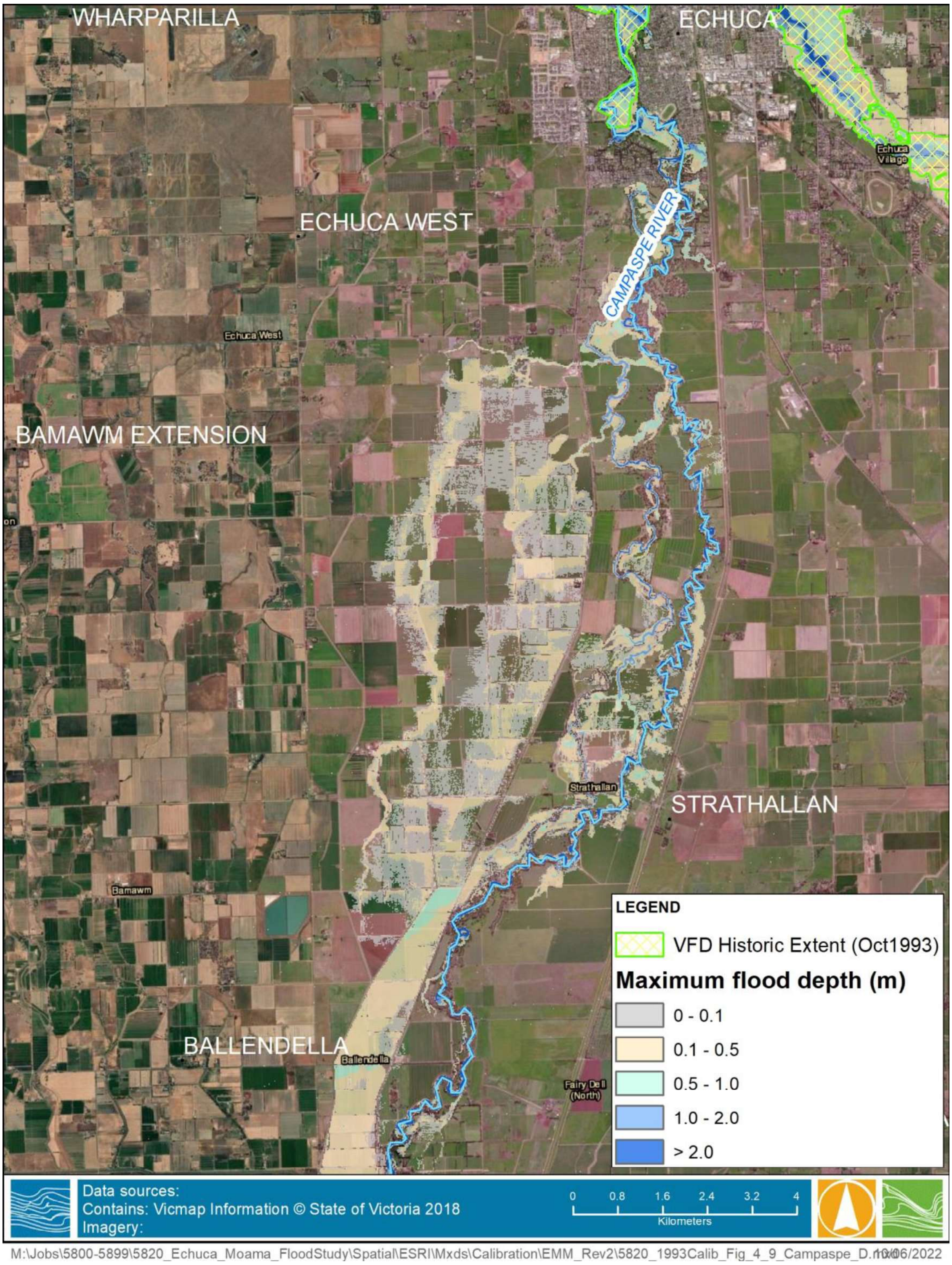

FIGURE 3-10 MODELLED FLOOD, OCTOBER 1993 FLOOD – CAMPASPE, UPSTREAM OF ECHUCA

3.3.1.4 Flood Imagery

The model was also validated by comparing the model results to the flood imagery and aerial photos taken during the event. The two most relevant flood images and one aerial photo are described below:

- Echuca-Moama image taken on 14th October 1993, sourced from the Rural Water Corporation (RWC) and Department of Natural Resources and Environment (DNRE) archive and covers Moama-Echuca township.
- Murray-Echuca-Kanyapella image taken on 23rd and 25th October, which is 9 to 11 days after the recorded peak at Echuca and covers Echuca-Moama township.
- Moama aerial photo taken on October 1993 and covers Maiden's Inn Resort, and private property between the Railway line to Chanter Street.

A satellite flood image captured on 14th October 1993 was sourced from RWC and DNRE were compared to the modelled extent and shown in Figure 3-11 and Figure 3-12. The image shows inundation and where inundation has been quite clearly with the darker green and brown colours. The modelled inundation matches the satellite image closely except in the east Moama area, where the extent is broader (shown in inset figure). There may have sandbagging around that area which information was not available, however, the depth around that area is around 100 mm.

Additionally, aerial photos were compared to the modelled result as shown in Figure 3-13. The Maiden's Inn resort, west of Deniliquin Street observed to be flood free during October 1993 flood event. Council indicated that Maiden's Inn remained flood free through its natural height or temporary levees and sandbagging.

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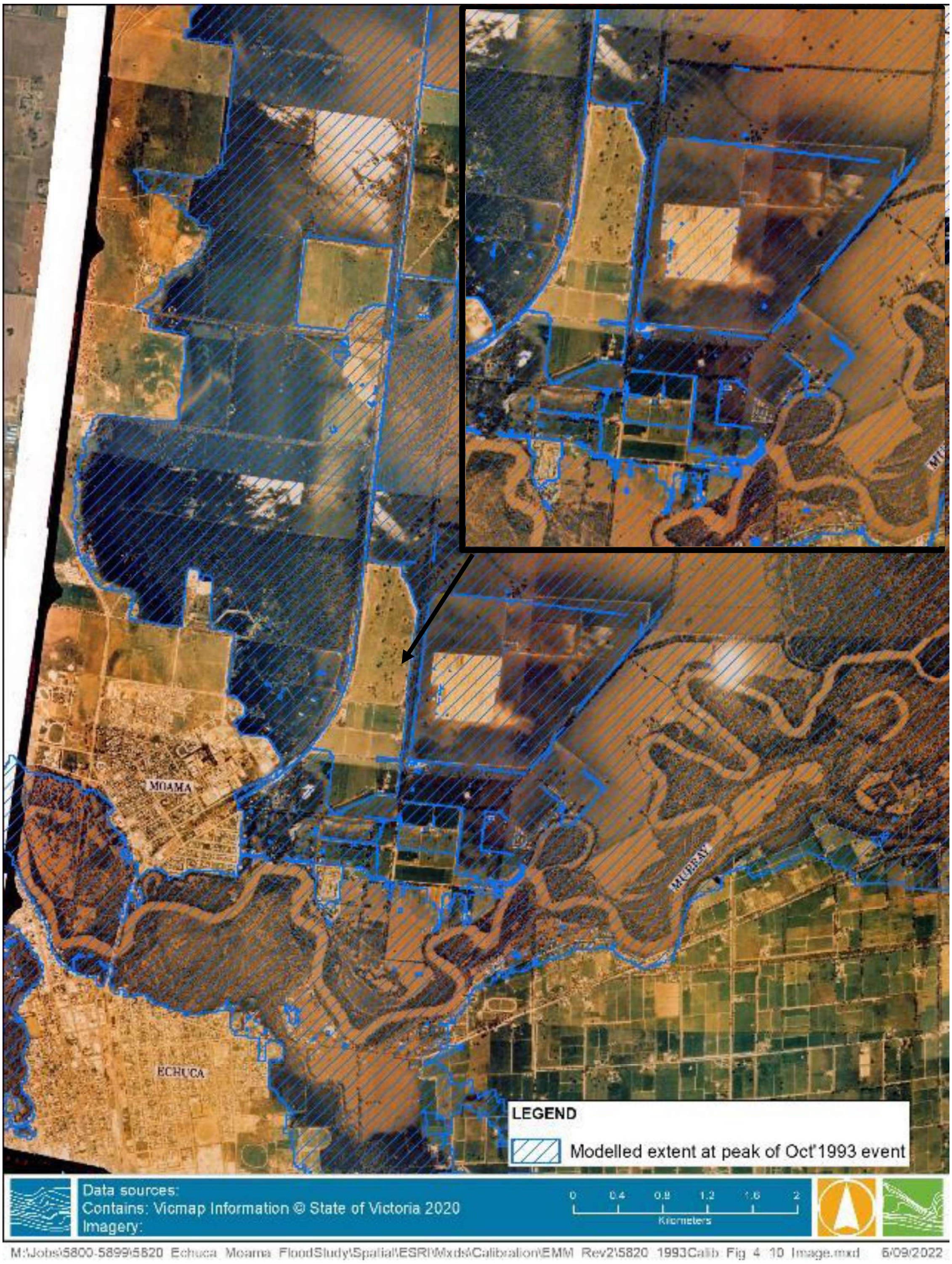

FIGURE 3-11 COMPARISON OF MODEL RESULTS TO FLOOD IMAGERY CAPTURED ON 14TH OCTOBER 1993 – MOAMA AREA. THE IMAGERY WAS CAPTURED AT THE TIME THE FLOOD PEAK AT ECHUCA

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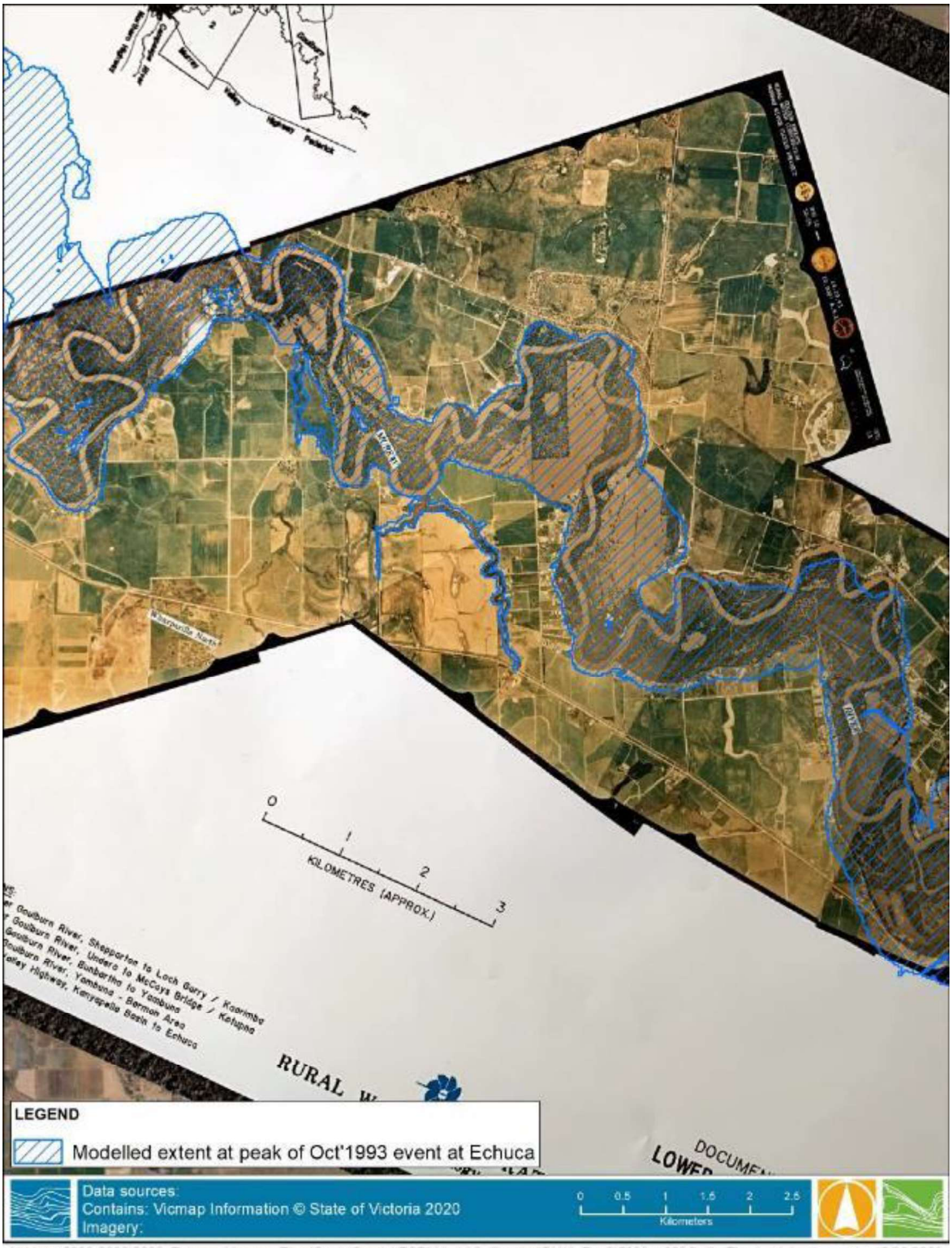

FIGURE 3-12 COMPARISON OF MODEL RESULTS TO FLOOD IMAGERY CAPTURED ON 14TH OCTOBER 1993 – MOAMA AREA. THE IMAGERY WAS CAPTURED AT THE TIME THE FLOOD PEAK AT ECHUCA

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FIGURE 3-13 AERIAL IMAGERY OCTOBER 1993 COMPARISON TO MODEL RESULT

3.3.2 January 2011 Event

The January 2011 flood event reached 92.85 m AHD on the Murray River at Echuca Wharf gauge, well below the minor flood level. The Murray and Goulburn River flows were only minor compared to other historic flood events, but the Campaspe River experienced its largest flood on record. The Campaspe River flood at Rochester inundated over 80% of the town, with over 250 properties flooded above floor level. Anecdotal accounts of flooding along the Campaspe River through Echuca describe the roaring sound of the flood approaching like nothing residents had ever heard. So, although the Murray River at Echuca Wharf gauge stayed below its minor flood level, some parts of Echuca along the Campaspe River floodplain were seriously impacted by flooding during the event.

The levees along Campaspe River were not overtopped, with a reasonable freeboard remaining. Adjacent to the Campaspe River there were many local roads, community facilities and private properties damaged as a result of the flood waters.

The flood model was calibrated to observed flood heights along the Campaspe River through Echuca, recorded gauge levels and flows, observed flood extents and was validated using community and Council feedback. The model was calibrated to January 2011 and October 1993 concurrently, with changes to the model made iteratively to achieve the best fit across both events. The main difference between the two models was the incorporation of the Moama urban town levee in the 2011 event and the various temporary sandbag levees constructed during the 1993 event.

3.3.2.1 Surveyed Flood Marks

The January 2011 event was calibrated using the available 109 surveyed flood marks along the Campaspe River. Some of the available survey points recorded flood levels significantly lower than the ground surface level at that location (based on LiDAR). This suggests that either the recorded level or the location of the point is in error, or that the water depth was very shallow and within the error bounds of the Lidar (+/- 150 mm). As previously mentioned, the survey is useful in the calibration of hydraulic models but needs to be used with judgement and consideration of the potential sources of error inherent in the data.

Of the 109 flood level points available for the 2011 event, 104 points were selected for comparison, with 4 points clearly in error. The modelled results were compared with the surveyed flood levels recorded at these points and the difference between the two was calculated. Across the study area, 72% of modelled water levels were within +/- 0.2 m of the surveyed levels and almost 90% within +/- 0.3 m.

Figure 3-14 shows the distribution of the difference in height between the modelled and recorded flood heights, a positive difference is when the modelled level is higher than surveyed. A good distribution was achieved. The modelled water levels upstream on the Campaspe River tended toward being lower than the surveyed flood marks, with the survey in town a mix of points being higher and lower. A map of the model and survey point differences is shown in Figure 3-15. The January 2011 calibration is considered to be acceptable and fit for purpose.

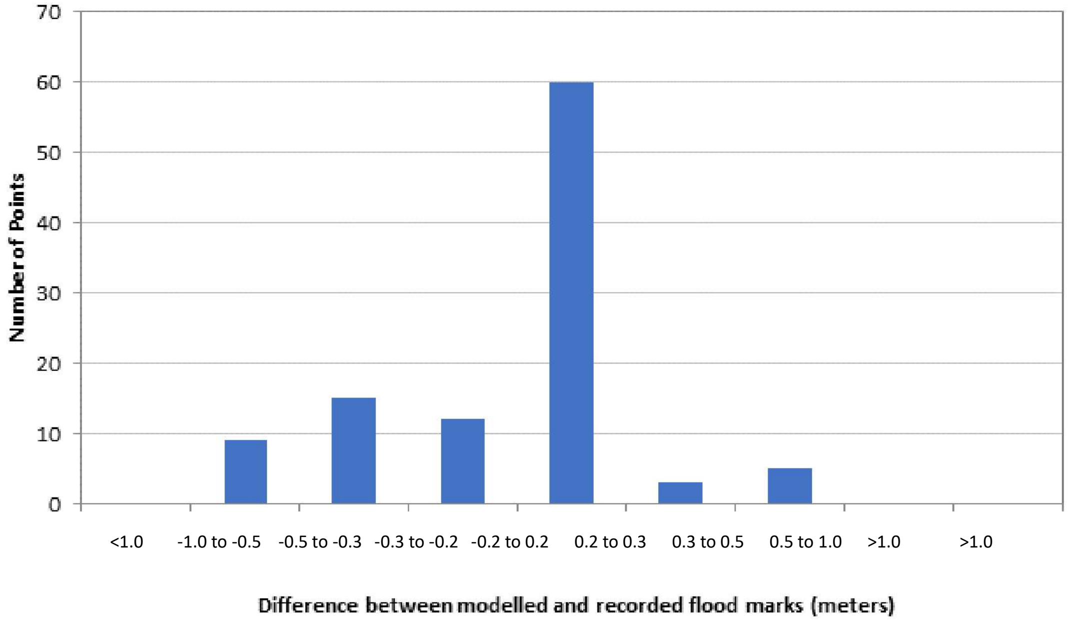

FIGURE 3-14 MODELLED AND HISTORIC FLOOD HEIGHT COMPARISON – JANUARY 2011

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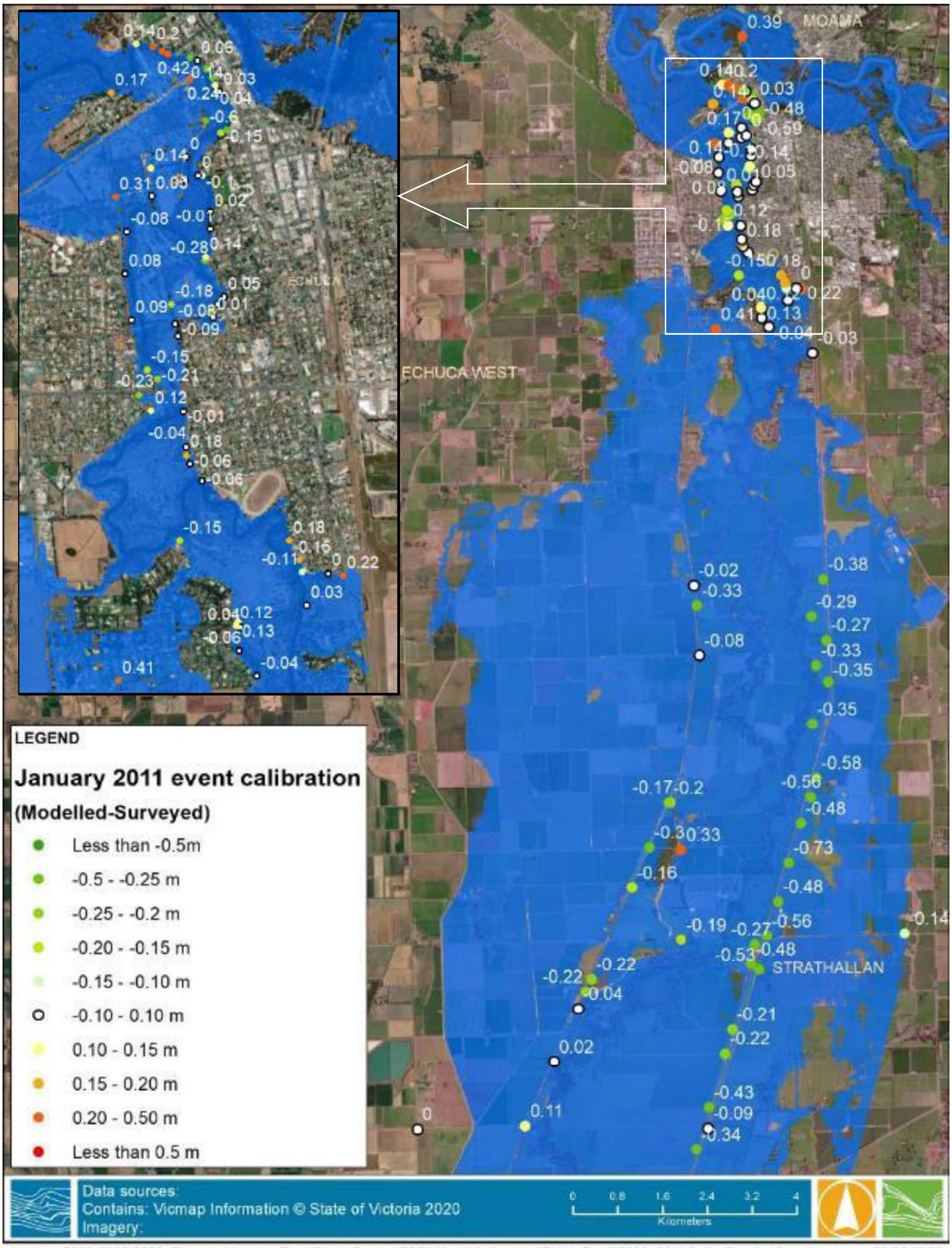

M:\Jobs\5800-5899\5820_Echuca_Moama_FloodStudy\Spatial\ESRI\Mxds\Calibration\EMM_Rev2\5820_2011Calib_Fig_4_13.mxd 22/06/2022

FIGURE 3-15 COMPARISON OF MODEL RESULTS TO FLOOD SURVEY, JAN 2011 – ECHUCA-MOAMA AREA

3.3.2.2 Gauge Results

During the January 2011 event, the high Campaspe River flows created a backwater upstream on the Murray River. The flow peaked on the Campaspe River at Rochester at around 7 pm on 15th January 2011. The flow peaked on the Campaspe River at Echuca gauge at 9.00 pm on Sunday 16th January 2011. The Murray River at Echuca Wharf peaked at around 5 pm on the 18th January as a result of the Murray River flows coming through on the receding limb of the Campaspe River and backing up behind the Campaspe River flows. The Goulburn River at Shepparton gauge peaked later at 6 am on the 19th January, with that peak reaching Echuca several days later and delaying the recession of the flood levels at Echuca. Over this period the Murray River at Barmah gauge was relatively steady, contributing a flow of around 15,000 to 20,000 ML/d.

Modelled water levels at the Murray River at Echuca Wharf gauge compared well for the January 2011 calibration event. Table 3-3 shows the modelled peak level being only 24 cm higher than the recorded level. The water level hydrograph over the flood event was also compared and presented in Figure 3-16. The comparison shows that the model represents the shape and the peak of the hydrograph well compared to recorded data, with the model peaking a little earlier than recorded.

The gauged water level at Echuca on Campaspe River is also compared to the modelled water level (Table 3-3) and presented in Figure 3-17. The comparison shows the modelled peak is only 2 cm higher than the recorded level, and the timing and shape of the hydrograph is quite good.

The modelled water level and flow was compared at McCoys Bridge gauge, with Table 3-3 and Figure 3-18 showing the modelled levels to be 43 cm lower than recorded. The comparison shows that the Goulburn flows at McCoys Bridge is calibrated well in terms of magnitude in the range where the rating curve is deemed to be accurate.

TABLE 3-3 COMPARISON OF PEAK WATER LEVEL FOR THE JANUARY 2011 FLOOD

Gauge	Gauged Peak Water Level (m AHD)	Modelled Peak Water Level (m AHD)
Murray River @ Echuca Wharf (409200)	92.84	93.08
Campaspe River @ Echuca (405265)	95.60	95.62
Goulburn River @ McCoys Bridge (405232)	100.05	99.62

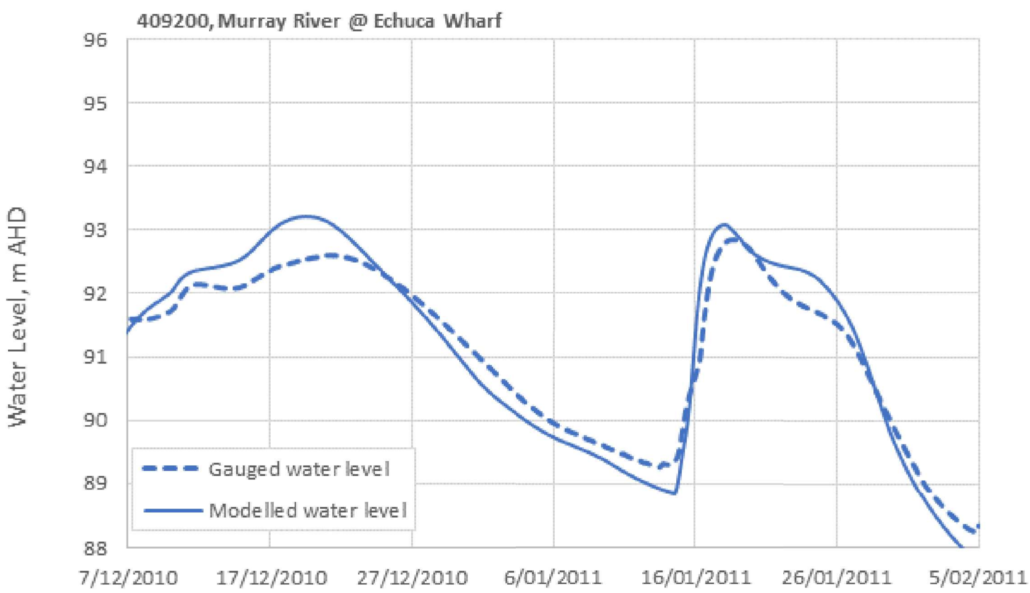

FIGURE 3-16 COMPARISON OF WATER LEVEL AT ECHUCA WHARF ON MURRAY RIVER – JANUARY 2011

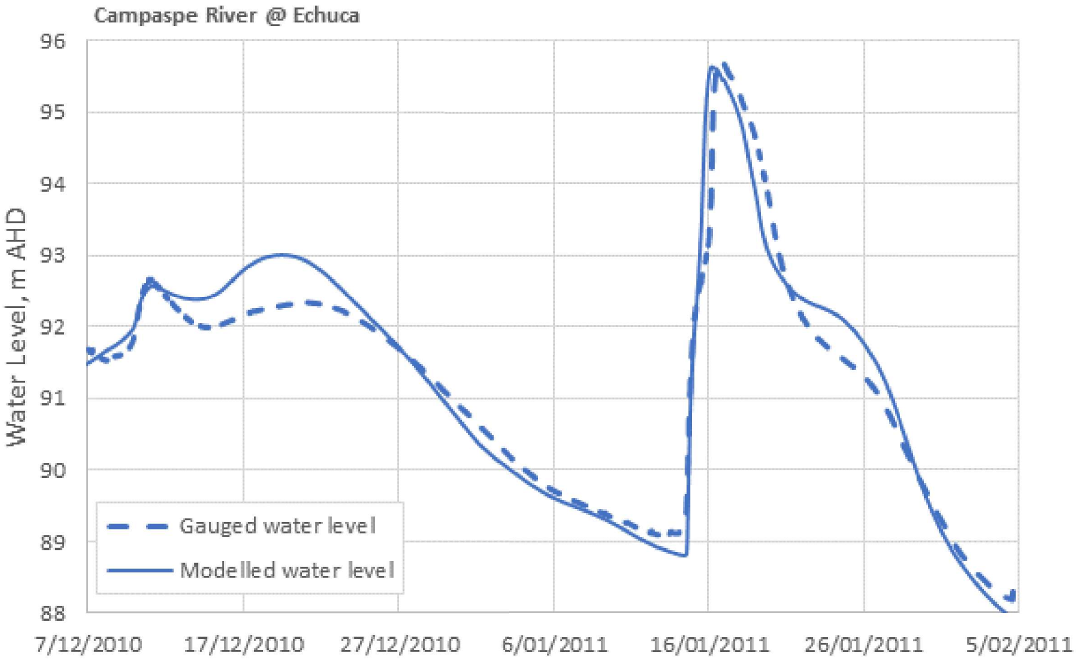

FIGURE 3-17 COMPARISON OF WATER LEVEL AT ECHUCA ON CAMPASPE RIVER – JANUARY 2011

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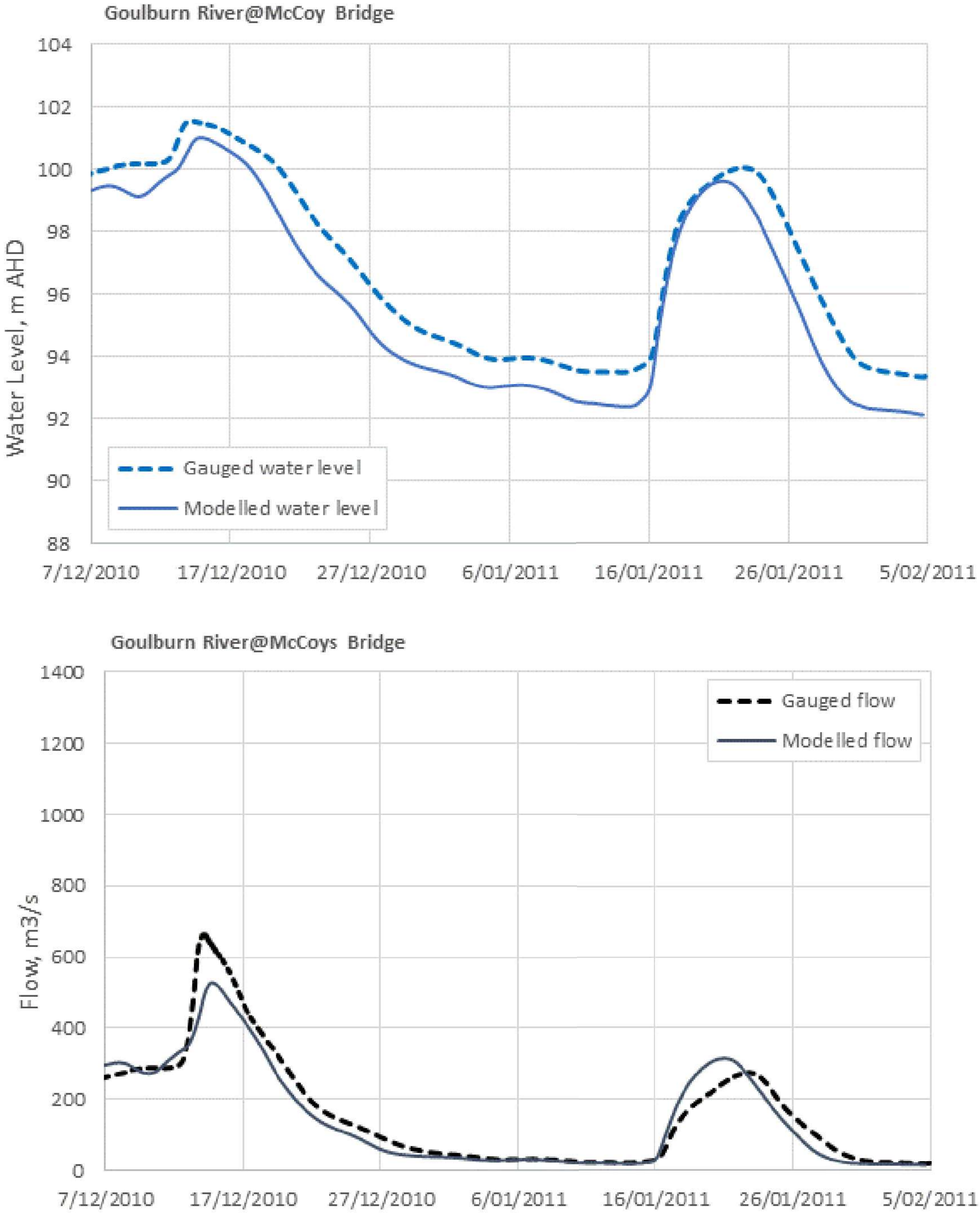

FIGURE 3-18 COMPARISON OF MODELLED AND OBSERVED WATER LEVEL AND FLOW AT MCCOYS BRIDGE ON GOULBURN RIVER – JANUARY 2011

3.3.2.3 Flooding Extents

The maximum extent of flooding in the study area produced by the model was compared with observed flood extents available in the VFD, these are presented in Figure 3-19 to Figure 3-22 below. The results generally show that the modelled extent is broader than the digitised extent in the VFD. This may be due to the date of aerial imagery capture that was used to digitise the extent. The comparison of flood imagery to modelled extent Figure 3-21 and an inset map of satellite imagery in Figure 3-22 shows the flooding extent much wider than that shown by the VFD digitised extents. This satellite image is captured 4 or 5 days after the peak inundation, but it shows where flood waters have been trapped behind roadways and along drainage lines.

Given that the modelled water levels calibrate well and don't show any real bias (most match well, some are higher, some are lower), we believe the flood extent matches well to what was observed. Additionally, community feedback has been very positive about the January 2011 calibration results made available through the ArcGIS Online mapping. Figure 3-19 to Figure 3-22 provide modelled flood depth maps of zoomed in areas across Echuca and Moama.

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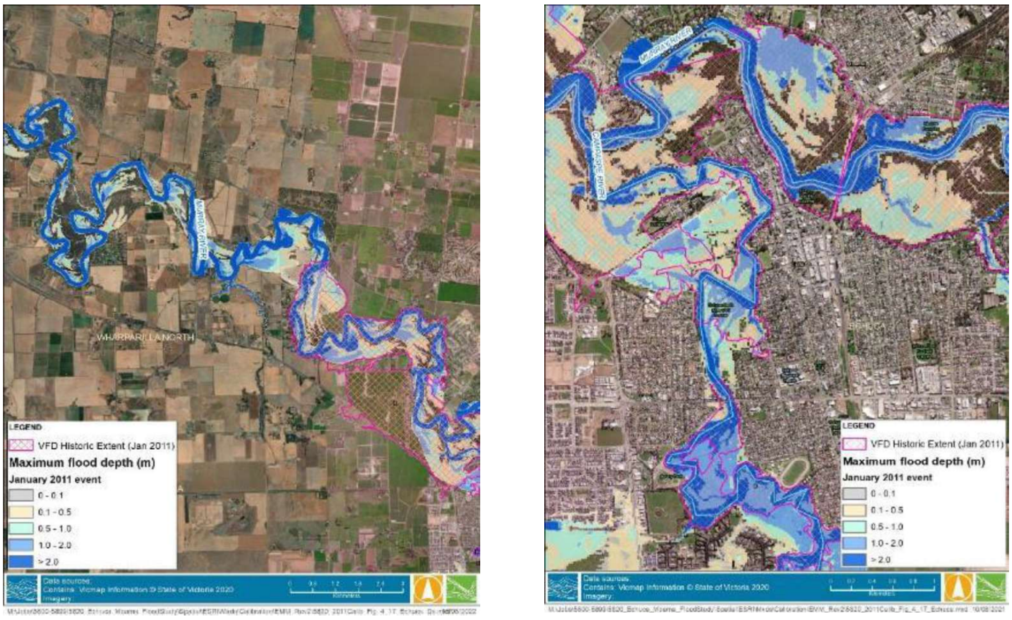

FIGURE 3-19 MODELLED FLOOD DEPTH, JANUARY 2011 – RIGHT: ECHUCA TOWN; LEFT: DOWNSTREAM OF ECHUCA-MOAMA AREA

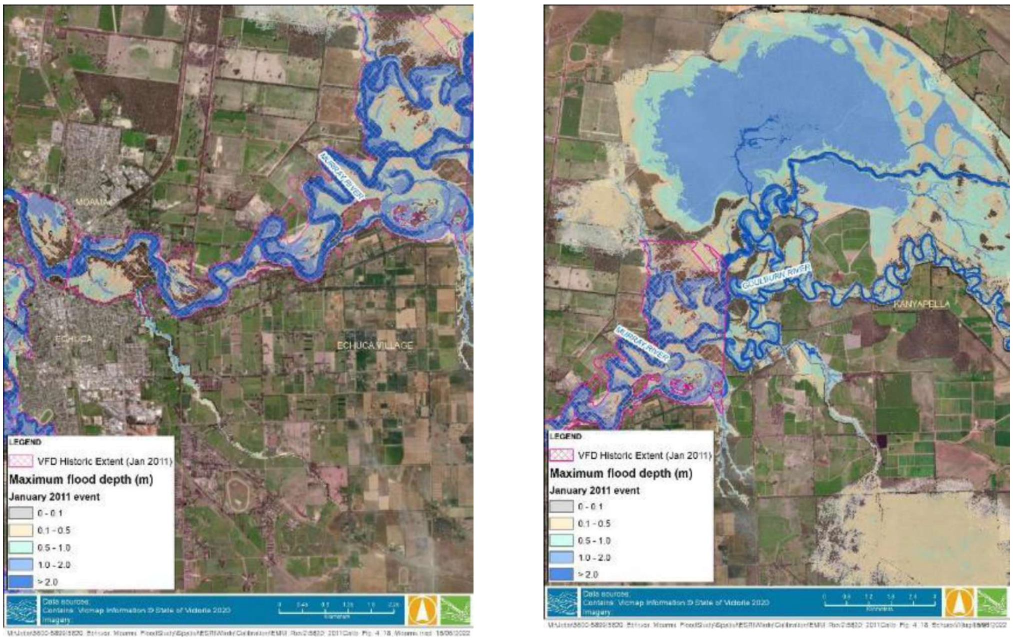

FIGURE 3-20 MODELLED FLOOD DEPTH, JANUARY 2011 – LEFT: MOAMA AREA; RIGHT: ECHUCA VILLAGE / KANYAPELLA AREA

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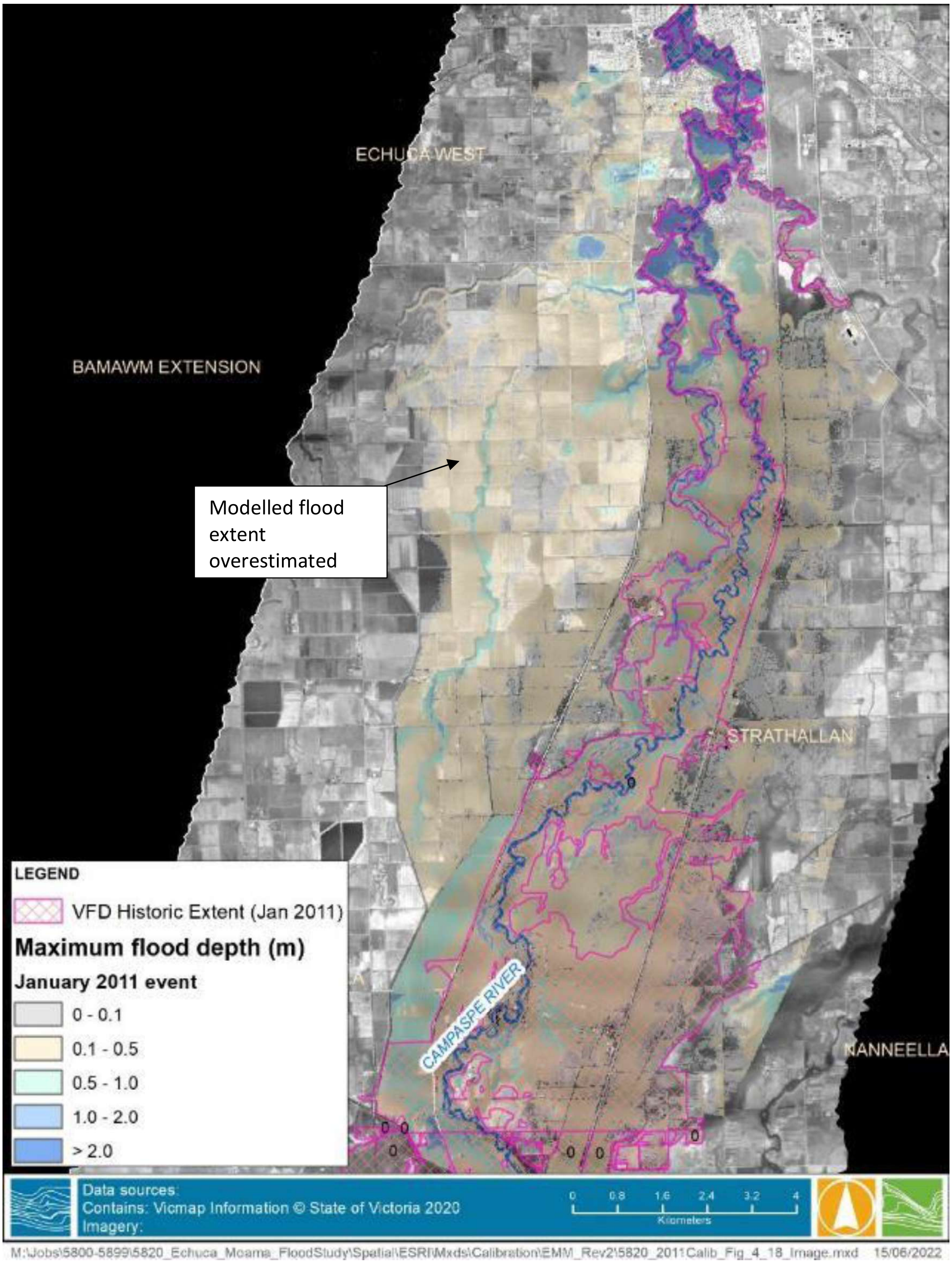

FIGURE 3-21 MODELLED FLOOD DEPTH AND FLOOD IMAGERY – JANUARY 2011, CAMPASPE RIVER

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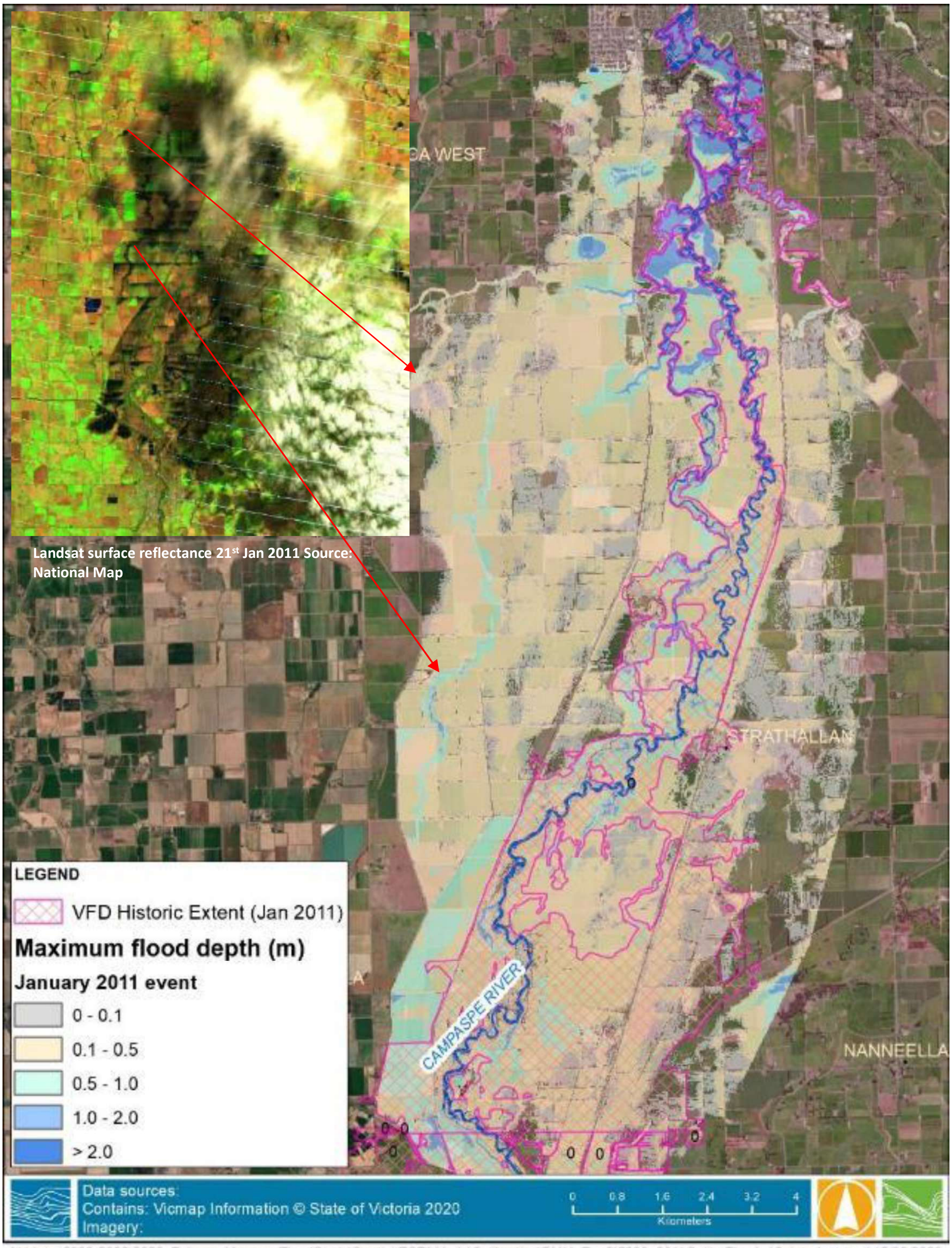

M:\Jobs\5800-5899\5820_Echuca_Moama_FloodStudy\Spatial\ESRI\Mxds\Calibration\EMM_Rev2\5820_2011Calib_Fig_4_18_Landsat.mxd 15/06/2022

FIGURE 3-22 MODELLED FLOOD DEPTH , JANUARY 2011 FLOOD – CAMPASPE RIVER

3.3.3 October 2016 Event

The October 2016 event was another minor flood event, with the flood level at the Echuca Wharf gauge peaking at 93.42 m AHD, just below the adopted minor flood level. The event was driven by high Murray River flows along with flow contribution from the Goulburn River. Given the event was recent it was felt that it should be used in the calibration as it would be fresh in the mind of the community.

As opposed to the other events, limited survey information was available for the event, and the model was validated primarily by comparing the model results to the flood imagery taken during the event. The two relevant flood images are:

- Murray-Barmah-Echuca image taken on 13th October 2016, which is 3 days prior to the recorded peak at Echuca-Moama and covers Echuca and upstream to the model boundaries.
- Murray-Echuca-Koondrook image taken on 23rd October 2016, which is 7 days after the recorded peak at Echuca and covers Echuca and extends all the way to the downstream model boundary.

Given both images were taken either side of the peak of the flood event, the modelled extents at the time of the image capture were compared to the aerial image. This method of validation can introduce some discrepancies in the comparison, if the model routing and time of peak is not accurate.

Modelled water levels were also compared to gauged data at three gauge locations and results are summarised below in Table 3-3. The result shows that at Echuca Wharf, the modelled peak level was approximately 24 cm higher than the recorded level. The comparison of water level hydrographs is shown in Figure 3-23, showing the model peak arriving earlier than the recorded data. This is thought to be primarily a result of the assumed inflows at Barmah, the gauge was offline for almost the entire peak and so an interpolated inflow hydrograph was constructed.

TABLE 3-4 COMPARISON OF PEAK WATER LEVEL FOR THE OCTOBER 2016 FLOOD

Gauge	Gauged Peak Water Level (m)	Modelled Peak Water Level (m)
Murray River @ Echuca Wharf (409200)	93.42	93.66
Campaspe River @ Echuca (406265)	N/A	93.45
Goulburn River @ McCoy Bridge (405232)	101.37	101.06

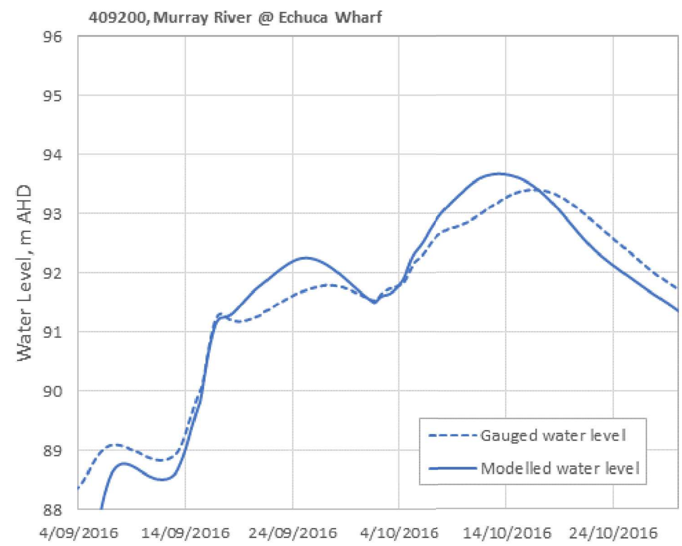

FIGURE 3-23 COMPARISON OF WATER LEVEL AT ECHUCA WHARF GAUGE ON THE MURRAY RIVER – OCTOBER 2016 EVENT

At the McCoys Bridge gauge on the Goulburn River, the model simulated the timing of peak flow and water level quite well as shown in Figure 3-24, with the modelled water level around 30 cm lower than the recorded level.

A comparison of the modelled flood extent to the flood imagery is provided below in Figure 3-25 to Figure 3-31. Both of the available images were not taken at the peak of the flood event and so need to be used with caution. The modelled flood extent was extracted 3 days prior to the modelled peak at Echuca Wharf and 7 days after the modelled peak at Echuca Wharf. Observed flooding is also difficult to discern in the imagery due to the presence of bushland and vegetation.

A satellite flood image was sourced from National Map for the 25th October 2016, Figure 3-32. The image shows inundation and where inundation has been quite clearly with the darker green and brown colours. The modelled inundation matches the satellite image closely except in the east Moama area, where the extent is broader. An analysis of the LiDAR topography suggests the modelled level may be approximately 30 cm too high in this area for the 2016 flood event, a similar margin to that from the comparison of the peak flood levels at the Echuca Wharf gauge.

Figure 3-33 to Figure 3-35 provide modelled flood depth maps of zoomed in areas across Echuca and Moama.

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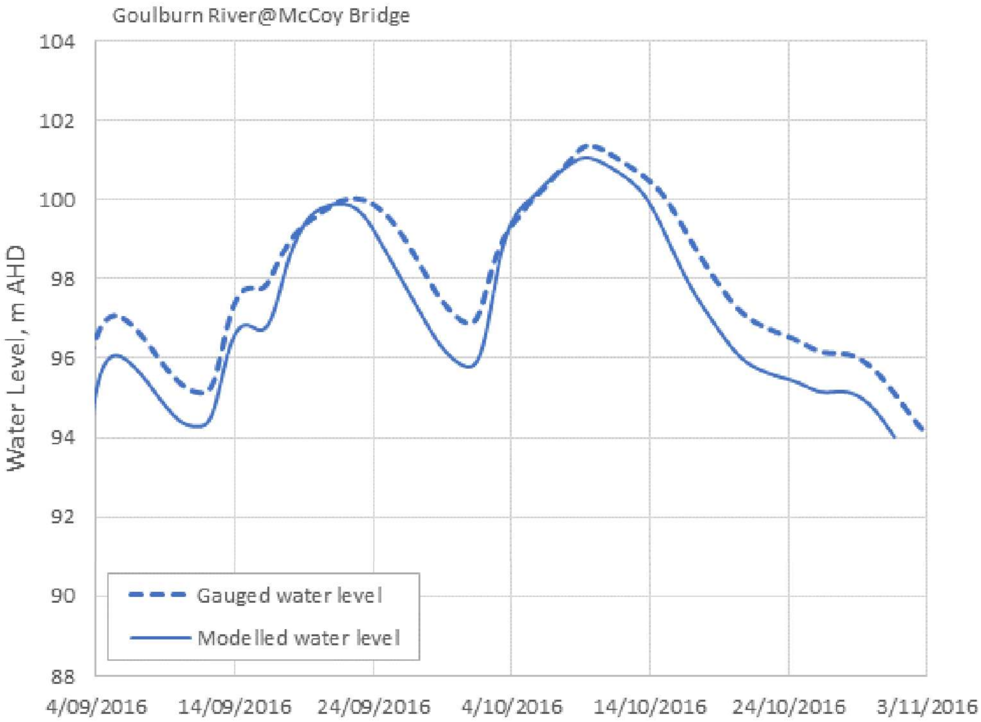

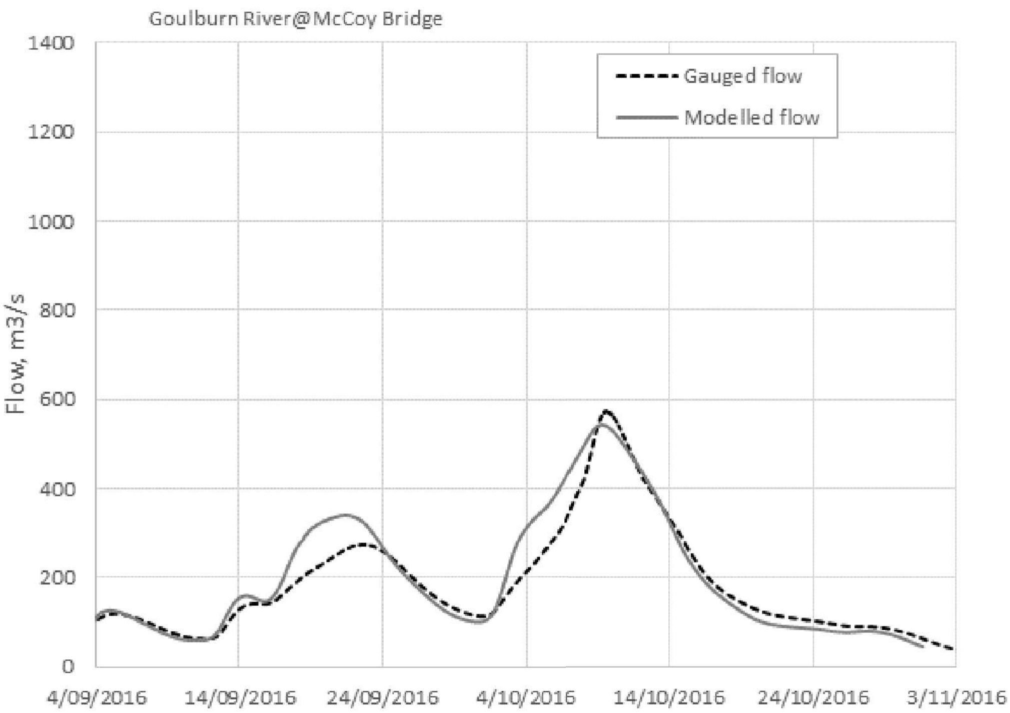

FIGURE 3-24 COMAPRISON OF WATER LEVEL AND FLOW AT MCCOYS BRIDGE GAUGE ON GOULBURN RIVER - OCTOBER 2016 EVENT

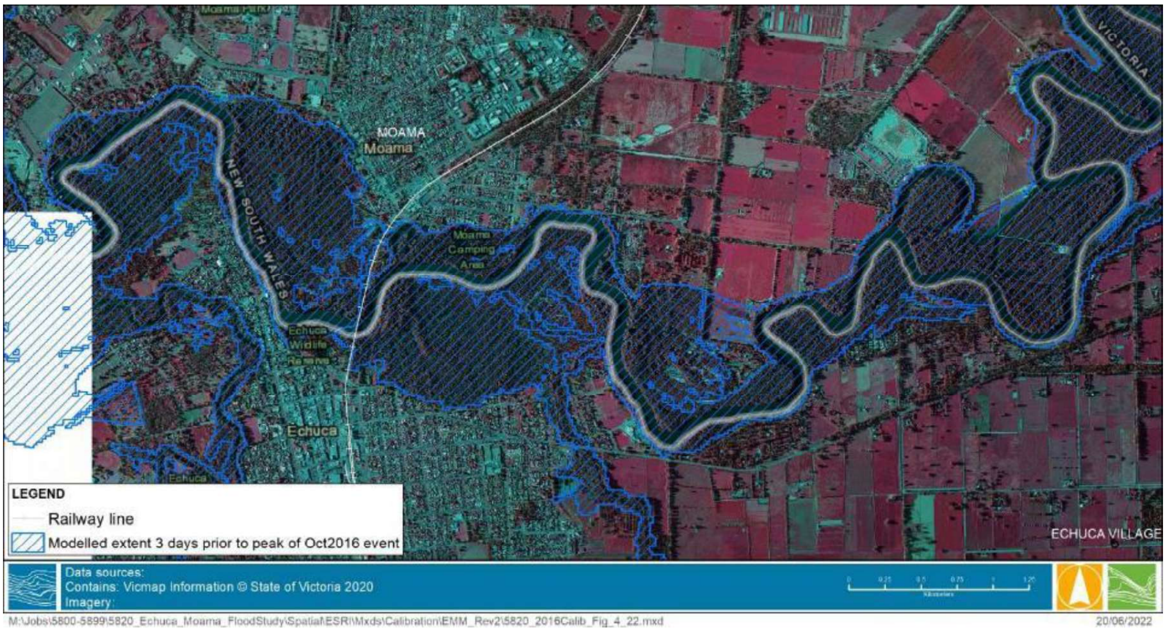

FIGURE 3-25 COMPARISON OF MODEL RESULTS TO FLOOD IMAGERY, 13 OCTOBER 2016 – ECHUCA-MOAMA AREA. NOTE: THE IMAGERY WAS CAPTURED 3 DAYS PRIOR TO THE FLOOD PEAK AT ECHUCA

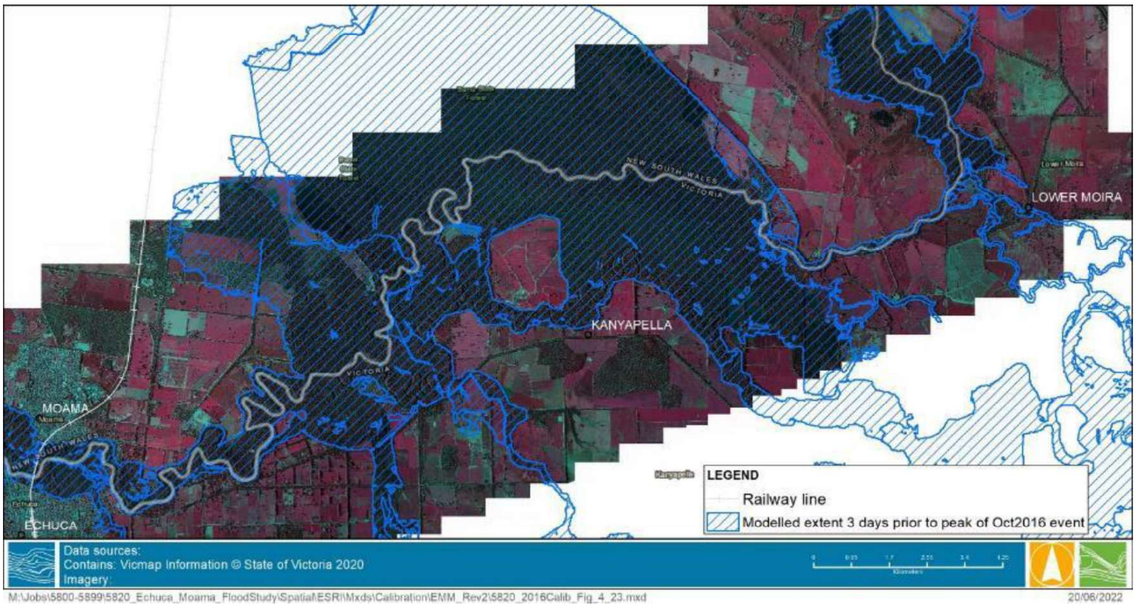

FIGURE 3-26 COMPARISON OF MODEL RESULTS TO FLOOD IMAGERY CAPTURED ON 13 OCTOBER 2016 – ECHUCA-MOAMA AREA. NOTE: THE IMAGERY WAS CAPTURED 3 DAYS PRIOR TO THE FLOOD PEAK AT ECHUCA

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FIGURE 3-27 COMPARISON OF MODEL RESULTS TO FLOOD IMAGERY CAPTURED ON 13 OCTOBER 2016 –MOAMA AREA. NOTE: THE IMAGERY WAS CAPTURED 3 DAYS PRIOR TO THE FLOOD PEAK AT ECHUCA

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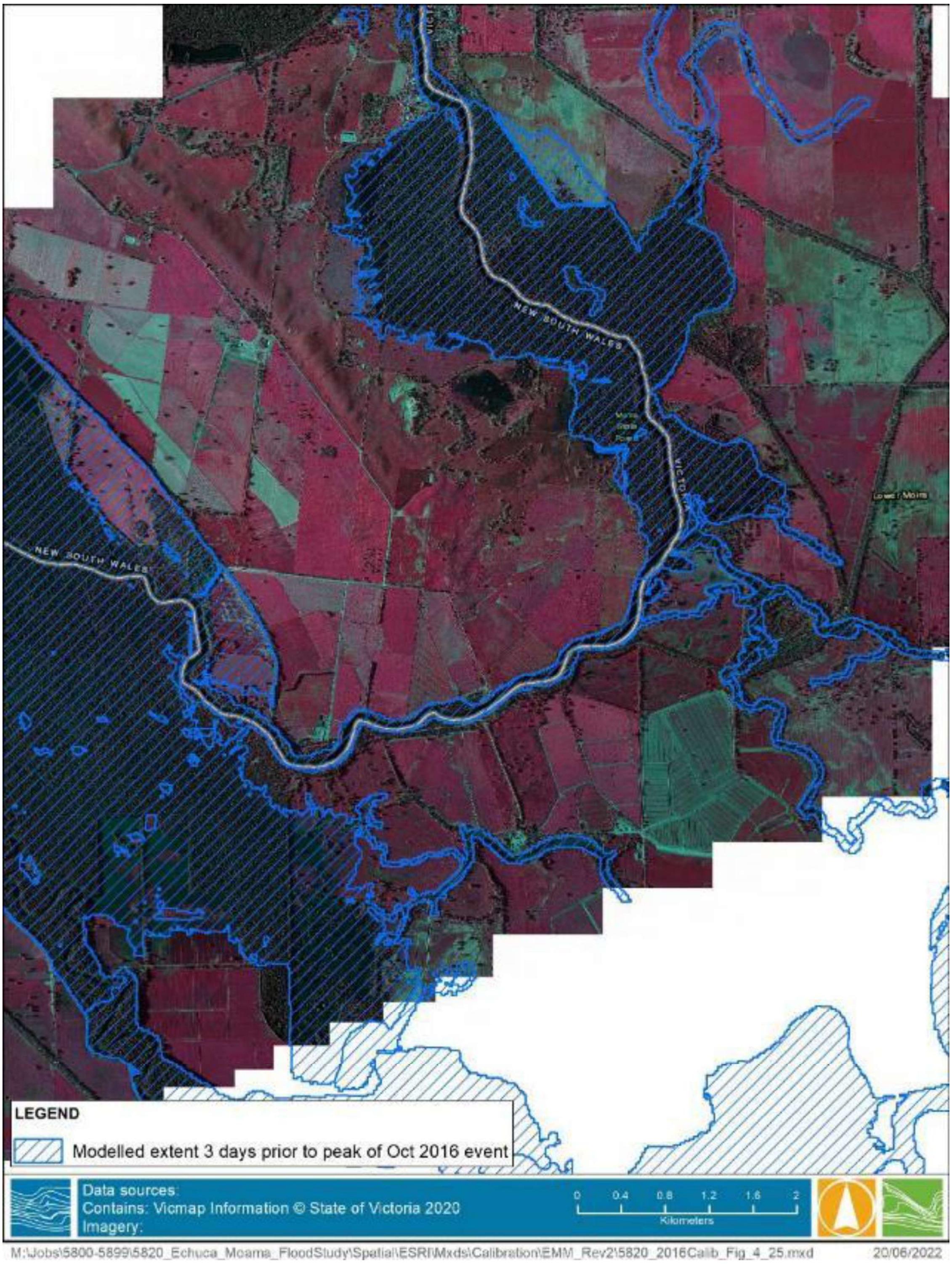

FIGURE 3-28 COMPARISON OF MODEL RESULTS TO FLOOD IMAGERY, 13 OCTOBER 2016 –BARMAH NOTE: THE IMAGERY WAS CAPTURED 3 DAYS PRIOR TO THE FLOOD PEAK AT ECHUCA

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FIGURE 3-29 COMPARISON OF MODEL RESULTS TO FLOOD IMAGERY, 23 OCTOBER 2016 – ECHUCA-MOAMA AREA. NOTE: THE IMAGERY WAS CAPTURED ONE WEEK AFTER THE FLOOD PEAK AT ECHUCA

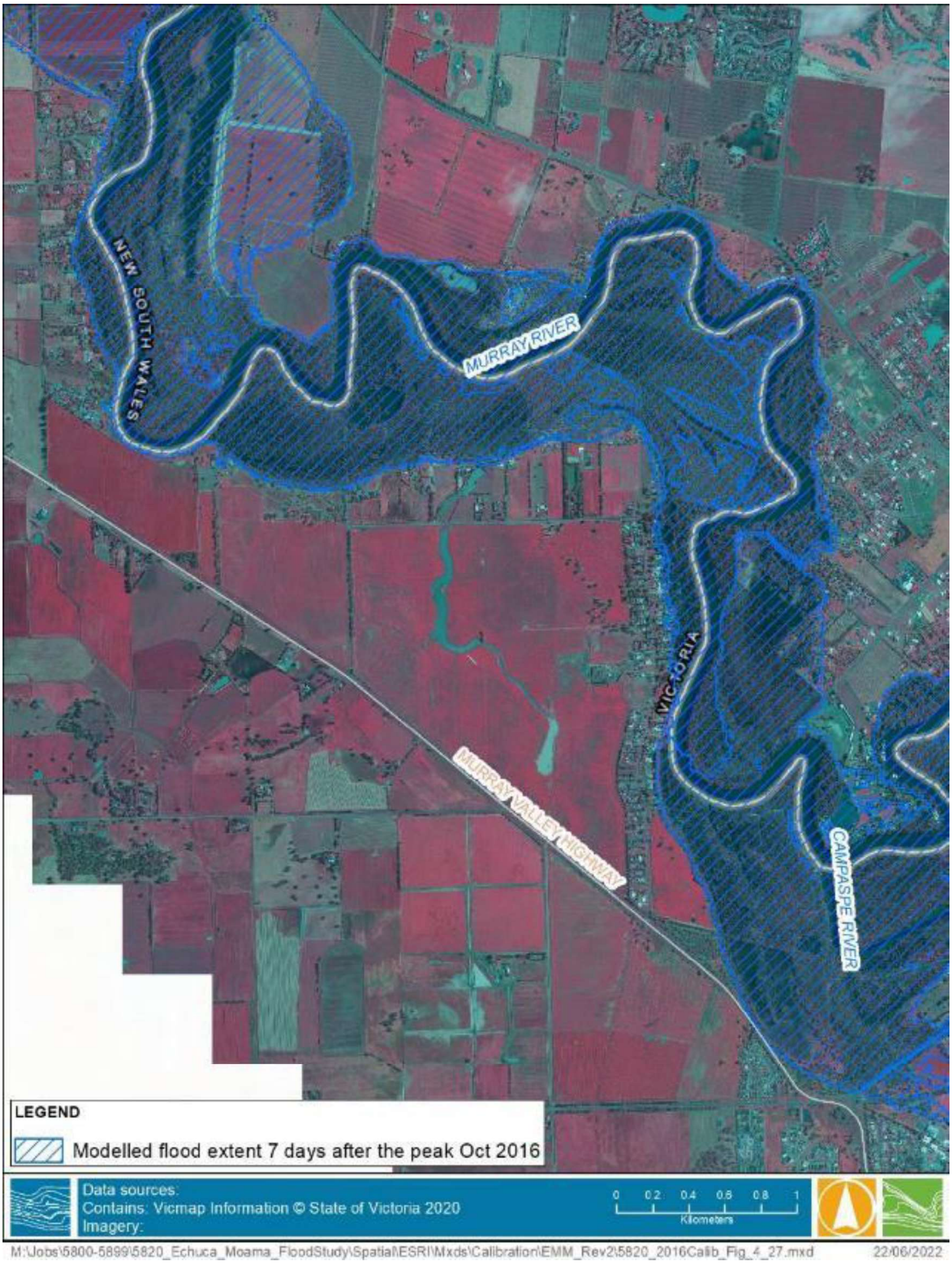

FIGURE 3-30 COMPARISON OF MODEL RESULTS TO FLOOD IMAGERY, 23 OCTOBER 2016 – MEROOL HOLIDAY PARK NOTE: THE IMAGERY WAS CAPTURED ONE WEEK AFTER THE FLOOD PEAK AT ECHUCA

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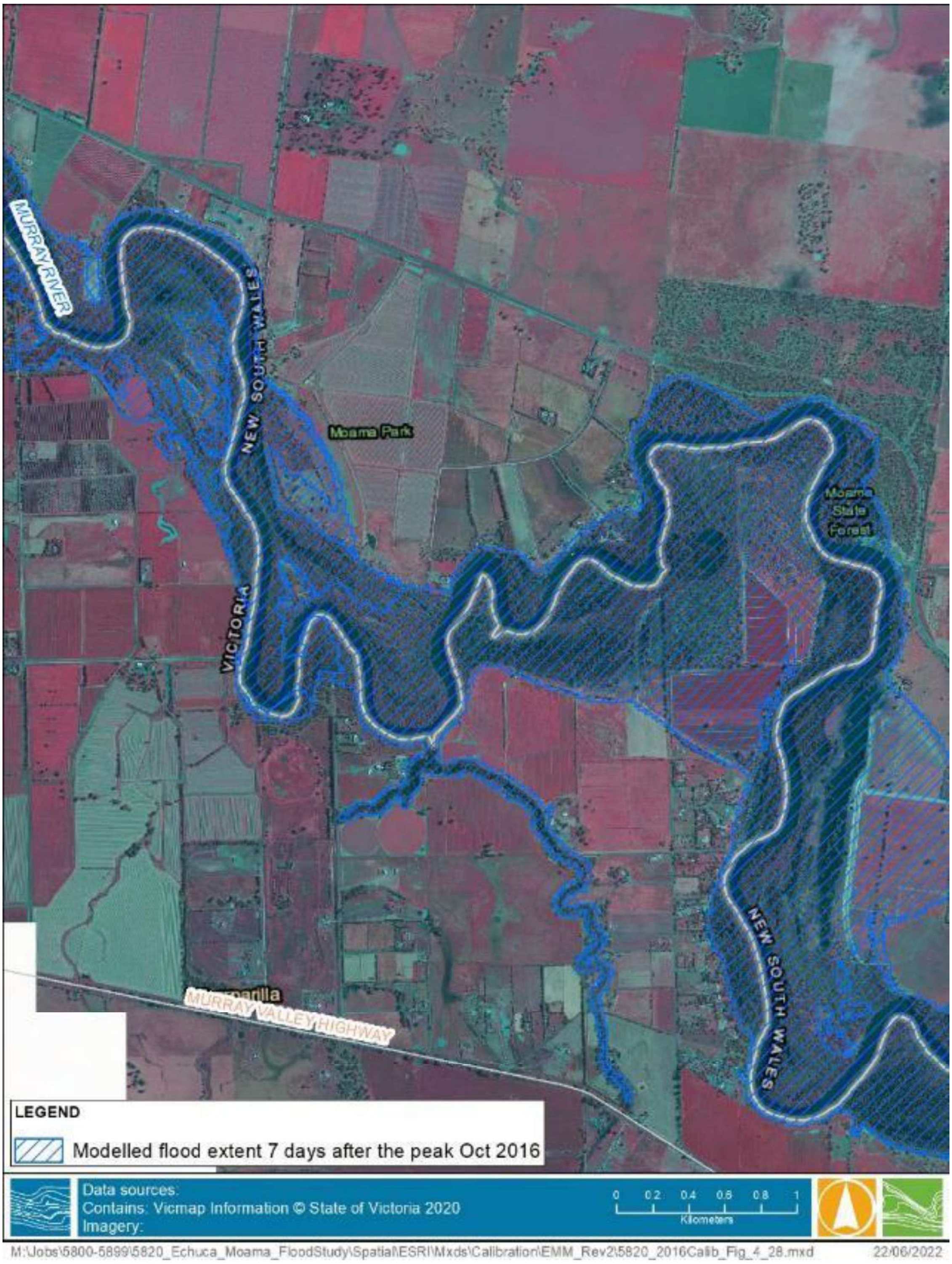

FIGURE 3-31 COMPARISON OF MODEL RESULTS TO FLOOD IMAGERY, 23 OCTOBER 2016 – WHARPARILLA NOTE: THE IMAGERY WAS CAPTURED ONE WEEK AFTER THE FLOOD PEAK AT ECHUCA

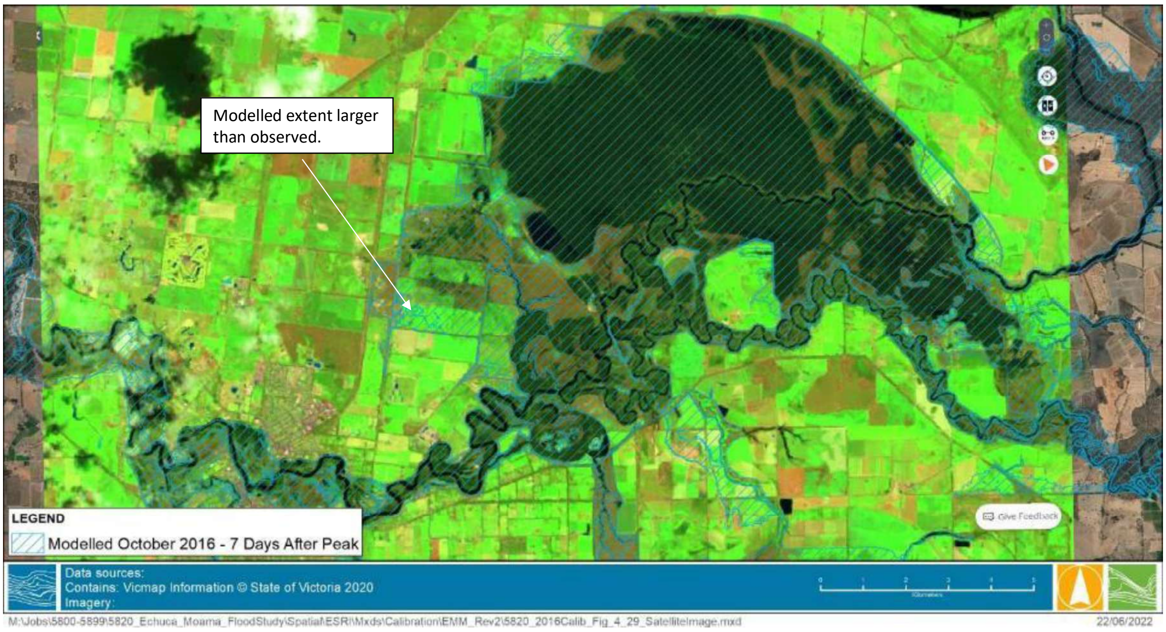

FIGURE 3-32 COMPARISON OF MODEL RESULTS TO SATELLITE FLOOD IMAGERY (25 OCTOBER 2016 – NATIONAL MAP)

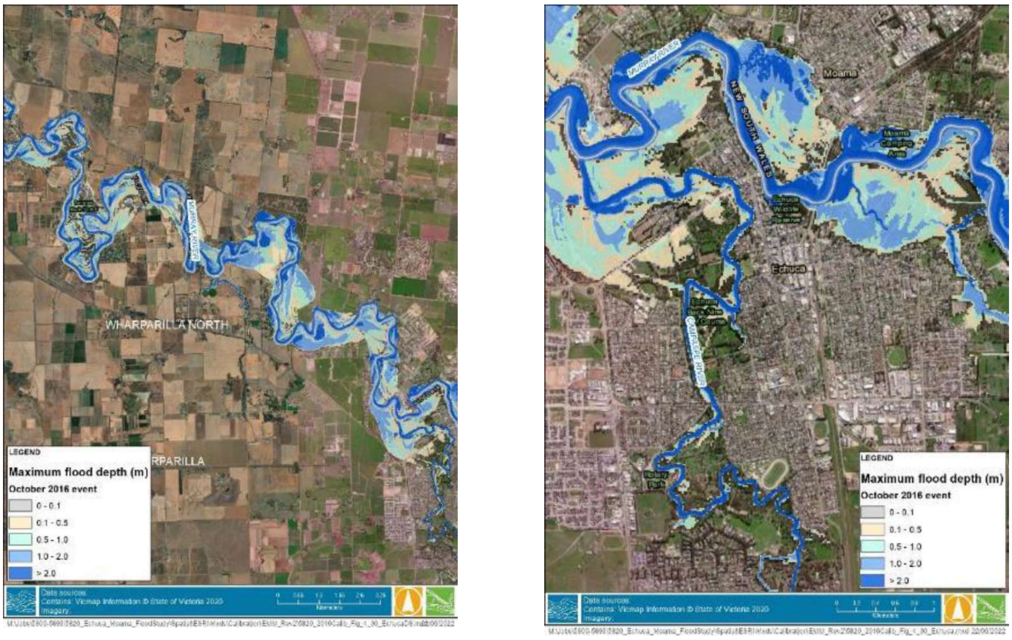

FIGURE 3-33 MODELLED FLOOD DEPTH, OCTOBER 2016 – LEFT: ECHUCA TOWN; RIGHT: DOWNSTREAM OF ECHUCA-MOAMA AREA

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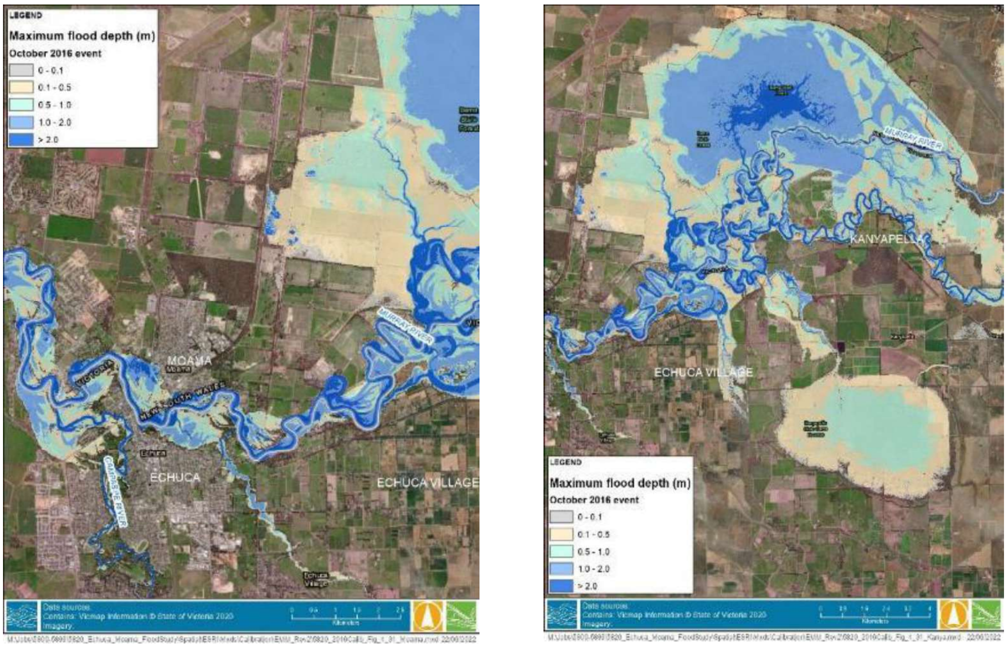

FIGURE 3-34 MODELLED FLOOD DEPTH, OCTOBER 2016 – LEFT: MOAMA AREA; RIGHT: ECHUCA VILLAGE / KANYAPELLA AREA

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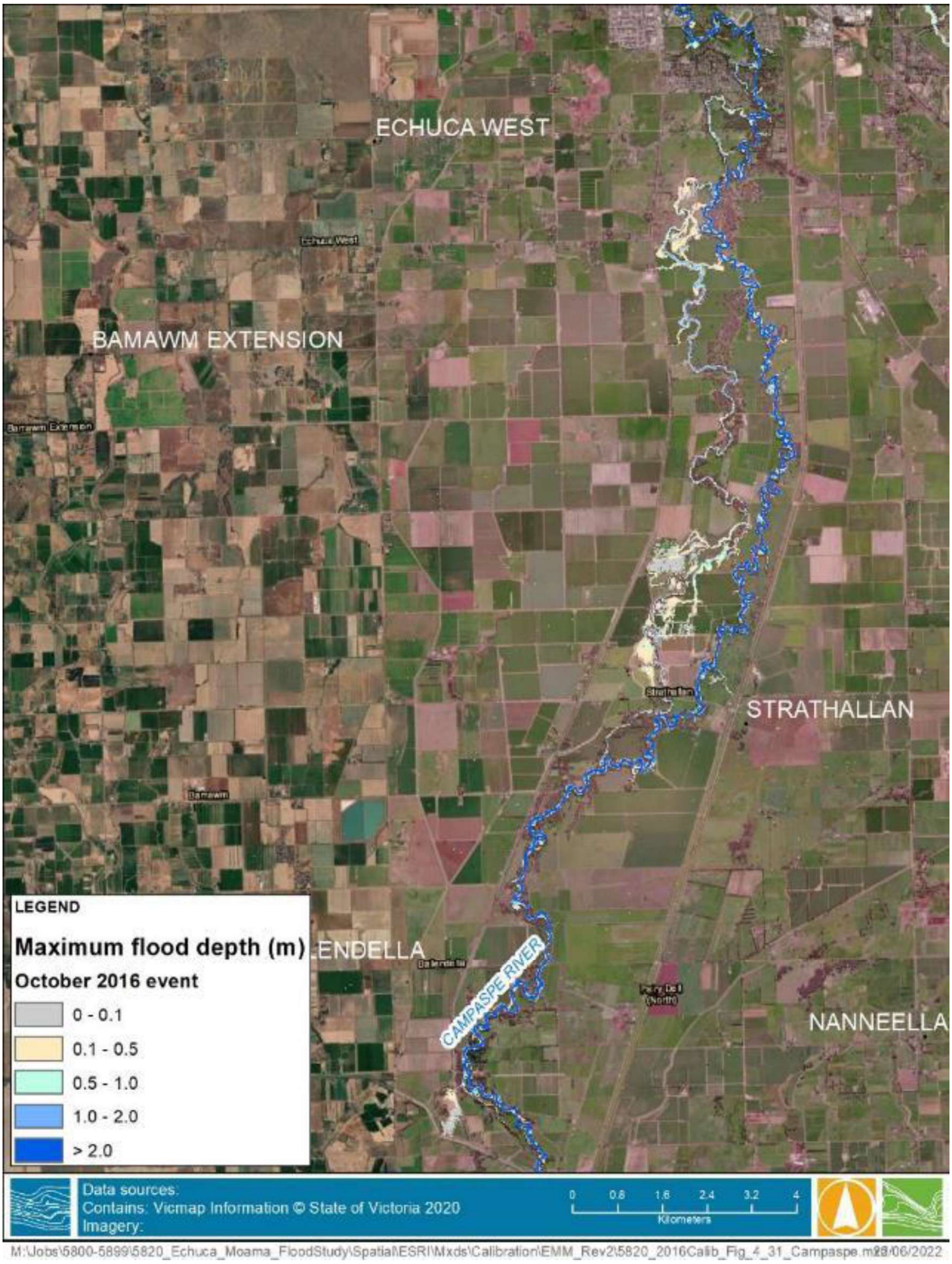

FIGURE 3-35 MODELLED FLOOD DEPTH, OCTOBER 2016 – CAMPASPE RIVER

3.3.4 October 2022 Event

The draft Echuca Moama Flood Study Report was about to commence the formal community consultation process when the October 2022 flood event occurred. It was subsequently decided that the additional information gathered during the October 2022 flood should be incorporated into the modelling to improve the accuracy of the model. Specifically, the lower Goulburn River levees were a focus for improvement, with the model predicting widespread inundation that did not occur during October 2022. It was found that the levee crests were not represented well in many locations, and that there were also irrigation channel banks and roads in the area acting like levees which were not in the model. In addition, there were two regulating structures at Warrigal Creek and Yambuna Outfall that were not represented in the model and were allowing water to spill into the Kanyapella Basin.

Significant rainfall in the Goulburn River catchment around October 13th on a saturated catchment resulted in a peak flow of 170,000 ML/d at the Goulburn River at Shepparton gauge on the 17th of October. The peak flow at the Goulburn River at Shepparton gauge was estimated to have a probability of around 1.5% AEP.

A number of the lower Goulburn River levees were breached in several locations, predominantly on the northern bank of the river. Combined with relatively high flows in the Murray River, the Goulburn River inflows saw the Murray River at Echuca Wharf gauge reach a peak flood level of 94.99 m AHD, which places it in the top 10 historic flood levels recorded since the 1860s, but a long way short of the largest ever recorded flood level of 96.19 m AHD in the 1870 flood.

3.3.4.1 Data Collection

The October 2022 event had involvement from a lot of authorities and volunteer organisations across both NSW and Victoria in the emergency response and data collection. The types of data collected and provided for the study included:

- Photographs
- Surveyed flood marks
- Locations, types and alignments of temporary levees
- Levee breach locations and data
- Measured flow data
- Directions provided for flood response decisions
- Anecdotal information from landowners

This data assisted in the hydraulic model setup and validation of results to ensure the most robust and accurate results are obtained to represent the events during the October 2022 flood.

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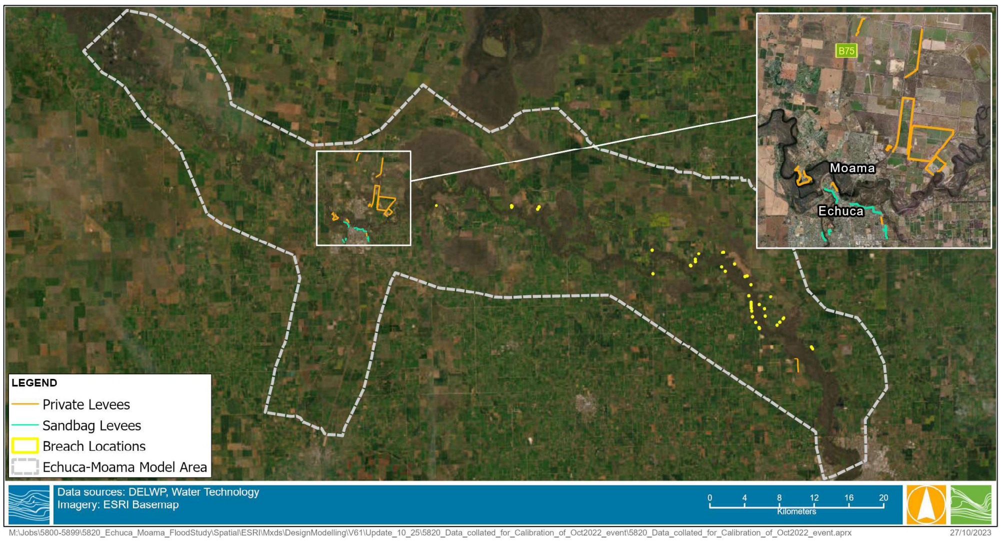

FIGURE 3-36 DATA COLLATED FOR CALIBRATION OF OCT 2022 EVENT

3.3.4.2 Refinement of gauge flows

While the gauge flow data at Shepparton and Barmah provide reliable boundary conditions for the model, the gauge on the Campaspe River at the Waranga Western Channel Syphon is known to have an unreliable rating table for flows above 22,000 ML/day (~255 m^3/s) (DEECA, 2023). This was confirmed by an initial run using the gauge data unedited, which resulted in water extents and levels being much wider and higher (~0.5 m too higher at Echuca) than observed along the Campaspe River. The rating curve for the Rochester gauge shown in Figure 2-21 indicates the unreliability with the flattening off of the curve for the upper level flow rates.

The hydrograph obtained from the gauge was modified above the 22,000 ML/day flow to better represent the actual flooding during the event. The event in October 2022 was estimated at a 0.2% (1 in 500) AEP for the Campaspe River, so the design peak flow for the event was used to set a new peak of 89,726 ML/d, reduced from the raw gauge peak of 146,943 ML/day. The timing and shape of the hydrograph from the gauge was maintained, with values above 22,000 ML/day interpolated to the modified peak as shown in Figure 3-37.

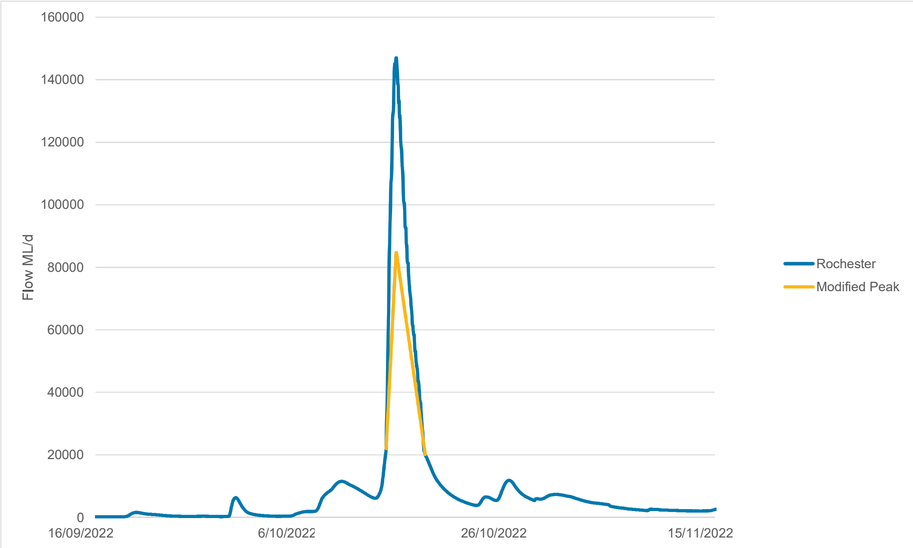

FIGURE 3-37 MODIFIED PEAK FOR CAMPASPE RIVER AT ROCHESTER

A run of the calibration model identified that flood levels were still slightly higher than observed along the Campaspe River. The peak flow was reduced slightly to 84,672 ML/day, which resulted in a good correlation of flood levels with observed data and was adopted for the final calibration.

3.3.4.3 Model Changes and additions

The previously calibrated design model was utilised as the starting point for the October 2022 event calibration model. Information obtained from the event helped identify features that required refinement within the model and confirmed other features as being accurate. Some of the changes made were due to actions taken during the flood event, such as temporary levees and repairs to flood gates.

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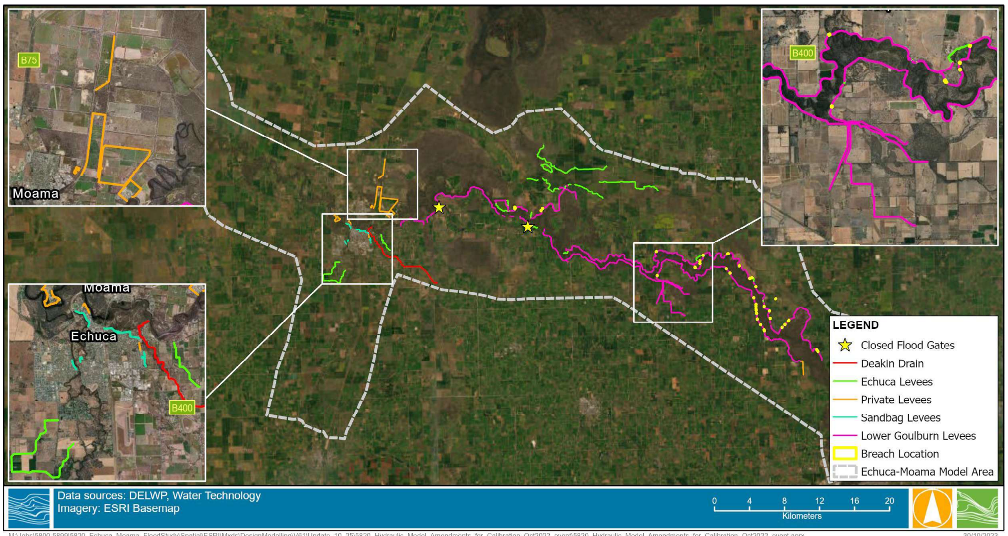

FIGURE 3-38 HYDRAULIC MODEL AMENDMENTS FOR CALIBRATION OF OCT 2022 EVENT

A list of the changes to the model to allow better matching with observed flood levels and extents are as follows:

- Inclusion of private levees that were constructed during the event
- Temporary earthen levee along Anstruther St/Pakenham St area in Echuca
- Temporary sandbag levees throughout the towns, with locations provided by Councils
- Adjustment to Meninya St floodway bridge to more accurately represent the full bridge opening width
- Addition of bridge crossings over Wells Creek
- Closing off flood gates that were left open at Warrigal Creek and Yambuna Outfall in previous models, and simulated Warrigal Creek flood gate failure and repair over a 3 hour period based on anecdotal information provided by a combination of sources.
- Levee breach locations and breach widths along the Goulburn River between Loch Garry and Barmah. Levee Breach information was provided by The Goulburn Broken CMA, with locations and breach widths estimated by aerial photography. The timing of breaches was estimated to coincide with peak flood levels at adjacent locations.
- Improvements to modelled levee crest heights using lidar information.
- Improved representation of irrigation channel banks with breaklines along Rodneys Drain and private drains east of the Deakin Main Drain, as well as improved representation of the Deakin Main Drain invert.
- The 2D code layer was expanded along the Barmah-Shepparton Road out to the No. 12 Irrigation channel to better represent flow over the road that was observed during the event.
- A Quad-tree polygon over a portion of the model in Moama, east of the railway was removed to improve model performance. This did not have a significant impact in flood level difference, with sensitivity testing showing most flood levels in the area within 20 mm of the previous model version.

3.3.4.4 Hydraulic Roughness

The hydraulic roughness values in the main waterways and the adjacent floodplain were initially adopted as per the previous calibration events. Although peak levels were being matched well initially, the timing of the peak and subsequent receding of flood levels was too quick compared to gauge records at Echuca Wharf. The hydraulic roughness, Mannings n value, was modified for the model iteratively to achieve a better fit of the gauge water level timings.

It was found that the timing of the Campaspe River floodplain did not improve much with modifications to the Mannings, therefore it was decided to maintain the previous values for the Campaspe River. Updating the mannings values had limited impact on the Campaspe due to the definition of the Tuflow materials layer in this area. The modifications to the Mannings n value were focussed on the Murray and Goulburn Rivers and their floodplains. A better fit with timing, while maintaining the peak water level at Echuca Wharf was achieved as shown in Figure 3-39. Further information on the hydraulic roughness is discussed in Section 2.7.

3.3.4.5 Gauge Comparison

Modelled water levels were compared to gauged levels along the Murray River (Echuca Wharf and downstream of Campaspe River), the Campaspe River at Echuca and the Goulburn River at McCoys Bridge for the October 2022 event. The results are summarised below in Table 3-5.

The model result matches the peak level recorded at Echuca Wharf to within 2 cm. The model matches just as close with the levels for Campaspe River at Echuca and Murray River at downstream of Campaspe River gauges.

At the McCoys Bridge gauge on the Goulburn River, the modelled peak water level is higher by 26 cm. A possible reason for the elevated modelled levels is the estimated timing of the breaches along the levees on the north side of the Goulburn River in the vicinity of the gauge. Improving the difference observed in this area may be difficult to match effectively due to extensive iteration of breach timing that would not be feasible within the timeframes of the study.

TABLE 3-5 COMPARISON OF PEAK WATER LEVEL FOR THE OCTOBER 2022 FLOOD EVENT

Gauge	Recorded Peak Water Level (m)	Modelled Peak Water Level (m)
Murray River at Echuca Wharf (409200)	94.99	94.97
Goulburn River @ McCoys Bridge (405232)	102.02	102.28
Campaspe River @ Echuca (406265)	96.25	96.26
Murray River @ D/S Campaspe Pianta Road (409222)	93.75	93.77

The comparison of recorded water level at the Murray River at Echuca Wharf gauge to the modelled water levels is shown in Figure 3-39. The comparison shows that the peak values and shape of curve are similar, however the timing of the peak is slightly out for the Murray River. The modification of hydraulic roughness discussed in Section 3.3.4.4 brought the timing as close as possible to the gauged data without increasing the peak level. Any further increases in Mannings values in the upstream catchments to match the timing would increase the modelled level above the gauge level.

The comparison of recorded water level at the Campaspe River at Echuca to the modelled water levels is shown in Figure 3-40. The comparison shows that the peak values and shape of curve are matching quite well to the recorded data.

The recorded water level was also compared at the Goulburn River at McCoys Bridge gauge and is shown in Figure 3-41. The comparison shows that the shape and timing of the modelled levels are similar to the recorded, however the peak water level is overestimated in the model. There is uncertainty around the timing of breaches within the vicinity of the gauge, possibly explaining the discrepancy in the observed and modelled levels. The drop in water levels after the levee breaches occur can be seen in both the modelled and recorded water levels, with the impact more pronounced in the model than the observed levels.

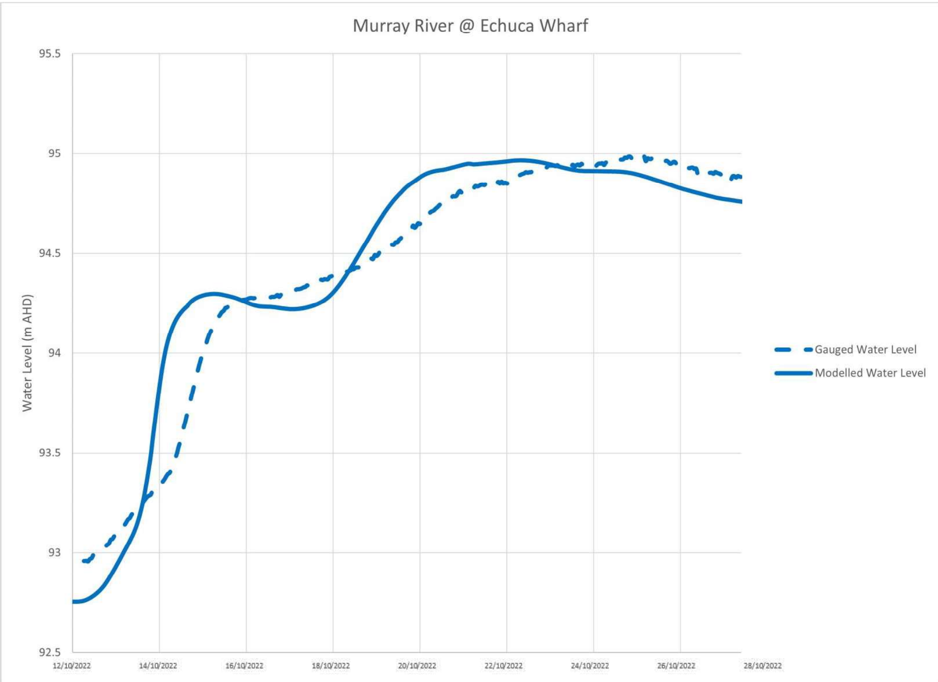

FIGURE 3-39 COMPARISON AT MURRAY RIVER @ ECHUCA WHARF (405200) – OCT 2022 EVENT

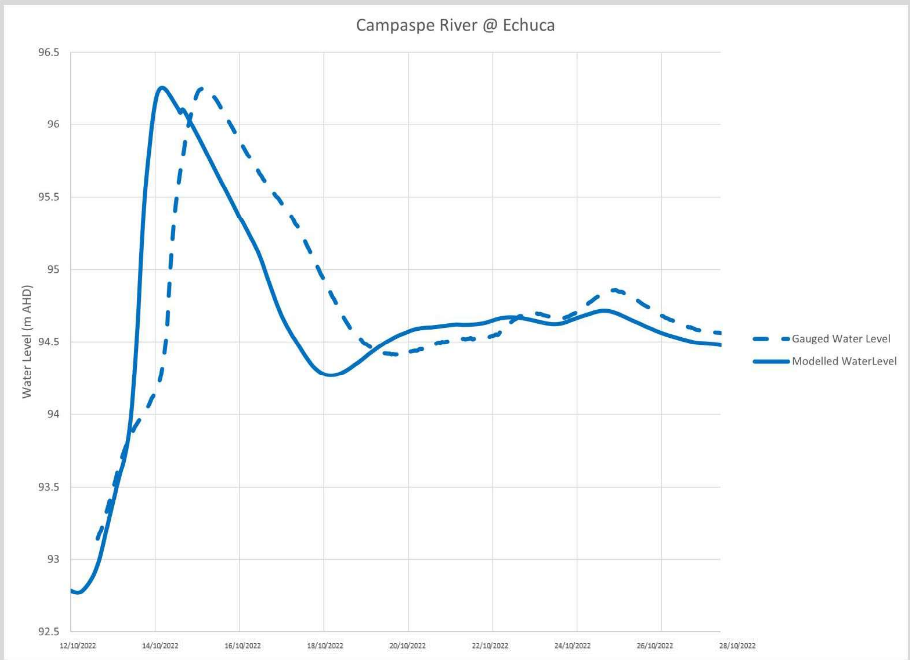

FIGURE 3-40 COMPARISON AT CAMPASPE RIVER @ ECHUCA (406265) – OCT 2022 EVENT

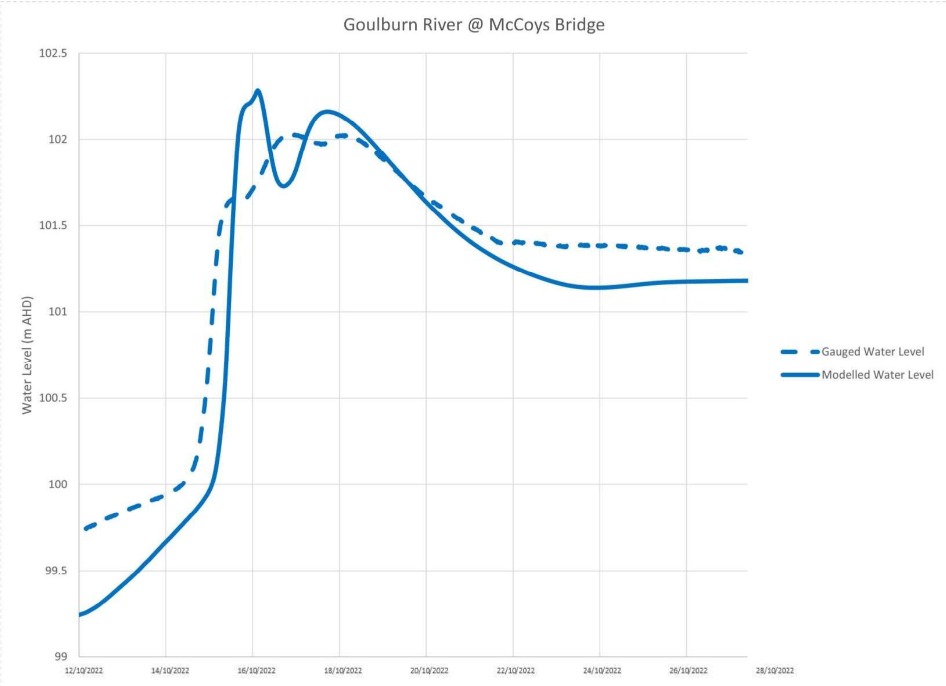

FIGURE 3-41 COMPARISON AT GOULBURN RIVER @ MCCOYS BRIDGE GAUGE (405232) – OCTOBER 2022 EVENT

3.3.4.6 Surveyed Flood Marks

The October 2022 event was calibrated using available surveyed flood marks along the Goulburn, Campaspe and Murray River floodplains.

The surveyed data points were received from three sources:

- Survey by Rich River Irrigation Developments – Moama and areas east of Echuca (59 marks)
- Survey by Rich River Irrigation Developments – Echuca along the Campaspe River (22 marks)
- Survey by Spiire – Shepparton, Mooroopna and Lower Goulburn area (222 marks)

There were some flood marks that had a large discrepancy to surrounding marks nearby, which were likely incorrectly surveyed, however they were kept within the assessment.

The modelled peak flood levels compare well to the survey within Echuca and Moama. The rest of the flood marks are located further upstream close to Barmah on the Murray River and McCoys Bridge on the Goulburn River. These have varying levels of correlation with the model results.

The model results were compared with the surveyed flood levels and the difference was calculated (modelled minus recorded water surface elevation). Across the study area, approximately 56% of modelled water levels were within +/- 0.2 m of the recorded levels. Around 68% of modelled points were within +/- 0.3 m of the recorded levels.

When looking at the Echuca-Moama flood marks in isolation (the key focus area of the study), the results improve with approximately 82% of modelled water levels were within +/- 0.2 m of the recorded levels About 88% of modelled points were within +/- 0.3 m of the recorded levels.

Figure 3-42 shows the distribution of the difference in height between the modelled and recorded flood levels. Figure 3-43 shows the distribution of the surveyed levels and modelled differences across the study area. Overall, the calibration to the surveyed flood levels is considered to be a suitable representation of the model behaviour for the October 2022 flood event, especially within the main focus area of the study.

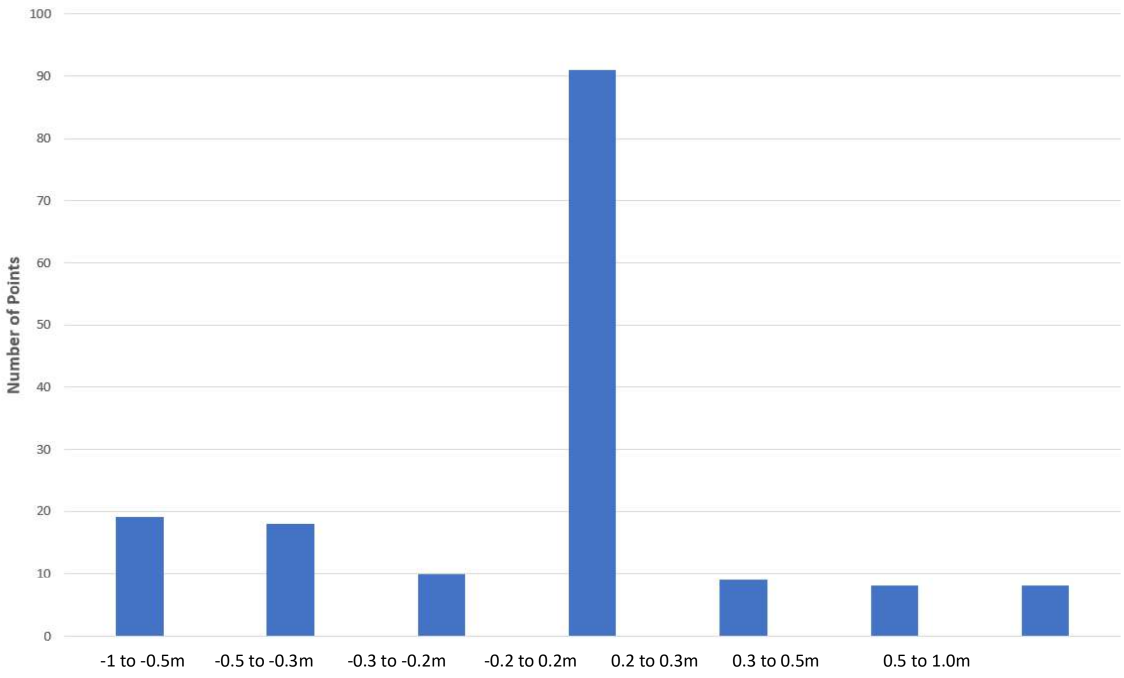

FIGURE 3-42 MODELLED AND HISTORIC FLOOD MARKS DIFFERENCE – OCTOBER 2022 EVENT

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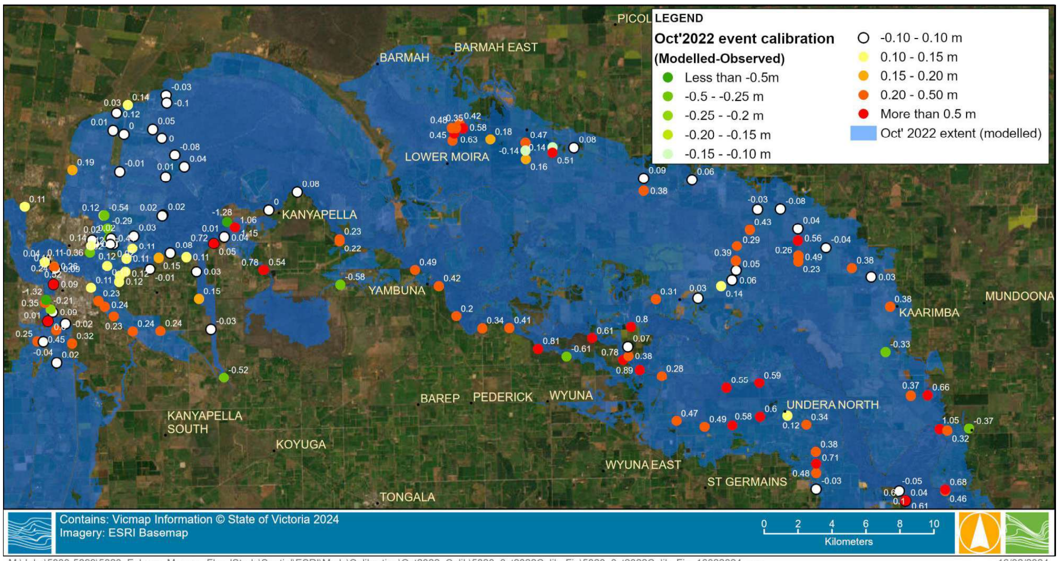

FIGURE 3-43 COMPARISON OF MODEL RESULTS TO FLOOD MARKS, OCTOBER 2022

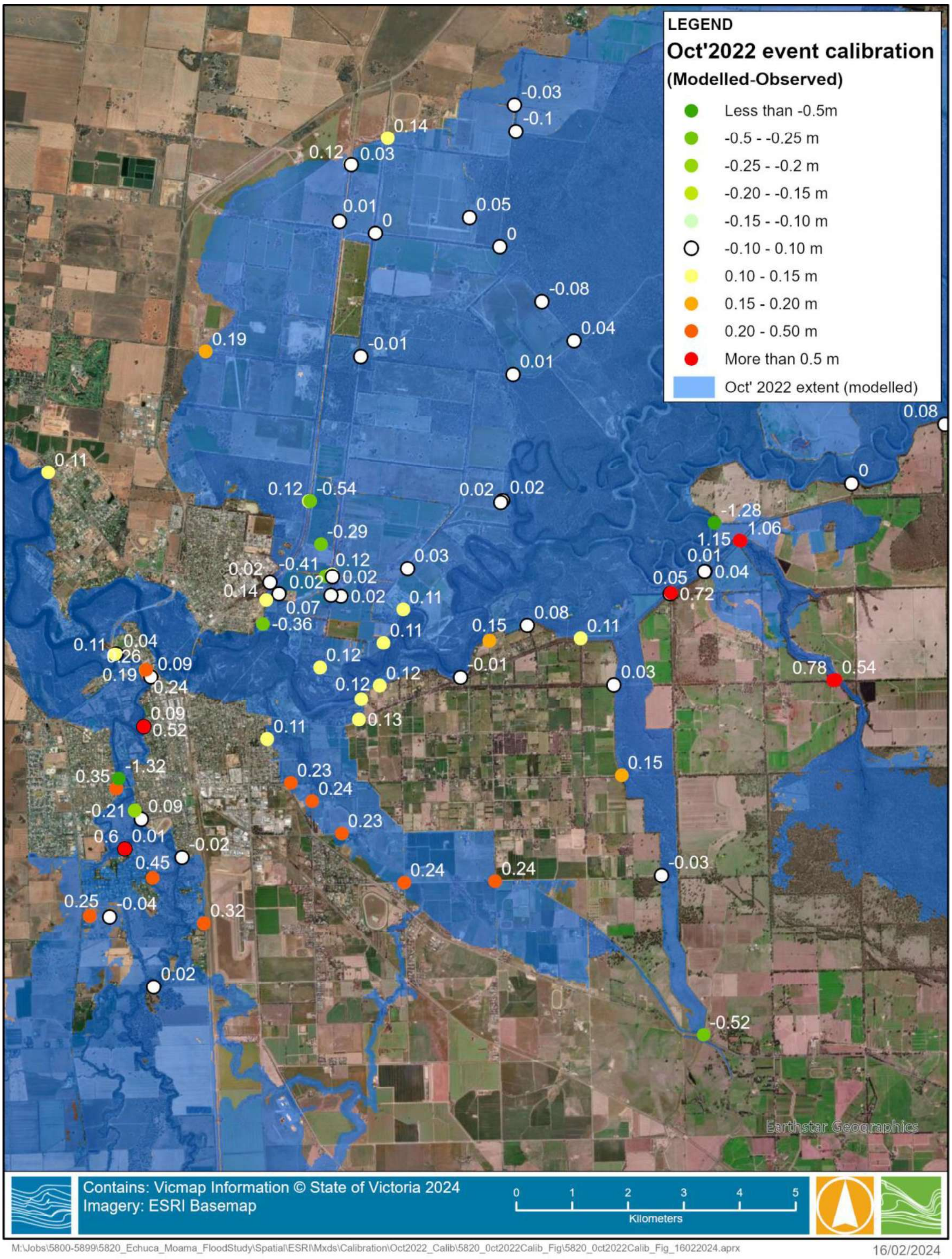

FIGURE 3-44 COMPARISON OF MODEL RESULTS TO FLOOD MARKS (ECHUCA-MOAMA), OCTOBER 2022

3.3.4.7 Flood Imagery

The model was also validated by comparing the model results to available satellite flood imagery and aerial photos captured during the flood event. The two most relevant satellite flood images and two of the available aerial photos are described below:

- Satellite image taken on 17th October 2022, sourced from Sentinel Playground online resource.
- Satellite image taken on 6th November 2022, sourced from Sentinel Playground online resource.
- Two aerial photos taken in east Echuca 25th October 2022, sourced from Victoria SES.

Satellite imagery was available for dates at the peak in Echuca – Moama, however they were obstructed by cloud cover. The two dates selected were the closest dates either side of the peak that were clear enough to assess extents.

The satellite flood image captured on 17th October was compared to the modelled extent at the same point in the model run and shown in Figure 3-45. The image is prior to the peak at Echuca however shows inundation in the lower Goulburn River between Shepparton, Loch Garry and Barmah. This was approximately the peak of the flood event in Shepparton with areas of Echuca-Moama townships yet to be inundated. The modelled inundation matches the satellite image closely for the lower Goulburn areas at the equivalent time in the model. The areas north of Loch Garry have a similar extent caused by flows leaving the main floodplain through a number of levee breaches. At the extracted timestep of the model (matching the satellite imagery timing), the areas to the west of Loch Garry weren't inundated as the breaches in the levee hadn't occurred in the model yet. However, by the next extracted timestep, 8 hours later there was similar extent in that area after the breaches had occurred (Figure 3-46).

The satellite flood image captured on 6th November was over a week after the peak at Echuca, however low-lying areas were still inundated and indicated how far the maximum flood extent reached for comparison with the modelled peaks.

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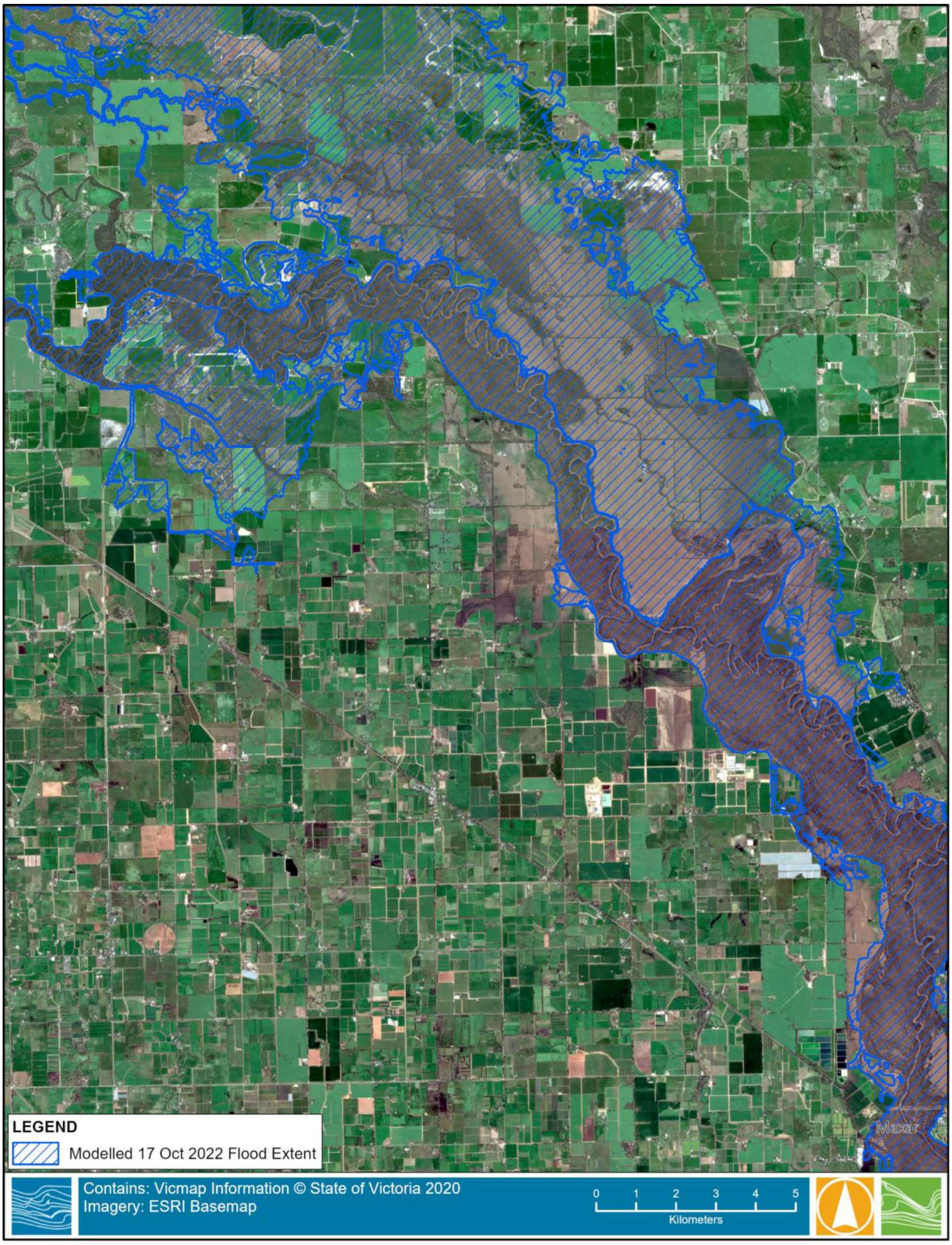

FIGURE 3-45 COMPARISON OF MODEL RESULTS TO SATELLITE IMAGERY CAPTURED ON 17TH OCTOBER 2022 – THE IMAGERY WAS CAPTURED ONE WEEK PRIOR TO THE FLOOD PEAK AT ECHUCA

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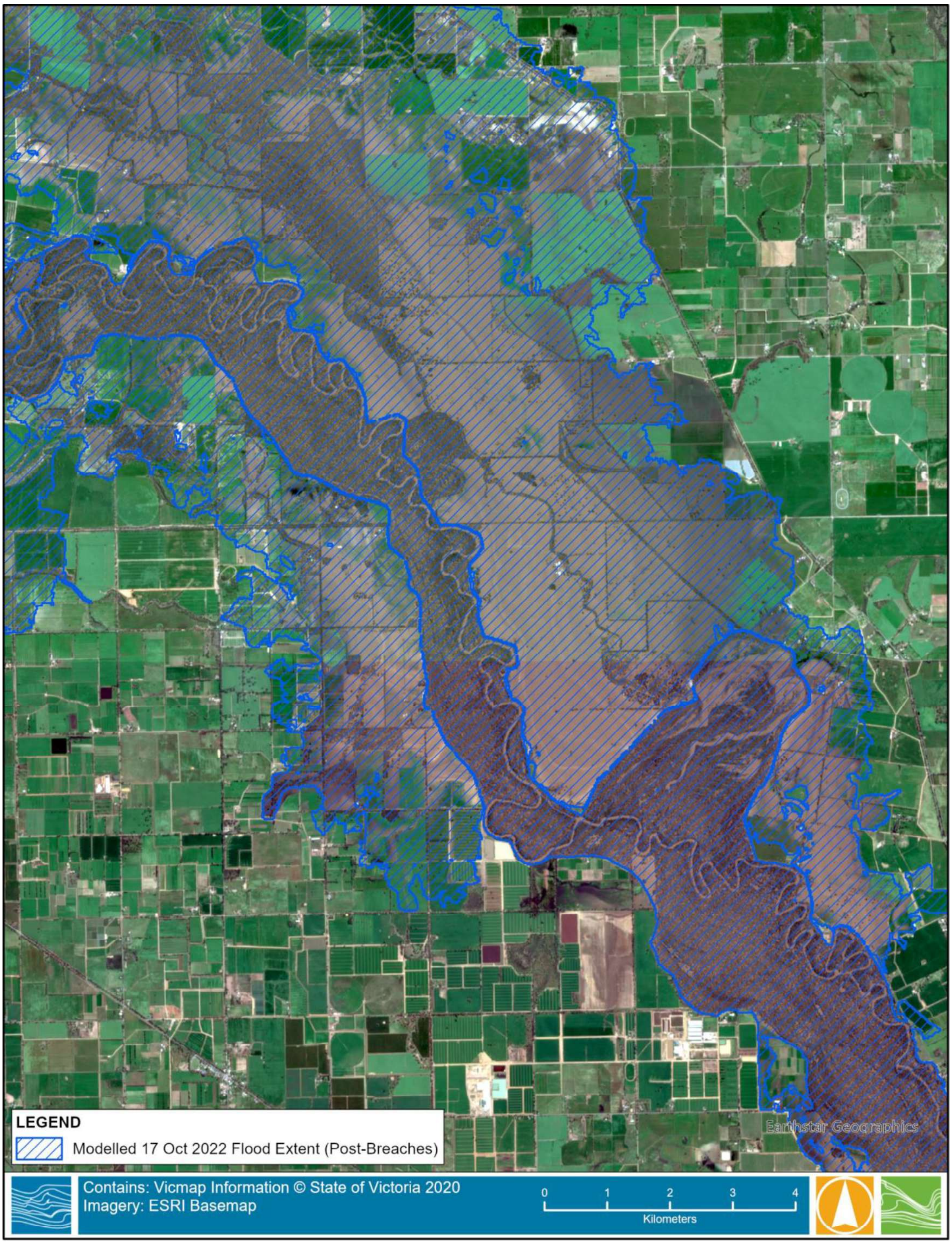

FIGURE 3-46 COMPARISON OF MODEL RESULTS TO SATELLITE IMAGERY CAPTURED ON 17TH OCTOBER 2022 – WEST OF LOCH GARRY AFTER BREACHES OCCURRED

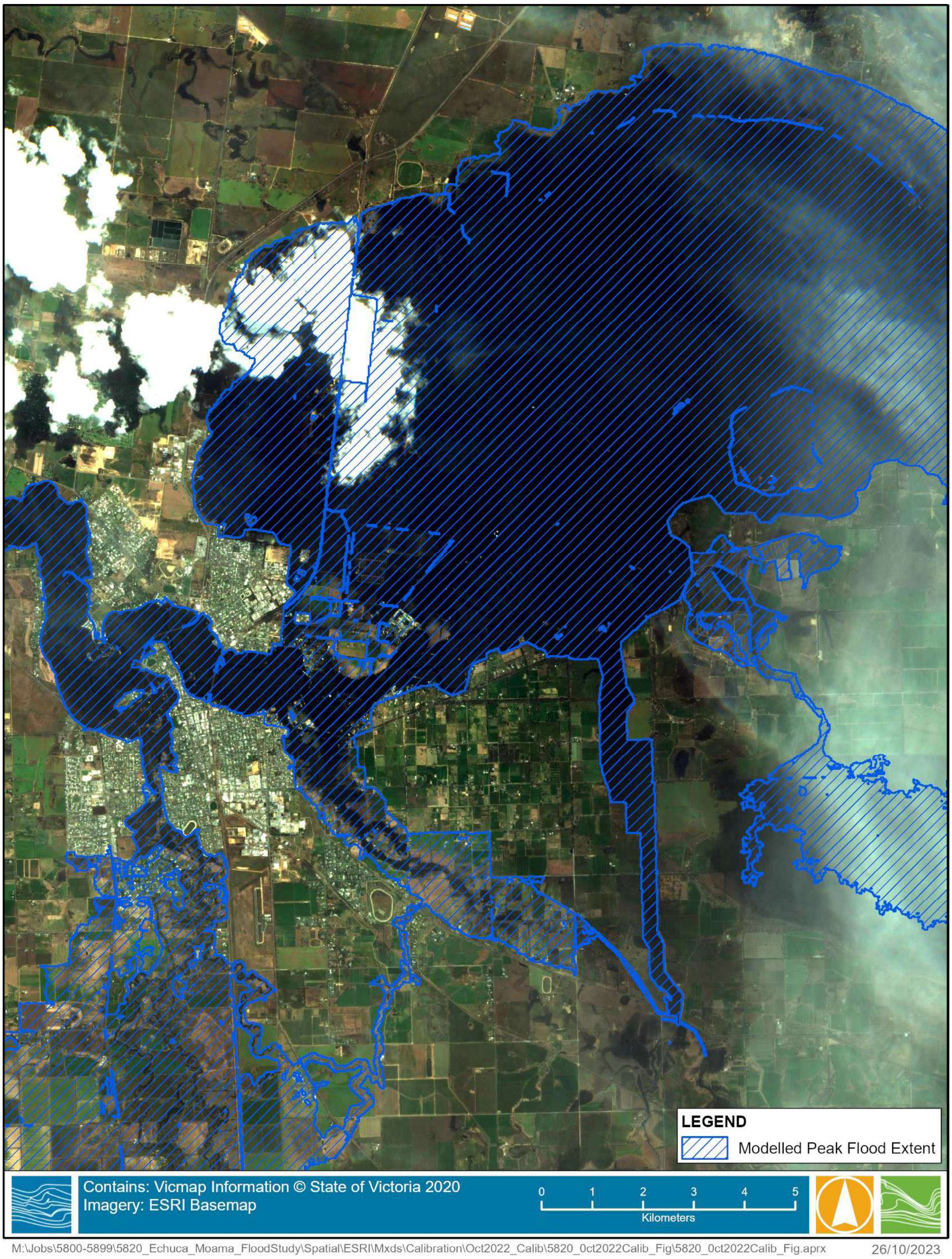

FIGURE 3-47 COMPARISON OF MODEL RESULTS WITH SATELLITE IMAGERY CAPTURED ON 6TH NOVEMBER 2022 – THE IMAGERY WAS CAPTURED ONE WEEK AFTER THE FLOOD PEAK AT ECHUCA

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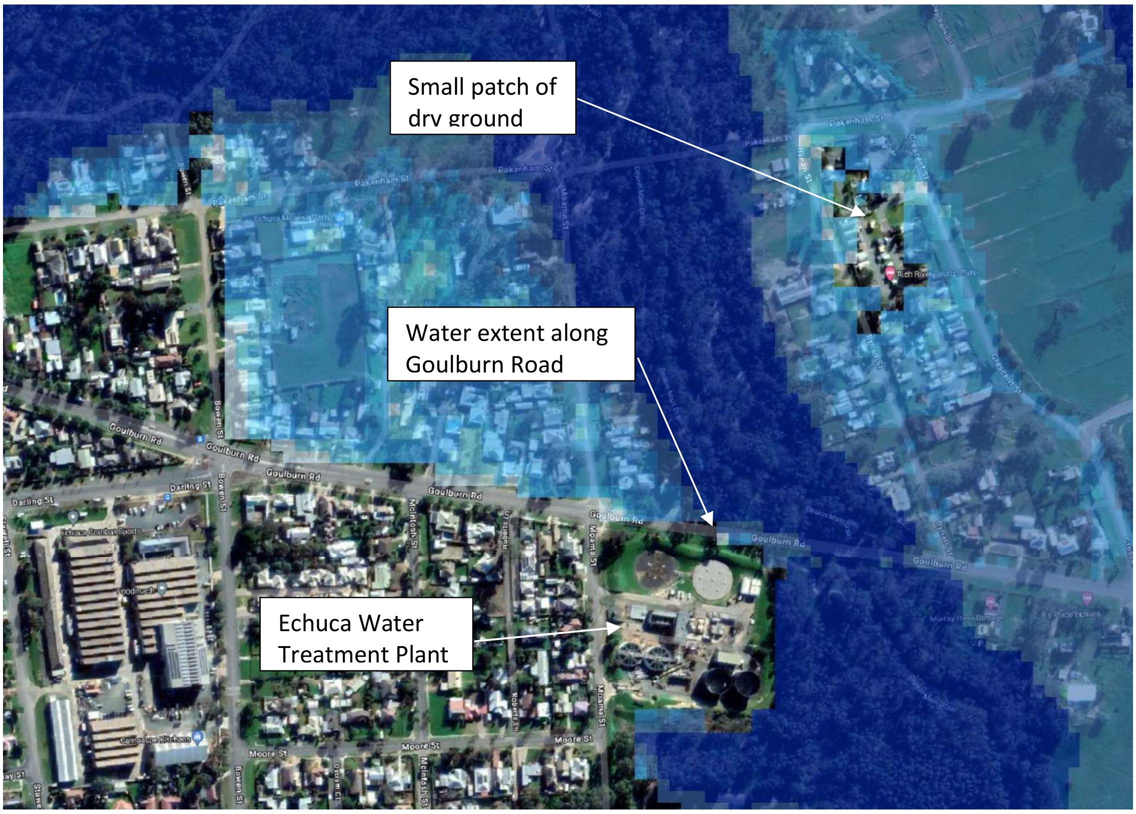

FIGURE 3-48 COMPARISON OF MODEL RESULTS WITH AERIAL IMAGERY CAPTURED ON 25TH OCTOBER 2022 NEAR GOULBURN ROAD – THE IMAGERY WAS CAPTURED SOON AFTER THE FLOOD PEAK AT ECHUCA

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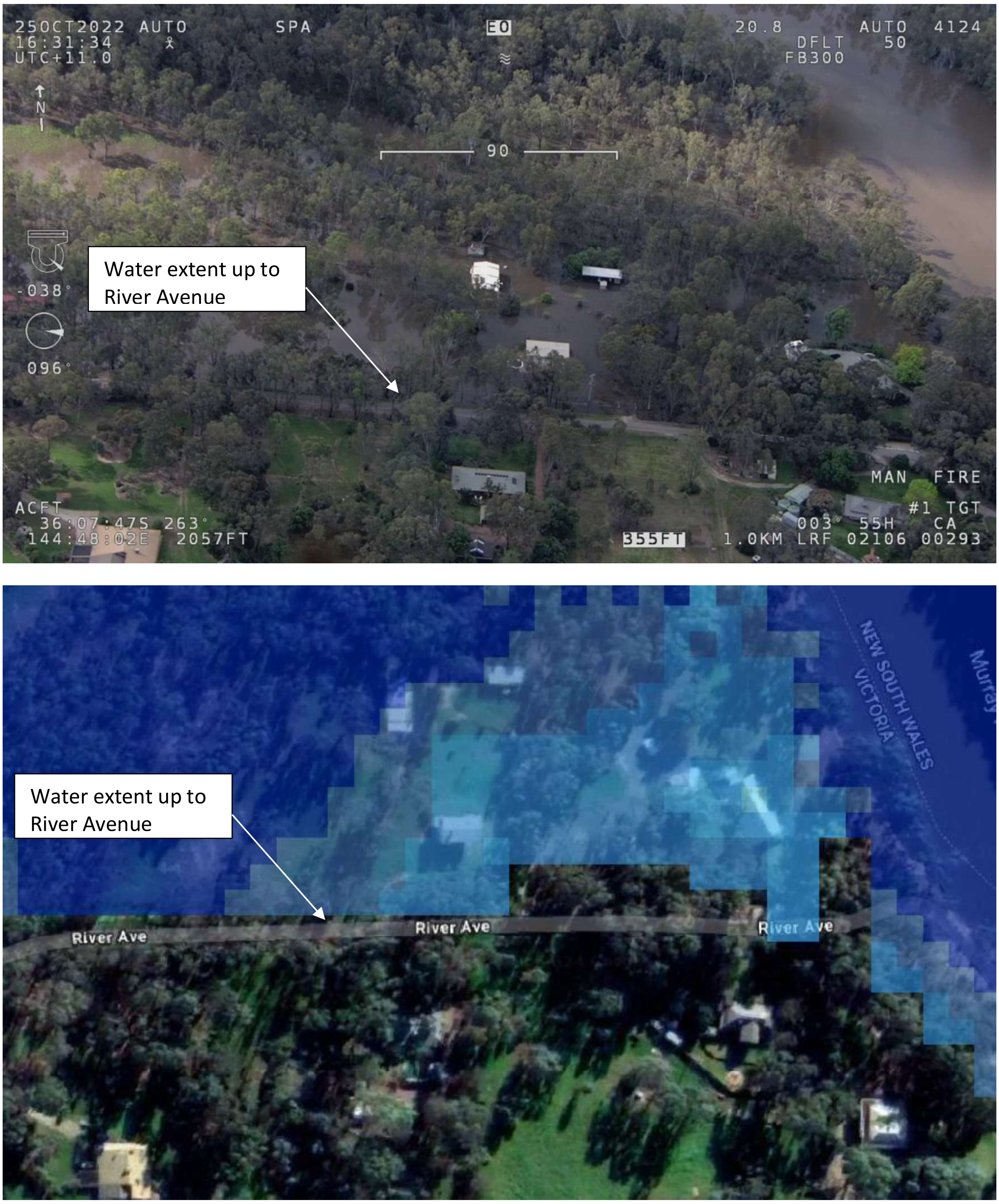

FIGURE 3-49 COMPARISON OF MODEL RESULTS WITH AERIAL IMAGERY CAPTURED ON 25TH OCTOBER 2022 NEAR RIVER AVENUE – THE IMAGERY WAS CAPTURED SOON AFTER THE FLOOD PEAK AT ECHUCA

3.4 Calibration Summary

The four flood events assessed as part of the hydraulic calibration have covered a range of flood magnitudes from minor to major floods. The events selected include the Campaspe River dominated January 2011 event, the Goulburn and Murray River dominated October 1993 event, the small Murray dominated October 2016 event, and the combined Campaspe, Goulburn and Murray River October 2022 event.

A very good calibration was achieved for the 1993, 2011 and 2022 events. The October 2016 event calibration was not as good as the other three events, possibly due to the missing data at the Murray River at Barmah inflow gauge. The calibration has made use of available observed flood information and has included an extensive period of community and stakeholder consultation. The project team has listened to anecdotal stories of flooding from the community and used these stories to improve the model calibration.

The calibration suggests that the model is suitable to apply for the next stage of the project, the design flood mapping.

4 DESIGN HYDROLOGY

4.1 General

Given the very large and complex catchment upstream of Echuca and Moama, including many major water storages, traditional rainfall-runoff modelling is not appropriate to develop design flood estimates for this study. Adding to the complexity is the issue of backwater effects from the Campaspe River on the Murray River levels, making it difficult to produce accurate streamflow estimates at the Murray River at Echuca Wharf gauge. In addition, the same flood level at the Murray River at Echuca Wharf gauge can be achieved by various combinations of inflows from the Murray, Goulburn and Campaspe River catchments.

Given all this complexity a method was developed to predict water levels at the Murray River at Echuca Wharf gauge using flow and volume at upstream gauges on the Murray, Goulburn and Campaspe Rivers. The method identified numerous events to study, estimate the probability of the event on each of the tributaries, develop correlations between the catchments and use that to predict flood levels at Echuca and Moama.

A Hydrology report was prepared by WMA Water in February 2019. This report was reviewed by a third-party independent expert. Several comments were provided back to the study team and were further discussed with the reviewer. All comments were considered reasonable and provided the study team opportunity to improve the hydrology reporting in the subsequent stages of the Flood Study.

As the study progressed, and various design scenarios were developed and tested, the approach to the design hydrology evolved in collaboration with the Technical Reference Group, comprising of representatives from the two Councils, the North Central and Goulburn Broken Catchment Management Authorities in Victoria and the New South Wales Department of Planning and Environment.

The final adopted design hydrology approach is discussed below in this section.

4.2 Data Collation and Review

Gauge data was sourced from Victorian and New South Wales State Government websites as well as data from previous flood studies. This data was used to construct annual series of flood peak flows and levels, and hydrograph volumes, for the purposes of flood frequency analysis. It was noted that there was significant data gaps in several of the gauge records.

The following gauge data was used which has the largest concurrent period of records:

- 405204C (Goulburn River @ Shepparton)
- 409207 (Murray River @ Barmah)
- 406202 (Campaspe River @ Rochester D/S of Waranga Western Channel Syphon)

4.3 Past Studies

The Moama-Echuca Flood Study (1997) completed by Sinclair-Knight-Merz is the most relevant past study. It improved on previous hydrology completed in 1978 by the Rural Water Commission, investigating the impact of the Campaspe River backwater on the rating curve at the Murray River at Echuca Wharf gauge. This allowed an improved understanding of design flood levels through Echuca and Moama. Flood frequency analysis was developed at upstream gauges and a MIKE11 1D hydraulic model was used to estimate flood levels through the study area. These design flood levels have been adopted in the planning scheme, and this study was used to design and construct flood mitigation works within Echuca and Moama.

The design levels determined as part of the SKM Moama-Echuca Flood Study are presented in Table 4-1 and have been in place since 1997.

TABLE 4-1 DESIGN FLOOD LEVELS AND FLOWS AT THE MURRAY RIVER @ ECHUCA WHARF GAUGE (SKM, 1997)

Design Event (AEP)	Discharge (m3/s)	Flood Level (m AHD)
10%	1055	94.45
5%	1195	94.85
2%	1343	95.20
1%	1431	95.45
0.5%	1505	95.60

4.4 Design Hydrology Approach

To understand the complexity of the design hydrology at this site a method was developed to understand the probability of events in the context of potential concurrent contributions from the tributary catchments, the correlation between the contributing catchment, and how they combine to cause flooding at Echuca and Moama. The key steps identified in the hydrological analysis were:

- Identifying historic events at available gauges.
- Understanding the probability of those events in a local context.
- Understanding the correlation of each event across the contributing catchments and to the resulting flood level at Echuca Wharf.
- Deriving a predictive relationship between upstream inflows and water levels at the Murray River @ Echuca Wharf gauge.

The Figure 4-1 provides an overview of the method.

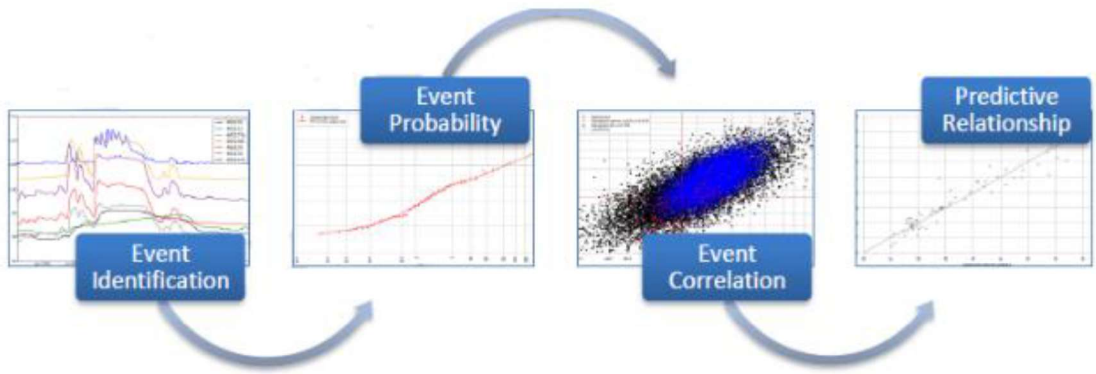

FIGURE 4-1 OVERVIEW OF DESIGN HYDROLOGY APPROACH

4.4.1 Event Analysis

The concurrent period of record was reviewed across the gauge network and 128 unique events were identified between 1976 and 2017 which could be used to investigate the correlation between the catchments. For each identified event, peak discharge, 3-day volume, 7-day volume and 14-day volume was extracted from each gauge record to inform the assessment.

4.4.2 Catchment Correlations

The correlation of event peak flows and event volumes between the three upstream gauges was calculated using the 128 unique events identified across the concurrent streamflow record. The analysis showed that the Goulburn River followed by the Murray River is the best predicter of flooding at the Murray River at Echuca Wharf gauge. The analysis also showed that the strongest correlation between the Murray River and the Goulburn River at Shepparton is for the 7 day volume descriptor.

4.4.3 Predictive Regression Relationship

Using the analysis described above, a linear regression relationship was developed using the 7 day volume at the upstream gauges on the Murray, Goulburn and Campaspe Rivers, to predict flood levels at the Murray River at Echuca Wharf gauge.

A relationship between the various upstream inputs and the flood level at Echuca Wharf was determined. The coefficient of determination for 7-day volume was the highest and was adopted for the determination of the relationship between upstream inflows and Echuca Wharf level.

This resulted in a very good match between the design flood levels at the Murray River at Echuca Wharf gauge predicted by the regression relationship and those developed in the Moama-Echuca Flood Study (SKM, 1997).

The regression relationship was validated through the hydraulic model by selecting a range of different inflow combinations and confirming the appropriate design levels at Echuca Wharf are produced. This relationship was applied to hydrograph shapes based on the 1992 flood event, scaling up the hydrograph for peak flow and volume. The 1992 hydrograph shapes were used as they showed the typical correlation and timing of peaks as determined in the catchment correlation step above.

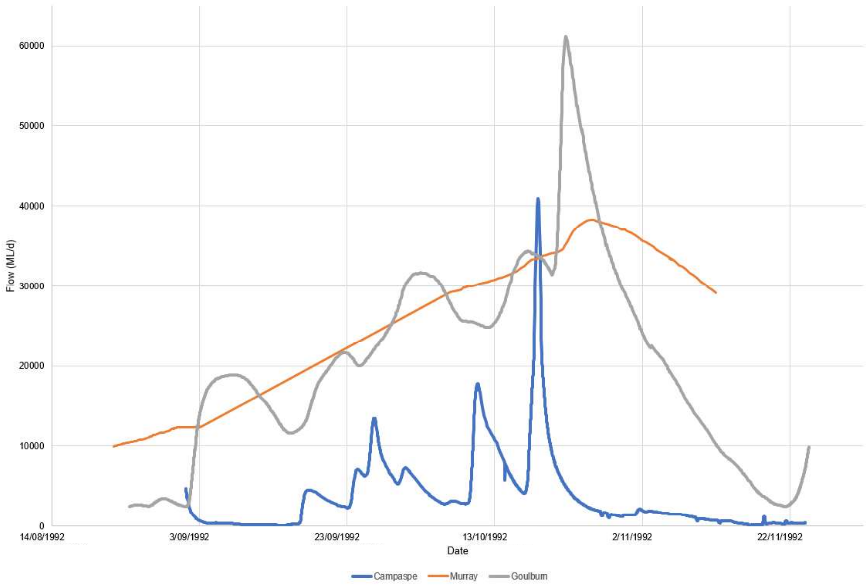

FIGURE 4-2 1992 FLOOD HYDROGRAPHS USED TO SET DESIGN FLOW HYDROGRAPHS

The relationship was tested and validated through several iterations run using the calibrated hydraulic model. It was found that using this 1992 hydrograph shape and timing, that the required flood frequency analysis design flood level at the Murray River at Echuca Wharf gauge was produced in the hydraulic model using inflows with the equivalent or very similar probability flow.

Figure 4-3 highlights that the Campaspe River and Goulburn River will be acting independently of each other therefore joint probability is not examined in this study.

4.4.4 Flood Frequency Analysis

An annual maxima series of peak flows and 3 day, 7 day and 14 day hydrograph volumes were prepared for the contributing catchments (Goulburn, Murray and Campaspe Rivers) and flood frequency analysis was carried out.

Flood frequency analysis of the peak level for the Murray River at Echuca Wharf gauge was also carried out. Flood frequency analysis was carried out using the best practice methods described in Australian Rainfall and Runoff (ARR, 2019), using the FLIKE software.

The annual series of peak flood levels at the Murray River at Echuca Wharf gauge was a major determinant of the design hydrology. The gauge was owned and operated by the Rural Water Commission until 1920, when it passed to the Bureau of Meteorology for flood warning purposes. The gauge was a manual gauge read once per day for much of its record. The Bureau of Meteorology provided an annual series of peak flood levels for an investigation completed by the State Rivers and Water Supply Commission in 1979. There were several missing years from the annual series, where the Bureau of Meteorology deemed that there was no flood observed in that year. For the period from 1865 to today, there are a total of 34 missing years from the annual series, 1874, 1913-1915, 1919,1922, 1924-1930, 1932-1933, 1935-1938, 1940, 1946, 1980, 1982, 1984-1986, 1994-2001. For the more recent missing years of data from 1970 onward, modelled streamflow data from Murray Darling Basin Authority (MDBA) was checked. Based on the MDBA modelled data, only 1996 is likely to have had a reasonable annual peak flow, the rest would be considered low flows and censored. However, the complexity of the system and the missing data means there is some uncertainty around the more frequent end of flood frequency analysis.

The initial flood frequency analysis (prior to the October 2022 flood), used FLIKE software, with a Bayesian maximum likelihood approach and a Log Pearson III distribution used. The fitting parameters were manually adjusted to achieve an improved fit. For further details on the analysis refer to the hydrology report (WMA 2019), Appendix G.

The updated analysis after the October 2022 flood and model recalibration used a similar but slightly different approach. FLIKE software was used, additional years of data were added to the annual series including the 2022 flood, and low flows were filtered from the annual series. Sensitivity testing was carried out looking at fitting different distributions and changing the low flow filtering thresholds. Filtering of the lower flow events did not make a significant change in the design levels. The selection of Bayesian or LH-moments did make a significant difference to the larger design events such as the 1% AEP. Bayesian produced higher 1% AEP peak levels, over half a metre higher than the previous SKM (1997) and WMA (2019) estimates of the 1% AEP design level. This was deemed inappropriate, so the LH-moments fit was used in preference. The flood frequency analysis curve from the Watertech analysis is in shown in Figure 4-3.

The adopted flood frequency analysis water levels at the Murray River at Echuca Wharf gauge were compared to previous estimates and are shown in Table 4-2. It must be noted that methodologies used for completing flood frequency analysis have evolved over the past 20 years. Previous analysis on design flood levels at Echuca and Moama, were best practice at the time. Today's current best practice is described in Australian Rainfall and Runoff (2019). The main changes have incorporated updates to fitting distributions to the annual series and ways of treating anecdotal data that may be missing from the gauge record.

For the larger and rarer design events, the levels are very similar, whereas the lower events have increased in height in the latest assessment. For the lower events the Water Technology revised flood levels are the highest, the earlier analysis completed by WMA Water are the lowest, and the previous study by SKM sit roughly between the two.

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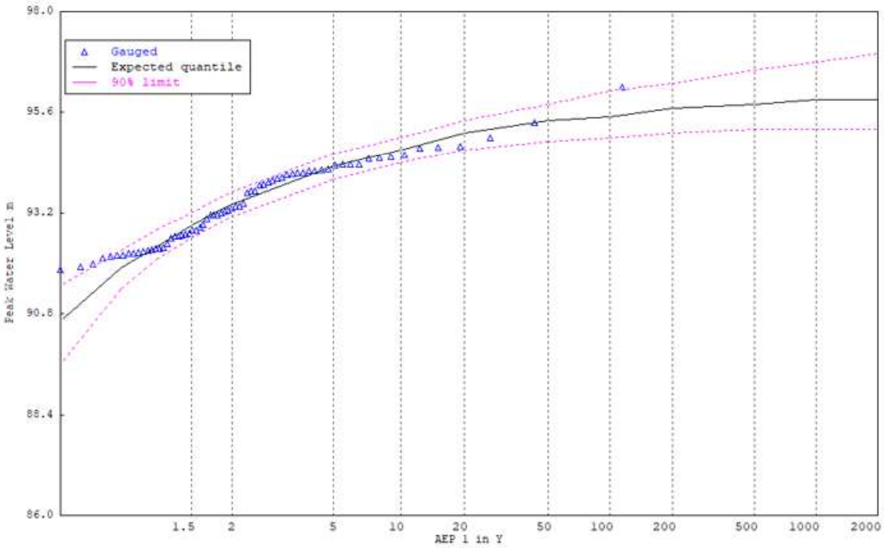

FIGURE 4-3 FLOOD FREQUENCY ANALYSIS CURVE OF LEVELS AT ECHUCA WHARF GAUGE

TABLE 4-2 COMPARISON OF FFA LEVELS WITH PAST STUDIES FLOWS AT THE MURRAY RIVER @ ECHUCA WHARF GAUGE

Design Event (AEP)	Current Study (Water Technology, 2023)	Earlier version of current study (WMA Water 2019)	Previous flood study (SKM 1997)
20%	94.3	93.5	-
10%	94.7	94.2	94.45
5%	95.1	94.7	94.85
2%	95.4	95.2	95.20
1%	95.5	95.5	95.45
0.5%	95.7	95.7	95.60

Given the changes in design flood levels for the lesser more frequent events, checks were performed using the hydraulic model, to assess what the probability of inflows need to be in the contributing waterways to generate the design peak flood level at the Echuca Wharf gauge. The hydraulic modelling showed that for the lesser more frequent events the lower flood levels from the earlier analysis by WMA Water prior to the October 2022 flood could only be achieved if lower probability inflows on the Goulburn and Campaspe Rivers were used as inflows to the model. For example, to achieve a 5% AEP design level at the Echuca Wharf gauge, lesser inflows were required closer to a 10% AEP on the Goulburn River. This then results in the flood mapping in upstream areas being too low, below the expected design flood levels.

Scenarios were tested using the accepted design AEP inflows to the hydraulic model at Shepparton on the Goulburn River, Rochester on the Campaspe River and Barmah on the Murray River in combination. For example, the 5% AEP inflows from all upstream tributaries were modelled together. The design peak inflows were based on previous flood studies completed for Shepparton (Water Technology, 2017) and Rochester (Water Technology, 2013). These scenarios resulted in flood levels on the Murray River at Echuca Wharf gauge within the range of the estimates provided by the different flood frequency analysis, and were closer to the previous flood study by SKM (1997). The final adopted design flows are presented below in Section 4.5.

To understand the design hydrology of the Murray River it is important to understand the context of the wider floodplain. The flood frequency analysis for the Murray River at Barmah gauge shows a flattening of the design curve for events rarer than 20% AEP (greater than 300 m^3/s), as a larger proportion of flows head north from the Barmah Choke and into the Edward River system. Given the physical constraint on the floodplain created by the Cadell uplift described in Section 1.3, there is a physical limit to the flow that can pass downstream of the Bama Sandhills on the Murray River.

Initially the upstream boundary of the study area on the Goulburn River was to be located at McCoys Bridge. However, through the calibration stage it was realised that in large floods, flow bypasses this gauge, so the boundary was moved upstream to the Goulburn River at Shepparton. In the 2022 event the modelling shows approximately 50% of the flow bypasses the McCoys Bridge gauge, flowing out through the Deep Creek floodplain. Flood frequency analysis was developed as part of the Shepparton-Mooroopna Flood Mapping and Flood Intelligence Study for the Shepparton gauge (Water Technology, 2017). To provide an improved boundary location to capture all the inflows to the study area the Shepparton gauge on the Goulburn River was used as the upstream boundary to the model.

Design hydrology was previously developed for the Campaspe River at Rochester during the Rochester Flood Management Plan (Water Technology, 2013). This used a combination of flood frequency analysis and RORB modelling.

4.5 Design Inflows

The final adopted design inflows input into the hydraulic model and the resultant design water levels for the Echuca Wharf gauge from the hydraulic model are provided below in Table 4-3.

TABLE 4-3 ADOPTED SCENARIOS TO BE MODELLED FOR DESIGN EVENTS

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)
20% AEP	93.75	70,000	27,216	15,898
10% AEP	94.40	97,800	31,104	22,464
5% AEP	94.88	128,200	38,292	33,178
2% AEP	95.3	173,800	38,292	49,939
1% AEP	95.48	213,200	38,292	62,122
0.5% AEP	95.7	237,366	38,292	74,390
0.2% AEP	96.1	305,047	38,292	89,730

To determine the design hydrograph shape, the historic 1992 hydrographs were scaled to represent the design peak flow and 7 day volume. The 1992 hydrograph was selected as it was found during the early stages of the hydrology, that it represented the event with "typical" contributions from the three tributaries. The design inflow hydrographs for the Goulburn River, Murray River and Campaspe River are plotted in Figure 4-4 for all the events modelled.

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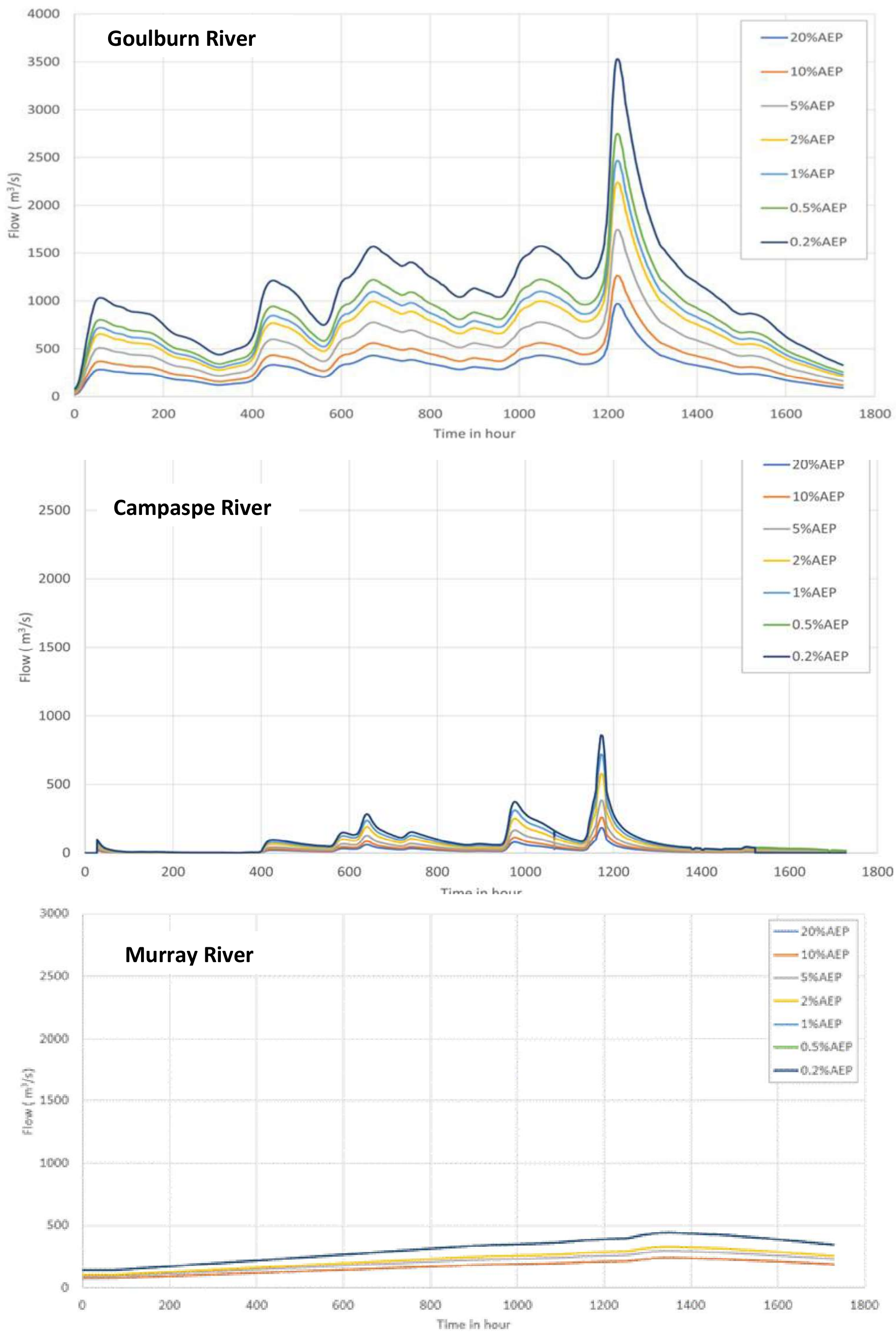


FIGURE 4-4 GOULBURN RIVER DOMINATED DESIGN INFLOWS

4.5.1 Extreme Flood

Initially, the study considered estimating a Probable Maximum Flood (PMF), which is the flow generated from the theoretical maximum precipitation for a given duration under current climate conditions. This was calculated using the "Quick Method" of Nathan as recommended in ARR2016 as the design flows are based on a flood frequency analysis method. The GSAM method could not be used to estimate PMF because a RORB model for all upper catchments was not used to developed hydrology for this study.

Initially, PMF flows were to be generated using the rapid assessment method detailed by Nathan et al, 1994. Nathan uses a prediction equation based on a sample of 56 catchments in South Eastern Australia, ranging in size from 1 km^2 to 10,000 km^2. The equation derived by Nathan et al (1994) was as follows:

$$Q_p = 129.1\ A^{0.616}$$
$$V = 497.7\ A^{0.984}$$
$$T_P = 1.062 \times 10^{-4}\ A^{-1.057}\ V^{1.446}$$

Where Q_p is the PMF peak flow (m^3/s), A is the catchment area (km^2).

At the Shepparton streamflow gauge, the area upstream of the Goulburn River is 16,000 km^2, which led to a peak flow of 50,200 m^3/s. This flow was thought to be too high at Shepparton, leading to the conclusion that an alternative method for estimating an extreme flow like a PMF was required. As an alternative method, it was decided to extrapolate the flood frequency analysis to the 1 in 100,000 AEP event. The extrapolated FFA curve estimated a peak flow of 12,222 m^3/s on the Goulburn River at Shepparton. A previous study by HARC (GBCMA, 2018) projected 16,300 to 18,300 m^3/s as an indicative estimate of the PMF. This previous estimate was deemed reasonable.

An indicative estimate of extreme flow in the Campaspe River at Rochester was estimated by extrapolating the FFA to 1 in 10,000 AEP and was calculated as 2,400 m^3/s.

To model the extreme flood appropriately, and to consider the amount of storage in the upstream Barmah Forest, the model was extended to include the Barmah Forest floodplain, and the grid size was increased to 30 m resolution.

The extreme flow in the Murray River at Tocumal was chosen as 8,900 m^3/s which is three times the 0.5% AEP flow. The extreme inflow at Broken Creek was chosen as 200 m^3/s.

An outflow boundary was added for the Edward River. The extreme flood modelling area is shown in Figure 4-5.

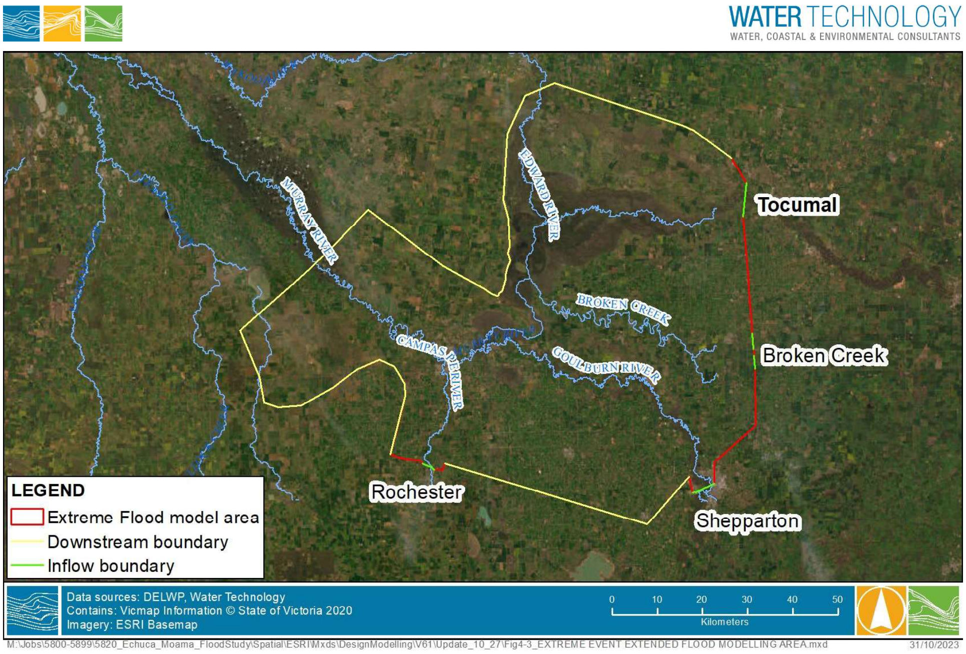


FIGURE 4-5 EXTREME EVENT EXTENDED FLOOD MODELLING AREA

4.5.2 Climate Change

The impact of climate change on stream flow is an important consideration for any flood risk management study. On large floodplains in downstream reaches such as at Echuca-Moama, the impact of climate change is a complex question, with many factors to consider.

The primary impacts of climate change on flood flows are a warmer climate leading to drier catchments more frequently, which have less soil moisture and less water in storages. This is likely to lead to higher rainfall runoff losses and a lower conversion of runoff as a percentage of rainfall. Climate change is also expected to bring higher intensity storms, which when they happen will be more severe.

These two factors of drier catchments and more intense rainfall storms counteract each other to some degree. Research by Wasko and Nathan (2019) suggests that for lesser floods up to the 10% AEP event, the reduction in soil moisture may be more dominant than the increase in rainfall intensity, but for more severe floods greater than a 10% AEP magnitude the more intense rainfall is likely to dominate and large flood magnitudes can be expected.

The Goulburn Broken CMA have recently completed a lengthy investigation into the impact of climate change on the Goulburn River, this study was completed by HARC (2018). This study investigated the impact of climate change on the Goulburn River using the RCP 4.5 pathway to the year 2090. With the Goulburn River being the main driver of flooding on the Murray River through Echuca and Moama, the results of this investigation can be directly transferred to this flood study.

The study showed that under climate change conditions it is predicted that the peak 1% AEP flood flows at the Goulburn River at Shepparton gauge downstream of the confluence with the Broken River, are very similar to the previously adopted 0.5% AEP flood flows. At Shepparton this is likely to result in water levels increasing by around 15 cm.

This previous work by the Goulburn Broken CMA means that we can understand the likely impacts of climate change on flood flows at Echuca and Moama. Section 6.1 discusses how the predicted change in hydrology due to climate change may impact flooding within the Echuca-Moama area.

5 DESIGN FLOOD MODELLING

5.1 Overview

Following the acceptance of the calibration by the Project Reference Group, modelling of the design hydrology scenarios described in Section 4 was undertaken and the results are presented and described in the following sections.

The calibration model from the October 2022 event was updated with changes to the model to reflect current day conditions, including:

- Removal of any temporary works included in the calibration model.
- As per the October 2022 calibration event, the low points in the Moama town levee plus closing of flood gates in the reinforced concrete wall section of the levee was included as they are agreed emergency response actions carried out by Murray River Council in compliance with the Moama levee owners manual.

This section discusses the application of the hydraulic model to simulate and map flood behaviour (extents, depth, velocities and hazards) for a range of flood magnitudes. Design flood modelling for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP events and an extreme flood event was completed using the hydraulic model parameters determined during the hydraulic model calibration.

The results of the design flood modelling scenarios were mapped and the flood risk was assessed across the floodplain. This is described further in the section below taking into account the uncertainties and limitations of the data as described in Section 2.2. The outputs from this flood mapping can be used for a range of purposes, including, flood response planning, community awareness, land use planning, and insurance purposes. Flood mapping produced as part of this study uses the most current approach following ARR guidelines and was peer reviewed on multiple occasions. Flood mapping results represents the best broadscale available flood data and information.

The remainder of Section 5 describes the flood behaviour for the modelled design events by describing how a flood may progress over time, how the maximum water levels, depths, velocities and hazard are distributed across the floodplain, and focusses in on some assets of particular interest. It should be noted that on this floodplain it is very true that every flood is different given the multiple sources of inflow, so the description is quite general in nature and future events may differ.

5.2 Design 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 5-1. 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.

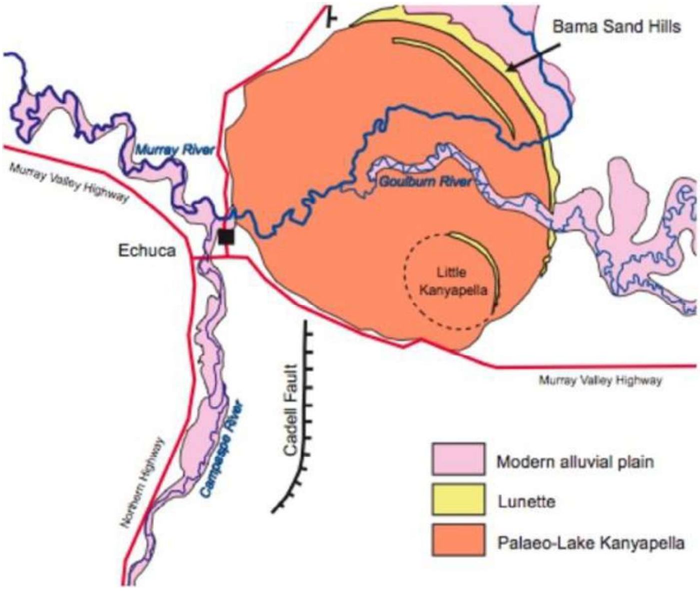
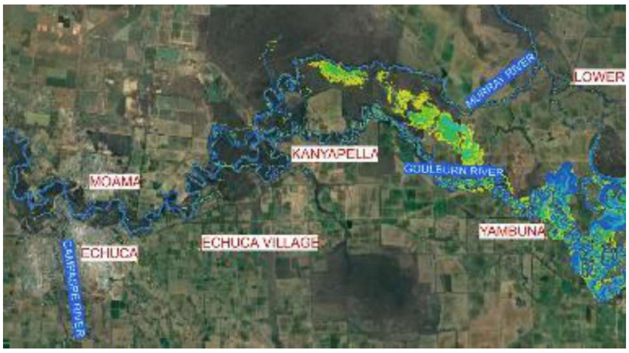


FIGURE 5-1 KANYAPELLA BASIN EXTENT (SOURCE: MODIFIED AFTER RUTHERFURD AND KENYON (2005); BARBERIAS (1983))

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. 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



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Creek floodplain, may enter the Murray River upstream of the Bama Sandhills, and may push back upstream along the Murray River.

After prolonged flooding, more water has spilled from the rivers and continues to fill the basin, with water now inundating a northern section of Old Deniliquin Road via Webb Road and Gregory Road, 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, and also back up along the Deakin Main Drain and the Bay of Biscay floodway in the southern part of the Kanyapella basin.

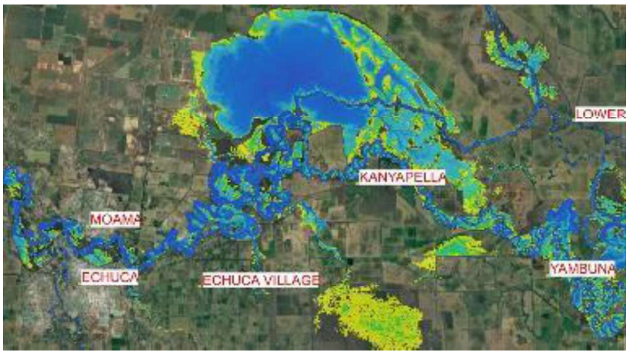
The property in the low-lying areas of Echuca along Goulburn Road are inundated as the river level continues to climb.

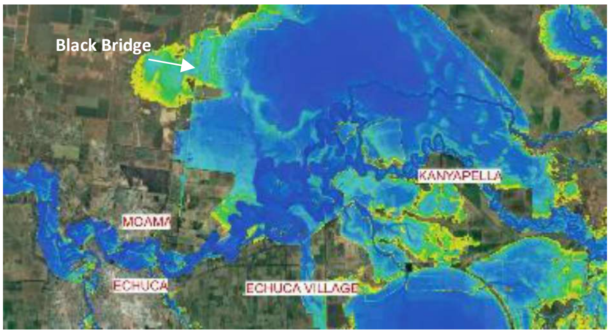
The flow that has passed under the Black Bridge north of Moama slowly heads south, flowing under a small railway bridge culvert and flowing back to the Murray River through east-Moama.

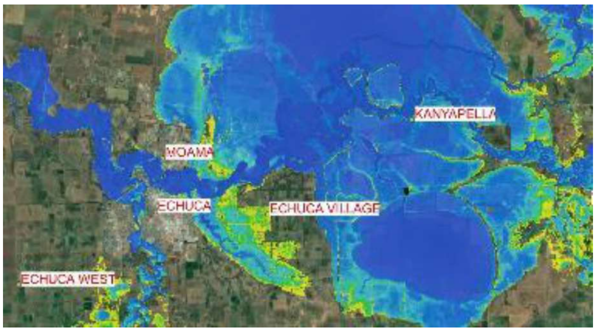
Levees on the south side of the Goulburn and Murray Rivers are likely to be overtopped or breached in large flood events, which rapidly increases the filling of the southern Kanyapella Basin by floodwaters. The Kanyapella Basin continues to fill with flood water spreading through the Echuca Village areas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







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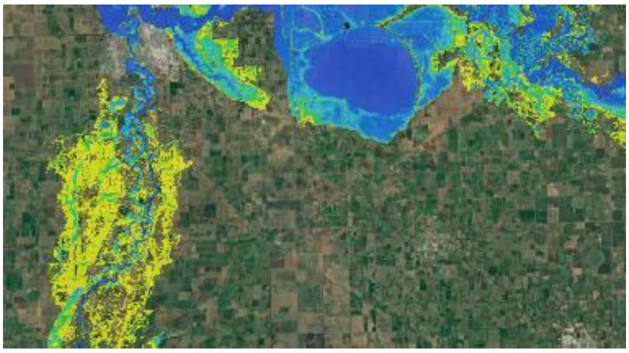
up flowing through to the Deakin Main Drain. Another breakway to the north of the intersection of McKenzie Rd and Echuca-Nanneella Rd also flows through to the Deakin Main Drain.

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.



5.3 Design Flood Mapping

This section describes the key flood characteristics within the study area for each design event. The flood mapping provides significantly more detail than any previous mapping of the study area.

The maximum water level at the Murray River at Echuca Wharf gauge for the design events derived from flood frequency analysis and that from the hydraulic modelling is presented in Table 5-1 below. Relevant historic events are included within the table for context.

A suite of flood maps were developed across a range of flood magnitudes (20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP, and an extreme flood event) and are provided in Appendix E. Figure 5-3 to Figure 5-7 shows the extents for all the design extents for different reaches across the study area. Figure 5-9 to Figure 5-13 show the 1% AEP results in terms of maximum flood depths across the site. Given the size of the study area, mapping is provided for five areas across the study area. Due to the size of the study area, results are more easily viewed in GIS software, but a series of figures have also been produced.

Broadly it can be seen that flooding from the Murray and Goulburn Rivers in the 20% AEP event is generally well-confined within the river, while all other larger events show a significant breakout over the Pakenham Street, Moama Street and Goulburn Road causing widespread inundation across the Echuca township west of Deakin Main Drain. The 5% to 1% AEP flood maps have a fairly similar inundation extent along the Murray and Goulburn Rivers with some incremental changes as the flood magnitude increases. The flood maps for 10% to 1% AEP along the Campaspe River at Echuca show similar inundation extents and are generally well-contained within the river floodway.

The Moama township levee was designed to protect against a 0.5% AEP flood event with a built-in freeboard of 0.6 m for the earthen levee section, and 0.3 m for the concrete retaining wall levee section. This standard of protection refers to the flood information at the time, and not the current flood levels from this study. The flood levels estimated from the current flood study suggests the Moama town levee has a lower degree of freeboard and the integrity of the levee is not guaranteed. The levee crest is above the 0.5% AEP flood level, but the levee has a very low amount of freeboard, and the lack of suitable freeboard means the levee may be prone to failure in such an event without significant intervention. As such, a note is added on the Moama township flood maps for the 1% AEP and 0.5 % AEP highlighting the potential area of inundation behind the levee should the levee fail. Section 5.5.1 and Section 6.4 provide more information on the Moama levee assessment and level of protection.

TABLE 5-1 DESIGN AND HISTORIC WATER LEVELS AT ECHUCA WHARF GAUGE

Flood Event, historic and design (AEP)	Historic water level recorded at the Echuca Wharf gauge		Design and calibrated model level determined via flood frequency analysis	
	Relative gauge level (m)	Gauge level (m AHD) Gauge Zero=84.605	Relative gauge level (m)	Model level (m AHD)
Jan 2011	8.25	92.85	8.48	93.08
Oct 2016	8.82	93.41	9.06	93.66
20%			**9.14**	**93.75**
Aug 1981	9.67	94.27		
10%			**9.8**	**94.4**
May 1974	9.92	94.52		
1956	9.98	94.58	N/A	N/A
Oct 1993	10.17	94.77	10.12	94.72
1916	10.20	94.80	N/A	N/A
Nov 1975	10.15	94.75	N/A	N/A
5%	N/A	N/A	**10.28**	**94.88**
Oct 2022	10.39	94.99	10.37	94.97
2%	N/A	N/A	**10.70**	**95.3**
1867	10.75	95.35	N/A	N/A
1%			**10.88**	**95.48**
0.5%			**11.14**	**95.74**
0.2%			**11.50**	**96.1**
Nov 1870	11.60	96.2	N/A	N/A
Extreme Flood Event	N/A		N/A	**97.2**

* The AEP level refers to the water level from the TUFLOW model in the calibration and design scenarios.

The differences in levels between the flood freqency analysis design flood level at Echuca Wharf and the level produced by the TUFLOW hydraulic model are within a reasonable range that can be accepted for the purposes of this flood study. The minor differences will not have any impact on the magnitude of flood extents throughout the floodplain.

The anticipated flood consequences for the design events are succinctly summarised below in the bullet points, which are divided into two sections individually for Moama and Echuca area. The data is presented in a way which describes the incremental changes in impact from one design event to the next. So to understand the impacts of a 1% AEP the reader should read the lesser magnitude events in sequence.

The Flood Risk Management Study and Plan will provide more in-depth information on flood intelligence and properties, roads, and homes that have been inundated above floor.

20% AEP

- Moama
  - In East Moama Flood water overtops the levee on the Old Deniliquin Road near Webb Road with inundation extending to Gregory Road.
  - On the Deniliquin Road, floodwater spreads further south. Flood water impacts property in east Moama.
  - On the Barmah Road, flood water passes Louies Hut Road and spreads further south. Flood water is contained within the Murray River near Moama Waters.
  - Floodplain to the east of the railway line fills with floodwater flowing under the railway line at the Black Bridge. A portion of Old Deniliquin Road is inundated in the north.
  -
- Echuca
  - The Yarraby Caravan and Holiday Park in the Echuca Village area on River Avenue is partially inundated.
  - The Port of Echuca Riverboat Dock area along Watson Street is partially inundated.
  - Property south of Warren Street and west of Campaspe River are partially inundated.

10% AEP

- Moama
  - In east Moama, flood water overtops Milgate Road and then heads south, inundating east Moama.
  - Water level in the Murray River near Moama Waters is below the bank for the northern portion of the site, while the southern portion is inundated.
  - The Tasman Holiday Park is inundated.
- Echuca
  - Water backs up the Deakin Drain and partially inundates Echuca Village area, with floodwater spreading further east. Etona Avenue and area north of River Avenue are inundated. Floodwater from the Murray River inundates properties between Goulburn Road, Pakenham Street, Bowen

Street and Moama Street. The Murray River Sawmills and other properties at the intersection of Anstruther Street and Sturt Street are inundated.

- Properties between Crofton Street and Warren Street as well as the Campaspe Lodge and Adelphi Apartments all are affected by flood water. Leslie Street is also partially inundated.
- On the western side of the Campaspe River, properties between Warren Street and Luth Street are inundated.
- Floodwater from the Campaspe River reaches the western end of Martin Street.
- Between Bowen Street and Bynan Street, water backs up into the Deakin Main Drain, flooding Mary Anne Road.

5% AEP

- Moama
  - In Moama East there is widespread flooding from the Murray River impacting on farmland, and inundating the Moama Waters and Discovery Parks along Old Barmah Road.
  - Flood water moves south through the culvert on the railway line and the area between Holmes Road and Chanter Street is fully inundated.
  - Properties at the intersection of Cobb Highway and Meninya Street are partially affected.
  - Maidens Inn is inundated.
  - The flood water moves south through the culvert on the railway line and the area between Holmes Street and Chanter Street are now fully inundated.
- Echuca
  - The Campaspe River inundates McBride Place and Murphy Way as well as the properties north of Eyre Street between Haverfield Street and McKenzie Street. Properties to the west of River Street are also inundated by the Campaspe River.
  - Areas of deep flooding are observed in Echuca west of the Campaspe River. Floodwater surrounds Hansen Street and Jarman Street, with several other streets west of the Campaspe River inundated. Properties in the Anstruther Street - Redman Street area south of Warren Street are fully inundated.
  - Echuca Aquatic Reserve and Echuca Moama Tourism centre is affected.
  - Echuca (NRMA) Holiday Park north of Crofton Street is partially under water due to flooding.
  - Inundation of area east of railway line and north of Pakenham Street commences.

2% AEP

- Moama
  - The properties on the corner of Holmes Road and Moama Street are inundated and the lots which were flood free in 5% AEP are now flooded.

  - To the west of Moama, near Perricoota Road, floodwaters breakout from the Murray River and spreads through Tindarra Resort.
- Echuca
  - Echuca Village experiences widespread flooding.
  - More properties inundated along Pakenham St in Echuca. More properties are flooded south of Goulburn Road in Echuca.
  - Echuca (NRMA) Holiday Park is now under flood water.
  - More properties along the Campaspe between Leslie Street and George Street, are flooded as the floodwater overtopped the levee near Warren Street on the eastern bank of the Campaspe River.
  - The flooding between McBride Place and Murphy Way from the Campaspe River is extended, inundating additional properties.
  - Floodwaters surrounding Hansen Street and Jarman Street, and the Anstruther Street – Redman Street area west of Campaspe River continue to extend, inundating additional properties.
  - Campaspe River inundates properties along Ogilvie Avenue.

1% AEP

- Moama
  - The north and east of Moama are completely inundated.
  - With the limited freeboard for the Moama town levee at this design flood height that the integrity of the levee is not guaranteed.
  - In west Moama, properties along Lignum Road, west of Charters Drive, are submerged by floodwater from the Murray River's breakout at Perricoota Road. The flood water from Perricoota Road breakout spreads further north up to Rich River Golf club.
  - A flow breakout from the bend in the Murray River at Tindarra Resort forms and travels along a depression. Recent residential development along Pericoota Road blocks the flow from extending beyond Chardonnay Avenue.
- Echuca
  - The Murray River inundation is similar to the 2% AEP event, with levels increasing slightly.
  - Additional properties inundated on and west of High Street between Radcliff Street and Pakenham Street on the east side of the Campaspe River.
  - Additional properties flooded from the Campaspe River between Jensen Court and McKenzie Street, south of Eyre Street.
  - More flooding occurs south of Snowden Street along Alastair Court, Struve Court from the Murray River at the west. Floodwater inundates properties in the area bounded by Ogilvie Avenue, Bowen and Snowden Street.

- Some properties in Echuca West around Falkner Court and Bateman Drive are now affected from flood water from Campaspe River.

0.5% AEP

- Moama
  - The north and east Moama is fully submerged with similar extent to 1% AEP with level increasing slightly.
  - The Moama town levee is likely to fail without significant intervention.
  - Flows north of Perricoota Road are contained primarily within drainage reserves constructed as part of recent residential development
- Echuca
  - More properties inundated north of Pakenham Street along railway line.
  - Breakout toward Northern Highway and flood water from Campaspe River now inundates properties in the Fehring Lane Estate, Echuca West

0.2% AEP

- Moama
  - The Rich River Golf Club is now affected by floodwater to the west of Moama. Floodwater overtops Martin Road and inundates the Murray River Resort east of Perricoota Road.
  - The Perricoota Vines Retreat, further north along Perricoota Road near Twenty Four Lane is partially inundated.
- Echuca
  - The majority of the town centre between High Street and the railway line are now affected as far as Mckinlay St to the south, excluding the block where the Big W is located.
  - The water treatment plant at Moama St is still protected.

The major roads overtopped in each modelled design event and number of properties impacted below or above floor level will be described in further detail in the Flood Risk Management Study and Plan.

Flood maps have been produced in high resolution and pdf format, they are provided as attachments to this report. These maps include maximum depth, water surface elevation, velocity and hazard.

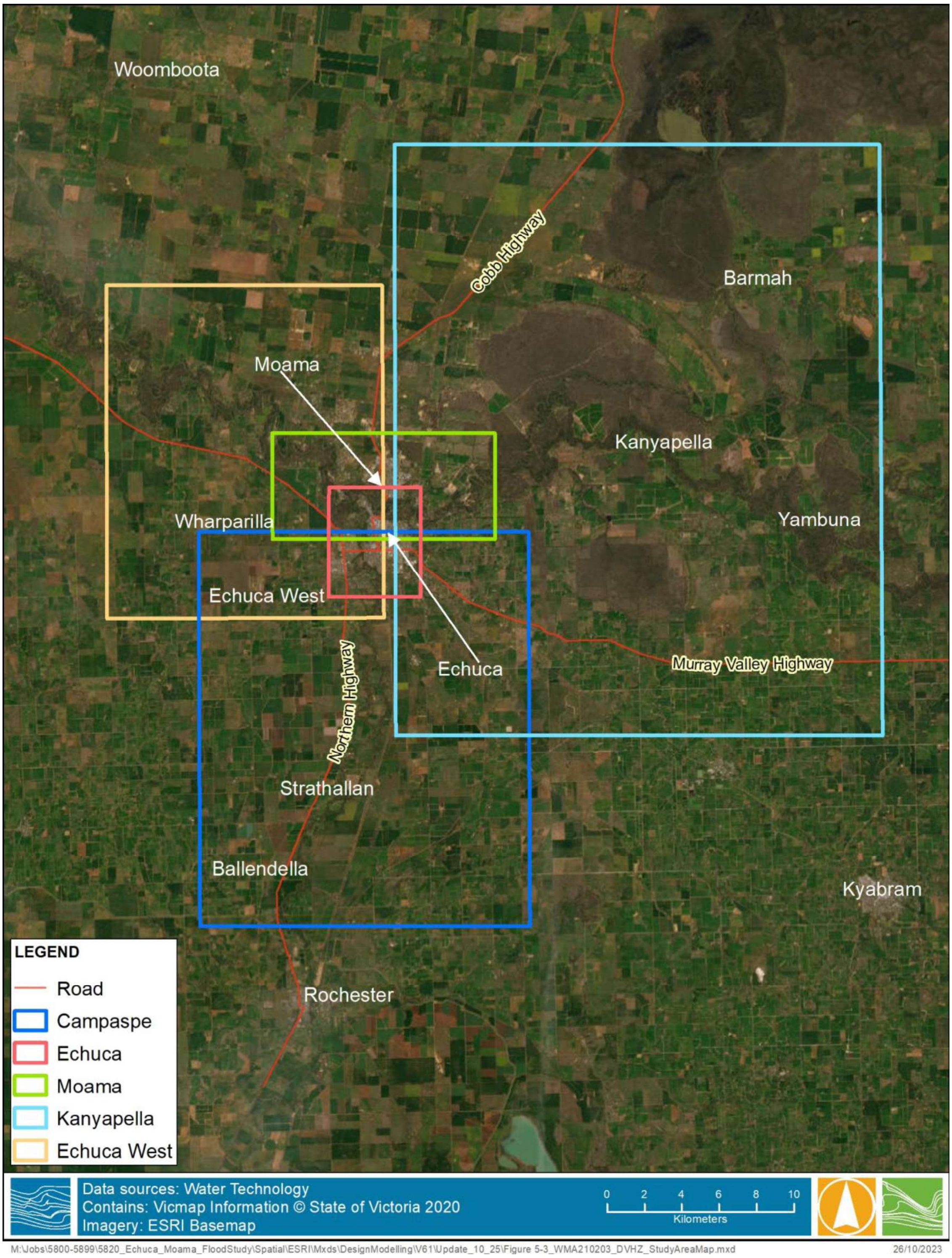


FIGURE 5-2 MAPPING AREAS FOR PRESENTATION OF DESIGN FLOOD RESULTS

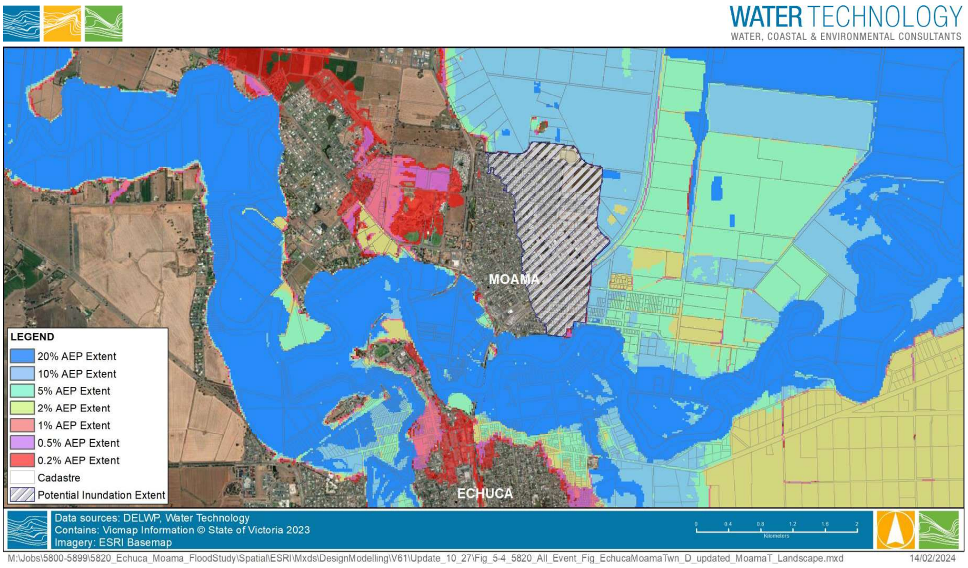


FIGURE 5-3 DESIGN MODELLING – EXTENTS (MOAMA)

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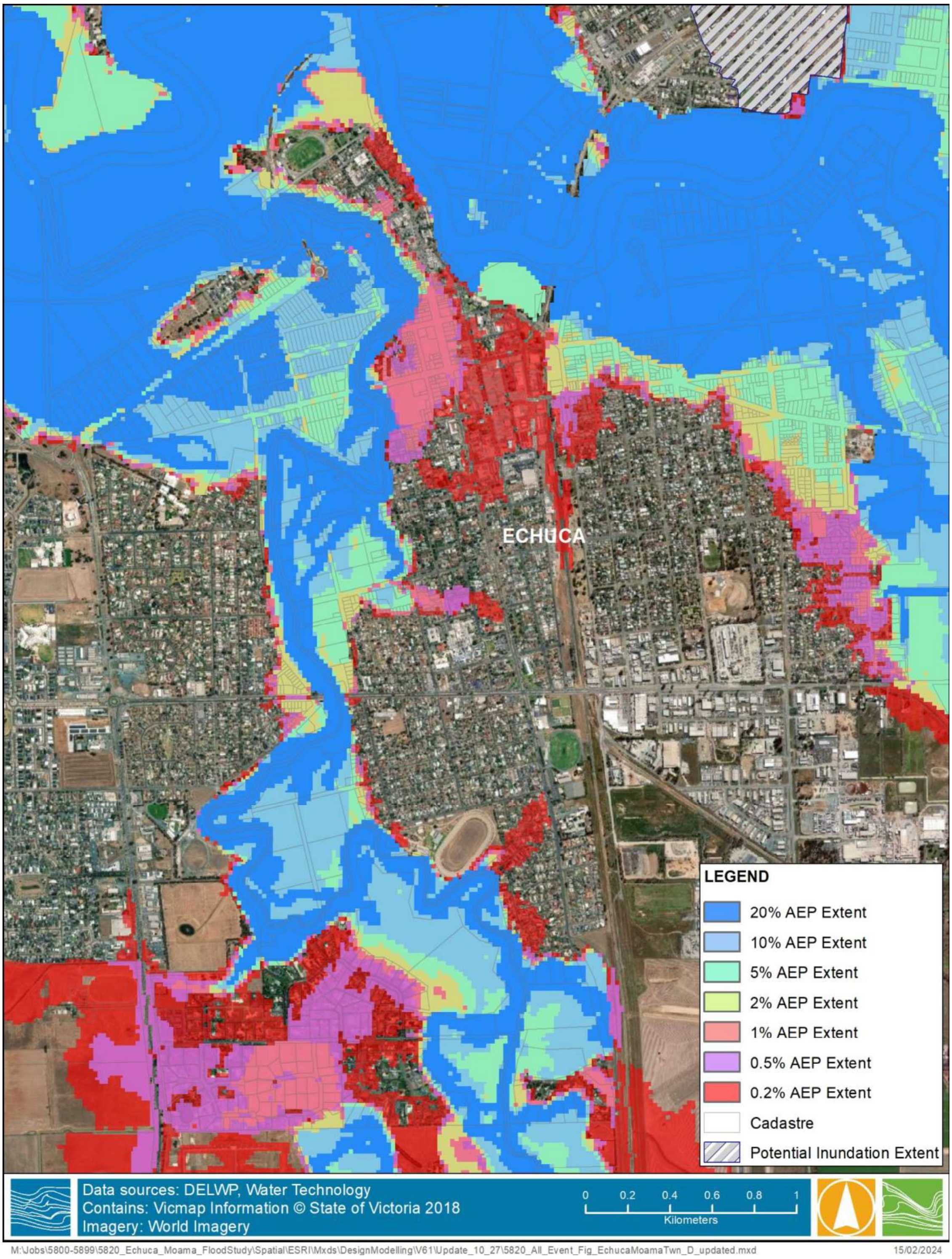

FIGURE 5-4 DESIGN MODELLING – EXTENTS (ECHUCA)

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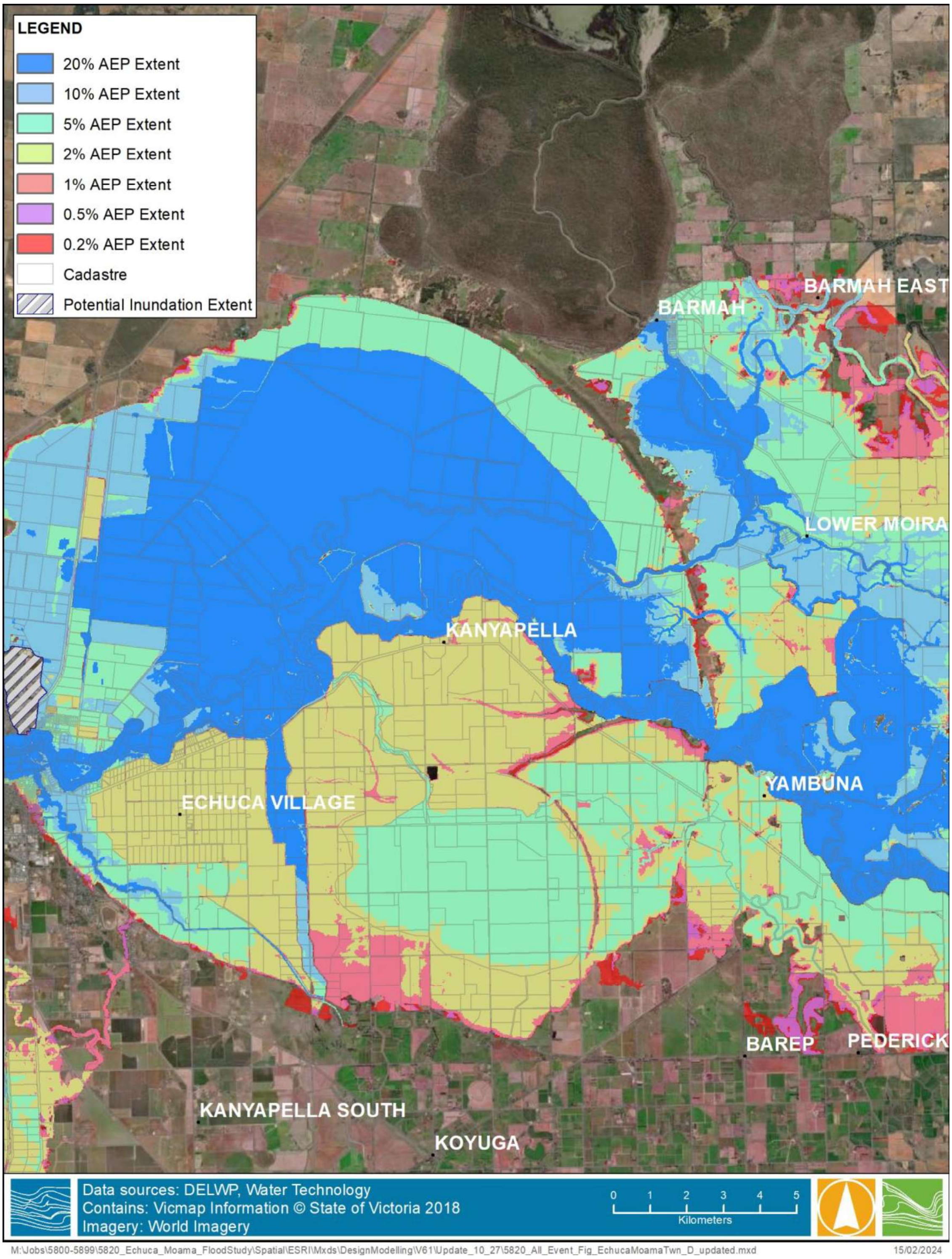

FIGURE 5-5 DESIGN MODELLING – EXTENTS (KANYAPELLA)

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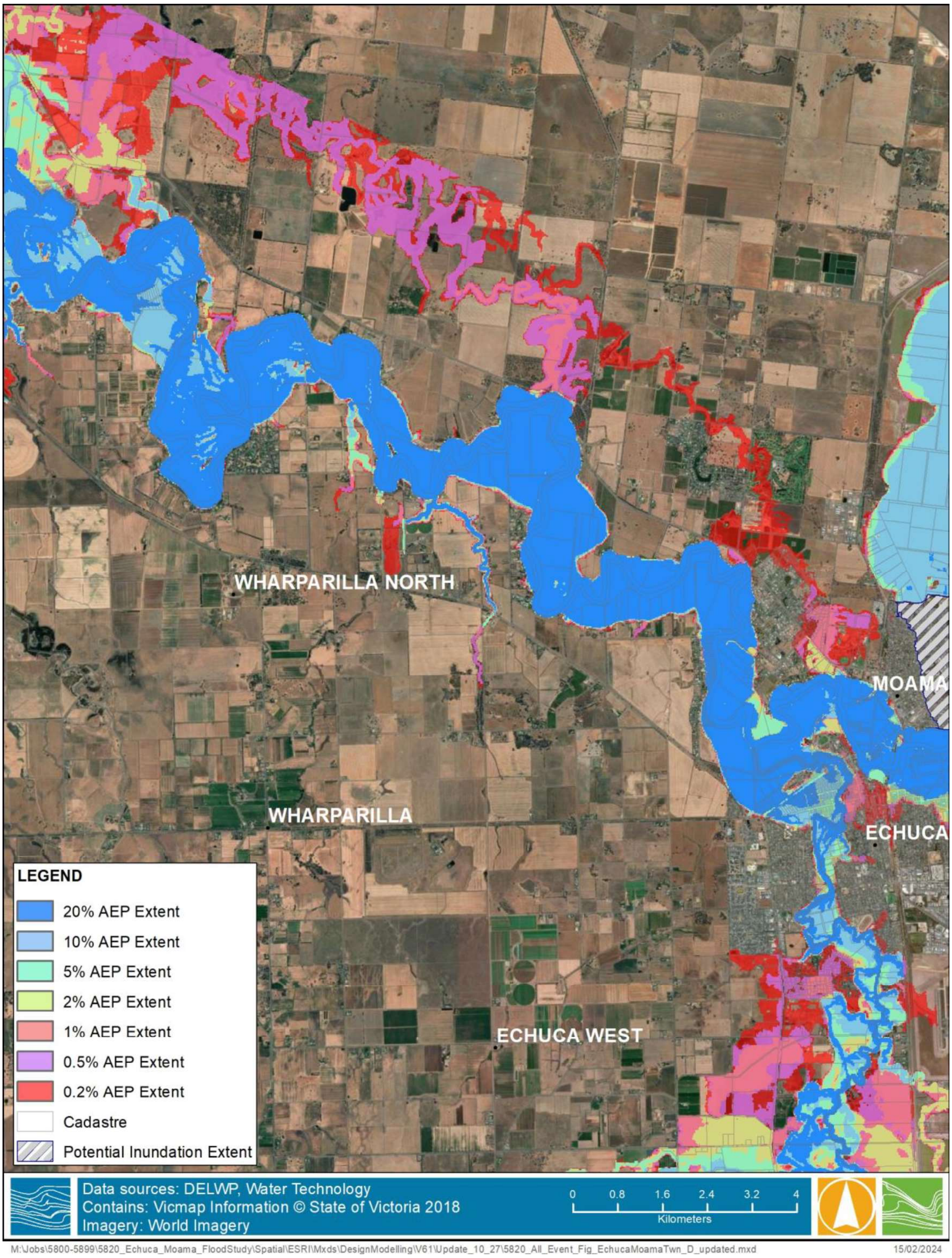

FIGURE 5-6 DESIGN MODELLING – EXTENTS (ECHUCA WEST)

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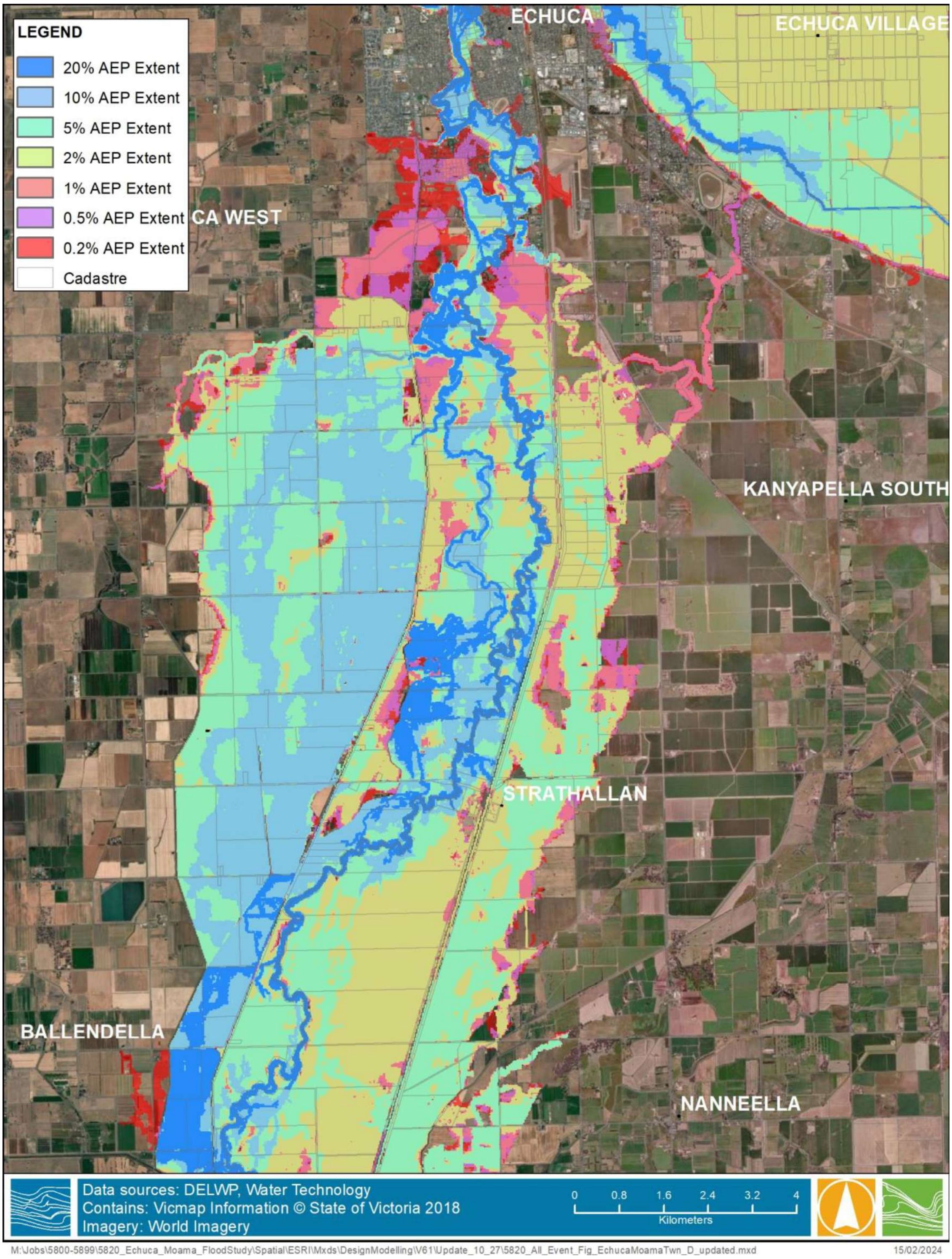

FIGURE 5-7 DESIGN MODELLING – EXTENTS (CAMPASPE)

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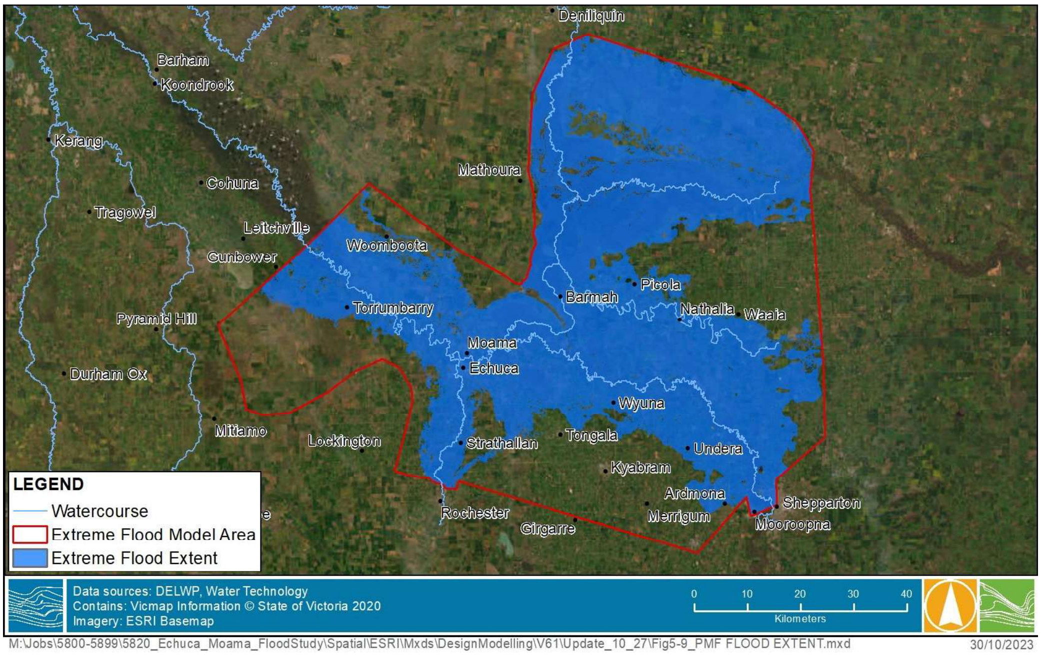

FIGURE 5-8 EXTREME FLOOD EXTENT

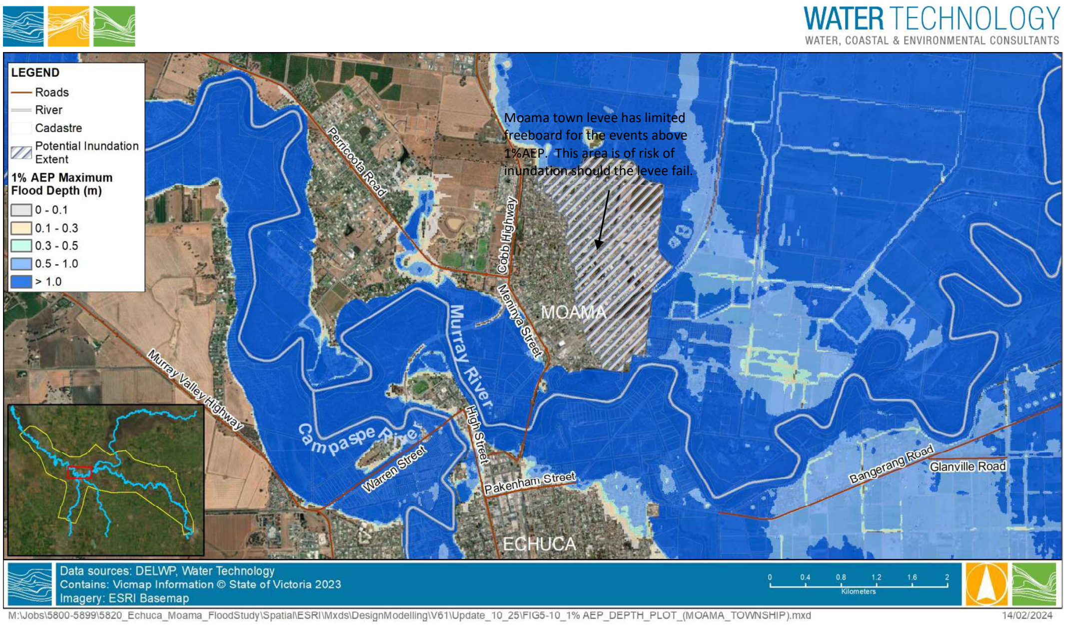

FIGURE 5-9 1% AEP DEPTH PLOT (MOAMA)

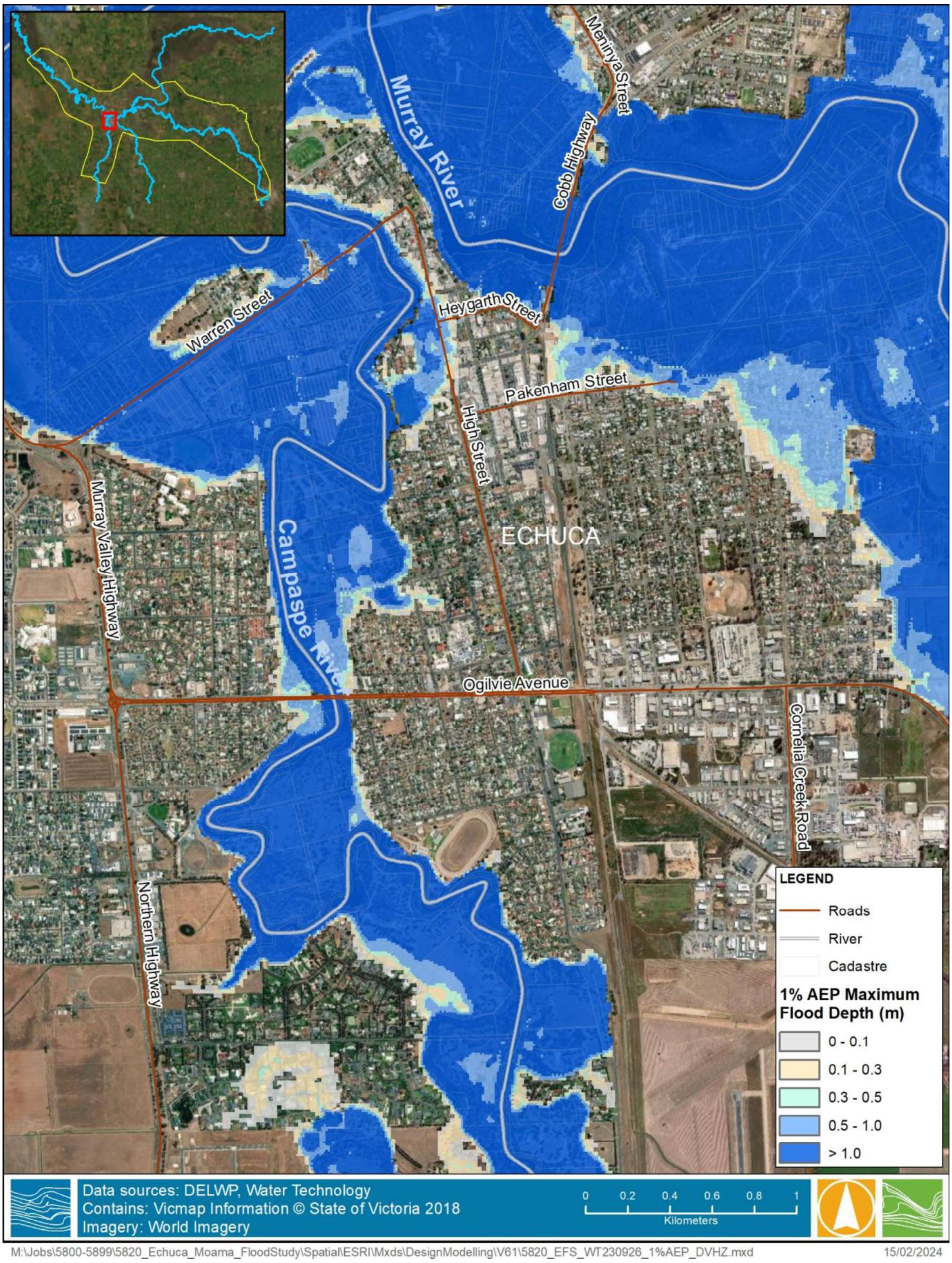

FIGURE 5-10 1% AEP FLOOD DEPTH (ECHUCA)

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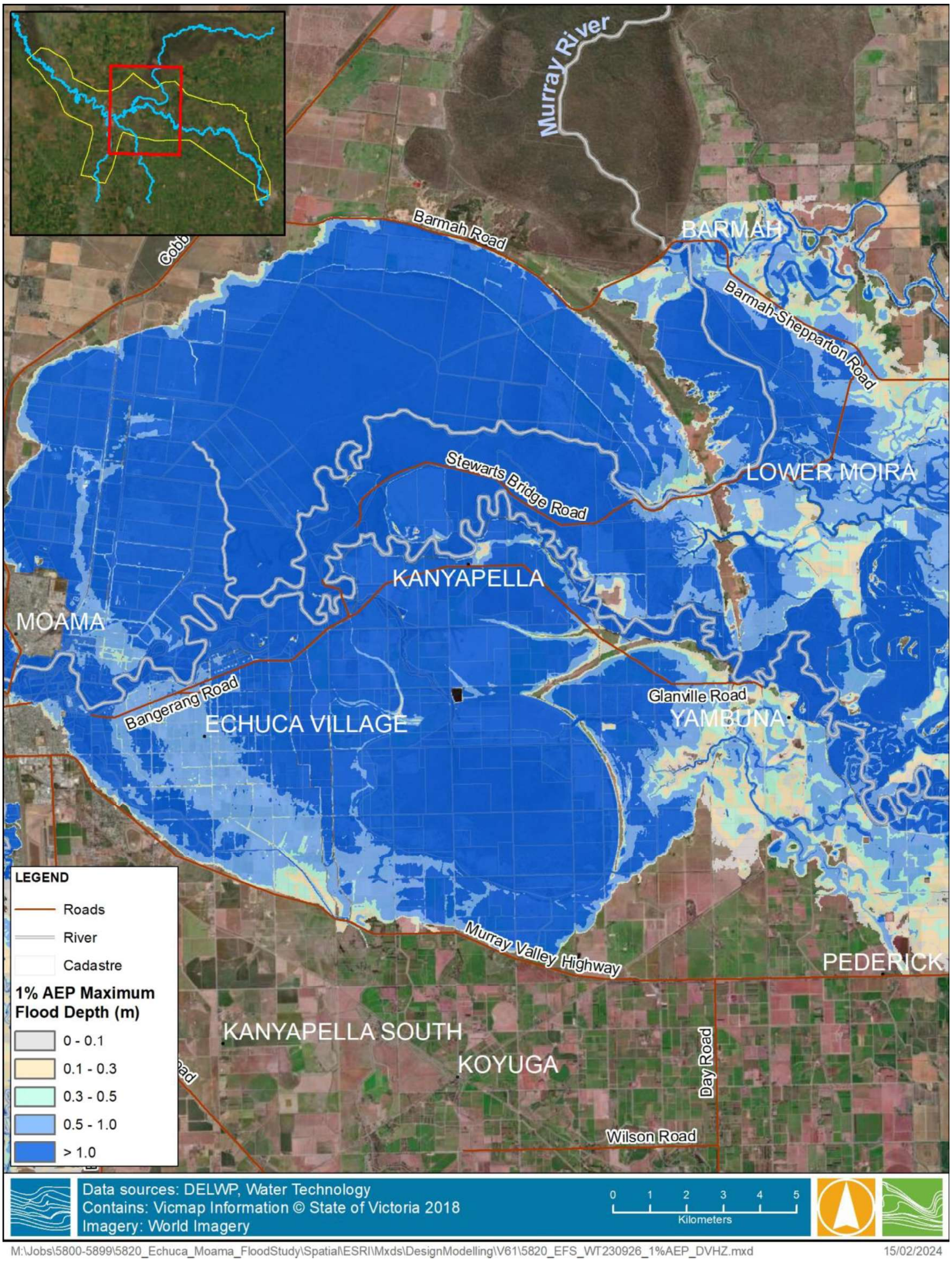

FIGURE 5-11 1%AEP FLOOD DEPTH (KANYAPELLA)

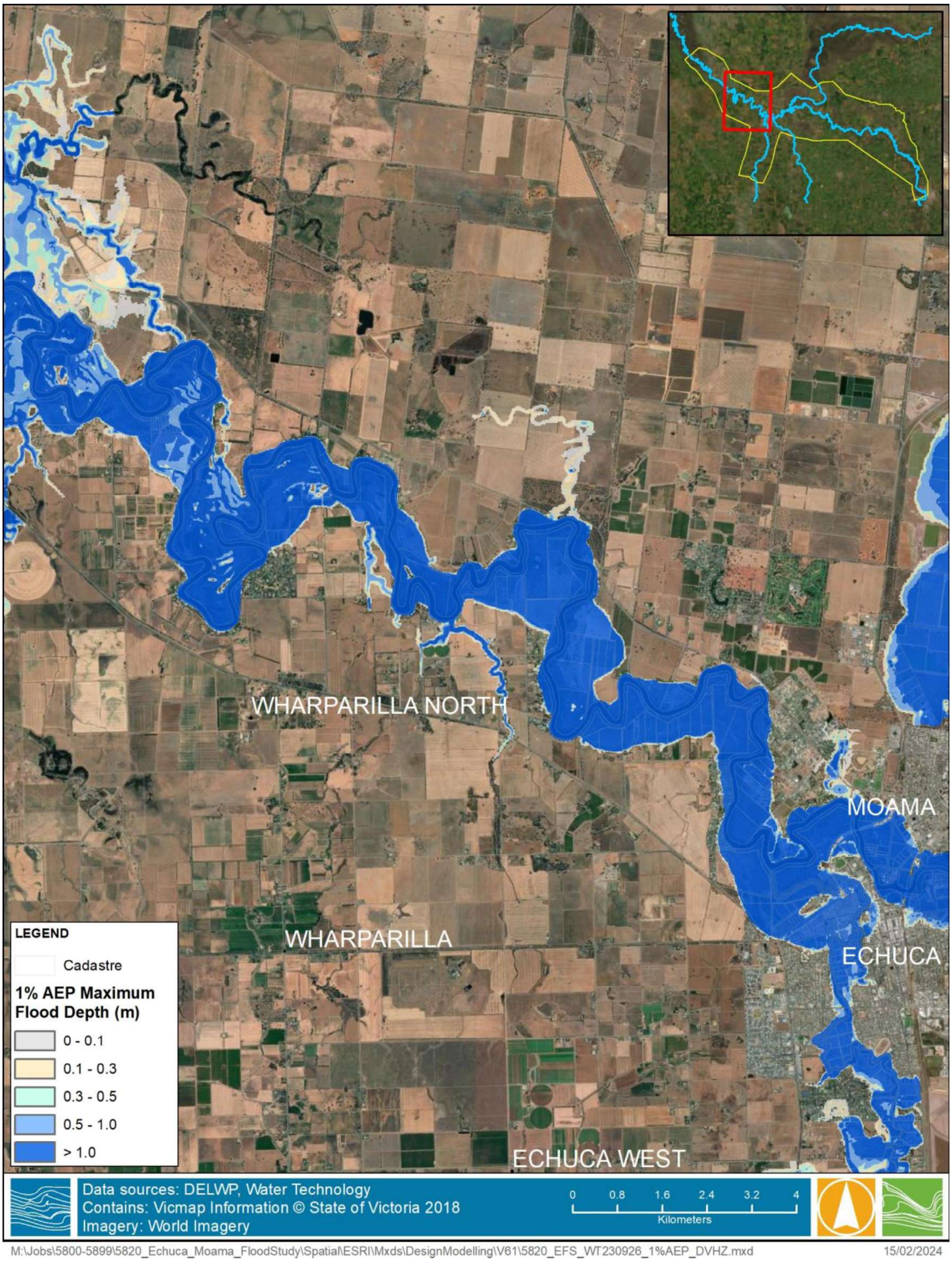

FIGURE 5-12 1%AEP FLOOD DEPTH (ECHUCA WEST)

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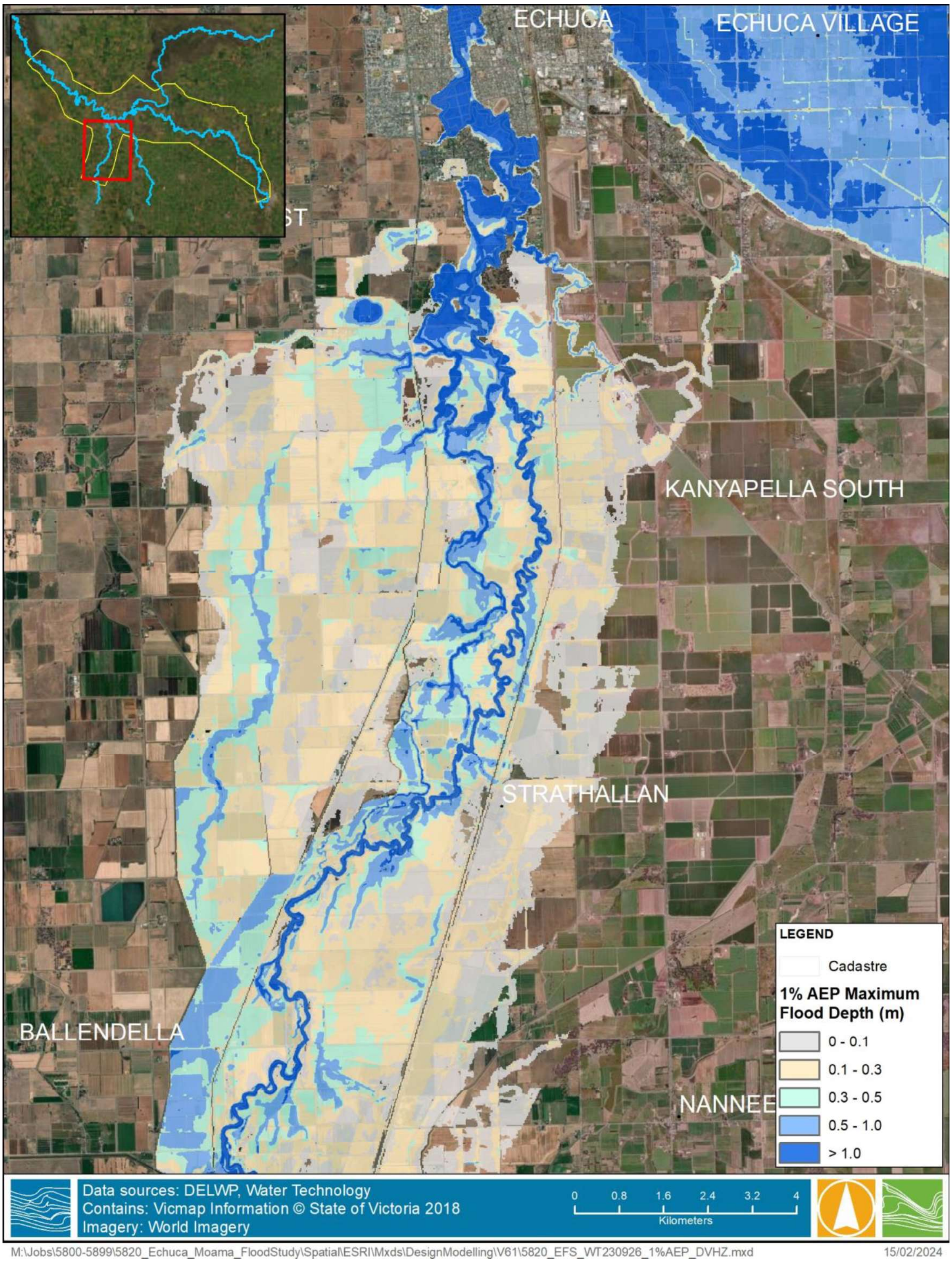

FIGURE 5-13 1% AEP FLOOD DEPTH (CAMPASPE)

5.3.1 Design Flood Comparisons

To validate the model results, the design modelling was compared with historical levels and previous design estimates.

- The October 1993 flood level at the Echuca Wharf gauge sits between the 10% (1 in 10) AEP and 5% (1 in 20) AEP design flood level, while the October 2022 flood level sits between the 5% (1 in 20) AEP and 2% (1 in 50) AEP design flood level. This suggests that the 1993 and 2022 flood events are not that rare, and given that we have had two events of similar magnitude in the last 30 years, this would seem reasonable.
- The Echuca Wharf gauge has only recorded two events since 1865 which have been higher than the 2022 flood, but one of those events in 1870 was over 1 m higher than the 2022 level.
- The 1% AEP flood level at Echuca Wharf is very similar to previous 1% AEP flood level estimates.
- The January 2011 event on the Campaspe River was very similar to the 1% AEP flood, with the October 2022 flood closer to a 0.2% AEP at Rochester.
- The extreme flood event modelled in this study produced a flood level of 97.2 m AHD at the Echuca Wharf gauge. This is 1 m higher than the largest historic event recorded in 1870 and is very close to the "extreme" event modelled in the SKM (1997) Moama-Echuca Flood Study.

5.4 Design Flood Profiles

The maximum flood level along the Murray River from Lower Moira to Wharparilla for all the design events is plotted in Figure 5-14. Figure 5-15 depicts the Goulburn-Murray river's peak water level profile from Yambuna to Richardson Lagoon. Figure 5-16 on the Campaspe River shows the peak water level profile from Baragwanath Road to the confluence.

When interpreting the design water surface profiles, the steepest sections are where the floodplain capacity is constrained, so water backs up behind the constraint and accelerates through the constraint showing a steep drop in the water level profile. Sections of the water surface profiles that are very flat are typically storage areas, where velocities are very slow and the water level does not change significantly over long distances.

The Murray River's backwater dominates the peak levels in the lower reaches of the Campaspe River, with the Campaspe River flows controlling the peak levels in the upper reaches.

The Murray Valley Highway bridge is located at a natural constriction of the floodplain on the Campaspe River. The deck is overtopped in the extreme flood but has immunity in a 0.2% AEP event. It is noted that the Murray Valley Highway approach road to the west of the bridge is lower than the bridge deck itself, and in the October 2022 flood, the approach road did overtop. The constriction in the floodplain at the bridge crossing is shown in the longitudinal section profiles, by the step gradient and drop across the structure.

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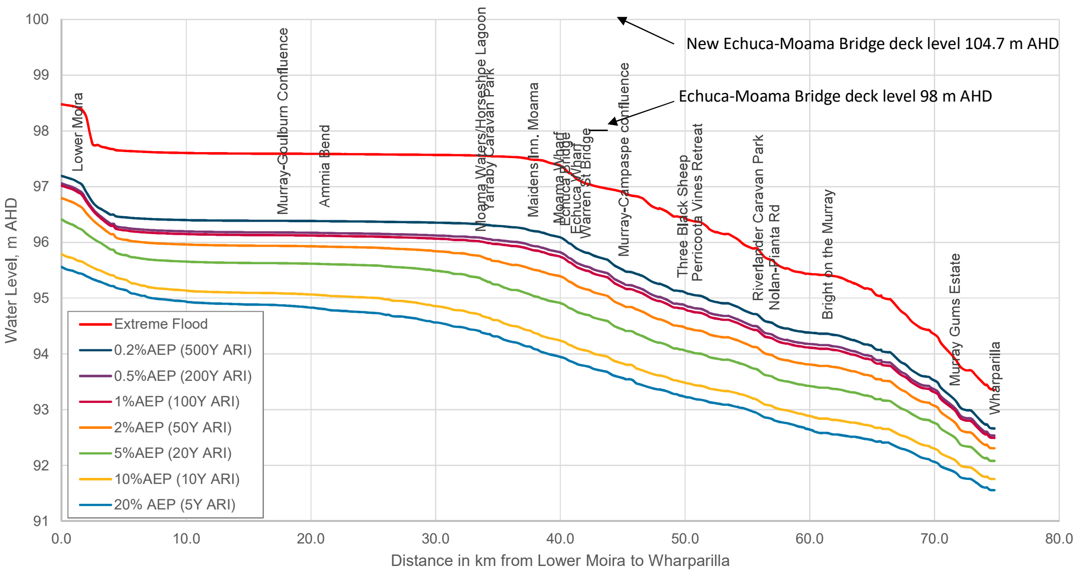

FIGURE 5-14 PEAK WATER LEVEL PROFILES MURRAY RIVER FROM LOWER MOIRA TO WHARPARILLA

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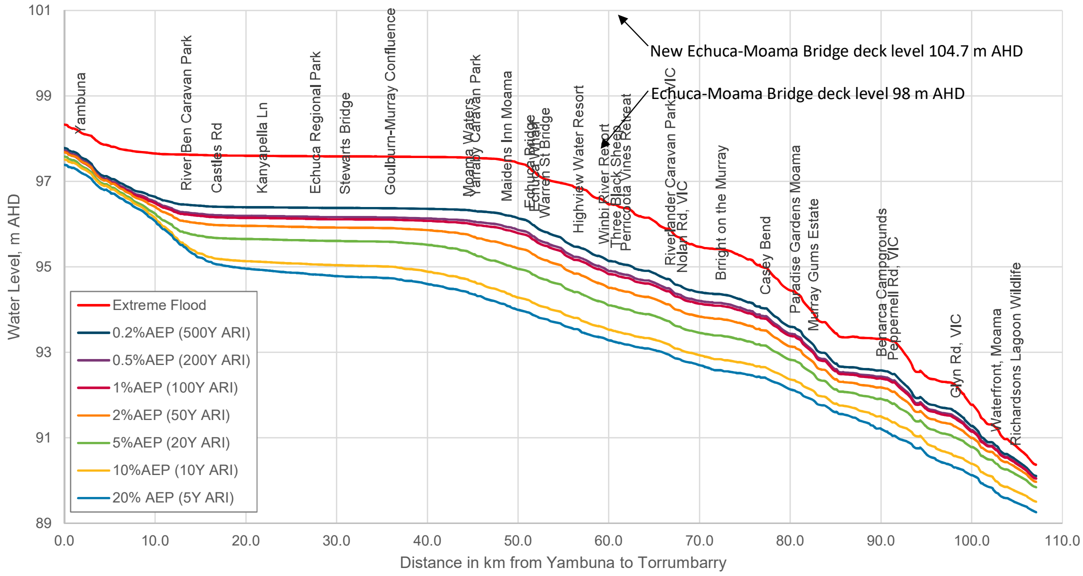

FIGURE 5-15 PEAK WATER LEVEL PROFILES MURRAY RIVER FROM YAMBUNA TO TORRUMBARRY

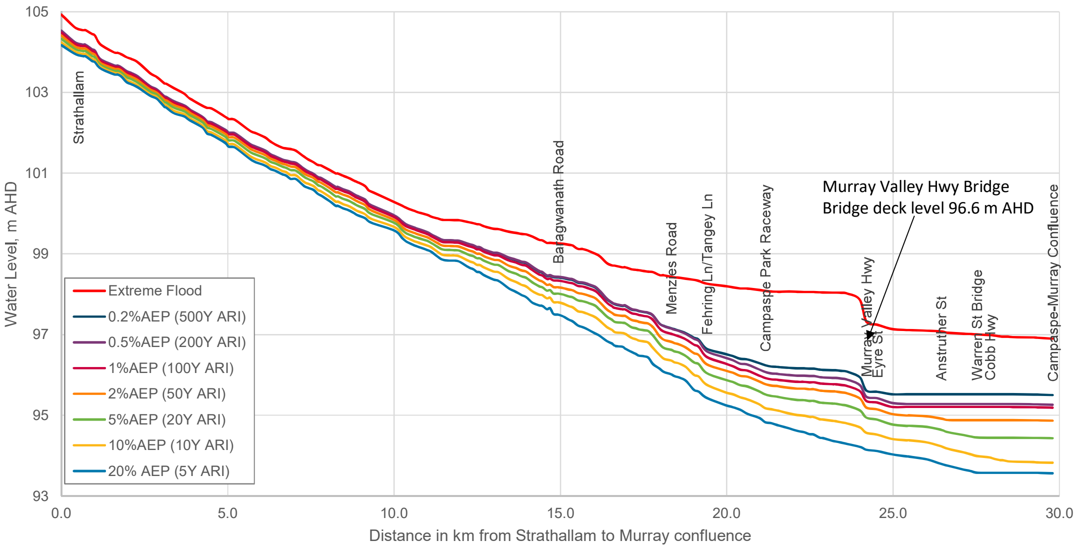

FIGURE 5-16 PEAK WATER LEVEL PROFILE ON CAMPASPE RIVER FROM BARAGWANATH RD (OR ECHUCA MITIAMO ROAD) TO MURRAY RIVER CONFLUENCE

5.5 Levee Assessment

An assessment of the levee crest against modelled design flood levels was carried out for a selection of levees of interest in East Moama. Figure 5-17 shows the levees which are assessed and the chainages.

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FIGURE 5-17 LEVEE ASSESSMENT LOCATION

5.5.1 Moama Town Levee

The Moama levee was constructed in 2004 by G. Goldsmith Constructions. The levee was constructed after the 1993 flood to an urban standard levee as a result of the recommendations from the previous Moama Floodplain Management Study (SKM, 2001). The crest levels were determined from the previous flood study. The levee was designed to protect against 0.5% AEP flood event with a built-in freeboard of 0.6 m for the earthen levee section and 0.3 m for the concrete retaining wall levee section. These standards of protection were based on the flood information available at the time, and differ slightly to the flood levels from this study.

The total length of the entire levee system is approximately 4.4 km. This includes around 184 metres at the beginning of the levee which is indistinguishable from Kiely Road.

The Moama levee system consists of a mix of earthen levee and concrete block retaining wall that tie into existing high ground at each end of the levee, offering flood protection from the Murray River. There are pipe culvert outlets across the levee draining stormwater trapped behind the levee into the Murray River. There are also a number of drop panel floodgates along the levee system for the purpose of pedestrian and vehicle access through the levee.

A crest level survey was carried out by PWA in March 2017. This survey indicates that there are four floodgates of obvious low spots:

- 95.04 m AHD drop panel floodgate driveway entry to property 1 Murray Street (Chainage 4,135 m);
- 94.92 m AHD drop panel floodgate pedestrian entry to property No. 1 Murray Street (Chainage 4,158 m);
- 94.77 m AHD drop panel floodgate, Murray Street access to Captains Cottage (Chainage 4,244 m);
- 94.76 m AHD drop panel floodgate pedestrian river access at Dorward Pl (Chainage 4,357 m);

The levee is maintained and operated by Murray River Council according to the Levee Owner's Manual (LOM) prepared by Public Works Advisory (PWA) in June 2018. The manual was prepared in accordance with the Levee Owner's Guidelines and was endorsed by the Department of Planning and Environment (Office of Environment and Heritage (OEH)).

The LOM suggests that during flood events, temporary emergency flood protection structures shall be installed at major road crossings to render the entire levee system 'completely closed' at the design crest level. Installation of temporary structures for crossings currently situated within the levee's freeboard (i.e. less than 0.6 m lower than the design crest level) to make up for the complete freeboard can be optional subject to the Levee Owner's flood tolerability (flooding at these locations is expected to be minor, e.g. storm winds may periodically blow waves of floodwaters over the crossing into the town side, etc.).

If resources and time are available after priority emergency activities such as inspections, closure of floodgates and 'low' major road crossings (i.e. more than 0.6 m lower than the design crest level), emergency repair works, etc., close off all 'high' road crossings if deemed necessary prior to the arrival of flooding.

A longitudinal profile of the Moama town levee with the 0.5%, 1% and 2% AEP water surface elevation, the levee crest (from 2017 survey) and the LiDAR ground levels on the floodplain side of the levee is plotted in Figure 5-18. The plot generally shows a lower degree of freeboard (to the 1% AEP event) than what is generally accepted. Typically, a minimum of 0.5 m is the normal freeboard adopted in the southern region of NSW for any type of levee construction, however a formal levee assessment is necessary to determine the correct freeboard. The levee was designed and constructed to have a nominal 0.6 m freeboard for the earthen sections and 0.3 m freeboard for the concrete wall sections above the 0.5% AEP design flood level at the time of design.

The design result shows that the present Moama levee does not allow for the level of freeboard typically required of a levee in NSW in a 1% AEP event. In general, the levee has around 0.4 m of freeboard on the earthen section and 0.2 m of freeboard on the concrete retaining wall section in a 1% AEP flood.

There are a number of low points that are identified along the Moama town levee that need closing during a flood event:

- The tie in on Kiely Rd in the north-west corner of the levee to be sandbagged
- Barnes Rd to be sandbagged
- Railway to be sandbagged
- Holmes Rd to be sandbagged
- Chanter St to be sandbagged
- Flood gates to be closed

According to the LOM, it was assumed in design modelling that the levee would be sandbagged at any low points before any significant floods, bringing the model's levee crest level to 96.2 m AHD. All flood gates were assumed to be closed during the modelling.

In considering the levee audit completed in 2017, the levee is generally in good condition, with a few saplings and ants nests identified north of the railway line. The major risk to the levee would be from failure of the sandbags on Chanter St or at the railway crossing. A breach of the levee in those two locations and also another location at the northern end of the levee was assessed, and is detailed in section below.

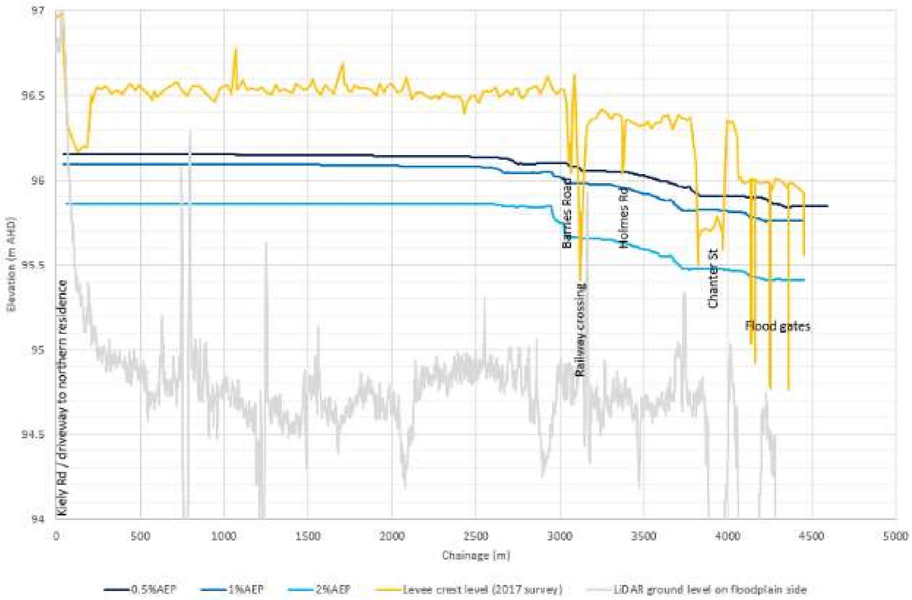

FIGURE 5-18 MOAMA TOWN LEVEE LONG PROFILE

5.5.2 Kooyong Park Levee

The Kooyong Park levee crest height as surveyed in 2016 is plotted along with the design flood level as presented in Figure 5-19. The levee has enough freeboard to hold back a 5% AEP flood with the typical 0.5 m of freeboard. The 5% AEP event is a little lower than the 2022 flood event.

The levee crest is overtopped in a 2% AEP event at its lowest points. The 1% AEP water level around the levee is 95.9 m AHD. The Echuca gauge level is at 95.48 m AHD.

Since the Kooyong Park levee is not a typical urban levee, it may not adequately protect residential property to its design level. The floor level of the buildings was determined by adding the 0.3 metre freeboard to the SKM 1% AEP flood level, which was 95.62 m AHD (Pla Right, 2015). The assumed floor level of 95.92 m AHD is just above the current 1% AEP flood level.

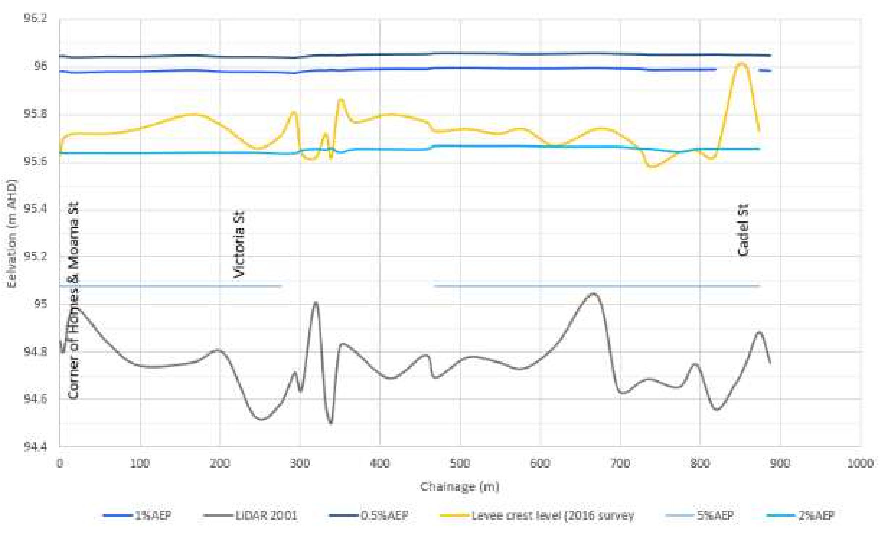

FIGURE 5-19 KOOYONG PARK LEVEE LONG PROFILE

5.5.3 Deniliquin Road Levee

The long profile of the levee crest on the east side of the Deniliquin Road is plotted in Figure 5-20. The peak water level for 20%, 5%, 1% and 0.5% AEP is plotted on the same figure. These levees, which were built on the banks of irrigation channels, are not urban standard levees and have a limited capacity to contain floodwater in the event of a reasonable-sized occurrence. In a less severe event, such as a 20% AEP, flood water will cross the road to the west.

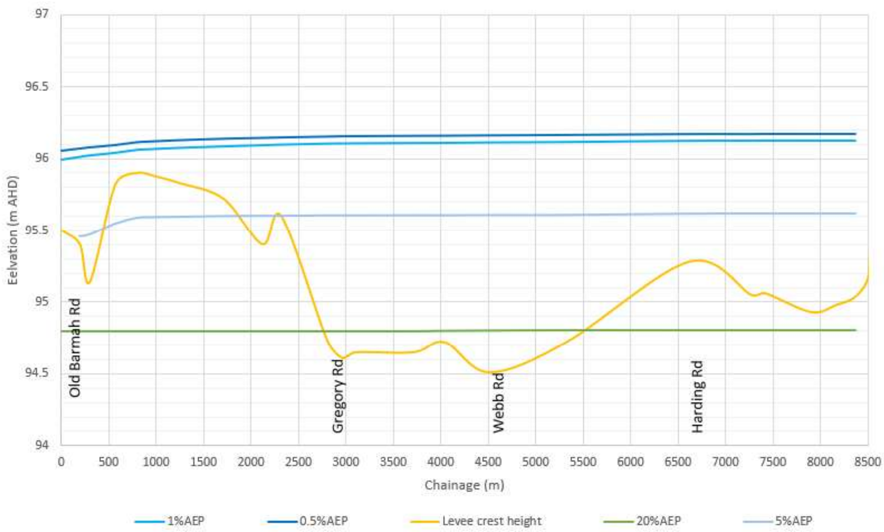

FIGURE 5-20 DENILIQUIN ROAD LEVEE LONG PROFILE

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6 MODEL SENSITIVITY

6.1 Climate Change Modelling

To assess the sensitivity of the floodplain to impacts of climate change, findings from a previous study by Goulburn Broken CMA on the Goulburn River were used, as discussed in Section 1.1.1. To summarise, this previous investigation found that the 1% AEP flows on the Goulburn River at Shepparton under a climate change scenario would be very similar to today's 0.5% AEP flows. This finding has been replicated across many other studies in Victoria, and it is reasonable that this be applied to the Echuca-Moama area also.

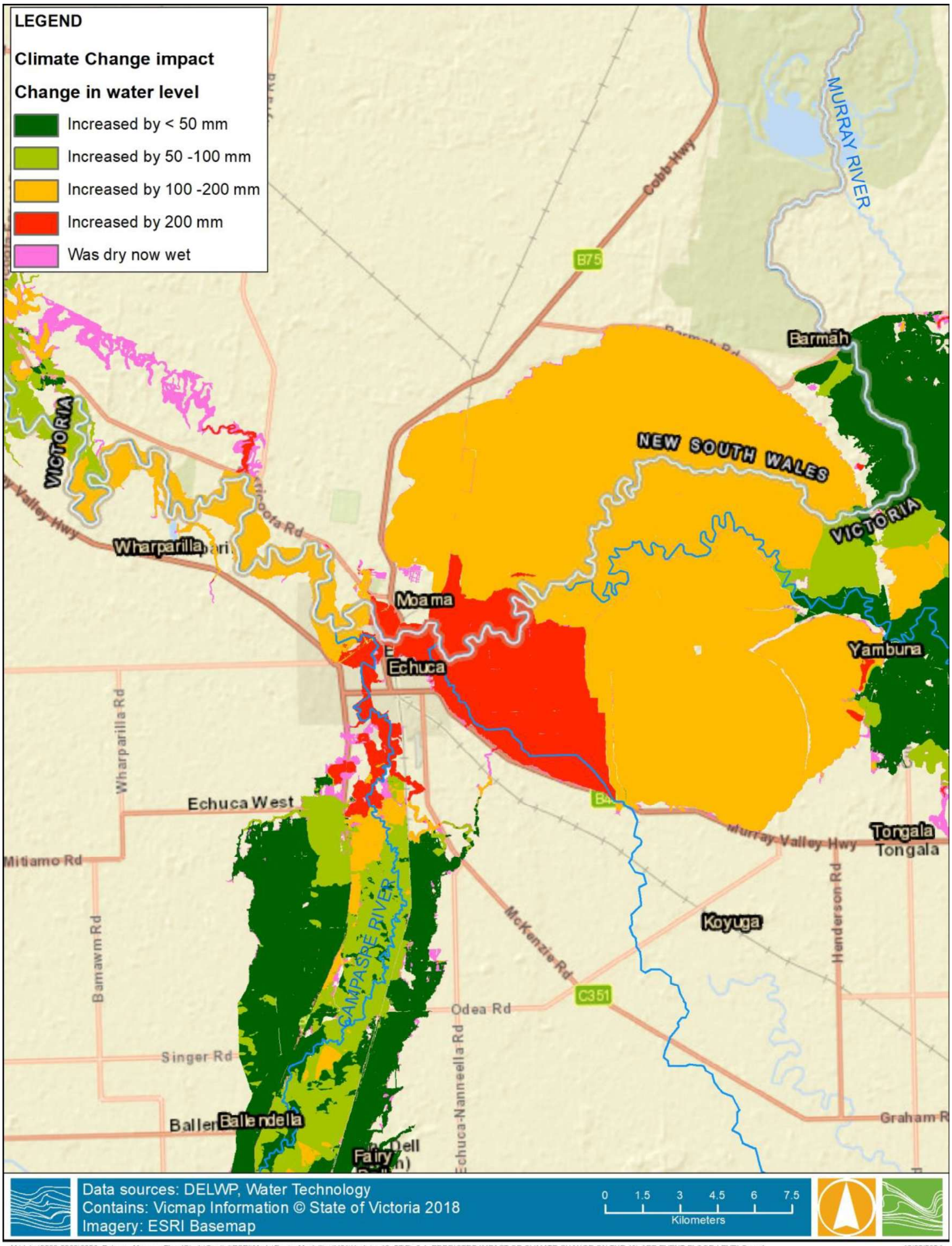
Assuming that the 1% AEP climate change scenario is similar to today's 0.5% AEP scenario, the potential changes to peak flood levels at the Murray River at Echuca Wharf gauge are summarised in Table 6-1. Under a climate change scenario, the level at the Murray River at Echuca Wharf gauge will increase by around 0.2 m, Table 6-1.

TABLE 6-1 SENSITIVITY OF CLIMATE CHANGE ON 1% AEP LEVEL AT ECHUCA GAUGE

Scenario	Existing Conditions	Climate Change	Difference
Peak Flow (ML/d)	107,654	109,815	2160
Water Level (m AHD)	95.5	95.7	0.2

To assess the likely impact of climate change on flood risk in Echuca and Moama and across the whole floodplain area, the 1% AEP flood extent was compared to the 0.5% AEP flood extent. Figure 8-1, which depicts the predicted change in the 1% AEP flood level, indicates that the water level in the Echuca-Moama and Kanyapella forest may rise by 50 to 100 mm due to climate change. The effect will be lessened as we move further east or west, where a 50 mm change in flood level is anticipated. At the Echuca Wharf gauge, increase in water level is around 200 mm.

This predicted increase in flood levels due to climate change warrants consideration in the adoption of planning flood levels in the Flood Risk Management Study and Plan for Echuca and Moama.



M:\Jobs\5800-5899\5820_Echuca_Moama_FloodStudy\Spatial\ESRI\Mxds\DesignModelling\V61\Update_10_27\Fig6-1_PREDICTED IMPACT OF CLIMATE CHANGE ON THE 1% AEP EVENT FLOOD LEVELS.mxd 13/02/2024

FIGURE 6-1 PREDICTED IMPACT OF CLIMATE CHANGE ON THE 1% AEP EVENT FLOOD LEVELS

6.2 Waterway Crossing – Blockage Assessment

An Australian Rainfall and Runoff (ARR) 2019 blockage assessment was undertaken for the key bridge structures included in the model. Table 6-2 shows the blockage applied for the bridges assessed. It is important to note that this blockage assessment was conducted via desktop study and not all bridges were visually inspected. The blockage sensitivity was carried out on the 5% AEP existing conditions event, and was completed prior to the October 2022 recalibration and design update. The mapped extents may have changed in the revised design modelling completed after the October 2022 recalibration, but the general sensitivity to blockage is unlikely to have changed.

An example of the ARR (2019) blockage form and summary table have been included in Appendix C. Judgements made in this assessment in terms of debris availability, mobility and transportability were subjective. In general, the availability of debris impacting the study area is relatively high. The rivers all have a good supply of potential debris from the riparian vegetation and redgum forests along the rivers. However, structures over the rivers are generally of significant size, i.e. multi-span bridges.

The assessment found several bridges had zero likelihood of blockage due to the factors outlined above. As a conservative approach, bridge openings across the Moama railway line, Black Bridge and Chanter Street culvert were tested with 100% blockage to assess the potential flood impact. As a further conservative approach, all bridges listed below were blocked at the same time.

The option considers the complete prevention of the flood waters from flowing west of the railway line through Black Bridge north of Moama. This removes a significant storage volume.

The results show that the blockages tested result in significant increases in flood levels in a 5% AEP event both upstream and downstream. This is a result of the loss of conveyance from the various culvert blockages, and the loss of storage due to the Black Bridge blockage.

TABLE 6-2 SUMMARY OF BRIDGE BLOCKAGE ANALYSIS

Modelling technique	Bridge location	Recommended Blockage level	Modelled blockage level
1D culvert	Railway line culvert-East	50%	100%
1D culvert	Chanter St culverts	15%	100%
1D culvert	Warren St flood relief	15%	50%
2D layered flow constriction	Echuca Bridge @ Murray River	0%	15%
2D layered flow constriction	New bridge @ Murray River	0%	15%
2D layered flow constriction	Cobb Hwy bridge @ Campaspe River	15%	15%
2D layered flow constriction	Warren St bridge @ Campaspe River	15%	50%

Modelling technique	Bridge location	Recommended Blockage level	Modelled blockage level
2D layered flow constriction	Murray Valley Hwy bridge @ Campaspe River	15%	15%
2D layered flow constriction	Black Bridge	50%	100%

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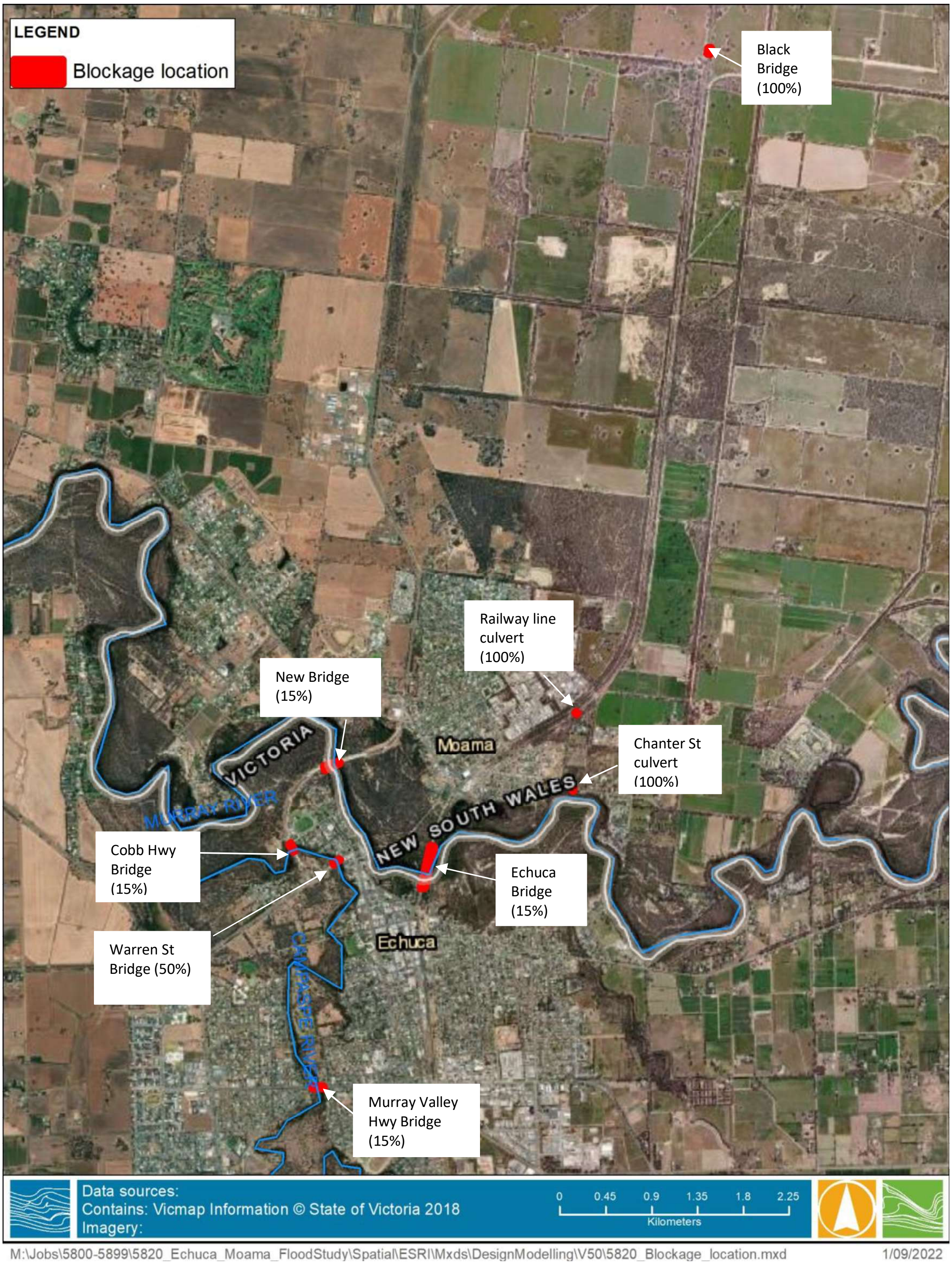

FIGURE 6-2 BLOCKAGE LOCATION

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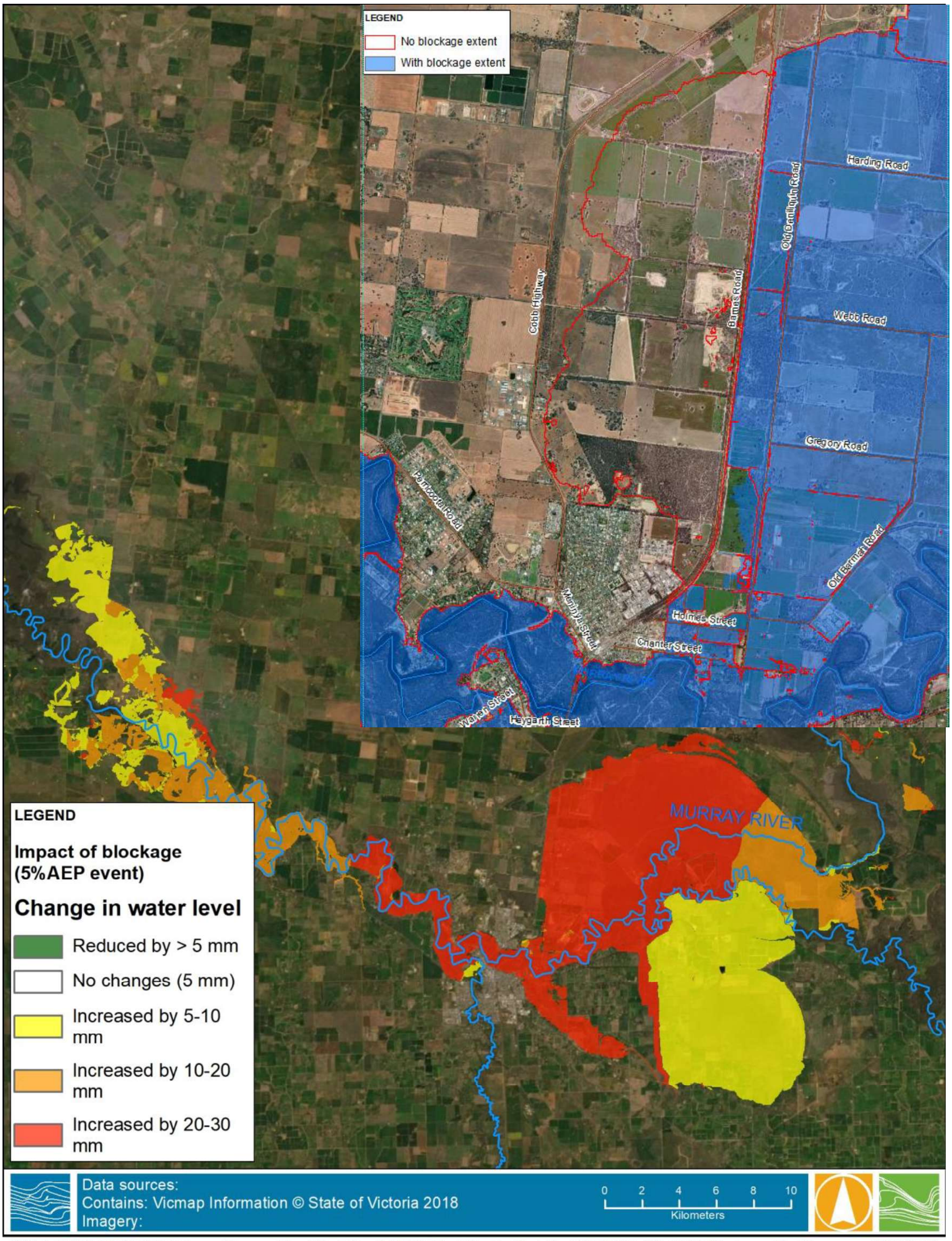

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FIGURE 6-3 5% AEP DESIGN FLOOD CULVERT BLOCKAGE SENSITIVITY

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6.3 Sensitivity of roughness

During the initial calibration phase the 1993 event was subject to close scrutiny. One of the model iterations considered changes to the roughness values within the waterway and along the riparian fringe. The sensitivity of the roughness was evaluated for roughness's that were 20% lower and 20% higher than the calibrated roughness.

Smoothing the roughness values by 20%, had the impact of lowering the flood levels by 10 to 19 cm. Increasing roughness by 20% increased the flood level by 10 to 22 cm. The sensitivity of roughness was measured by comparing the peak water level at few key locations in the study area. The results are shown in Table 6-3, Figure 6-4 and Figure 6-5. This suggests the model is relatively sensitive to the roughness values adopted.

TABLE 6-3 SENSITIVITY OF ROUGHNESS

Location	Difference in peak water level (m)	
	20% lower roughness	20% higher roughness
McCoy Bridge	-0.06	0.05
Murray-Goulburn confluence	-0.17	0.16
Echuca Bridge on Murray River	-0.18	0.22
Echuca Gauge	-0.19	0.22
Murray Valley Hwy Bridge on Campaspe	-0.18	0.21

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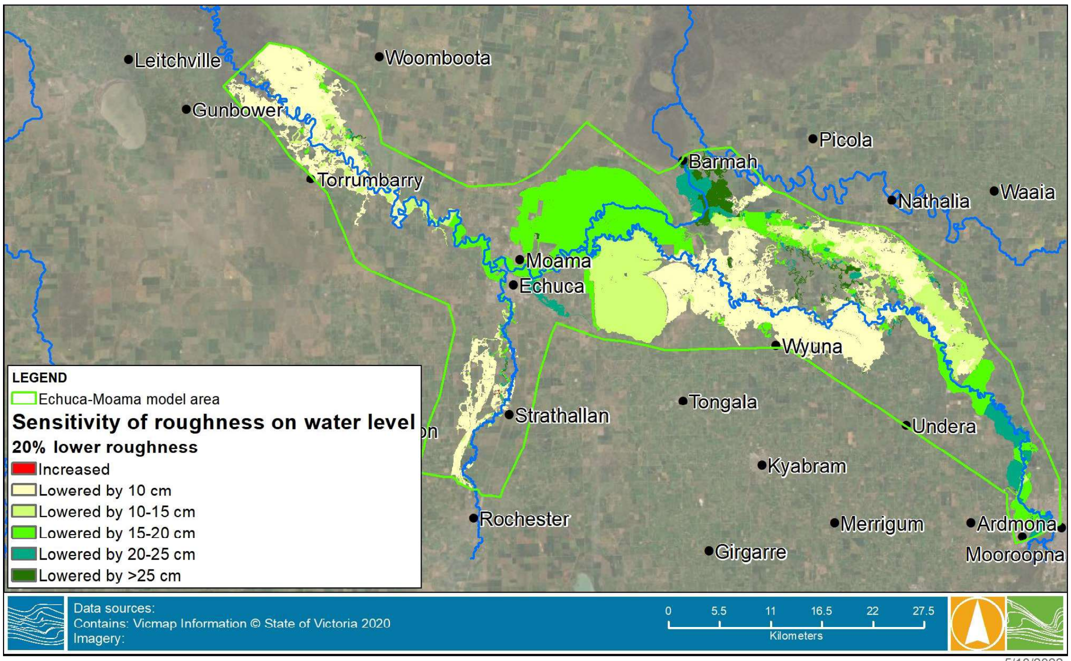

FIGURE 6-4 SENSITIVITY OF 20% LOWERED ROUGHNESS ON WATER LEVEL

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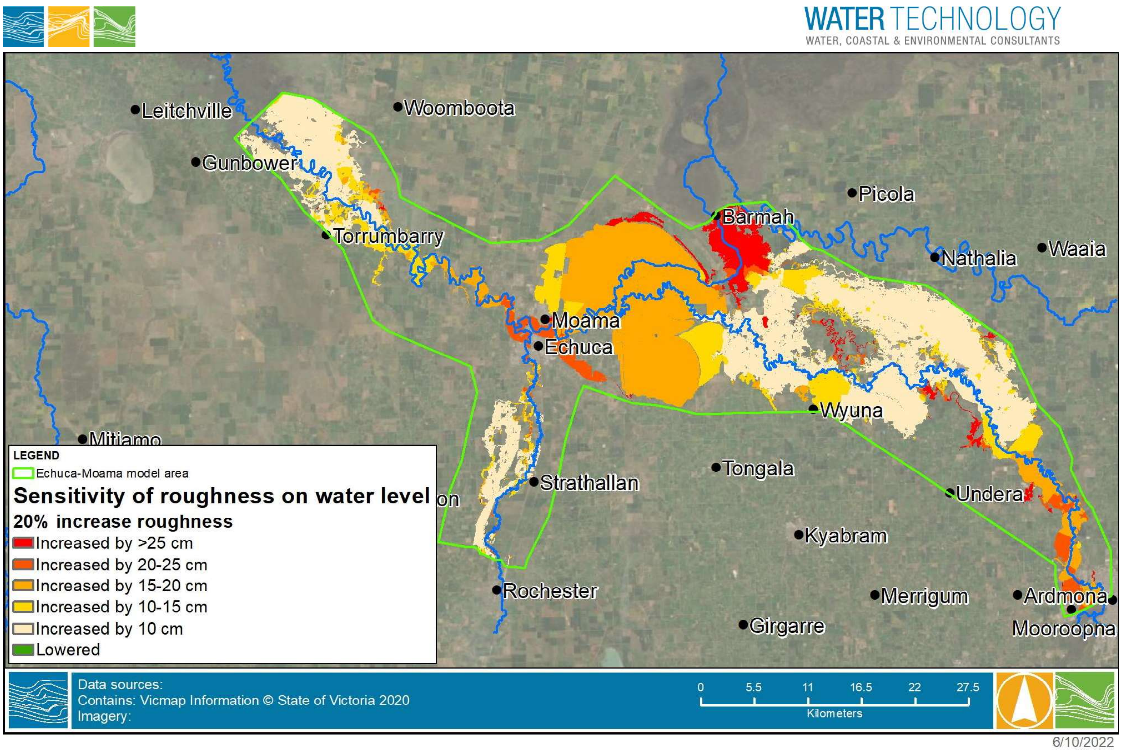

FIGURE 6-5 SENSITIVITY OF 20% INCREASED ROUGHNESS ON WATER LEVEL

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Further testing of roughness values was conducted during the recalibration of the October 2022 event. The roughness of the waterways and floodplain of the Goulburn River was increased to slow down the propagation of the flood wave and better represent the timing of the peak flows at Echuca Wharf. It was found that the higher roughness did result in a significant delay in the arrival of the flood peak at Echuca and Moama.

6.4 Levee Breach Assessment

A common misconception for people living behind a levee is that a levee is fail-proof or might only fail in extreme flood events. Research by Dufty et. al. (2022) demonstrated via survey of community members living behind levees in Launceston Tasmania, that these communities can also have a low level of flood risk awareness and elevated optimism regarding the protection the levee affords them. It is thus important to consider what could happen if a levee is overtopped or breached.

In order to understand the impact and risk of levee breach to the community in Echuca and Moama, a targeted levee breach assessment was conducted for the 1% AEP event.

The criteria used to identify breach locations was:

- Levee conditions or low points which required sandbagging.
- Vulnerable infrastructure behind levee.

Figure 6-6 shows the selected locations for the breach assessment. The breach location on the Moama levee were based on the low points identified as discussed in Section 5.5.1 and as shown on the long section of the levee (Figure 5-18).

The low points along the Moama town levee assessed for levee breach are listed below:

- The tie in on Kiely Rd in the north-west corner of the levee which required sandbagging
- Barnes Rd which required sandbagging
- Railway which required sandbagging
- The Chanter St which required sandbagging

The levee breaches were modelled using variable 2D elevations with associated trigger points for each location. The levee breach was design to start once the water level reached the 1% AEP flood level, with the levee breached to the ground level. The details of the modelled breaches are outlined in Table 6-4.

TABLE 6-4 MODELLED LEVEE BREACHES

Location	Breach Width (m)	Trigger Level (m AHD)	Breach duration (min)
1	35	96.00	12
2	35	96.08	12
3	35	96.00	12

Location	Breach Width (m)	Trigger Level (m AHD)	Breach duration (min)
4	30	95.85	12
5	50	95.00	12
6	45	95.10	12

Figure 6-7 and Figure 6-8 show the 1% AEP flood hazard maps for levee breaching scenarios along the Moama levee and Campaspe levees respectively. The flood hazard generally falls within classification 4 near the levee as a result of high flood depth, and classification 3 as the flow attenuates. The hazard classifications refer to those of Australian Institute for Disaster Resilience (2014). These classifications suggest that the impacted area is unsafe for people and vehicles.

Given the potentially devastating impact caused by levee breaching, visual inspections should be scheduled at least daily during the flood event as outlined in Levee Owner's Manual (LOM). As the flood approaches the design flood event level, inspections should be scheduled more frequently (provided the area is deemed safe to inspect). If there is a threat of a breach or overtopping, actions should be taken quickly. To bring the entire levee system up to the design crest level, temporary emergency flood protection structures must be erected at significant road crossings and floodgates must be closed as described in section 5.5.1.

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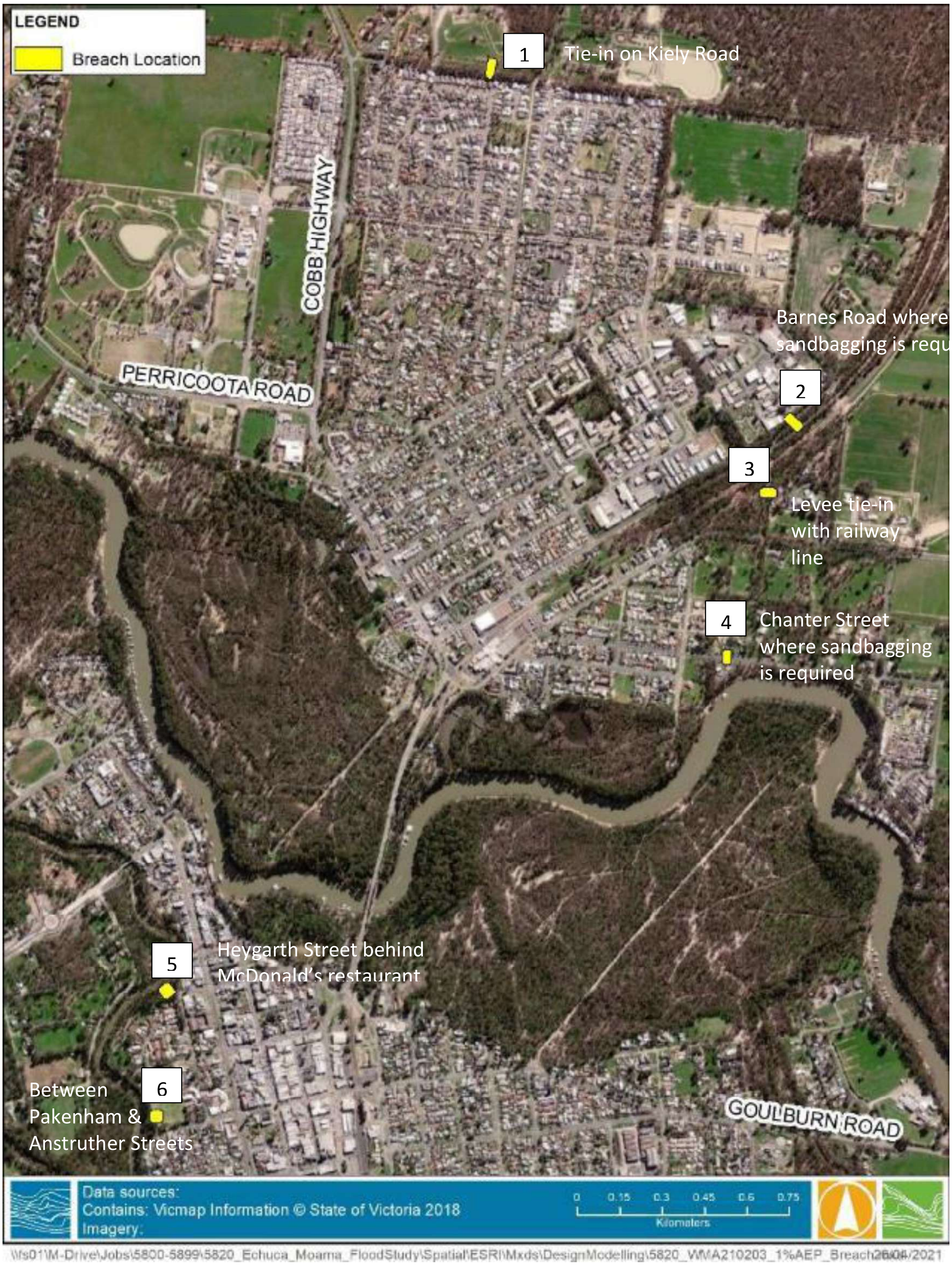

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FIGURE 6-6 BREACH ASSESSMENT LOCATION

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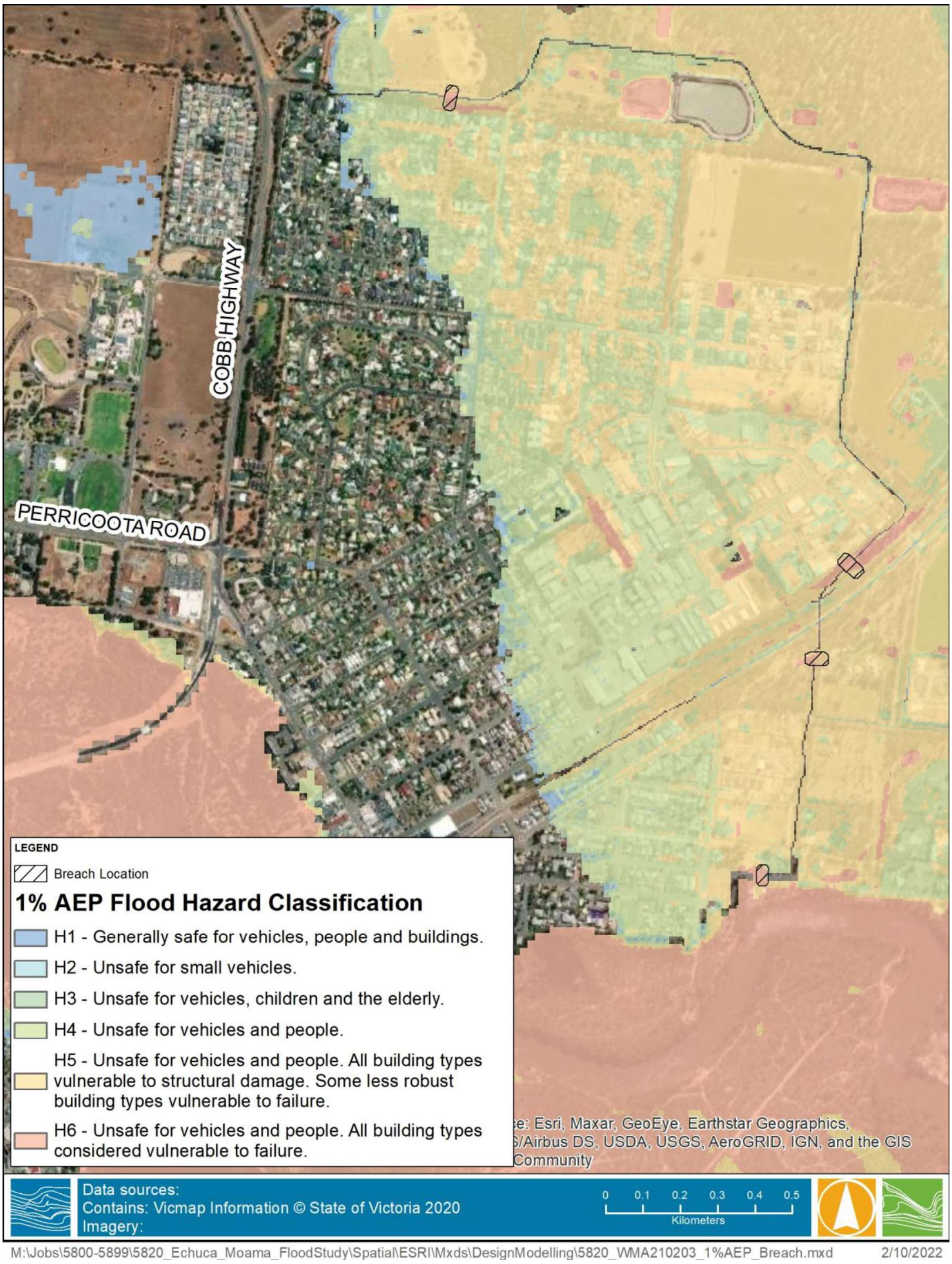

FIGURE 6-7 1% AEP FLOOD HAZARD – MOAMA LEVEE BREACH

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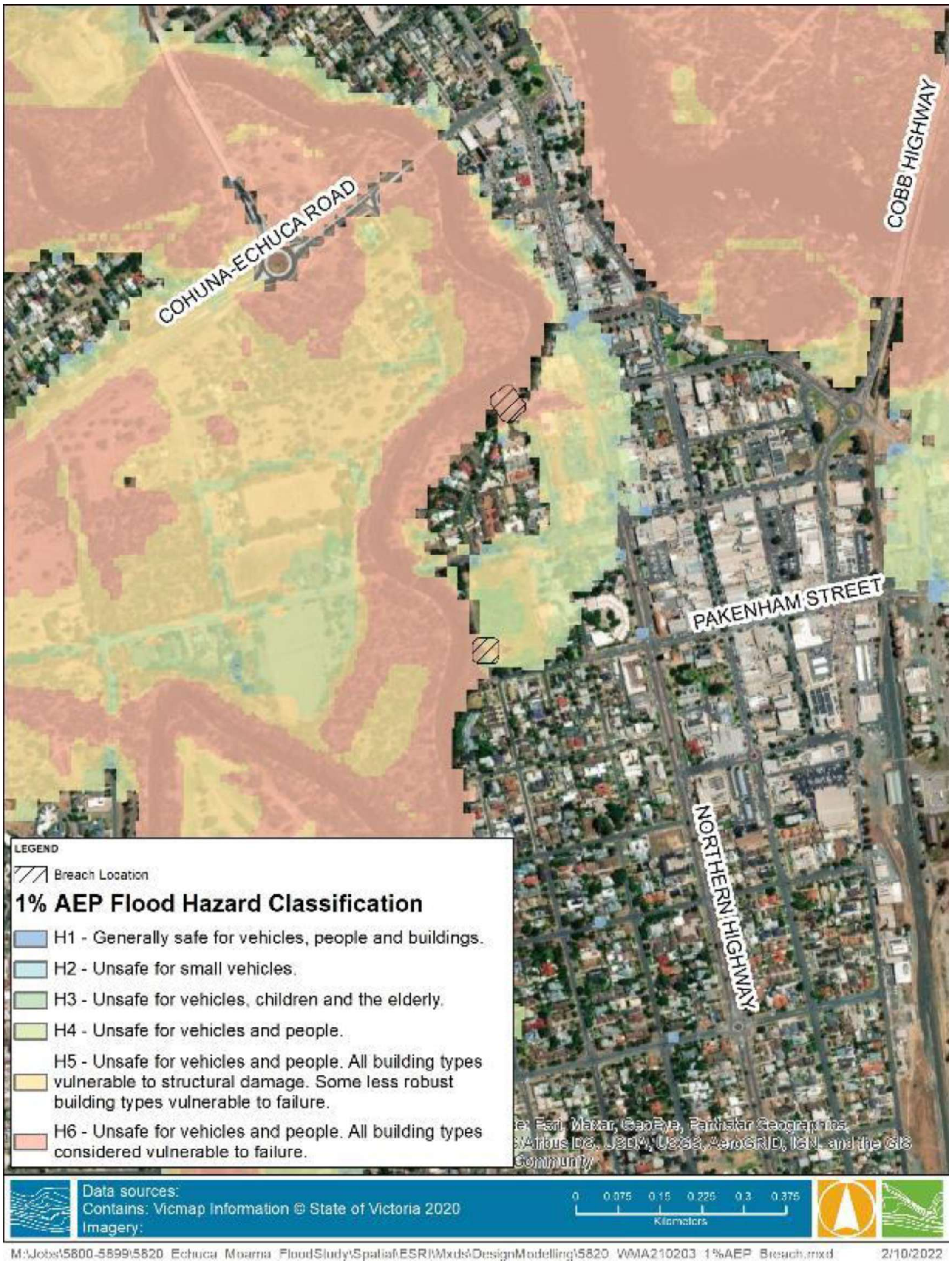

FIGURE 6-8 1% AEP FLOOD HAZARD – CAMPASPE LEVEE BREACH

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7 FLOOD HAZARD CATEGORISATION

7.1 Flood Hazard

The flood modelling results have demonstrated the diverse nature of the types of flood behaviour that can be observed across the floodplain in the Echuca-Moama area. These different flood behaviours can result in different levels of hazard, with more or less potential to cause harm to people and damage to property and infrastructure. The AIDR (2017) hazard mapping categories provide a good measure of hazard, these are presented in figures throughout Section 7.2, and are defined in Figure 7-1. The hazard is highest where water is deep and flowing fast, and lowest when water is shallow and flowing slow.

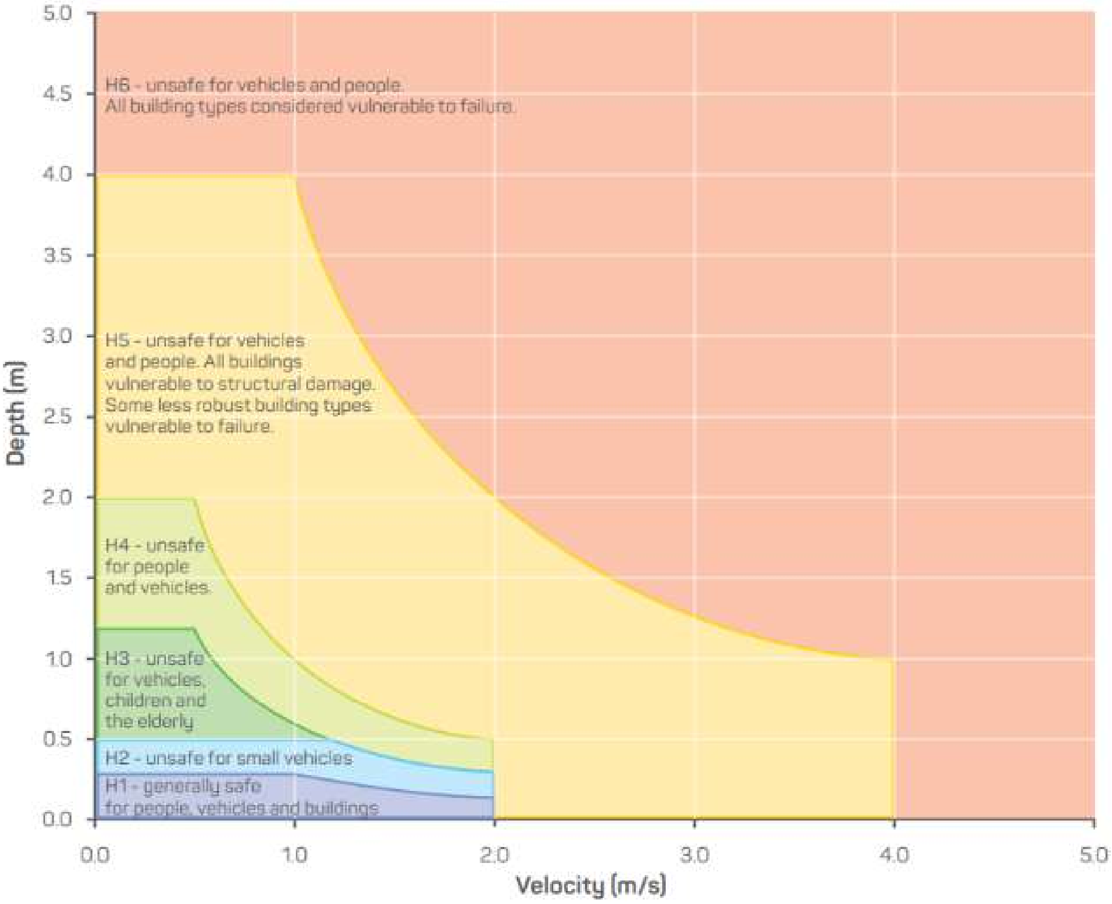

FIGURE 7-1 HAZARD CATEOGORIES, SOURCE: AIDR (2017)[5]

Typically, the velocities across the floodplain are low except within the river channels, but the depths are high. This combination results in most of the floodplain being categorised as H4 to H6, with some areas of higher land on the fringes of the floodplain falling into the H1 to H3 categories.

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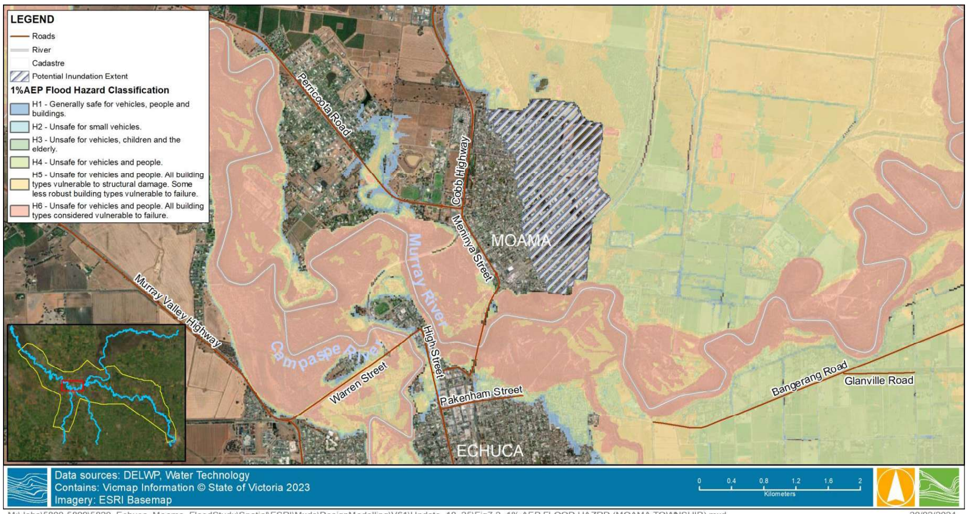

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FIGURE 7-2 1% AEP FLOOD HAZARD (MOAMA)

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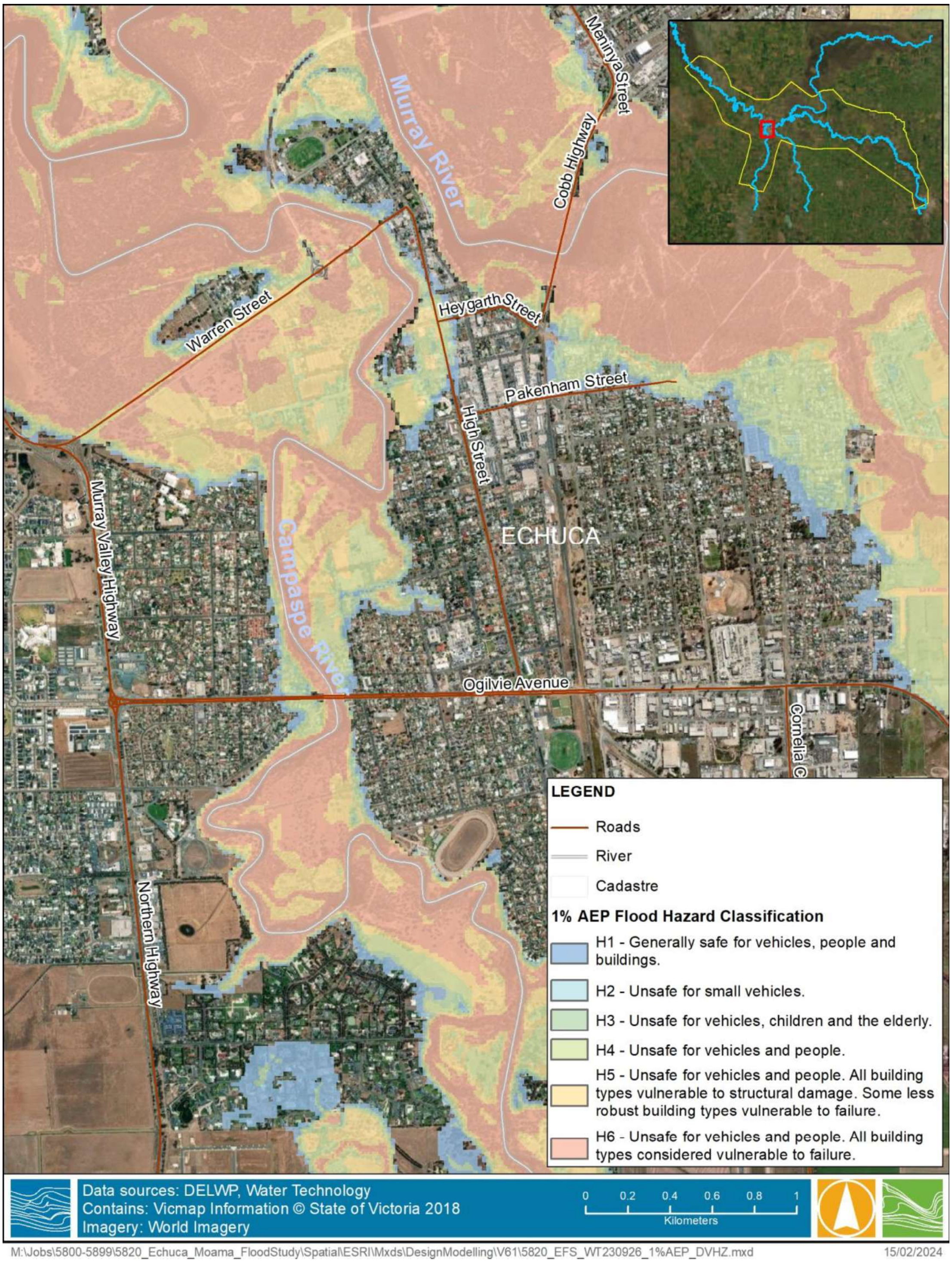

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FIGURE 7-3 1% AEP FLOOD HAZARD (ECHUCA)

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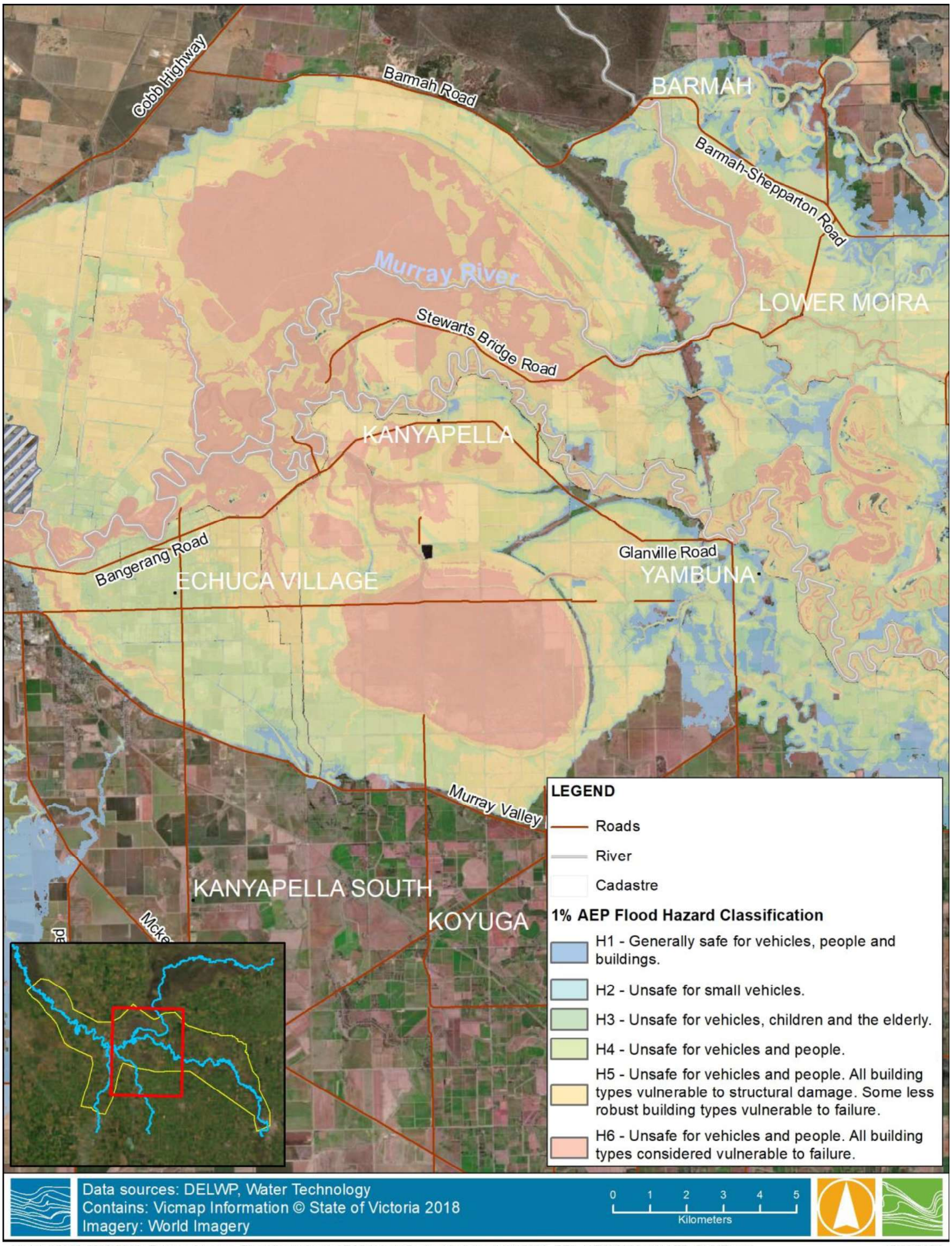

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FIGURE 7-4 1% AEP FLOOD HAZARD (KANYAPELLA-ECHUCA VILLAGE)

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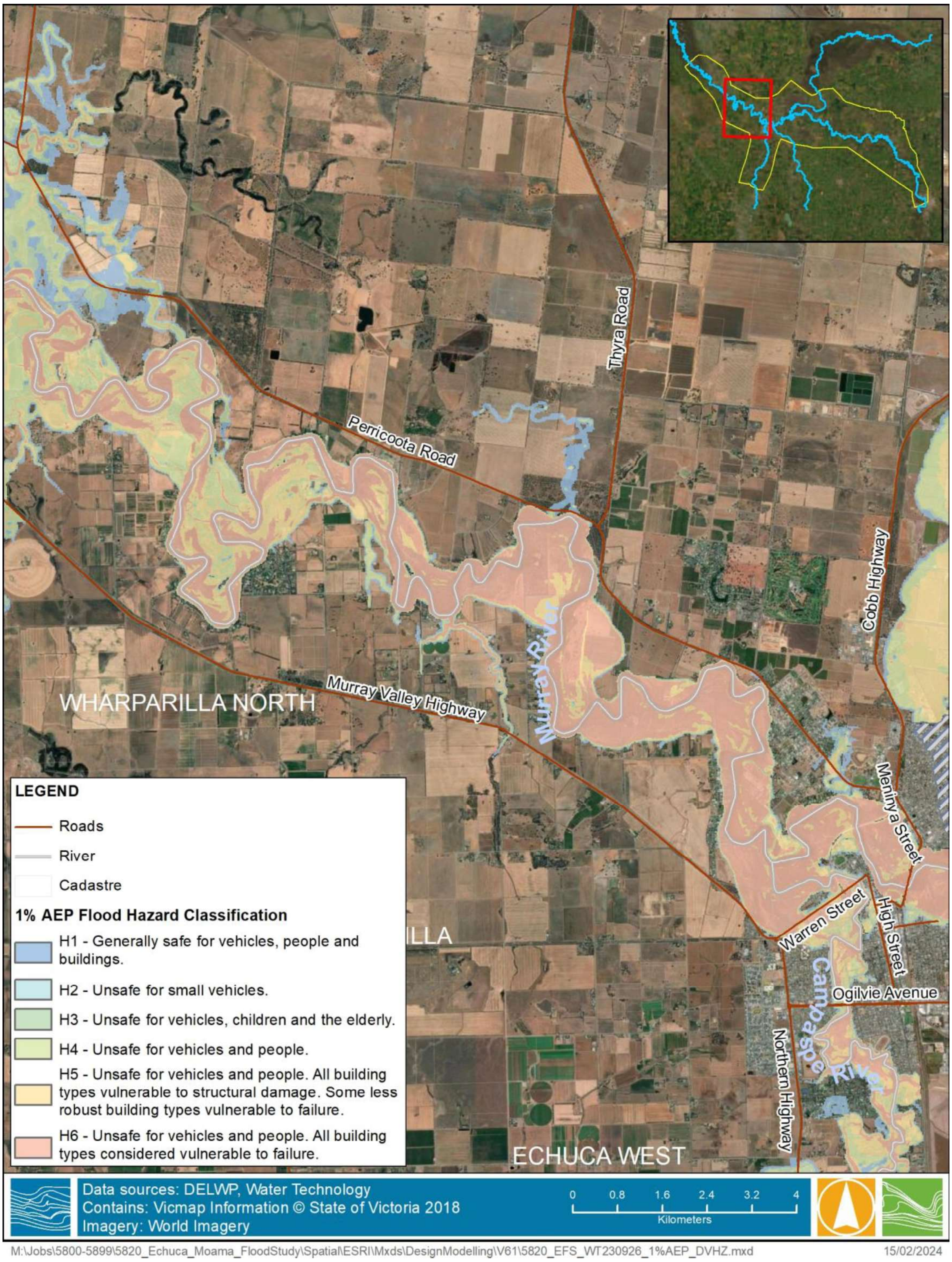

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FIGURE 7-5 1% AEP FLOOD HAZARD (ECHUCA WEST)

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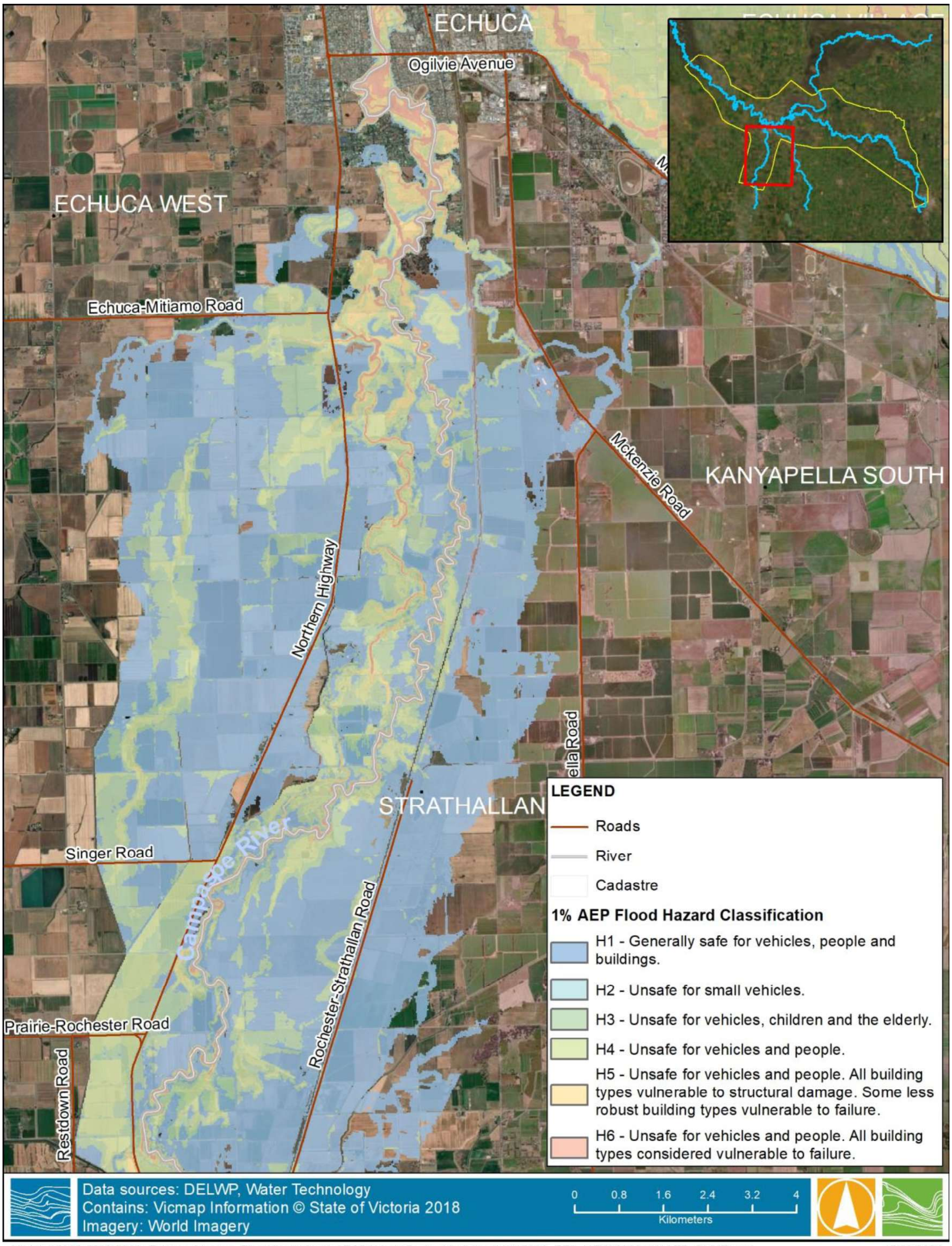

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FIGURE 7-6 1% AEP FLOOD HAZARD (CAMPASPE)

7.2 NSW Hydraulic Categorisation

In New South Wales flood studies, it is common to delineate hydraulic categories, describing the function of flood prone land as either floodway, flood storage and flood fringe. The New South Wales Flood Risk Management Manual (2023) defines these hydraulic categories as follows:

- **Floodways** are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas with higher velocities.
- **Flood Storage** areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of a levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
- **Flood Fringe** is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

The Flood Risk Management Manual (2023) provides qualitative descriptions of the three hydraulic categories, with some principles for how to map them, but is not prescriptive. Methods have evolved as modelling has evolved from 1D to 2D. The Department of Planning and Environment developed the Flood Function: Flood Risk Management Guideline FB02 (DPE, 2022), which provides further advice for more contemporary methods for mapping the flood function categories, and states there is no one size fits all approach.

An initial ‘indicator’ method approach was developed that considers the specific nature of this floodplain, with its exceptionally large storage characteristics with slow velocities, and deep water. The method adopted is similar to that adopted in other large, lower catchment floodplains in NSW. The approach considered a range of different velocity and depth criteria, and through a process of iteration, defined criteria that on a visual examination appropriately defined the three flood function categories for this floodplain. The initial ‘indicator’ criteria are as follows:

- Floodway
  - Velocity x Depth > 0.25 m^2/s AND Velocity > 0.25 m/s
  - 10% AEP flood extent
- Flood Storage
  - Depth > 0.5 m
- Flood Fringe
  - Remaining area of flood prone land

Using the above criteria the provisional flood function hydraulic categories are shown in Figure 7-7 for the 1% AEP flood event for the Moama area. The final mapping and recommendations regarding planning scheme amendments will be further investigated and finalised in the early stages of Flood Risk Management Study and Plan phase of this project.

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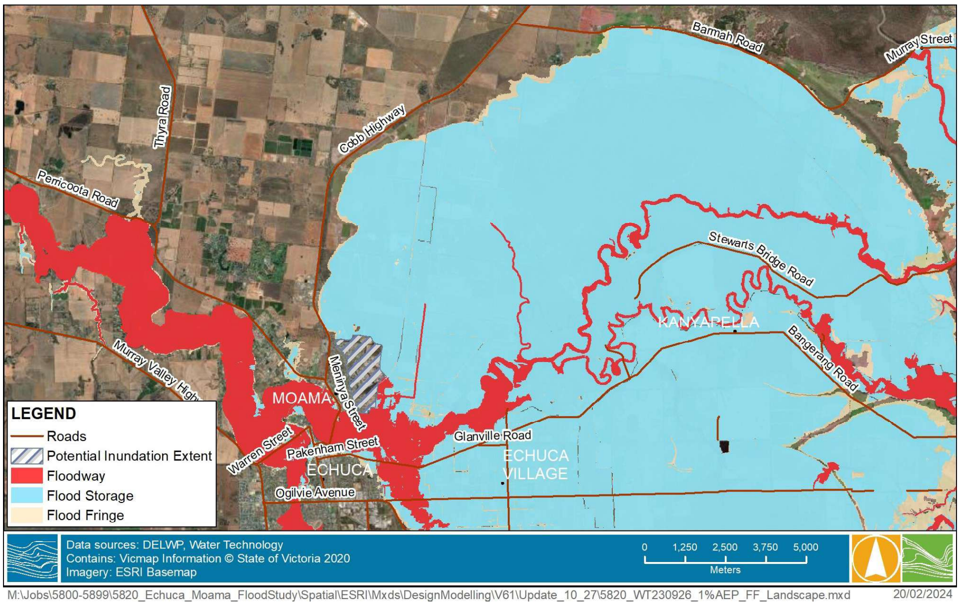

FIGURE 7-7 PROVISIONAL HYDRAULIC CATEGORISATION – MOAMA

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7.3 Victoria Hydraulic Categorisation

In Victoria, it is typical to define hydraulic categorisation within the Planning Scheme. The Urban Flood Zone (UFZ) and Floodway Overlay (FO) combined typically define what would be termed Floodway or Flood Storage in NSW. The Land Subject to Inundation Overlay (LSIO), for riverine floodplains is similar to the Flood Fringe in NSW. In the North Central CMA region, the typical definition for areas that would make up the LSIO and the combined FO and UFZ are as follows:

- Floodway Overlay (FO) and Urban Floodway Zone (UFZ) areas
  - Depth > 0.5 m in the 1% AEP event, or
  - Velocity > 1.5 m/s in the 1% AEP event, or
  - Depth x Velocity > 0.4 m^2/s in the 1% AEP event
- Land Subject to Inundation Overlay (LSIO) areas
  - Remaining area of flood prone land in the 1% AEP event

An indicative FO/UFZ and LSIO delineation for the Victorian floodplain to consider further during the next stage of the project is shown in Figure 7-8. The high depths in the floodplain mean that the majority of the floodplain would likely be recommended to be defined as Floodway Overlay or Urban Flood Zone should an amendment be considered within the Victorian Planning Scheme. In the rural areas of the floodplain Floodway Overlay would be preferred to Urban Flood Zone. Some urban areas of Echuca currently have Urban Flood Zone applied and it is unlikely that these will be rezoned.

As with the New South Wales hydraulic categories, the final mapping and recommendations regarding planning scheme amendments will be further investigated and discussed in the Flood Risk Management Study and Plan stage.

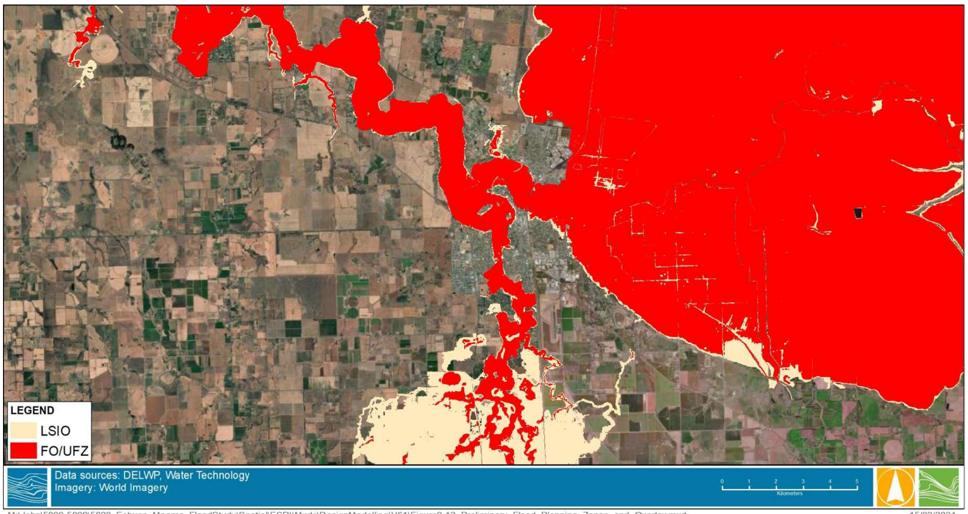

FIGURE 7-8 PROVISIONAL FLOOD PLANNING ZONES AND OVERLAYS

8 CONCLUSION

The townships of Echuca and Moama are situated on opposite sides of the Murray River floodplain. The Campaspe and Goulburn Rivers flow into the Murray River in close proximity to the towns.

The Campaspe Shire Council (CSC) and Murray River Council (MRC) require 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.

This flood study has taken a considerable effort to complete. It has 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 hydrology and hydraulics have been calibrated to a range of historic floods including the October 1993, January 2011, October 2016 and the October 2022 events. The modelling has developed updated design flood information for Echuca and Moama, superseding the previous flood study completed in 1996. The data available and the modelling methods have progressed significantly since the previous flood study, but reassuringly the design flood levels have not changed considerably at the Murray River at Echuca Wharf gauge location. 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. This flood behaviour through East Moama is quite nuanced, and the modelling developed in this current flood study is far better placed to represent it appropriately than in the previous flood study.

This report presents the results of the flood modelling and mapping and has presented some preliminary analysis of the impacts of flooding through Echuca and Moama, along with some investigation 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. It is noted that these flood function maps will be further investigated and finalised in the early stages of the Flood Risk Management and Plan phase of this project. This next phase will begin after both Councils have considered the Flood Study Report, have exhibited the report and considered any feedback received, and then made a determination as to whether the report is to be adopted.

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9 REFERENCES

Australian Institute for Disaster Resilience (2014), Australian Disaster Resilience Guideline 7-2: Technical Flood Risk Management Guideline: Flood emergency response classification of the floodplain

Australian Rainfall and Runoff (2019), Institution of Engineering Australia

Bureau of Meteorology weather and climate data, http://www.bom.gov.au/climatedata/, accessed March 2019.

Currey, D.T. and Dole D.J. (1987). River Murray flood flow patterns and Geomorphic tracts. Symposium on the Murray Darling River System

Cameron McNamara Pty. Ltd. (1987). Lower Goulburn Floodplain Management Study – Phase III

Department of Environment, Land Water and Planning Victorian Water Resources Website, https://data.water.vic.gov.au/static.htm, accessed March 2019

Department of Planning Environment (June, 2023), Flood Risk Management Manual: the policy and manual for the management of flood liable land.

Department of Planning and Environment (2022) Flood Function: flood risk management guide

Earth Tech (October, 2004). Moama West Flooding and Drainage Investigation. Prepared for Murray Shire Council

GHD (March, 2006). Torrumbarry Gunbower Flood Risk Mitigation Strategy, Prepared for North Central CMA

GHD (March, 2001). RiverLife Property Group, Report for RiverLife Estate Barham, Flood Risk assessment.

HARC (2018), Goulburn and Broken Rivers Flood Study, Hydrology Report, report prepared for Goulburn Broken CMA

Nathan. R. J., Weinmann, P. E. and Gato, S. A. (1994), 'A Quick Method for Estimating Probable Maximum Flood in South Eastern Australia', Water Down Under 94 Conference Proc., Adelaide, November, 1994, pp. 229-234

PlanRight, March (2014), CS8575 Kooyong Park Rev B, (Source: Murray Shire Council)

Rural Water Commission (1978). Flood Frequency Analysis-Echuca Wharf, Internal Report

Rural Water Commission of Victoria and Water Resource – Shepparton to Kanyapalla: Main Report and Technical Reports: Rural Water Corporation of Victoria. Commission of New South Wales (1986). Murray River Flood Plan Management Study, Detailed Report

Rutherfurd, I.D. & Kenyon, C.E. (2005). Geomorphology of the Barmah-Millewa Forest. Proceedings of the Royal Society of Victoria 117(1): 23-39

5820_R04_V15_Final_FloodStudyReport.docx

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

Sinclair Knight Merz (May, 1997). Moama-Echuca Flood Study. Prepared for Shire of Murray, Shire of Campaspe

Wasko, C. and Nathan, R (2019), Influence of changes in rainfall and soil moisture on trends in flooding, Journal of Hydrology

Water Technology (June, 2013). Rochester Flood Management Plan, Final Study Report. Prepared for North Central CMA, Shire of Campaspe

Water Technology (June, 2007). Flood Report for Kooyong Park Planning, Final Report. Prepared for EDM Group

Water Technology (March, 2018). Shepparton Mooroopna Flood Mapping and Flood Intelligence Study. Prepared for Goulburn Broken CMA

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APPENDIX A GLOSSARY

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Taken from the Floodplain Development Manual (April 2005 edition)

TABLE A-1 GLOSSARY

Term	Description
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3 /s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3 /s or larger event occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
caravan and moveable home parks	Caravans and moveable dwellings are being increasingly used for long-term and permanent accommodation purposes. Standards relating to their siting, design, construction and management can be found in the Regulations under the LG Act.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.

Term	Description
consent authority	The Council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the Council, however legislation or an EPI may specify a Minister or public authority (other than a Council), or the Director General of DIPNR, as having the function to determine an application.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (EP&A Act). **infill development:** refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. **new development:** refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

Term	Description
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m3 /s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act 1993. The use of sustainability and sustainable in this manual relate to ESD.
effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

Term	Description
Flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood liable land	Is synonymous with flood prone land (i.e. land susceptible to flooding by the probable maximum flood (PMF) event). Note that the term flood liable land covers the whole of the floodplain, not just that part below the flood planning level (see flood planning area).
flood mitigation standard	The average recurrence interval of the flood, selected as part of the flood risk management process that forms the basis for physical works to modify the impacts of flooding.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
flood risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a flood risk management plan requires a detailed evaluation of flood risk management options.
flood risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.

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Term	Description
flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at State, Division and local levels. Local flood plans are prepared under the leadership of the State Emergency Service.
flood planning area	The area of land below the flood planning level and thus subject to flood related development controls. The concept of flood planning area generally supersedes the flood liable land concept in the 1986 Manual.
Flood Planning Levels (FPLs)	FPLs are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for flood risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the standard flood event in the 1986 manual.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate flood damages.
flood prone land	Is land susceptible to flooding by the Probable Maximum Flood (PMF) event. Flood prone land is synonymous with flood liable land.
flood readiness	Flood readiness is an ability to react within the effective warning time.

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Term	Description
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks. They are described below. **existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. **continuing flood risk:** the risk a community is exposed to after flood risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any flood risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	floodway areas Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flows, or a significant increase in flood levels.

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Term	Description
freeboard	Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.
habitable room	**in a residential situation:** a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. **in an industrial or commercial situation:** an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in the Manual.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
local drainage	Are smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.

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Term	Description
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purpose of this manual major drainage involves: ■ the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or ■ water depths generally in excess of 0.3 m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or ■ major overland flow paths through developed areas outside of defined drainage reserves; and/or ■ the potential to affect a number of buildings along the major flow path.
mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

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Term	Description
merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well being of the State=s rivers and floodplains. The merit approach operates at two levels. At the strategic level it allows for the consideration of social, economic, ecological, cultural and flooding issues to determine strategies for the management of future flood risk which are formulated into Council plans, policy and EPIs. At a site specific level, it involves consideration of the best way of conditioning development allowable under the flood risk management plan, local flood risk management policy and EPIs.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **minor flooding:** causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **moderate flooding:** low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **major flooding:** appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
modification measures	Measures that modify either the flood, the property or the response to flooding. Examples are indicated in Table 2.1 with further discussion in the Manual.
peak discharge	The maximum discharge occurring during a flood event.

Term	Description
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a flood risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
probability	A statistical measure of the expected chance of flooding (see AEP).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to water level. Both are measured with reference to a specified datum
stage hydrograph	A graph that shows how the water level at a particular location change with time during a flood. It must be referenced to a particular datum.

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Term	Description
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	The horizontal distance in the direction of wind over which wind waves are generated.

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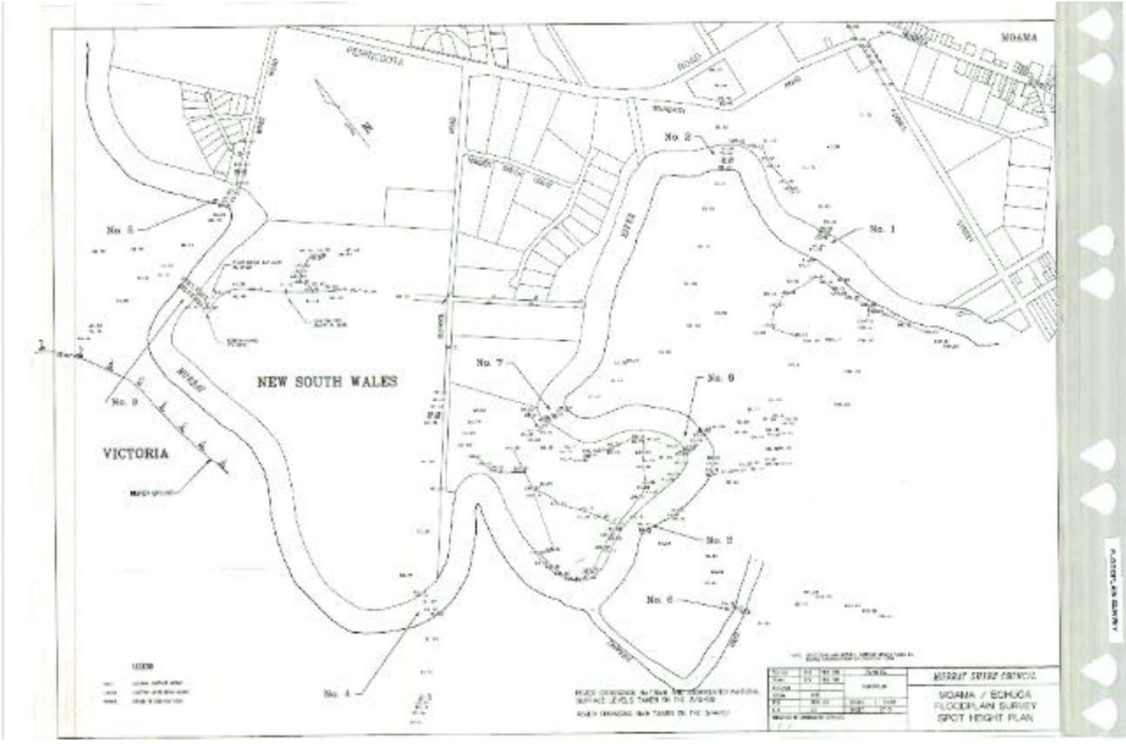
APPENDIX B
RURAL LEVEES & FLOOD IMAGERY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No. 4
NEW SOUTH WALES
VICTORIA
MURRAY SHIRE COUNCIL
MOAMA / ECHUCA
FLOODPLAIN SURVEY
SPOT HEIGHT PLAN

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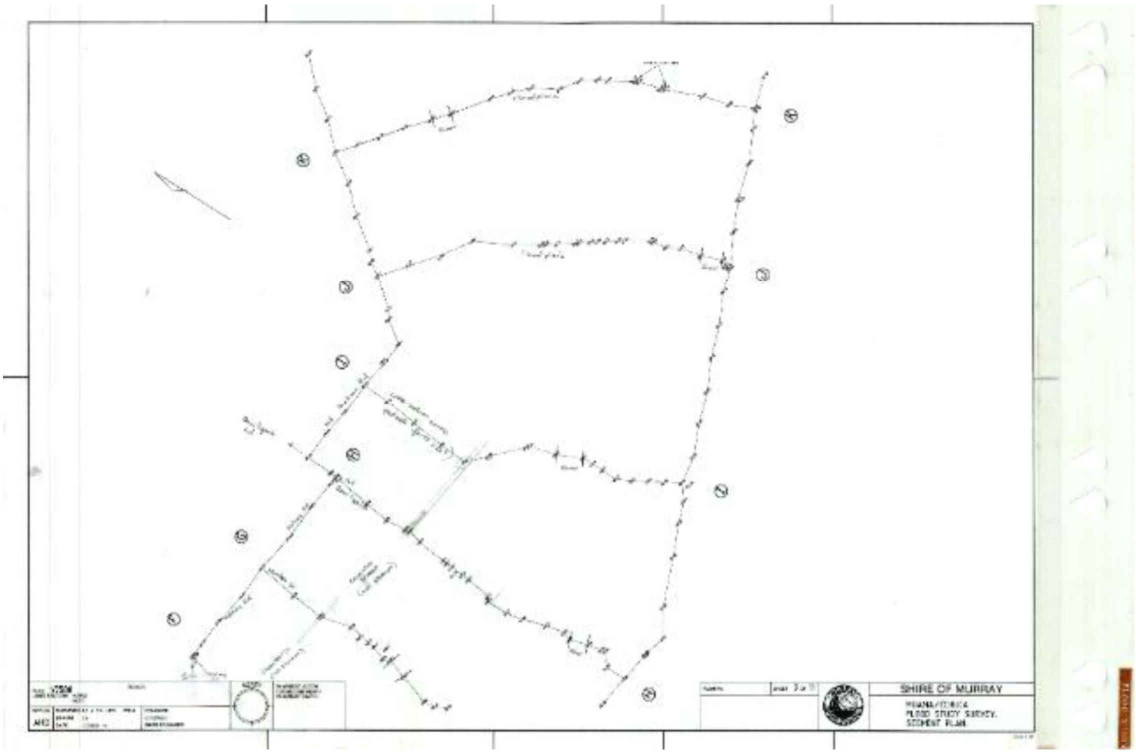

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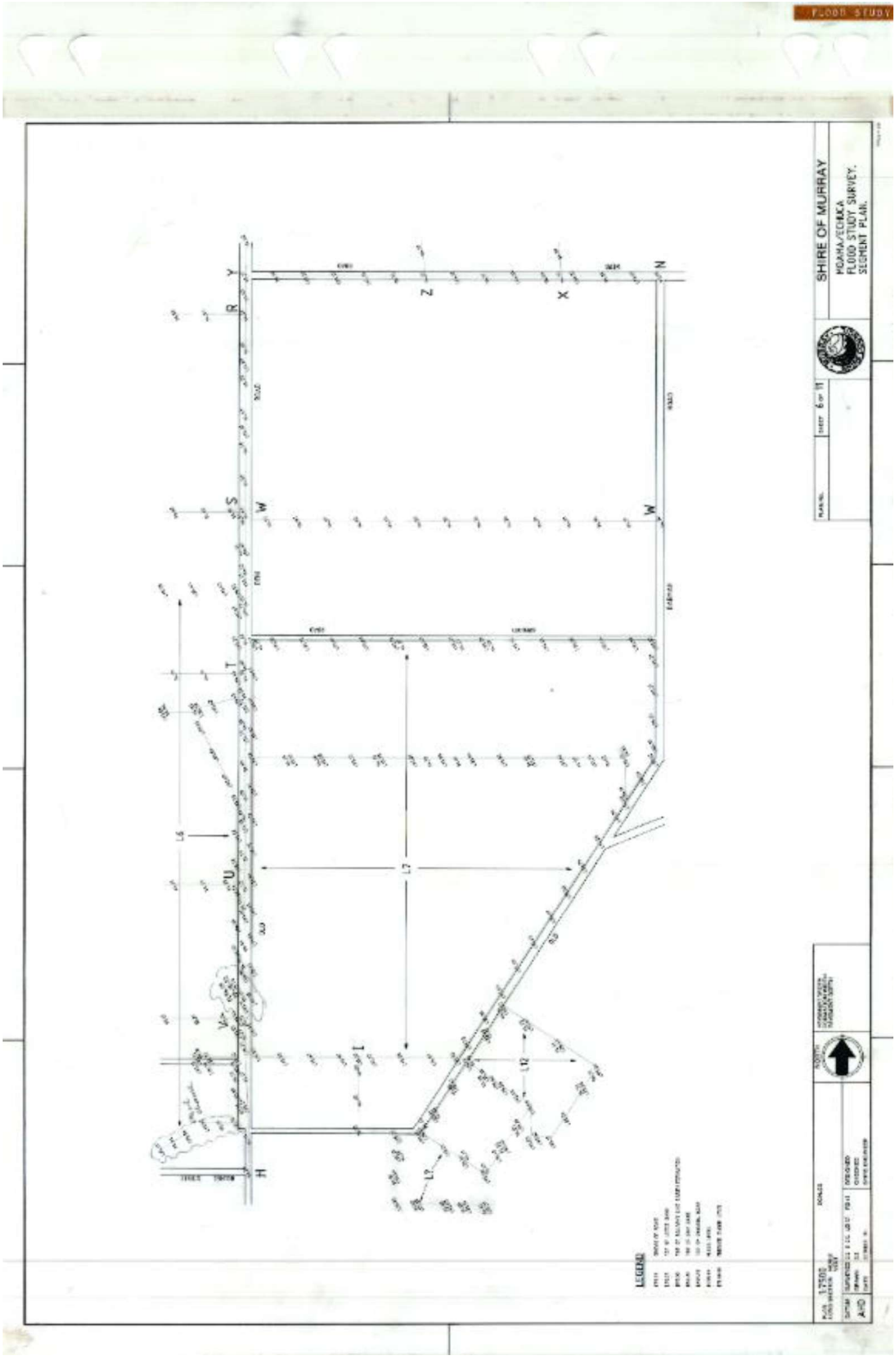

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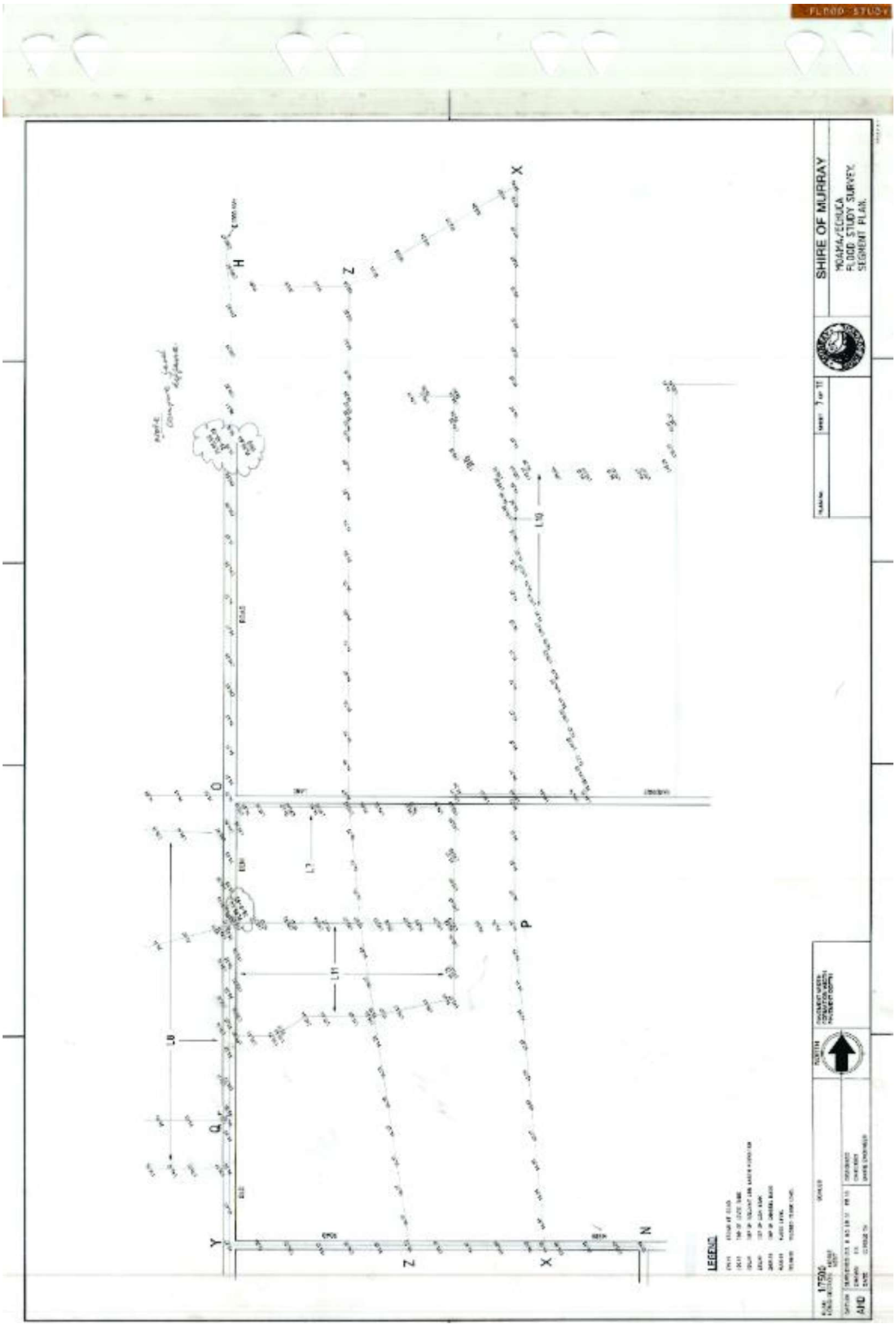
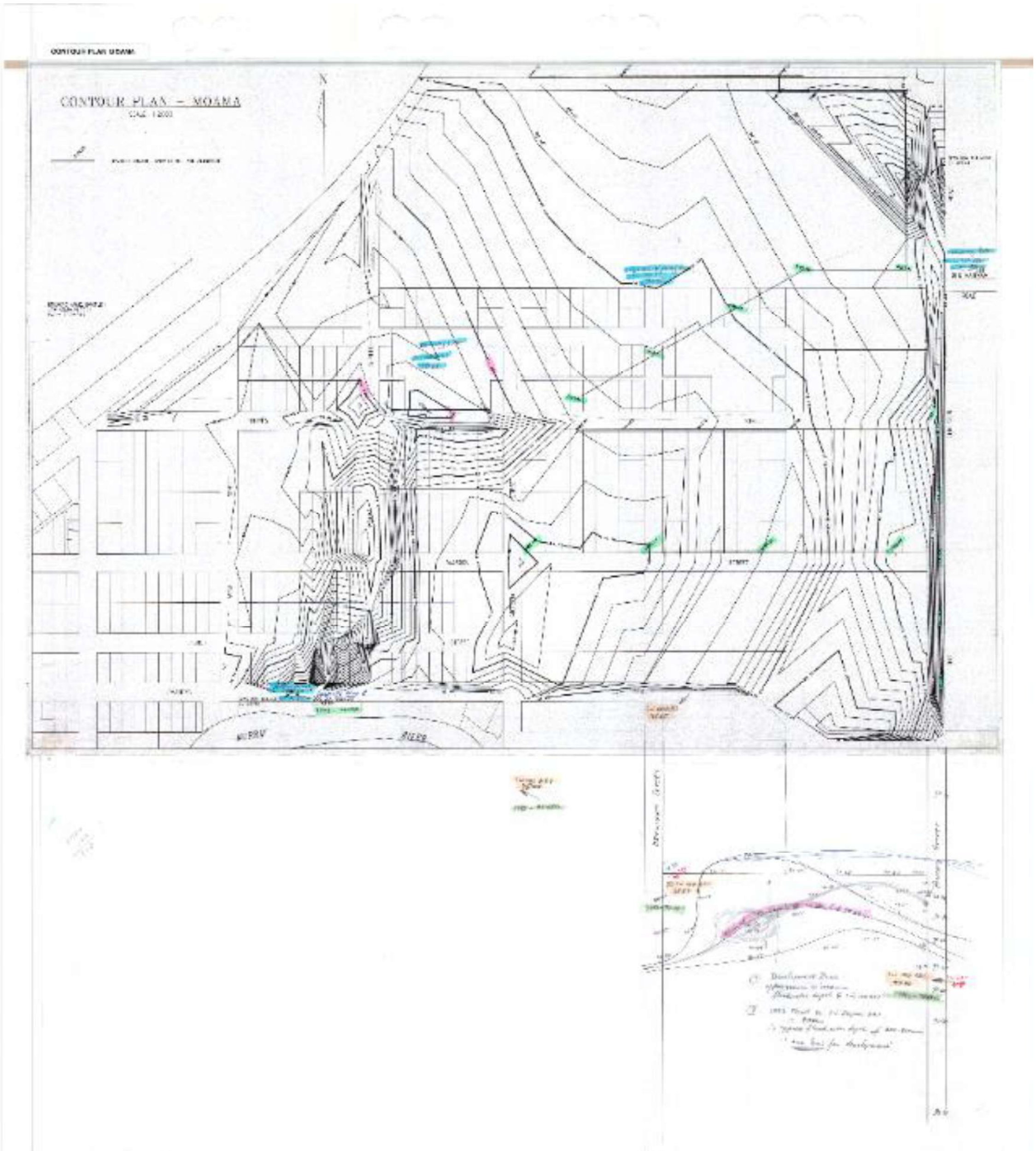
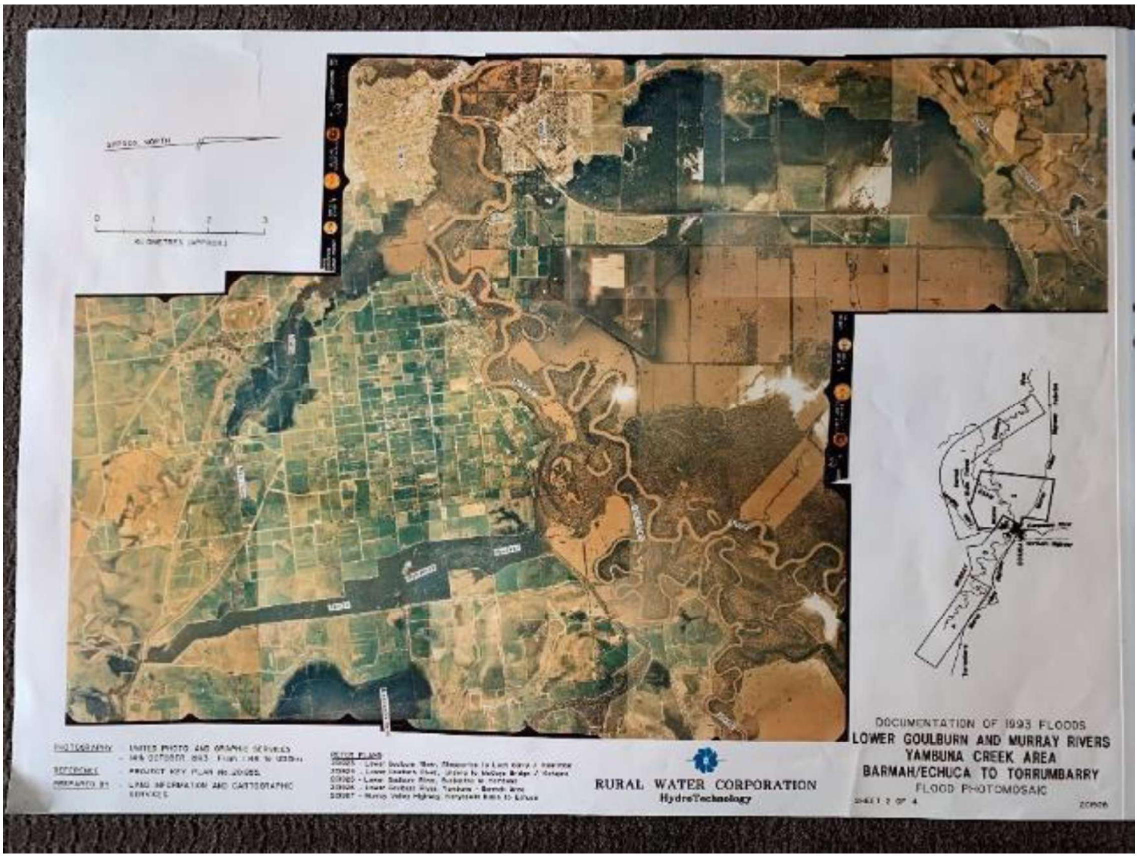
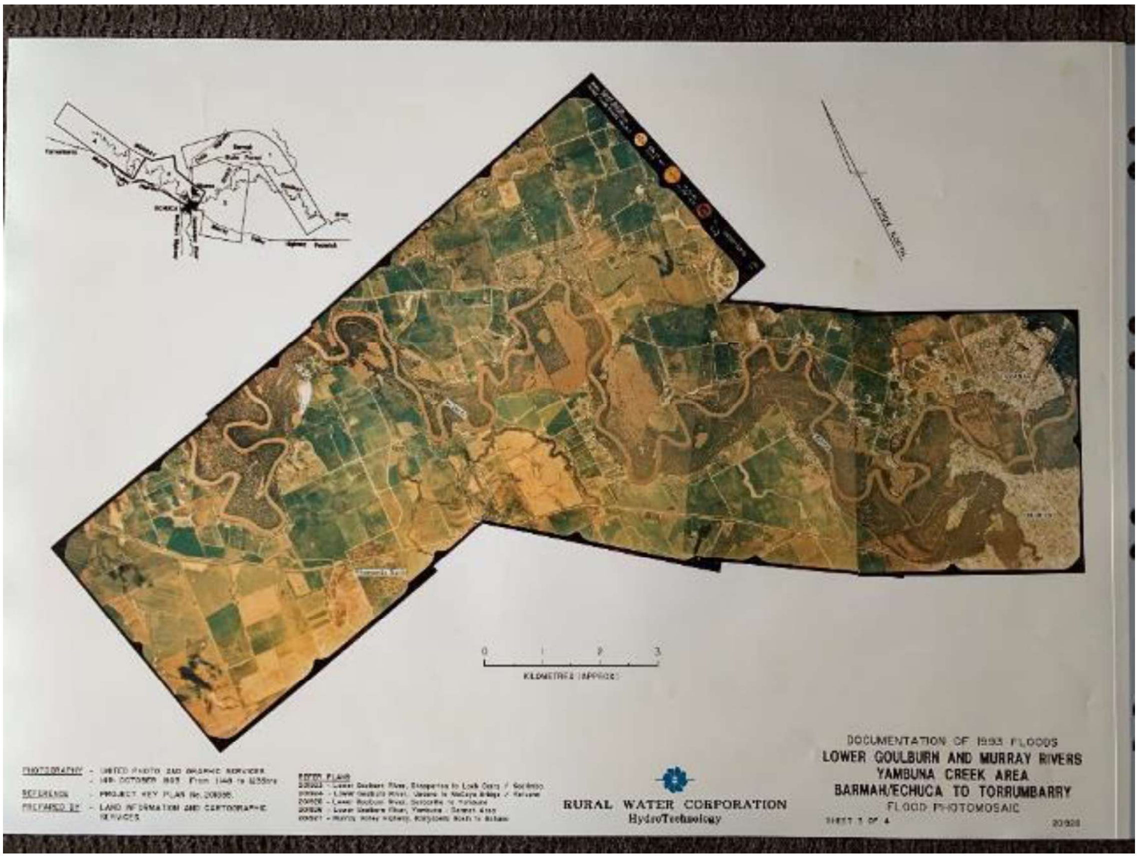



CONTOUR PLAN - MOAMA


DOCUMENTATION OF 1993 FLOODS
LOWER GOULBURN AND MURRAY RIVERS
YAMBUNA CREEK AREA
BARMAH/ECHUCA TO TORRUMBARRY
FLOOD PHOTOMOSAIC
RURAL WATER CORPORATION
HydroTechnology



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DOCUMENTATION OF 1993 FLOODS
LOWER GOULBURN AND MURRAY RIVERS
YAMBUNA CREEK AREA
BARMAH/ECHUCA TO TORRUMBARRY
FLOOD PHOTOMOSAIC
RURAL WATER CORPORATION
HydroTechnology


DOCUMENTATION OF 1993 FLOODS
LOWER GOULBURN AND MURRAY RIVERS
YAMBUNA CREEK AREA
BARMAH/ECHUCA TO TORRUMBARRY
FLOOD PHOTOMOSAIC
SHEET 1 OF 4
DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

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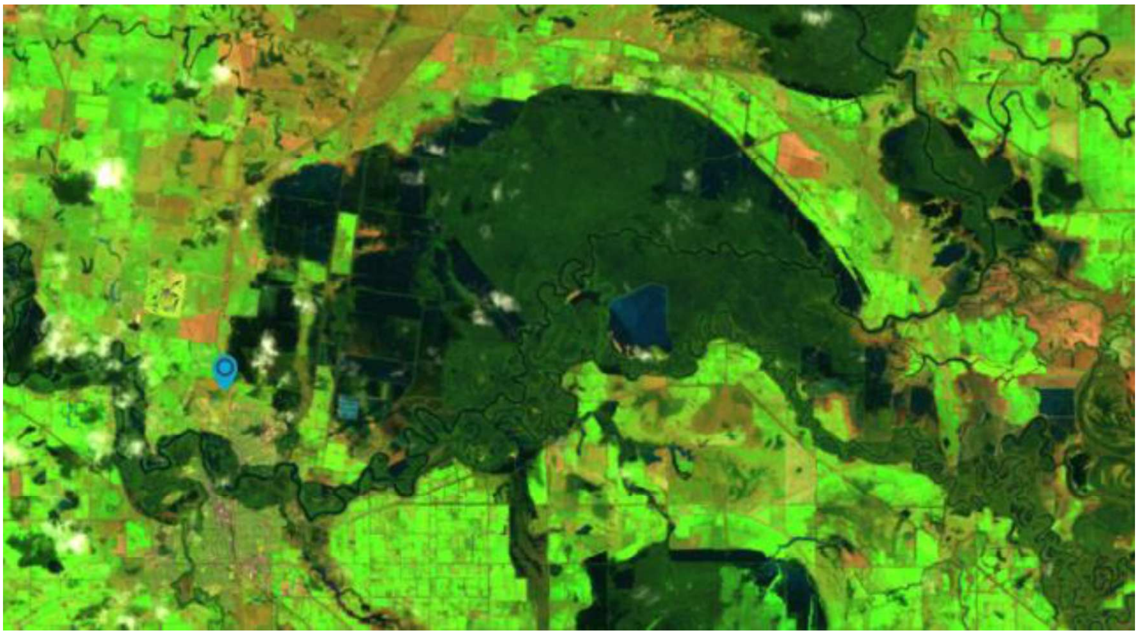

LandSat image 25th October 1993- (https://nationalmap.gov.au/)

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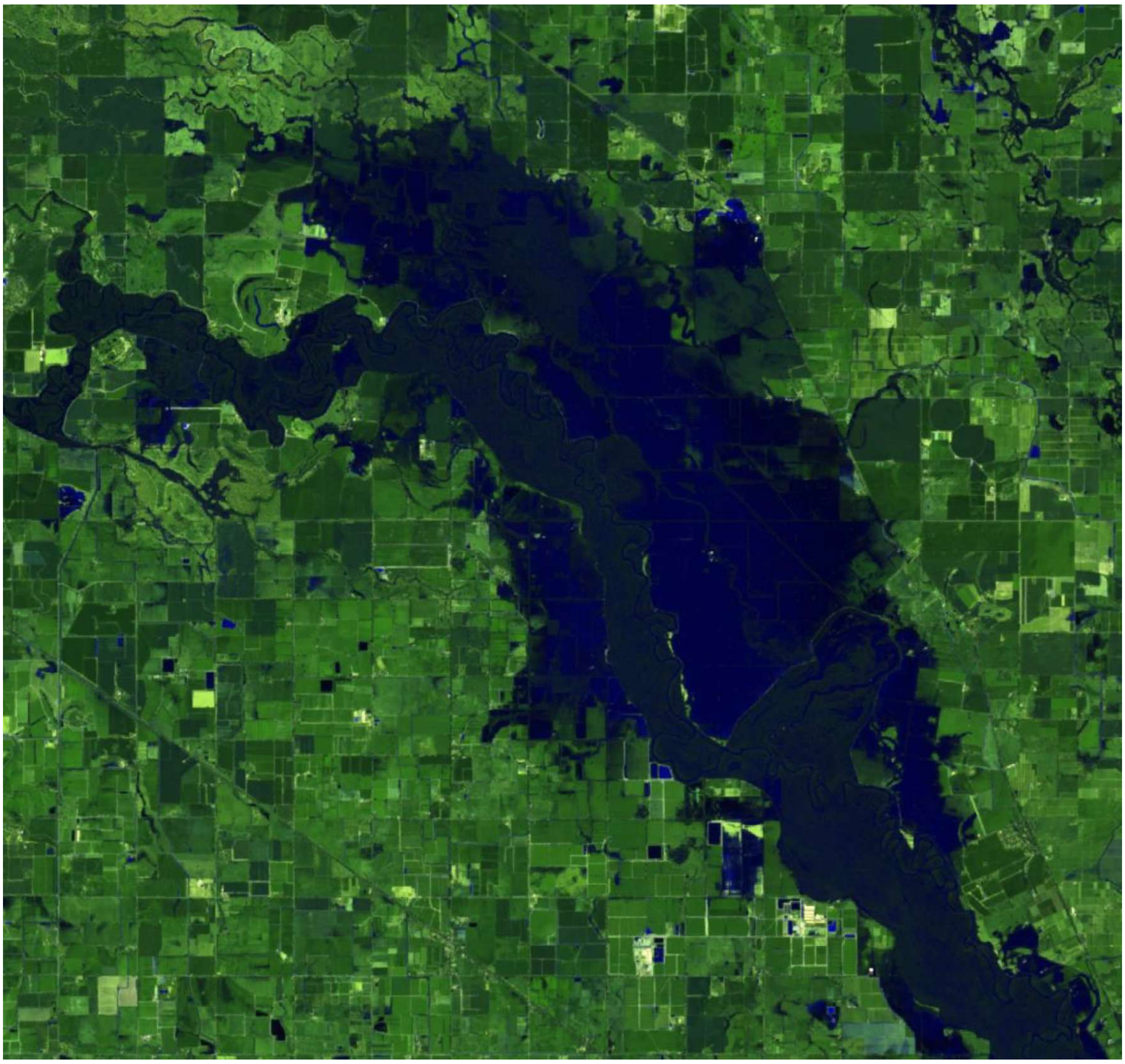
Sentinal Image 17th October 2022 (https://apps.sentinel-hub.com/sentinel-playground)



Sentinetl Image 6th November 2022 (https://apps.sentinel-hub.com/sentinel-playground)

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List of information provided for October 2022 flood event which will be provided in electronic format as part of the study.

Source	Information
John McCartney, Campaspe Shire	■ Levee photos ■ Aerial flood photography
Murray River Shire	■ Levee mapping ■ Flood response lessons learnt ■ Post flooding inspections and intelligence
North Central Catchment Management Authority	■ Flood level survey ■ Levee Survey
Goulburn Broken Catchment Management Authority	■ Flood level survey ■ Breach locations
VIC SES	■ Aerial photography ■ Satellite imagery ■ Ground based photography and flood marks
NSW SES	■ Aerial photography ■ Damage assessments
Rich River Irrigation	■ Flood level survey

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APPENDIX C
HYDRAULICS OF BRIDGE AND WATERWAYS (BRADLEY 1987) & BLOCKAGE ASSESSMENT

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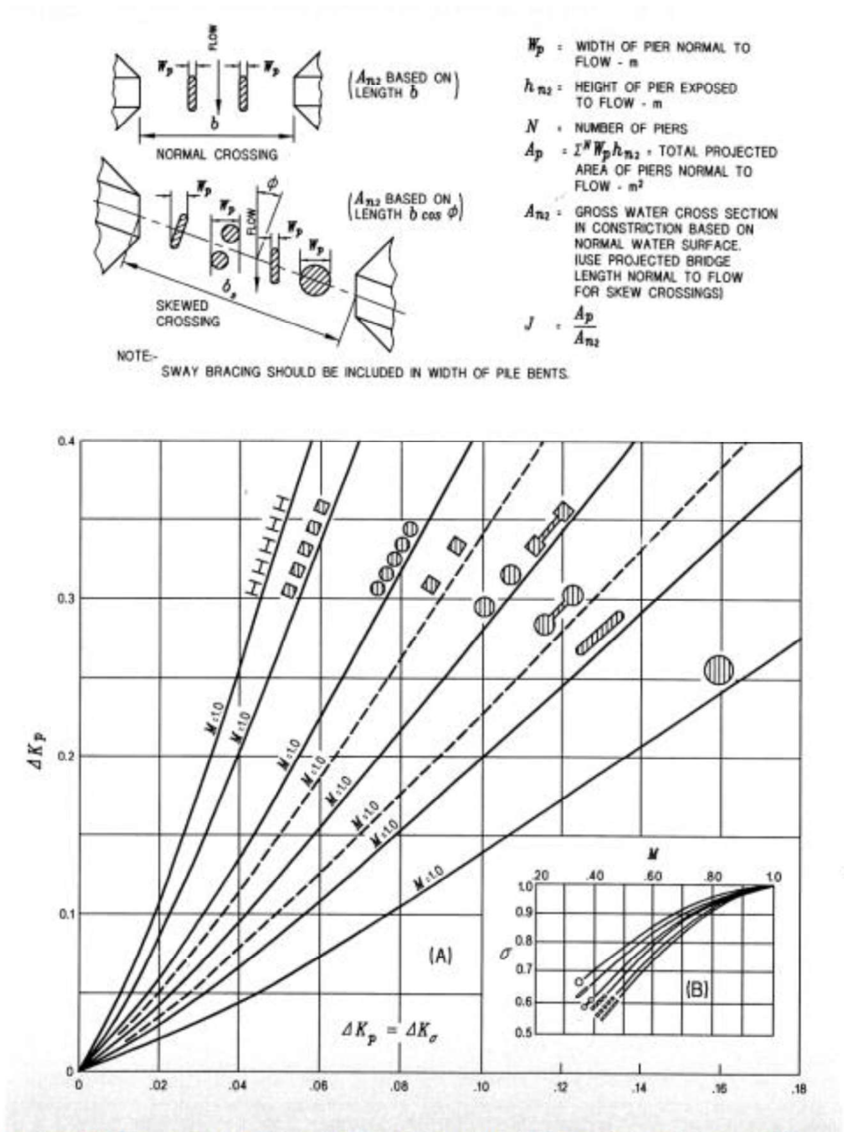

Incremental Backwater Coefficient for Piers (Hydraulics of Bridge and Waterways, 1978)

Campaspe Shire Council / Murray River Council | 18 June 2024
Echuca-Moama Flood Study

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Railway Culvert blockage assessment (ARR 2019)

1	**Choose Debris Availability**			
	(H,M or L)	High		
2	**Choose Debris Mobility**			**INSERT VALUES INTO YELLOW CELLS**
	(H,M or L)	Medium		
3	**Choose Debris Transportability**			
	(H,M or L)	Low		
5	**Adjustment for AEP**			
	Chooses AEP	1	%	
6	**Design Blockage Level (inlet)**			
	L10	3.9	m (check catchment, 1.5 for Urban)	
	Culvert W	2.5	m	span width
	Culvert H	0.75	m	Height invert to deck soffit
	Inlet Blockage	50	%	
7	**Check Vertical Opening**			
	Vertical Blockage			
	adjust L10	1.95	m	
	Inlet Blockage	50	%	
8	**Barrel Blockage**			
	Estimate Velocity	1.16	m/s	
	Mean Sediment Size	Sand		
	Likelihood	Low		
	Adjusted Debris Potential	Medium		
	Barrel Blockage	15	%	
	Culvert Blockage			
	greater of blockage factors			
	50	%		

Campaspe Shire Council / Murray River Council | 18 June 2024
Echuca-Moama Flood Study

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APPENDIX D
ECHUCA WHARF PEAK WATER LEVEL ANNUAL SERIES

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Year	Water Level
1865	90.2
1866	91.39
1867	95.35
1868	90.27
1869	91.19
1870	96.2
1871	93.3
1872	93.36
1873	92.46
1874	
1875	93.93
1876	90.43
1877	90.2
1878	92.2
1879	92.13
1880	92.92
1881	90.15
1882	91.21
1883	92.36
1884	87.97
1885	92.23
1886	90.86
1887	93.86
1888	90.96
1889	94.36
1890	93.14
1891	93.27
1892	92.33
1893	93.68
1894	94.16
1895	92.38
1896	90.05
1897	91.93
1898	91.32
1899	92.2
1900	92.66
1901	91.57
1902	87.28
1903	91.24
1904	91.85
1905	93.2
1906	94.33
1907	89.92
1908	89.87
1909	94.21
1910	92.69
1911	93.35
1912	92.31
1913	
1914	
1915	
1916	94.8
1917	94.55

Year	Water Level
1918	93.88
1919	
1920	94.1
1921	94.2
1922	
1923	93.14
1924	
1925	
1926	
1927	
1928	
1929	
1930	
1931	94.36
1932	
1933	
1934	93.73
1935	
1936	
1937	
1938	
1939	94.49
1940	
1941	92.28
1942	92.79
1943	90.22
1944	87.2
1945	83.95
1946	
1947	92.26
1948	0.78
1949	92.67
1950	91.98
1951	93.73
1952	94.12
1953	93.25
1954	92.18
1955	94.19
1956	94.58
1957	89.46
1958	94.03
1959	33.57
1960	93.98
1961	89.36
1962	89.08
1963	89.69
1964	94.16
1965	91.06
1966	90.86
1967	86.9
1968	91.62
1969	90.88
1970	93.14

Year	Water Level
1971	92.23
1972	83.57
1973	94.24
1974	94.52
1975	94.75
1976	88.09
1977	88.87
1978	91.2
1979	92.72
1980	
1981	94.36
1982	
1983	92.66
1984	
1985	
1986	
1987	88.76
1988	90.18
1989	92.78
1990	93.06
1991	92.36
1992	94.01
1993	94.77
1994	
1995	
1996	
1997	
1998	
1999	
2000	
2001	
2002	87.5
2003	89.36
2004	88.11
2005	88.92
2006	87.14
2007	87.03
2008	87.14
2009	87
2010	92.61
2011	92.85
2012	91.19
2013	89.9
2014	89.12
2015	87.65
2016	93.42
2017	89.73
2018	88.303
2019	88.445
2020	88.474
2021	89.777
2022	94.994
2023	91.969

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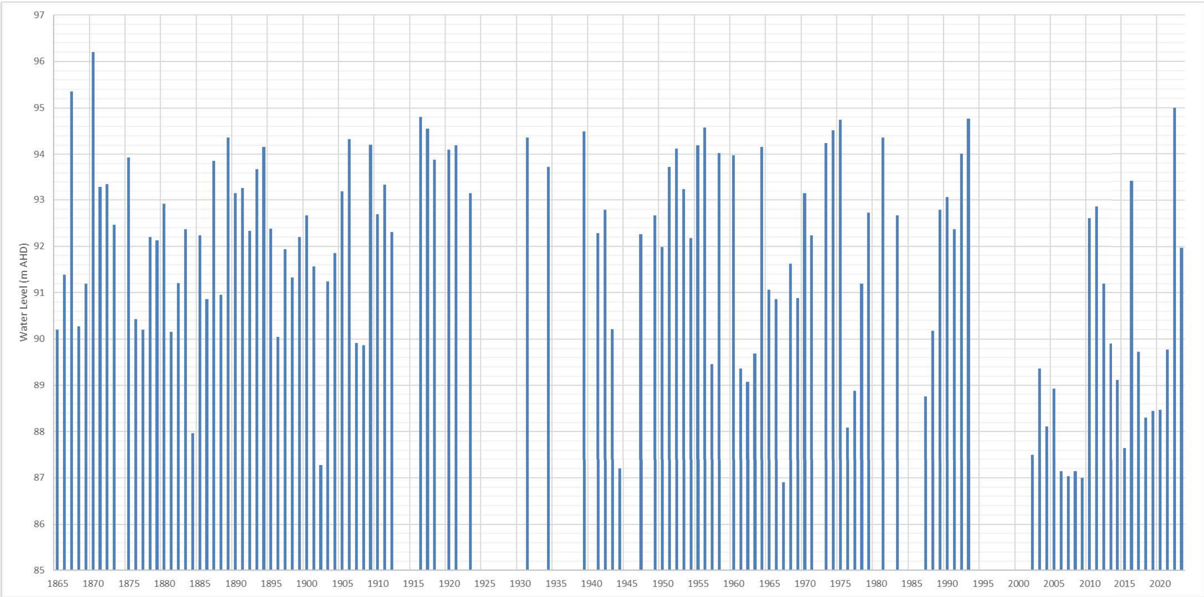

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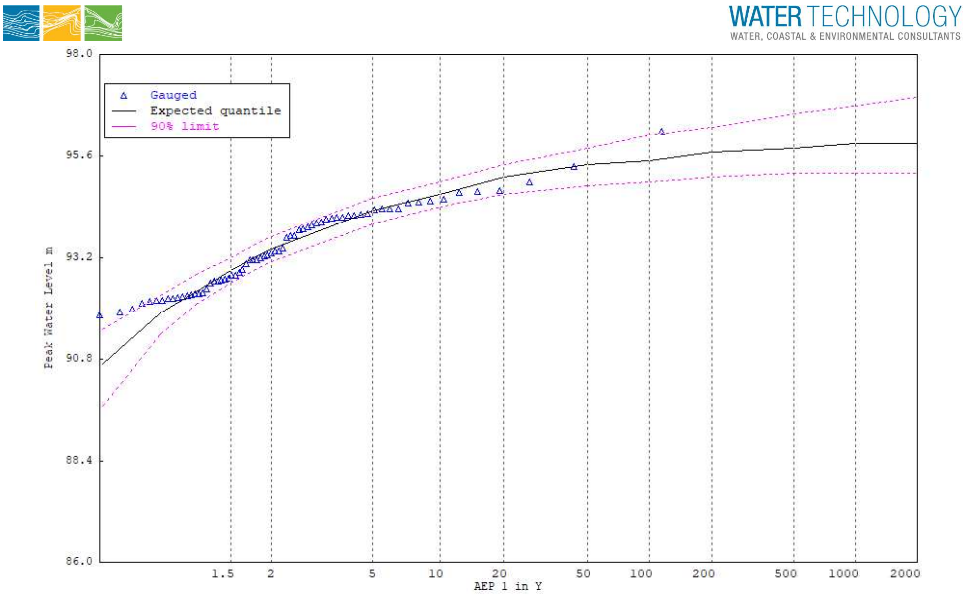

Updated FLIKE Flood Frequency Analysis Curve Including October 2022 Event

Probability Method: Generalised Extreme Value (GEV)

Fit Method: Higher Order Linear Moment (LH Moment)

Lower Censoring Threshold: 91.8 m AHD

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APPENDIX E
DESIGN MAPPING

APPENDIX F
RESPONSES TO SUBMISSIONS ON DRAFT ECHUCA MOAMA FLOOD STUDY REPORT

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No.	Submission	Comment
1	62 Redman St was not flooded in 2022 as shown on mapping Mapping is very pixelated and not sufficiently accurate	Scale of model prevents accurate delineation at a lot scale. The final mapping for planning purposes will have edges smoothed to match terrain, and should improve definition of flood extents.
2	Campaspe Esplanade should have been sandbagged from Butcher St all the way to the cemetery so water not forced onto downstream properties.	Comment about management of emergency works, not related to modelling. Flood emergency and intelligence management is part of the later stage of the study.
3	SES and first responders need more than predicted level at wharf as flood levels vary between the rivers at Echuca	Comment about management of emergency works, not related to modelling. Flood emergency and intelligence management is part of the later stage of the study.
4	Details of approx. 20 additional flood marks with embedded time, date and georeferenced details provided. (Note subsequently surveyed)	Additional levels added in calibration section.
5	Campaspe Shire urban drainage system records require updating to accurately reflect configurations.	Comment about management of works, not related to modelling. Flood emergency and intelligence management is part of the later stage of the study.
6	PMF flood levels require review as properties in Echuca East are above that level yet shown flooded	Floor levels and individual pads for dwellings aren't within Lidar, so these levels would not be represented. The levels shown on mapping relate to the surrounding terrain, which are likely lower, therefore shown as flooded. As a part of the study floor level survey was captured for buildings within the approximately 5% AEP flood extent and they will be compared to flood levels in the model for property specific assessment in the next phase of the study.
7	Extent of flooding along depression between Tindarra Resort and Rich River Golf Club requires review to take into account as-built levels of the new subdivisions.	Already considered and information of new terrain has been sent through. Modelling has been updated.

No.	Submission	Comment
8	Request for proper consultation before installing temporary works in future floods	Comment about management of emergency works, not related to modelling. Flood emergency and intelligence management is part of the later stage of the study.
9	Report requires correction to state 1993 sandbag levee followed the same line as the 2022 temporary earth levee. i.e. east end of Pakenham St and north end of Moama St outside 1993 levee. (See Photos Sub14 / Issue 20)	Noted and updated.
10	Property in McColl Rd Rochester shown as dry on maps but was knee deep during Flood.	Boundary of mapping was Waranga Western Channel. Property is on south side of channel, so is not considered within this study.
11	Will works include extension of the levee bank along Pakenham St to Moama St and south to the water treatment plant to protect residences outside of the temporary levee in 2022	Suggestion for next stage of project that can be looked at.
12	Flood mapping shows flooding of properties in Hermitage Dve, Moama that did not flood. Filling during development not taken into account	Already considered and new lidar flown in 2024 to capture the area. Modelling has been updated.
13	Suggest a levee along the Tindarra river bank either permanent or temporary would mitigate flooding of the properties along the depression to the Golf Club	Suggestion for next stage of project. Also, model was updated with new lidar flown in 2024 that included recent residential development and now indicates that most properties and the Golf Club are not inundated in 1% AEP event.
14	Believes 2022 event was 40 Yr event yet nowhere near entering properties in Maidensmith Drive which inundated in modelled 50 Yr event flood. Suggests level differences require review.	Only rear of properties inundated in 50Y event. The level difference at the breakout location between 2022 event and lowest ground level is only 0.1 m. As soon as the breakout at this location occurs, flow reaches the rear of those properties as they are in a depression that is lower. So, the 2022 event was only just short of inundating the Maidensmith Drive area, which aligns with its placement between a 20Y and 50Y event. The 50Y model does not include a temporary levee, which was built in the 2022 event, although it thankfully was not reached.

No.	Submission	Comment
15	Link provided to MDBA Study re: improving flows through the Barmah choke. Suggest incorporate the proposed Murray River Trail through the Banyule Forest into a levee and summer fire break. Suggest using former 19th C railway spur lines into levees – locations unknown	Suggestion for next stage of project that can be considered.
16	Rural levees installed after 1993 changed the flow of water in Old Deniliquin Road area which incorrectly represented in Study. Water came west along Webb Rd, then north to Black Bridge.	Rural levees were included in the study, and the modelled flow in the area in the lead up to the peak did occur as stated in the comment in addition to flows from the north. Text in the report has been amended to better explain the flow direction.
17	Recommend second railway bridge at Webb Rd / Milgate Rd to enable post flood drainage.	Suggestion for next stage of project that can be considered.
18	2022 flood photos and survey supplied of property at 114 Chanter St showing lower-level water than modelled. Query of accuracy of flood model.	Photo and survey indicate level of about 95.1m AHD whereas model estimate is 95.2m AHD. The model accuracy is within a reasonable range that is typical of a flood modelling standard.
19	Request permanent multi-purpose levee / fire break / cycle/walk/running track with removeable gates through Banyule Forest behind all houses between the bridge and water treatment plant. Path to form part of the 'Murray River Adventure Trail'.	Suggestion for next stage of project that can be looked at.
20	Request for flood levels at Tindarra breakaway that leads to the new developments and Rich River Golf Club in 1%AEP event	Suggestion for next stage of project and already a priority for Council.
21	As above. Added advantage of restricting illegal 4WD activity in Banyule Forest.	Suggestion for next stage of project that can be looked at.

No.	Submission	Comment
22	Model classifies 2022 as just above 5% event yet highest in 150 years. This makes little mathematical sense	The 5% AEP is the probability of the event occurring in any given year and is based on statistical analysis for the Flood Frequency methodologies set out in Australian Rainfall and Runoff. It does not correlate with how many times a certain flood occurs in a set period of time. There is just under 160 years of record, and the 2022 event is the third highest on record. The SKM Flood Study from 1997 set the 5% AEP level as 94.85, with the current study level set at 94.88 m AHD. It would be anticipated that the revised flood level would be higher than the previous given that additional larger events in the last 25 years has been added to the historical annual series.
23	Pre 2022 event, highest 4 events around 95.7m. i.e., 95.7 reached approx. once every 40 years. 2022 event at 94.97 must be greater than 20-year event. Setting 5% AEP at 95.7 is not supported by historical data and will adversely affect insurance etc.	See response for submission #22.
24	Report does not include sufficient information on flow velocities which is critical to hazard assessment and for people to relate their observations to.	Velocity maps have been provided in the Appendix. Critical locations can be tabulated for specific values, however greater detail than that cannot be provided across the whole study area in this report. Digital GIS deliverables are made available to the authorities and they are able to query velocities at any point in the model area.

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No.	Submission	Comment
25	2016 flood modelling shows Old Deniliquin Road inundated which did not occur. Dysons school bus operated along it throughout the flood. This should be corrected to give the community confidence in the results	Figure 3-32 identifies the area as not being observed as inundated although the model did show some inundation, although other areas were matching well. The calibration work completed prior to the 2022 event set the foundations for the final model, which was further improved with the additional information gathered in the 2022 event. 2016 event had a very limited amount of calibration data available and a large portion of the Barmah gauge on the Murray River was missing. Therefore the calibration of the 2016 event was not treated with the same weighting as the 1993 and 2022 calibration events.
26	0.5% AEP modelling shows flood level above the levee crest at Holmes Rd yet not overtopping it. No mention in report of need for temporary works. Where else are there temporary works involved?	There are a number of locations along the Moama town levee, such as Chanter Street, that are below the crest level along the levee. These locations are known and are topped up during a flood event as part of Council's flood response plan and therefore included in the design modelling.
27	Presented data indicates the water gradient in this part of the floodplain is increasing at a faster rate than at the Echuca gauge, as floods move up the AEP scale. This seems illogical as the flooding extends over a much greater area in east Moama than at the wharf so the level increases should be less in east Moama. See supplied Table of levels.	As demonstrated by the longsections in Figure 5-14, the water gradients are flat within the Kanyapella basin, then steepening past Echuca Wharf. The profiles for each design event are consistent and are shown along the Murray River centreline.
28	Explain why 2022 peak water level at intersection of Old Barmah and Old Deniliquin Roads is 95.55m when where it originates from at Horseshoe Lagoon is only 95.5m. Assume flows along Old Barmah Rd to Old Deni Rd then south to Chanter St.	Water originates from much further north toward Barmah flowing around the perimeter of the Kanyapella bowl and south along the railway line. Refer to Section 5.2 – Design Flood Behaviour that explains this.

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No.	Submission	Comment
29	House floor levels in Kooyong Park are set at 95.92. (0.3 above pad levels. 2% AEP mapping shows these houses inundated – some by 0.5m, others by 1.0m when 2% AEP level at that location is 95.71m	Kooyong Park levee was included in the model using as constructed survey. The earthworks within the levee were not updated in the LiDAR. The model does not take into consideration building footprints. This can be represented in greater detailing during the floodplain risk management plan phase.
30	Modelled depths prior to 2022 event varies significantly to post 2022 update for 5%, 2% and 1% AEP events. How can this occur if model previously finalised and reviewed?	Inclusion of the 2022 event forced us to change the hydrology with the third largest event on record. This update resulted in no change in the 1% AEP event flood level at Echuca Wharf and minor increases for smaller events.
31	How can 2022 event recalibration result in 2022 level being assessed as 5% AEP event when previous calibrations considered to be robust suggested the 2022 event was a much rarer event.	See response for submission #22.
32	The GBCMA assessed the Goulburn flows at Shepparton and McCoys Bridge 1 in 80 year AEP (sic) ARI. How is flooding at Moama assessed as a 1 in 20 ARI when it is primarily determined by the Goulburn River. Even allowing for the Lock Garry breach, the difference is considered to be too great to mathematically justify.	Between Shepparton and Echuca lies the large floodplain storage of the Kanyapella Basin. This results in flood levels at Echuca and Moama driven more by volume than peak flow. This makes it difficult to compare a single historical event to a design event because the volume in the hydrograph may vary. Added to this, in 2022 there was a significant number of levee breaches to the northern floodplain, which results in water being attenuated behind the Bama sand hills.
33	P156 of report states 5% AEP at Kooyong Park is lower than 1993 flood yet modelling shows the higher 2022 flood as a 5% AEP flood.	Amended in the report to 2022 event.

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No.	Submission	Comment
34	P56 Sec 5.5.2 of report re: Kooyong Park Levee states '*the assumed floor level of 95.92 m AHD is just below the current 1% AEP flood level.*' This is incorrect as: current 1% AEP flood level at this location is 95.50 m AHD (see SKM Table A, and current study data showing 1% AEP is 95.88 at this location – still below the floor levels.	The current study is the level that should be applied. The floor level is just above the flood level, so the wording has been amended.
35	The existing ratified SKM Moama flood study when applied to the 2022 event proved itself to be exceptionally accurate around the east of Moama. The levels it predicted corresponded almost exactly to the 'actual' 2022 event levels shared as part of the new flood study. Why replace an accurate proven predictive tool with an unproven one.	The SKM Moama Echuca Flood Study made no predictions regarding the 2022 event. The calibration of the 2022 event in this latest study proved to be accurate through Echuca and Moama.
36	Providing dated flood photographs at 114 Chanter St with site survey plan showing less flooding than model suggests	Photo and survey indicate level of about 95.0 to 95.1m AHD whereas model indicates 95.2m AHD. Scale of model prevents accurate delineation at a lot scale. The final mapping for planning purposes will have edges smoothed to match terrain, and should improve definition of flood extents.
37	Seeking landowner details further south along Campaspe River for further 2022 Campaspe River flood data	Noted and can be considered once additional photos are received.
38	Rutley Crescent flooded in 2022 event yet is shown dry in model and modelled flooding extent in Fehring Lane is too great and deep	Investigated and deemed to be stormwater within Rutley Crescent, not riverine flooding. Additional ground survey around Fehring Lane was obtained and re-run in model to determine whether recent changes in topography were not originally captured in the model. However the calibration results were similar in the area.
39	Photos supplied of 2012 and 2022 flood on Campaspe at south of Echuca	These were considered and compared to calibration results.

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No.	Submission	Comment
40	Need to protect houses outside of the temporary levee along Goulburn Road	Suggestion for next stage of project that can be looked at.
41	Restrictions in UFZ need relaxing to permit private flood protection works and sheds	Suggestion for next stage of project that can be looked at.
42	Building restrictions should be same in flood zones as other areas	Suggestion for next stage of project that can be looked at.
43	Request for assistance to reinstate retaining wall adjacent Campaspe River	Not relevant to the study, however Council has noted the request.
44	Please explain the differences between the Echuca Gauge water level AMS in the WMAWater hydrology report and the one provided by Watertech. This will potentially be the historical record so should be accurate even if it doesn't impact the FFA.	The only difference between the Annual Series in the WMA and WT FFA, is that the level used by WMA for 1993 was incorrect (too low) and this was updated in the WT analysis. Also, the WT analysis extended the period of the Annual Series to 2023.
45	The annual series does not seem to account for the missing years of data in the record (it includes 124 records and no prior information – full record (1865 to 2023 should be 158 years).	There are 34 years of missing data. They are largely due to the fact that the Bureau did not consider them flood years, so did not record a peak flow for that year of the annual series. The missing data from 1970 onward was checked against a modelled timeseries of flow available form MDBA for river operations. All missing years except for 1996 were low flow years.
46	Show the impact of/sensitivity test the lower censoring threshold (and justification for the current proposed ~90.43m) in the FFA analysis	The sensitivity testing of censoring did not create any significant differences.
47	Show the impact of Bayesian (used by WMAWater) vs LH moments fit in the FFA analysis	Using Bayesian in Flike resulted in 1% AEP design levels 0.5 m higher than the WMA estimate. LH moments seemed to provide a far better fit.

No.	Submission	Comment
48	Show the impact of LPIII (used by WMAWater) vs GEV in the FFA analysis	LPIII tended to produce higher design levels than GEV, see below examples.
49	Concern that 2 key base assumptions that underpin the whole new flood model are not accurate. These assumptions the models' current maps are based on are: ▪ the 2022 flood was only equivalent to a 1 in 20 year event and ▪ the 'flood planning level' at the Echuca gauge needs to be increased from 95.34 to approximately 95.50. Submitter undertook their own analysis indicating: ▪ Extensive annual peak data at the Echuca gauge is available for the last 65 years. The 2022 event was the highest flood peak in this whole period. ▪ The 2022 flood event was the highest at the Echuca gauge in 152 years. ▪ Binomial distribution models calculate the 2022 flood event was a 1 in 35 year event (AEP of 2.90%). This is the result of probability analysis of an event being greater than or equal to the 94.97 level reached in 2022. ▪ Goulburn River flood levels are a key driver of flooding in Moama. The 2022 flood event for the Goulburn River at Shepparton was a 1 in 80 year event (AEP of 1.25%). ▪ Statistically the data provided gives little mathematical support for the new model increasing the 1 in 100 flood planning height above the current 95.34 AHD level at the Echuca gauge.	Review of the flood frequency analysis has confirmed the 1% AEP level at the wharf has been calculated correctly. For events less than the 2% AEP event the levels do vary depending on which of the industry standard methods are employed. The 2022 event lands within the range of about a 4% AEP to 2% AEP which are the error bounds within which the frequency assigned to that event lie. The submitters assessment of 2022 event being a 1 in 35 year event is not unreasonable as it lies within that range. Critically though the 1% AEP and greater level events on which development controls are based are consistent and unaffected by the calculation method. The AEP is the probability of the event occurring in any given year and is based on statistical analysis for the Flood Frequency methodologies set out in Australian Rainfall and Runoff. It does not correlate with how many times a certain flood occurs in a set period of time. Section 11.4 of the Murray Development Control Plan 2012 which states: "*Flood Planning Area 1 (FPA1) is defined as land considered to be subject to inundation in a 1 in 200 year ARI flood within the area to which the Moama Floodplain Management Study 1999 applies (see Figure 11.1). The flood level that determines the extent of FPA1 is the height of 95.58 metres AHD measured at the Echuca Wharf.*" The level of 95.58 compares to the 0.5% estimate in the SKM report of 95.6m AHD and 95.7m AHD in the current Water Technology report.

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APPENDIX G
WMA WATER HYDROLOGY REPORT

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APPENDIX H
COUNCIL MEETING MINUTES FOR ADOPTION OF FLOOD STUDY

OFFICIAL

8.7 Infrastructure

8.7.1 Adoption of Final Echuca Moama Torrumbarry Flood Study

Directorate: Infrastructure

Responsible Officer: Consultant Project Manager

Manager: Director Infrastructure

Attachments: Due to the size of the Flood Study Report, the document is attached separately.

The purpose of this report is to:

1. To consider submissions following formal community consultation, and
2. To seek adoption of the final draft Echuca Moama Flood Study Report.

Moved by Cr Pentreath

Seconded by Cr Marwood

That Council having considered the submissions made in response to exhibition of the draft Echuca Moama Flood Study Report September 2023 and associated recommendations:

1. **Adopt the final draft Echuca Moama Flood Study Report February 2024, and**
2. **Publish the report and submit the associated data files to DEECA for inclusion in the Victorian Flood Database.**

CARRIED

Cr Zobec left the chamber at 7.42pm.

9.2.3 KPW LAWYERS HOMES OUT WEST VEHICLE

RESOLUTION 090424

Moved: Cr Nikki Cohen
Seconded: Cr Ann Crowe

That Murray River Council (Council) resolve:

1. to transfer the ownership of vehicle asset number 3000340 a Ford Focus, registration number EBF48T, to KPW Lawyers, and
2. that the value to be placed on the registration transfer form be $16,000, and
3. the aforesaid transfer of ownership be conditional to Council being reimbursed for all outstanding registration and insurance cost incurred on the vehicle.

CARRIED

9.2.4 POWER PURCHASE AGREEMENT - DELEGATION TO THE CHIEF EXECUTIVE OFFICER

RESOLUTION 100424

Moved: Cr Nikki Cohen
Seconded: Cr Neil Gorey

That Murray River Council (Council) delegate to its Chief Executive Officer (CEO) the necessary delegations to enable the CEO to negotiate, enter into, and sign one or more Power Purchase Agreements, with a total contract value not exceeding Twelve Million Dollars ($12,000,000)

CARRIED

9.3 DIRECTOR IINFRASTRUCTURE REPORT AND SUPPLEMENTARY MATTERS

9.3.1 ECHUCA-MOAMA FLOOD STUDY FINAL ADOPTION

RESOLUTION 110424

Moved: Cr Geoff Wise
Seconded: Cr Dennis Gleeson

1. To consider submissions following formal community consultation; and
2. To seek adoption of the Final Draft Echuca Moama Flood Study Report.

In Favour: Crs Frank Crawley, Neil Gorey, Ann Crowe, Dennis Gleeson, Kron Nicholas, Thomas Weyrich and Geoff Wise

Against: Cr Nikki Cohen

CARRIED 7/1

CARRIED

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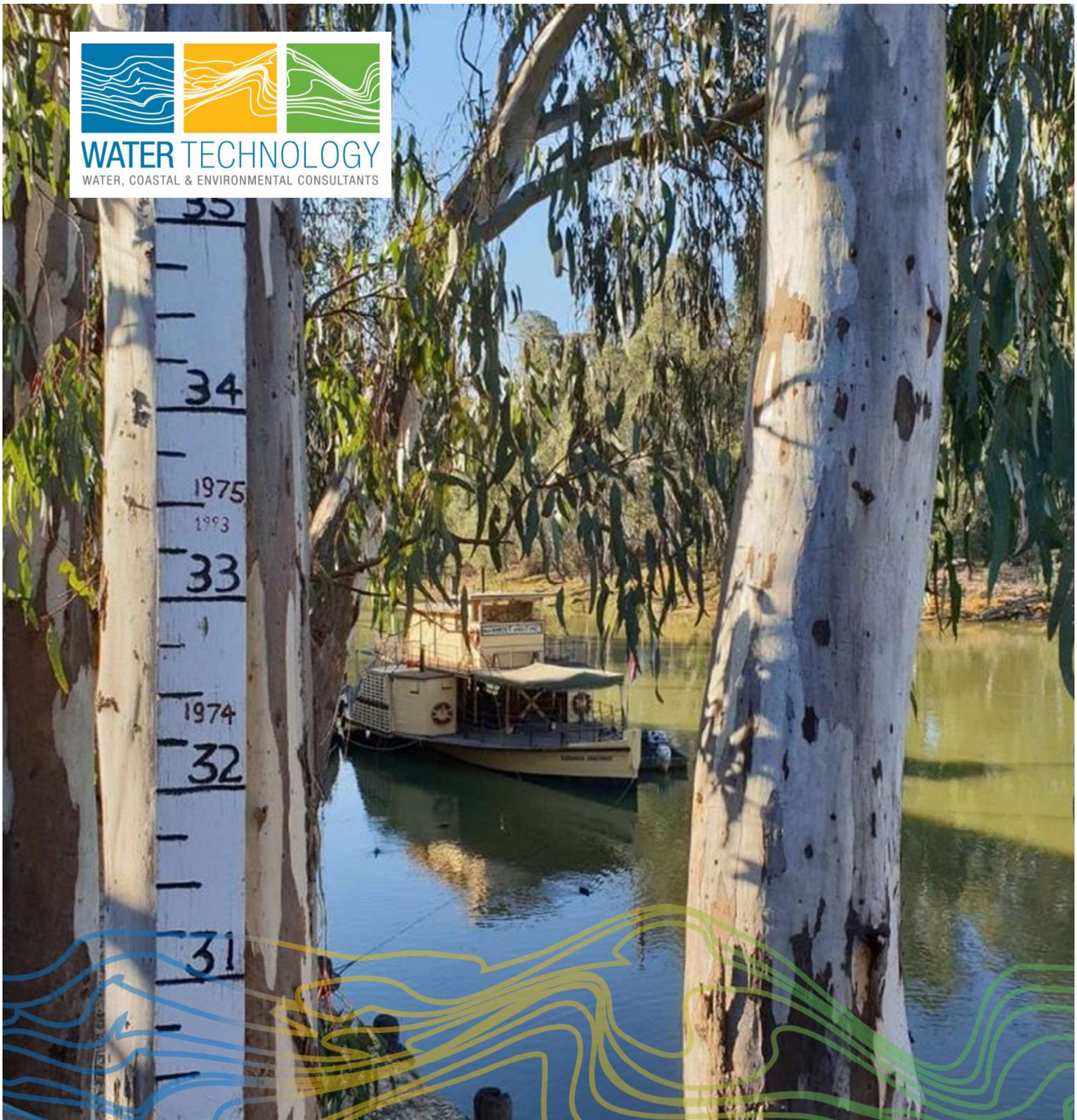

Report

Moama Flood Risk Management Study and Plan

Murray River Council

11 April 2025

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Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
1	Draft	Ben Tate	Ben Tate	10 March 2025
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Project Details

Project Name	Moama Flood Risk Management Study and Plan
Client	Murray River Council
Client Project Manager	John McCartney
Water Technology Project Manager	Aram Manjikian
Water Technology Project Director	Ben Tate
Authors	Aram Manjikian, Bonnie Beare
Document Number	5820_R05_V02_DRAFT_FRMP_NSW.docx

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Certified System OHS ISO 45001 SAI GLOBAL

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*

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1 INTRODUCTION

The Echuca-Moama Flood Study (Water Technology, 2024) was completed and adopted by both Campaspe Shire Council and Murray River Council in early 2024. The study improved the understanding of flood risk within Echuca and Moama for various design riverine flood events, using up-to-date flood information that has been gathered from recent flooding events (1993, 2011, 2016, and 2022).The following Moama Flood Risk Management Study and Plan investigates and recommends measures to address the flood risk as defined in the preceding Echuca-Moama Flood Study (Water Technology, 2024).

1.1 The Flood Risk Management Approach

The NSW State Government's Flood Prone Land Policy sets the direction for flood risk management in NSW. The policy aims to make the community more flood resilient by promoting the sustainable use of floodplains. The policy prioritises the social and economic welfare of owners and occupiers of flood prone property by reducing public and private losses. The Government's Flood Risk Management (FRM) Manual (2023) provides a framework that supports and guides the implementation of this Policy. As per the Policy, the management of flood prone land remains the responsibility of local government. However, under the FRM framework, the State Government subsidises studies and flood mitigation work and provides specialist technical advice to assist Councils with their floodplain management responsibilities.

A key part of the FRM framework is the FRM Process, which provides technical and financial support to the councils by the Government through the following sequential stages:

1. Data Collection - Stakeholder engagement and information sharing to identify the best available flood information to support informed decision-making.
2. Flood Study - Determines the nature and extent of the flood problem.
3. Flood Risk Management Study - Evaluates management options for the floodplain in respect of both existing and proposed development.
4. Flood Risk Management Plan - Involves formal adoption by Council of a plan of management for the floodplain.

This report addresses stages 3 and 4 of the FRM Process.

1.2 Activities conducted for 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 by SKM 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 Study and Plan is the NSW area of the latest Echuca-Moama Flood Study, as shown by the yellow outline in Figure 2-1. The flood model extended upstream on the Murray River to Barmah, on the Goulburn River to Shepparton, and on the Campaspe River to Rochester to make use of reliable streamflow gauge locations, but the focus for detailed flood mapping was really the Echuca and Moama areas.

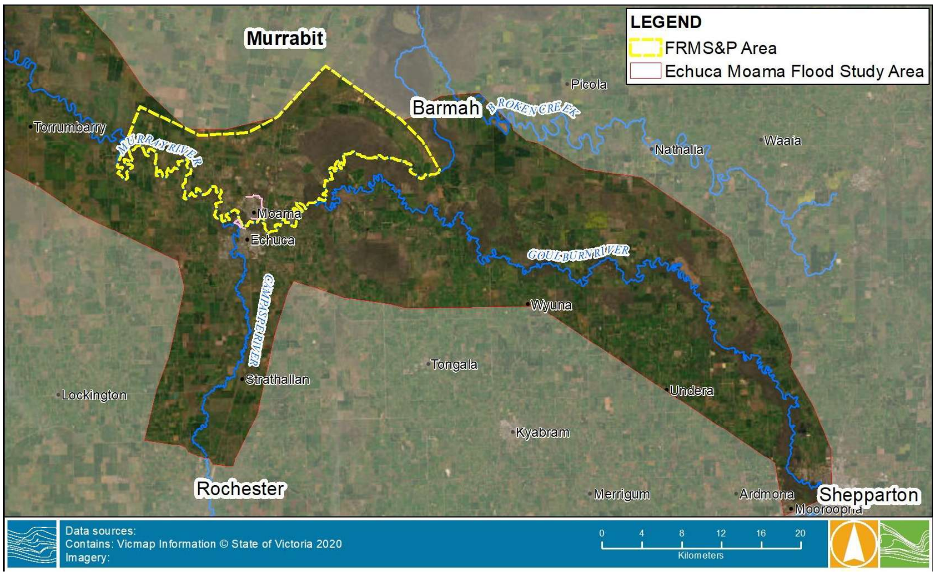

Figure 2-1 **Study Area**

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. Government funded public works like the Moama and Echuca town levees, and many private earthen levees have been constructed, particularly in the East Moama area.

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*	Equivalent AEP	Rank
Nov 1870	11.60	96.2	0.2%	1
1867	10.75	95.35	1.2%	2
Oct 2022	10.39	94.99	2.6%	3
1916	10.20	94.80	3.9%	4
Oct 1993	10.17	94.77	4.2%	5
Nov 1975	10.15	94.75	4.3%	6
1956	9.98	94.58	6.2%	7
1917	9.95	94.55	6.6%	8
May 1974	9.92	94.52	7.0%	9
1939	9.89	94.49	7.5%	10
Other more recent events for context				
Oct 2016	8.82	93.41	>50%	32
Jan 2011	8.25	92.85	>63%	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.

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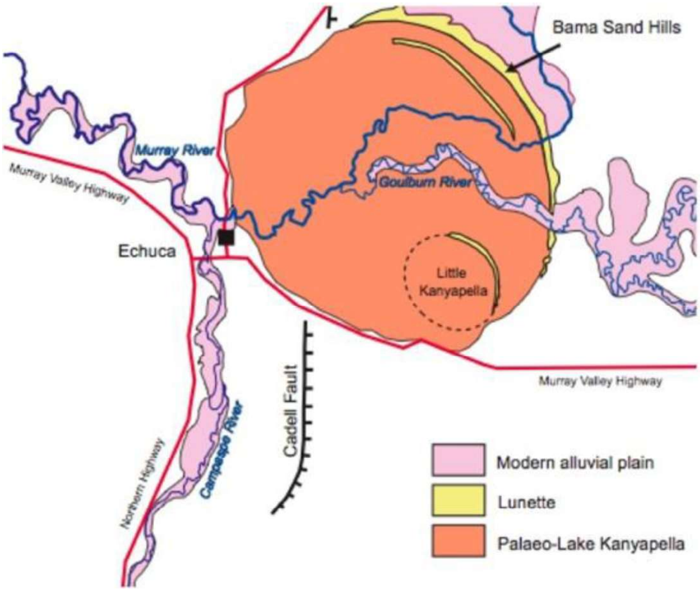

Figure 2-2 Kanyapella Basin Extent (Source: modified after Rutherfurd and Kenyon (2005); Barberias (1983))

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 back 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 considered the Flood Study Report and adopted the study in the first half of 2024, which allowed the next phase of the project, 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)
- Moama Floodplain Management Plan (SKM 2002)
- Lower Goulburn Floodplain Rehabilitation Scheme (Water Technology 2005)
- Echuca South East Rural Flood Study (Water Technology 2015)
- Goulburn River Constraints Levee Risk Assessment & 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)

The last reporting that considered the management of flood risk in the area was the Moama Floodplain Management Study (SKM 2001) and Plan (SKM 2002). The outcomes of the study identified the findings and recommendations listed in Table 2-2.

Table 2-2 Previous FMS&P Recommendations

Recommendation	Recommendation Implemented
A single, continuous town flood protection levee to be built to the standard of the recommended Flood Planning Level for general planning purposes around the north and east sides of the township.	Complete

Recommendation	Recommendation Implemented
Provision of a floodway with associated culverts under the railway line and around the eastern side of the levee, including expanded culverts under Chanter Street, to improve the flow of water around the town from the northern flood storage area.	Complete
The designation of strategic floodways and the associated removal of physical obstructions to preserve strategic areas of flood flow distribution.	Partial
The designation of high hazard flood storage areas to the north and east of Moama and associated limitations on rural levees which threaten to reduce flood storage capacity and adversely affect flood heights and surrounding flood behaviour.	Partial
The raising of Old Bama Road in the vicinity of Horseshoe Lagoon Caravan Park, to the level of existing flanking levees, or 5% AEP, whichever is lower, to provide for 5% AEP flood-free access to/from Moama and to avoid the road becoming a channel for flood flows below this level.	Unsure if works were completed, updated modelling shows shallow inundation over roads in 5% AEP
Increasing the height of Chanter Street to provide flood-free access to the eastern area of Moama up to the 5% AEP level.	
The identification of key flood zones (floodway and flood storage) and their associated hazard categories for a range of possible flood events.	Complete
The identification of flood planning levels up to and including an extreme flood with the recognition that while such a flood is possible the risk of its occurrence is low. A flood planning level for general planning purposes (identifying what has become known as flood liable land) is also established based on the current application of the 95.63m AHD flood level at the Echuca Wharf Gauge.	Complete
The development of a draft Development Control Plan (DCP) outlining the principles and policies to be applied by Murray Shire Council in the consideration of developments within the designated areas of the floodplain.	Complete
For all approved developments, minimum floor levels for structural design purposes are to be 300 mm above the 1% AEP flood level.	Complete
Revoking the previous development consent for the Edward Street caravan park.	Not implemented
Establishing flood spillway areas over/across Cobb Hwy for extreme flood events.	Unknown
Increasing flood awareness (of the full range of flood events, up to and including the extreme flood) of all landholders through general education, signage and issuing of regular flood certificates.	Complete
The voluntary acquisition of properties between Winall and Moama Streets, to remove dwelling entitlements and to rezone to flood compatible land uses such as open space / nature conservation	Not implemented
The voluntary acquisition of properties in the Forbes Street area of the main riverside floodway on which structures have been erected.	No
Imposition of a height restriction on existing rural levees, with levee crests limited to the current height or the 1993 flood level, whichever is the lesser.	Today's process for flood works permits and compliance is most likely quite different to 2002 when the FRMS was completed.
Revoking the existing licenses for unconstructed, rural levees – however, consistent with current legislative changes to Part 8 of the NSW Water Act, applicants should have the opportunity to prove (through an hydraulic study) that the proposed work, either in isolation or cumulatively with other similar works, does not have a significant impact.	

Once finalised and adopted, this Flood Risk Management and Study Plan will supersede the SKM studies.

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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.

3.1.1 Moama 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:

- NSW Residents were receiving Victorian warnings. This was considered to be overreaching by the NSW SES. This was due to how the emergency alert polygon area were drawn that sent messages out to all mobile phones within the polygons.
- NSW flood classifications require review as levels are too low in the Koondrook Perricoota forest areas.
- Distribution of sandbags was a challenge. Victorian residents were coming over the border to get sandbags from New South Wales. Communication between the two communities is critical.
- Distribution of sandbags was a bit slow, so improvements in efficiency in getting sandbags out should be considered.
- Chanter Street culverts were blocked off and water on the north side was pumped out to reduce inundation with temporary pumps. A recommendation for permanent pumps to be installed was made.
- A temporary levee was put along part of the Tindarra breakout based on the flood mapping for a 1% AEP event. A recommendation was made to build a permanent levee to prevent the breakout from occurring in events larger than the 2022 event.
- Sandbagging along Chanter St affected traffic management. Recommendation to provide sandbagging off the side of the road, rather than along the crown, which was done to reduce the amount of sandbags required.
- The railway was impacted by the construction of a temporary earthen levee. Recommendation to have permanent concrete on the railway to provide a good base for sandbagging so that the railway doesn’t have to be closed in a similar magnitude flood event.

- The East Moama private levees need reviewing. There are many with no height restrictions which potentially impact other landholders.

3.1.2 Moama Community

The publicly advertised community session was attended by a small number of community members who mainly came to look at the flood study results and ask questions regarding the study. No suggestions for mitigation options in Moama were received during this session to treat riverine flood risk. There were some community members who described drainage issues in the area to the west of Moama, generally associated with driveways or constructed dams on drainage courses, backing water up on private land during large storm events.

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, one submission was made and this was included in the options modelled and assessed.

3.3 Feedback

The feedback from agencies and the community gathered from the drop-in sessions and written submissions are summarised in Table 3-1 below.

Table 3-1 Community and stakeholder feedback

Respondent	Source	Comments
NSW SES	Drop-In Session	Sandbag allocation and communication to be improved
NSW SES	Drop-In Session	▪ Permanent pumps should be installed at Chanter Street to operate when culverts are blocked as a flood response.
Department of Climate Change, Energy, Environment and Water	Written Submission	▪ Investigate upgrading the Moama Town Levee, in particular to ensure protection for the 1% AEP plus sufficient freeboard. This would also include permanently raising Chanter Street (a recommendation from the Moama FRMS&P (SKM, 2001)). ▪ Undertake a comprehensive review and update the planning and development controls for Moama and surrounds. ▪ Investigate flood mitigation options to address a breakout flow near Maidensmith Drive and Tindarra Resort heading north through to Rich River Golf Club. ▪ Increase community awareness by establishing a highly visible sign or similar detailing historic flood depths and design flood levels. ▪ Increase community awareness regarding bank stability – in particular impacts of recreational boating. ▪ Investigate new/proposed development areas to determine appropriateness and additional mitigation options. ▪ Formalise emergency evacuation centres specific to flood events. ▪ Review flood warning system/procedure. ▪ Review and discuss options recommended in previous FRMS&P from 2001
Murray River Council	Drop-In Session	Recommendation to place a permanent levee to prevent the breakout from occurring at the Tindarra Resort.

Respondent	Source	Comments
Community member	Drop-In Session	Investigate drainage issues associated with works (driveways and constructed dams) on drainage lines in areas to the west of Moama.

As the purpose of the Flood Risk Management Study and Plan was to consider mitigation measures for riverine management, investigation of drainage and stormwater issues was considered out of scope. As such, following review, only the Moama town levee upgrade and Tindarra Resort levee installation suggestions were assessed in further detail as structural mitigation options.

Non-structural measures that are discussed in the FRMS&P the review of the planning and development controls in Moama, review of flood preparedness and response measures, and investigate proposed development areas to determine appropriateness in regard to flood risk.

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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 number of properties affected by the existing design flood events determined by the Echuca-Moama Flood Study (Water Technology, 2024) were identified and included in the NSW Flood Damage Assessment Tool developed by the Department of Climate Change, Energy, the Environment and Water (DCCEEW), which calculates the potential financial costs of damages to each property due to flooding. The assessment uses flood height-damage curves to assign dollar values to the impact upon each property from flooding, dependant on parameters including 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 generally depends upon many other factors, including:

- The magnitude (depth, velocity and duration) of the flood.
- Land use and its susceptibility to damages.
- Awareness of the community with regards to flooding, and their ability 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 ground level, added to LiDAR ground levels.
- Addition of 0.3 m to LiDAR ground levels if Google Street View imagery was obscured.

4.2 Current conditions

The flood extents for the modelled design flood events for the Moama area are shown in Figure 4-1. The numbers of flood impacted properties for each design flood event are summarised in Table 4-1. Figure 6-1 further details the event in which over floor level flooding first occurs for buildings in Moama.

The eastern side of Moama outside of the Moama town levee is located within the floodplain, and along with the area to the north of Moama, are inundated in 10% to 2% AEP events.

The main urban area of Moama is protected by the Moama Town Levee, shown as the hatched area in Figure 4-1. The crest of the levee is above the 1% AEP flood level, but the level of freeboard does not meet NSW standards, therefore there is a risk posed to all properties behind the levee that may be impacted should the levee breach.

The western side of Moama is situated on higher ground above the Kanyapella Basin. But there are low depressions where breakaway flows can occur. The main area identified is to the north of the Tindarra Resort, which shows a flow path becoming inundated in events equal to or greater than a 2% AEP flood event. Given this area is outside of the Kanyapella Basin on higher ground, this area has been the focus of recent residential growth within Moama, with further demand for future development in the area continuing. Prevention of flooding of this breakaway flow to the west of Moama would allow further development to progress in the area of Moama with the lowest flood risk.

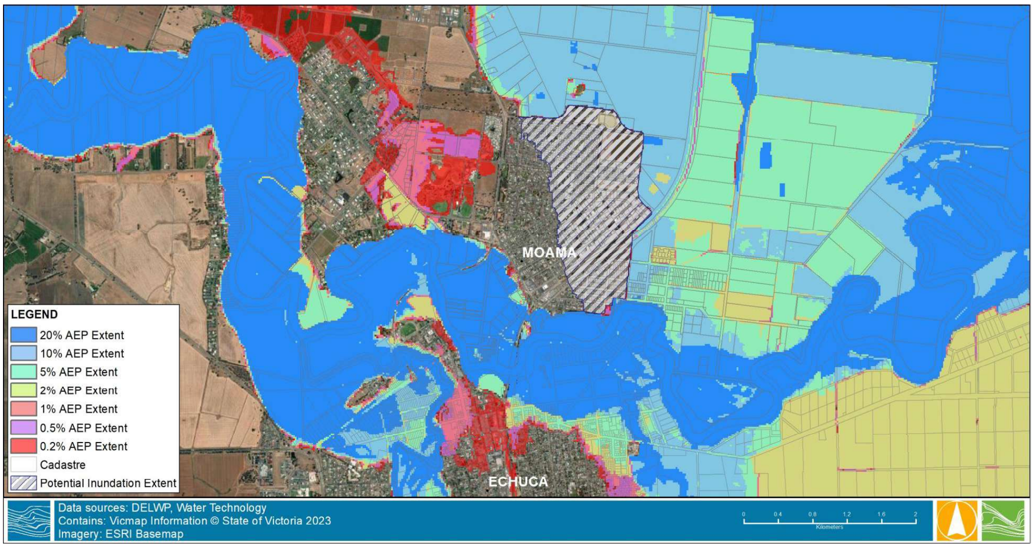

Figure 4-1 Design Modelling Flood Extents

4.3 Average Annual Damage Summary

DCCEEW's Flood Damage Assessment Tool for determining flood damages was used for both the New South Wales and Victorian communities.

The tool calculates the annual average damages (AAD), which represents the equivalent average damages that would be experienced on an annual basis weighted by the frequency of the flood event. For example 20% AEP damages are given greater weighting than 5% AEP damages, as 20% AEP events occur more frequently. The Flood Damages Assessment Tool includes the following tangible and intangible costs and considerations that are used to determine the AAD:

- Road repair costs
- Dwelling replacement values
- Residential property damages
- Commercial property damages
- Public buildings damages
- Average contents replacement cost
- External damages
- Clean up costs
- Fatality and injury costs
- Agricultural costs for crops and livestock output
- Relocation costs
- Mental health impacts
- Regional cost variation factor
- Infrastructure damages uplift

The monetary values for each of the categories listed can be found in the Flood Damages Assessment Tool available on the online NSW SES Flood Data Portal.

The lack of sufficient freeboard on the Moama Town Levee poses a risk to the town meaning that upgrade works need to be considered. Therefore, the assessment has to consider what the potential damages would be if the levee was to fail because of the inadequate freeboard, and set that as the "base case" scenario.

The annual average damages for the existing conditions was adjusted to include the properties within the potential inundation extent shown on Figure 4-1 as being inundated in events greater than a 2% AEP event, where freeboard is insufficient.

The results of the Base Case exiting conditions flood damages assessment for the Moama area are shown in Table 4-1. .

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

Event	Number of Properties Affected	Number of buildings Flooded Above Floor Level	AEP Event Damages	Average Damage per Flood Affected Property	Annual Average Damages Contribution for Event	% Contribution to AAD
20% AEP	12	5	$2,005,590	$167,130	$803,590	3.2%
10% AEP	308	60	$12,856,050	$41,740	$776,880	3.1%
5% AEP	554	368	$89,478,270	$161,510	$2,753,680	10.8%
2% AEP	1,873	1,691	$450,928,850	$240,750	$8,684,734	34.1%
1% AEP	1,965	1,805	$519,427,266	$264,340	$4,858,148	19.1%
0.5% AEP	1,966	1,854	$579,231,870	$294,620	$2,746,648	10.8%
0.2% AEP	2,363	2,212	$752,307,411	$318,370	$1,997,309	7.8%
Extreme Event	5,201	5,110	$2,091,954,420	$402,220	$2,830,041	11.1%
Average Annual Damages (AAD)					**$25,451,030**	100%
Average Annual Damage Per Dwelling						$4,890

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 that flood mitigation measures can deliver to flood prone communities. 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

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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 NSW Flood Damage Assessment Tool does make an allowance for this cost by factoring up 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.

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5 POTENTIAL FLOOD MODIFICATION MEASURES

The protection of flood impacts for the town of Moama can be in the form of both structural and non-structural mitigation measures. Structural mitigation measures provide direct protection of properties and safe access avenues and are further discussed in this section. Non-structural measures aim to minimise impacts on flooding by actions taken before and during flood events, which are discussed further in Section 6.

The community consultation and opportunities for input discussed in Section 3 provided feedback on the type of measures to be considered for the FRMS&P. The structural mitigation options selected for assessment with modelling from the consultation process are:

- Tindarra Levee along Murray River.
- Upgrades to Moama Town Levee.

5.1 Suggested Structural Mitigation Options

The proposed structural mitigation options to address riverine flood risk for the Moama township included a levee near Tindarra Resort to prevent breakaway flooding in a 1% AEP event, and an upgrade of the Moama township levee to provide an acceptable level of freeboard.

Other structural options such as investigation of blockages on drainage lines to the west of Moama, installation of pumps at the Chanter Street bridge and modification of the railway line to provide a more stable base for temporary levee tie ins are supported by Council. These options did not require modelling to determine their effectiveness but will be included in the Flood Risk Management Plan.

5.1.1 Tindarra Levee along Murray River to prevent breakout flows

To prevent flood flows along the depression near to the Tindarra Resort in flood events greater than or equal to a 1% AEP event, a relatively long and continuous levee would be required. A suggest concept alignment of the levee is shown in Figure 5-1. This concept levee is described below:

- An earthen levee with a length of 590 m.
- The levee crest height would be set at 96.15 m AHD with heights varying up to 1 m above ground. This crest level would allow for around 650 mm freeboard in a 1% AEP event under existing climate conditions.
- Earthen levees would typically include a cut off trench and compacted clay core to minimise risk of piping failure, and would have a minimum of 200 mm topsoil to allow hydroseeding for grass coverage to reduce the risk of erosion and rilling.
- Top width and side batters would be as per NSW levee design guidelines shown in Figure 5-2.

The levee would need to be designed by a qualified engineer and signed off for compaction testing and final inspection after construction to ensure the levee stability.

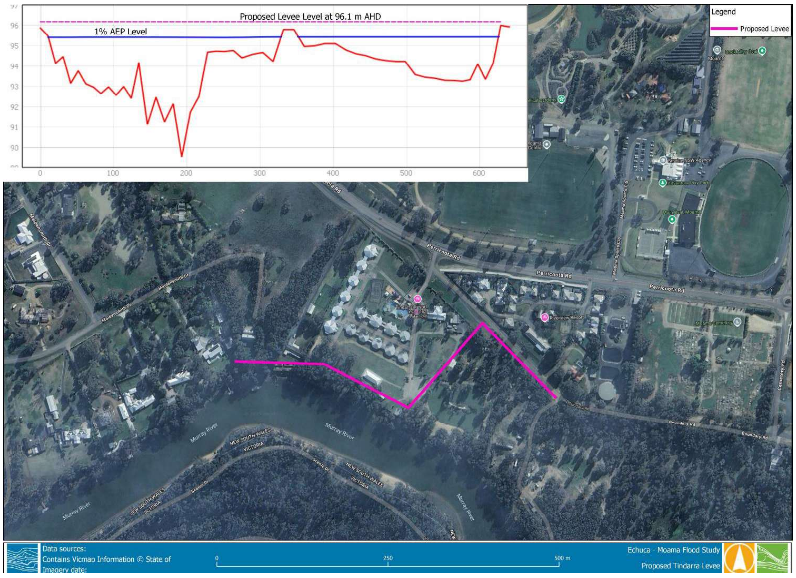

Figure 5-1 Tindarra Resort Levee Alignment

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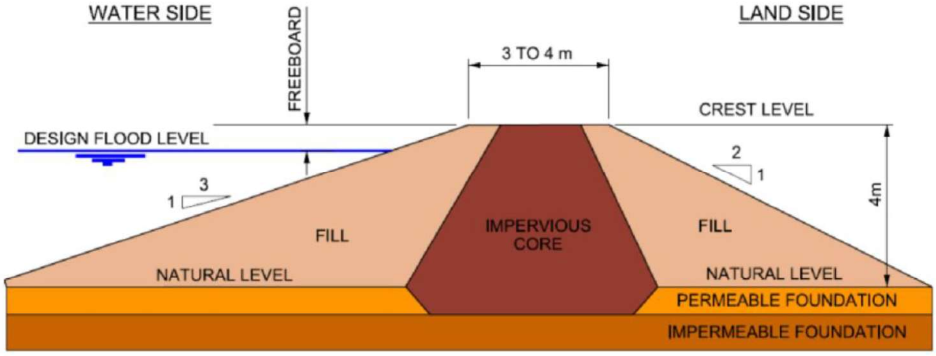

Figure 5-2 Typical NSW earth embankment levee cross section

5.1.2 Upgrades to Moama Town Levee

The levee for the Moama township was included in the design events modelled as part of the Echuca-Moama Flood Study (2024), 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.

It is standard practice in NSW floodplain management to consider a scenario in which there is no freeboard and the levee is breached when conducting a damages assessment. This is because freeboards are added to structural flood mitigation works as a factor of safety that can only provide reasonable certainty of achieving the desired level of protection.

The proposed improvement works for the Moama township levee is to increase the height of the levee crest to provide appropriate freeboard above the 1% AEP flood level along the whole length of the levee. The assumptions of the proposed concept levee upgrade include:

- A levee length of 5,030 m.
- Earthen levee sections to have topsoil stripped off and stockpiled. Levee core to be reworked and topped up to required levels, batters may need to be widened, then topsoil respread to a minimum of 200 mm thickness to allow hydroseeding for grass coverage.
- Concrete sections of the levee to be raised with additional concrete to match thickness and dowelled in appropriately to ensure good adhesion and stability with existing concrete. An alternative may be bolted on sheetpile parapet walls. Designs can be optimised at detailed design phase.

Earthen sections of the levee will need to be designed by a qualified engineer and signed off for compaction testing and final inspection after construction to ensure the levee stability. Concrete sections of the levee will need to be designed by a qualified structural engineer and signed off for final inspection after construction.

5.2 Model Results

The proposed mitigation measures were tested within the hydraulic model developed as part of the Echuca-Moama Flood Study (2024) to determine both positive and negative impacts that may arise from the construction of the proposed works.

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5.2.1 Tindarra Resort Levee

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.

5.2.1.1 Freeboard assessment and area protected

To assess an appropriate freeboard for the Tindarra Resort Levee, a similar approach to that used on an Albury levee design project was used. Freeboard is a way to treat the inherent uncertainty in determining design flood levels, and allows for additional factors that may see a levee overtopped unexpectedly. The following components are generally considered in a freeboard assessment:

- Wave Action and Runup - Where the levee is exposed to a large expanse of flood water, significant waves can be generated under windy conditions and may overtop the levee.
- Local Water Surge - Local flood water levels can be higher than the general flood level due to local blockages or obstructions in the floodplain, or if the levee alignment is oblique to the direction of the flow.
- Flood Model Uncertainties – Including hydrology assumptions, accuracy of topography data and other modelling factors that may lead to inaccuracy in design flood levels.
- Levee Settlement – Post construction of earthen levees, the settlement of the soils used in the levee core construction and compaction may result in a reduction in the crest level of a levee.
- Defects in the Levee – Constructed levees may have sections that are built lower or not to the correct specifications that cause defects to form, reducing the levee performance.
- Climate Change – Increased flood heights due to climate change need to be considered.

The freeboard method adopted is an additive approach, which multiplies the individual freeboard component allowance with an estimate of the probability of the event occurring, and then sums up the total freeboard amount. Table 5-1 lists the probability classifications that are used.

Table 5-1 Probability Classifications

Description	Probability
1. Virtually certain	0.999
2. Likely	0.9
3. Neutral	0.5
4. Unlikely	0.1
5. Virtually impossible	0.001

The results of the freeboard assessment are provided in Table 5-3.

Table 5-2 Freeboard Assessment Results for Tindarra Resort Levee

Freeboard Item	Allowance (m)	Probability Description	Probability	Joint Probability Component (m)
Waves and Runup	0.40	3. Neutral	0.5	0.05
Local Water Surge	0.02	1. Virtually certain	0.999	0.02

Freeboard Item	Allowance (m)	Probability Description	Probability	Joint Probability Component (m)
Flood Model Uncertainties	0.27	1. Virtually certain	0.999	0.27
Levee Settlement	0.02	3. Neutral	0.5	0.01
Defects in the Levee	0.1	3. Neutral	0.5	0.05
Climate Change	0.27	2. Likely	0.9	0.24
			Total Freeboard Allowance	**0.65**

The above assessment shows that an appropriate freeboard for the earthen Tindarra Resort levee is 0.65 m (Table 5-2). This would mean that the crest level of the Tindarra Resort Levee should be designed at 96.1 m AHD.

The area protected by the levee in a 1% AEP event is shown in Figure 5-3. The results indicate that the entire area north of the Murray River between the Athletics Centre and Merool Road/Lakeview Drive would be protected from flooding.

5.2.1.2 Impacts on surrounding areas

The hydraulic modelling of the proposed Tindarra Levee indicates that in the 1% AEP event there is no afflux caused in any areas adjacent to the levee or upstream, Figure 5-3. This is because floodwater backs up into the depression, and provides no real conveyance, and removing the relatively small amount of storage compared to the broader Murray River floodplain has very little impacts on flood levels. Therefore, there is no adverse flood impacts on private property that would prevent the implementation of this flood protection measure.

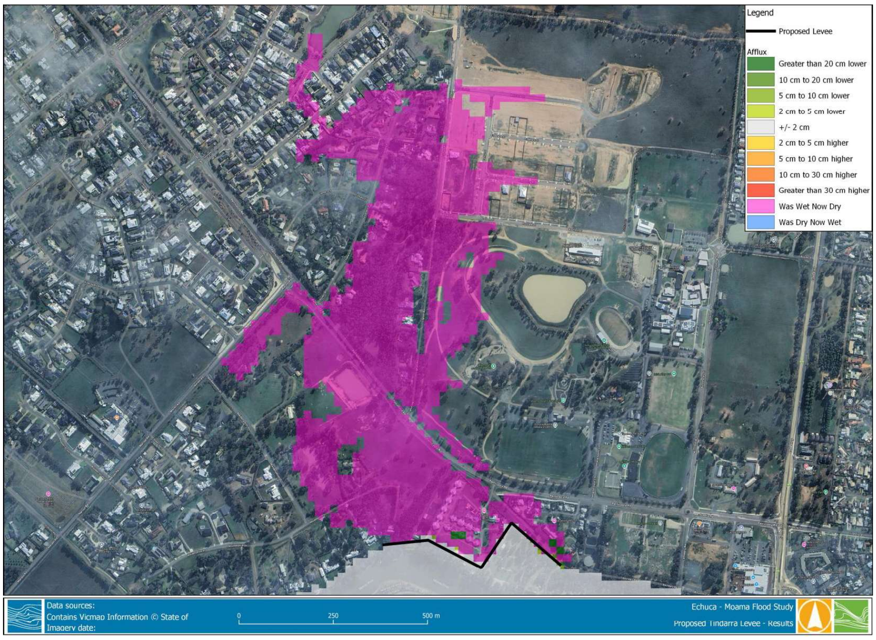

Figure 5-3 Tindarra Resort Levee Flood Protection 1% AEP Modelling Result

5.2.2 Upgrades to Moama Town Levee

As described in Section 5.1.2, the Moama Town Levee currently protects properties behind the levee from inundation during flood events up to the 1% AEP flood event. However, the minimum freeboard requirement is not met, and the levee has an unacceptable risk of failure from a levee breach due to the low freeboard.

The current levee has a variable crest level as shown in Figure 5-4. The levee has several sections that require temporary works to infill gaps in the levee at road crossings, and in the concrete retaining wall section it has several flood gates which must be closed.

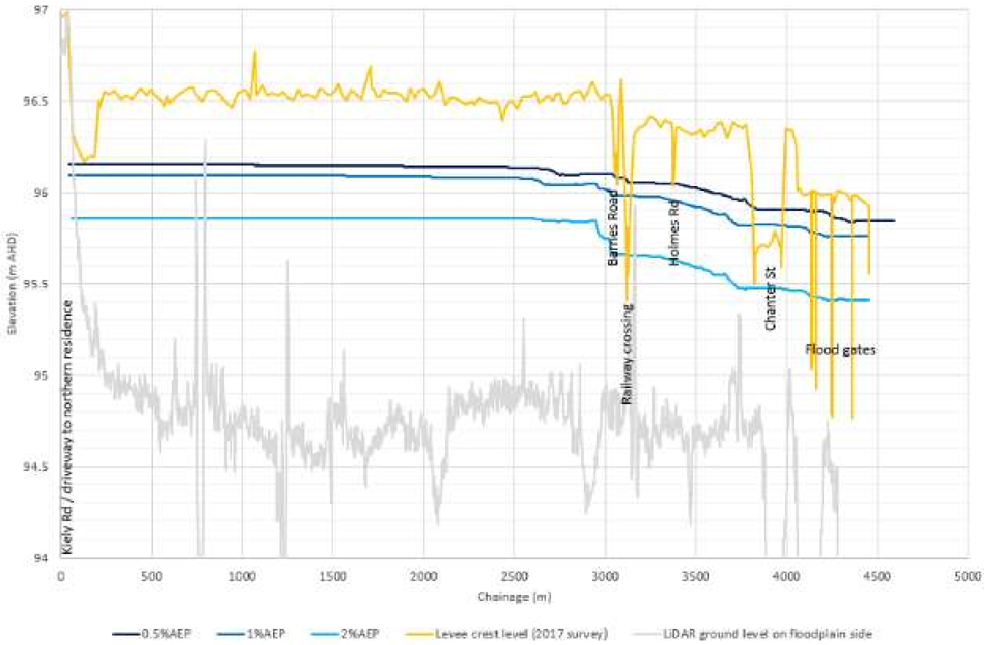

Figure 5-4 Current Moama Town Levee Crest Level

5.2.2.1 Freeboard assessment and area protected

The freeboard approach described earlier was repeated for the earthen and concrete wall sections of the Moama town levee, Table 5-3 and Table 5-4. The differences in the calculated freeboard allowance for the two sections of levee is in relation to different fetch distances for the waves and runup, and also the levee settlement and defects, meaning that the freeboard required on the concrete wall section is lower than the earthen levee section.

Table 5-3 Freeboard Assessment Results for Earthen Sections of Moama Town Levee

Freeboard Item	Allowance (m)	Probability Description	Probability	Joint Probability Component (m)
Waves and Runup	0.40	3. Neutral	0.5	0.20
Local Water Surge	0.02	1. Virtually certain	0.999	0.02
Flood Model Uncertainties	0.27	1. Virtually certain	0.999	0.27
Levee Settlement	0.02	3. Neutral	0.5	0.01
Defects in the Levee	0.1	3. Neutral	0.5	0.05
Climate Change	0.27	2. Likely	0.9	0.24
			Total Freeboard Allowance	**0.80**

Table 5-4 Freeboard Assessment Results for Concrete Sections of Moama Town Levee

Freeboard Item	Allowance (m)	Probability Description	Probability	Joint Probability Component (m)
Waves and Runup	0.11	3. Neutral	0.5	0.05
Local Water Surge	0.02	1. Virtually certain	0.999	0.02
Flood Model Uncertainties	0.27	1. Virtually certain	0.999	0.27
Levee Settlement	0.02	3. Neutral	0.5	0.00
Defects in the Levee	0.1	3. Neutral	0.5	0.00
Climate Change	0.27	2. Likely	0.9	0.24
			Total Freeboard Allowance	**0.59**

Considering these components as they apply to the Moama Town Levee, the above assessment shows that an appropriate freeboard for the earthen and concrete sections of the levee are 0.80 and 0.59 m respectively. The area protected by the levee in a 1% AEP event is shown in Figure 5-5.

5.2.2.2 Impacts on surrounding areas

Given the existing levee is not overtopped in a 1% AEP flood, there is no adverse impact on flood levels outside the levee in a 1% AEP flood should the levee be upgraded.

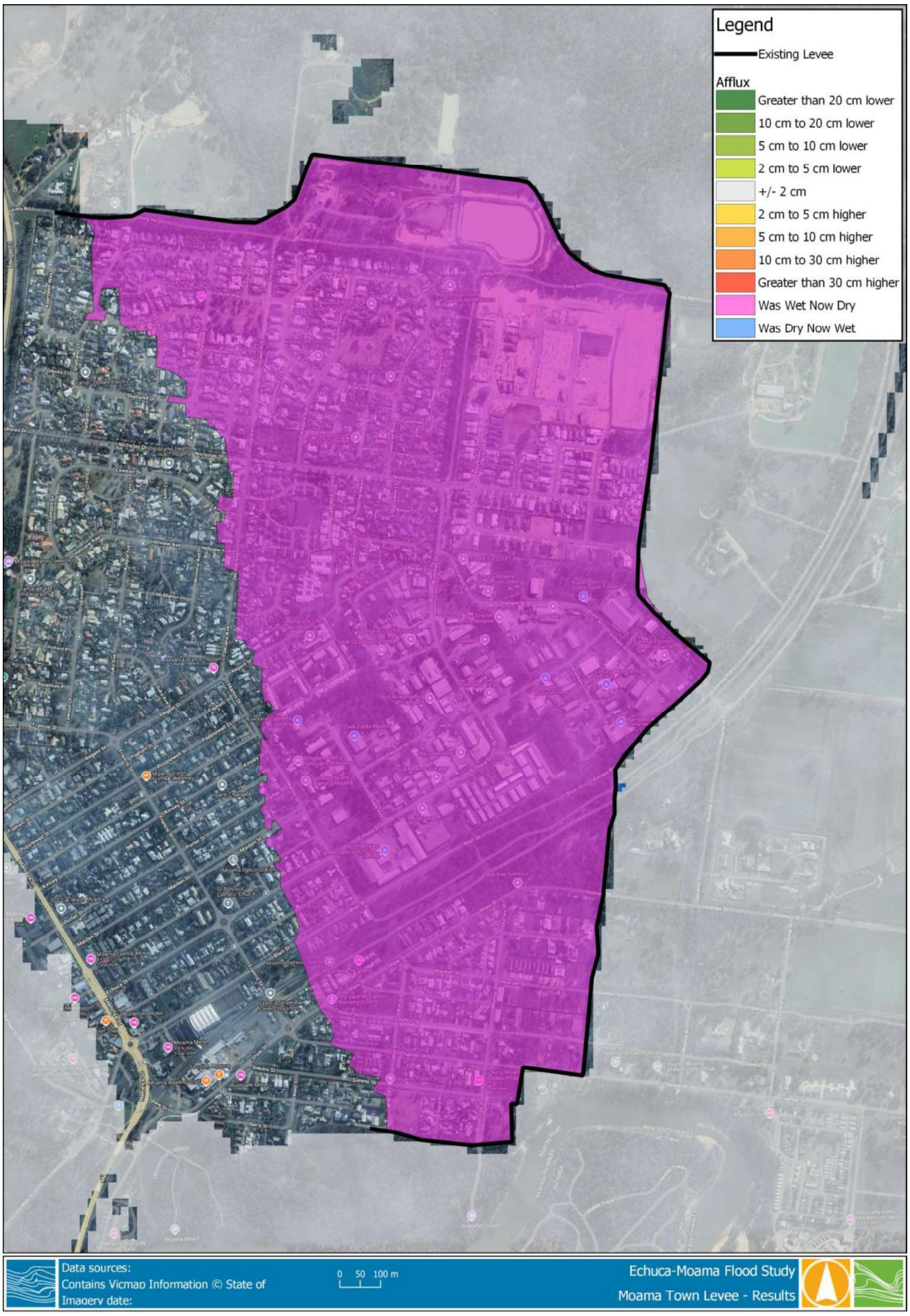

Figure 5-5 Moama Town Levee Flood Protection Modelling Result

5.3 Cost Benefit Analysis

The cost effectiveness of flood protection options in reducing flood risk was measured by using a cost benefit analysis (CBA) approach.

The NSW Flood Damage Assessment 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 above and below floor level flood damages, for residential, commercial and industrial properties, and also factors to scale up the damages for other indirect and intangible costs due to flooding.

The determination of the cost benefit analysis uses the Net Present Value (NPV) of the construction and maintenance costs compared to the benefits using a 5% discount rate for the annual average damages over a 30 year period.

5.3.1 Mitigation Option Costs

The mitigation measures that were considered for the Moama township as part of the floodplain risk management study included the construction of a new earthen levee near Tindarra Resort and an upgrade of the existing Moama town 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.

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 lengths of levees used in determining the overall cost for each mitigation option are as follows:

- Tindarra Resort Levee – 590 m
- Moama Town Levee
  - Earthen Levee – 4,060 m

- Concrete Levee – 380 m

The estimated cost of each levee using the above parameters are as follows:

- Tindarra Resort Levee - $1,426,000
- Moama Town Levee - $4,284,311

5.3.2 Cost Benefit Analysis Results

5.3.2.1 Tindarra Levee

The results of the CBA analysis for the Tindarra Levee is shown in Table 5-5. It is noted that this is low, but what is not included in this analysis is the benefit that is realised by protecting the lowest flood risk area of Moama, which is currently a focus for development. Maintaining flood free access along Perricoota Road, which services all this flood free development is needed from an emergency services perspective. Note that this assessment is across the entire Study Area, not just the area protected by the levee.

Table 5-5 Tindarra Levee CBA Analysis Results

Event	Number of Properties Affected	Number Flooded Above Floor Level	AEP Event Damages	Average Damage per Flood Affected Property	Average Annual Damages for Event	% Contribution to AAD
20% AEP	12	5	$2,005,590	$167,130	$803,590	3.2%
10% AEP	308	60	$12,856,050	$41,740	$776,880	3.1%
5% AEP	554	368	$89,478,270	$161,510	$2,753,680	10.8%
2% AEP	1,869	1,688	$450,317,910	$240,750	$8,674,190	34.1%
1% AEP	1,942	1,794	$516,939,060	$264,340	$4,842,200	19.1%
0.5% AEP	1,966	1,854	$579,231,870	$294,620	$2,746,648	10.8%
0.2% AEP	2,363	2,212	$752,307,411	$318,370	$1,997,309	7.8%
Extreme Event	5,201	5,110	$2,091,954,420	$402,220	$2,830,041	11.1%
Average Annual Damages (AAD)					**$25,418,315**	**100%**
Average Annual Damages (AAD) Per Dwelling						**$4,890**
Present Value of Costs						**$1,425,949**
Present Value of Benefits						**$600,652**
Net Present Value						**-$825,296**
Benefit Cost Ratio						**0.42**

5.3.2.2 Moama Township Levee Upgrade

The results of the CBA analysis for the Moama Town Levee upgrade works is shown in Table 5-6. Note that this assessment is across the entire Study Area, not just the area protected by the levee.

Table 5-6 Moama Town Levee CBA Analysis Results

Event	Number of Properties Affected	Number Flooded Above Floor Level	AEP Event Damages	Average Damage per Flood Affected Property	Average Annual Damages for Event	% Contribution to AAD
20% AEP	12	5	$2,005,590	$167,130	$803,590	5.1%
10% AEP	308	60	$12,856,050	$41,740	$776,880	5.0%
5% AEP	554	368	$89,478,270	$161,510	$2,753,680	17.7%
2% AEP	682	636	$171,729,130	$251,800	$4,039,080	26.0%
1% AEP	749	676	$193,939,980	$258,930	$1,830,510	11.8%
0.5% AEP	819	726	$223,331,780	$272,690	$1,043,180	6.8%
0.2% AEP	2,364	2,212	$751,648,950	$317,960	$1,462,470	9.4%
Extreme Event	5,201	5,110	$2,091,954,420	$402,220	$2,829,205	18.2%
Average Annual Damages (AAD)					**$15,538,593**	**100%**
Average Annual Damages (AAD) Per Dwelling						**$2,990**
Present Value of Costs						**$4,284,311**
Present Value of Benefits						**$145,466,106**
Net Present Value						**$141,181,794**
Benefit Cost Ratio						**33.95**

5.4 Combined Structural Mitigation Option for Moama

The CBA analysis demonstrates a strong financial argument to support upgrading the Moama town levee to provide the required freeboard. Given the levee crest is currently above the 1% AEP flood level, there will be no adverse impacts outside the levee due to an upgraded crest level in a 1% AEP event. Therefore an upgrade of the Moama town levee to provide appropriate freeboard is strongly supported. Murray River Council should consider progressing this option further, with a functional and detailed design phase, leading to design drawings and costings allowing them to tender for construction of the works.

The modelling of the proposed Tindarra Levee showed no adverse impacts on flood levels on the riverside of the levee, and it protects a large area which has been the focus of recent development to the west of Moama. The levee would also have the benefit of preventing inundation of Perricoota Road, which is important for providing access to many developed areas west of Moama, servicing areas out of the floodplain which are preferable areas of future development. The CBA analysis shows a low benefit-cost ratio based on the relatively low number of buildings inundated above floor. But this analysis does not include the benefit of maintaining flood free access to current development and facilitating future development in an area of low flood risk. Given the need for development in the area, and the fact that west of Moama is the lowest flood risk location, it is suggested that Murray River Council consider progressing this option further also, with a functional and detailed design phase, leading to design drawings and costings allowing them to tender for construction of the works.

Combining the two structural mitigation measures discussed in this section provides a strong financial justification for investment in the proposed flood mitigation infrastructure for Moama. There are also strong community planning benefits for the Tindarra levee, removing inundation and providing flood free access up to the design flood to allow development in the least flood prone area of Moama. The information in Table 5-7 indicates the high benefit cost ratio that is still achieved when combining the costs of works for both options.

The Tindarra levee section should be ultimately constructed as a permanent levee. In the interim, it is recommended that Council provision to construct it as a temporary levee should a flood event of a 1% AEP magnitude occur prior to construction.

Table 5-7 Combined Structural Mitigation CBA Analysis Results

Event	Number of Properties Affected	Number Flooded Above Floor Level	AEP Event Damages	Average Damage per Flood Affected Property	Average Annual Damages for Event	% Contribution to AAD
20% AEP	12	5	$2,005,590	$167,130	$803,590	5.1%
10% AEP	308	60	$12,856,050	$41,740	$776,880	5.0%
5% AEP	554	368	$89,478,270	$161,510	$2,753,680	17.7%
2% AEP	677	636	$170,927,470	$252,477	$4,025,220	26.0%
1% AEP	712	676	$191,206,840	$258,930	$1,812,380	11.8%
0.5% AEP	819	726	$223,318,520	$268,550	$1,036,310	6.8%
0.2% AEP	2,364	2,212	$751,648,950	$317,960	$1,666,620	9.4%
Extreme Event	5,201	5,110	$2,091,954,420	$402,220	$2,829,205	18.2%
Average Annual Damages (AAD)					**$15,499,710**	**100%**
Average Annual Damages (AAD) Per Dwelling						**$2,980**
Present Value of Costs						**$5,664,911**
Present Value of Benefits						**$146,157,010**
Net Present Value						**$140,492,099**
Benefit Cost Ratio						**25.80**

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5.5 Summary of Measures

- FM01 – A new levee to be installed along the Murray River behind the Tindarra Resort. Provision for a temporary levee to be incorporated in the Moama Town Levee operation manual until the installation of the permanent levee is complete.
- FM02 – Upgrade the Moama Town Levee to provide freeboard that is currently lacking. 0.8 m of freeboard for earthen sections and 0.59 m of freeboard for concrete sections.
- FM03 – Council review the condition and adequacy of their stormwater drainage system, including pumps, and valves/gates to prevent back flooding from the river.
- FM04 – Installation of permanent pumps at the Chanter Street bridge.

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6 RESPONSE MODIFICATION 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 River has a long lead time to inundation at Moama due to the catchment size and the large floodplain storage volume upstream in the Kanyapella Basin, on the lower Goulburn floodplain and in the Barmah Forest, and the flood flow diversions north into the Edward River. This provides opportunities to put in place effective warnings, temporary measures, action flood response plans and evacuate the community if required in a timely manner to reduce financial, social and emotional damages.

The previous Moama Floodplain Management Plan describes the flood preparedness and flood awareness in the lead-up, during and after a flood event and was completed in 2001. Section 1.6 of the previous plan details measures which will be built upon for improvement in the current plan.

6.1.1 Monitoring and warning systems

There is typically a warning time of multiple weeks before the Murray River peaks at Moama due to upstream rainfall. Flooding at Moama 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 New South Wales through several methods, including:

- Emergency Alert: A national system that sends voice messages to landlines and text messages to mobile phones in areas at risk. Emergency services use this system to warn about events like floods and fires.
- The Hazards Near Me app provides alerts and warnings.
- State Emergency Service website.
- Local ABC radio provide updates on situations.
- TV news media
- Social media, including
- Council news, 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 NSW to reduce flood damages and protect lives.

The Bureau of Meteorology (BoM) 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 Emergency Management Information

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.

6.2.1 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 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 6-1 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 6-1 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

6.2.2 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.

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Table 6-2 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 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 floodplain has a lot of storage volume when floods overtop the levees. 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.

6.2.3 Consequences and Actions

Peak flood level surfaces for the 20% AEP up to the extreme flood were assessed against surveyed and estimated floor levels for Moama. A summary of the analysis is shown below in Table 6-3 and related to gauge levels at Echuca Wharf gauge. This is also shown in Figure 6-1.

A 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. 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.

During the 2022 event Council staff listed the following flood mitigation actions that were implemented, this provides a good summary of the required actions if an event of similar magnitude was to occur.

- Flood gates – all flood gates were installed including Dorward Place and Murray Street.
- Chanter Street road closure – sand bagged on centreline and east and west bound lanes.
- Railway Crossing (Barnes Road) – tracks removed and fill installed
- Kiely Road – temporary levee constructed and driveways sand bagged.
- Tindarra Resort – temporary levee constructed and 2x stormwater pits blocked.
- Penstocks: all penstocks were closed which includes Chanter Street, Murray Street, Dorward Place and Moama public school locations.
- Additional fill installed – Chanter Street penstock
- Sang bagged stormwater pit lid outside levee bank
- Pump installations: Chanter Street x 2, Murray Street, Dorward Place and Tindarra Resort

The consequences of properties impacted as summarised below assumes that the Moama town levee is not breached prior to overtopping. Should the levee breach, the consequences and properties impacted would be far larger

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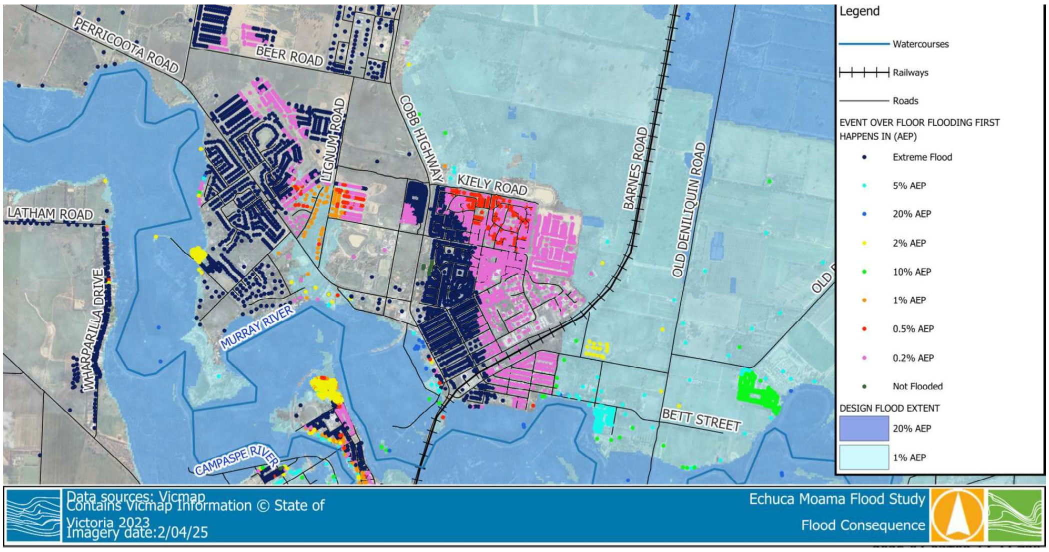

Figure 6-1 Location of above floor flooding in Moama

Table 6-3 Property Consequence Summary for Moama

Modelled Flood Level at Gauge (mAHD)	Flood Event	Inundated Above Floor Level	Inundated Above Ground Level
93.75	20% AEP	5	12
94.40	10% AEP	60	308
94.88	5% AEP	368	554
95.30	2% AEP	1,691	1,873
95.48	1% AEP	1,805	1,965
95.74	0.5% AEP	1,854	1,966
96.10	0.2% AEP	2,212	2,363
97.20	Extreme Flood	5,110	5,201

Table 6-4 Road Closure Locations

Gauge Height (mAHD)	AEP Event	Likely Roads Inundated
93.75	20% AEP	Chanter Street, Deniliquin Street, Gregory Road, Barmah Road, Old Deniliquin Road, Old Barmah Road, Louies Hut Road, Blair Street and Moama Street.
94.40	10% AEP	In addition to lesser events: Council Street, Warden Street, Winall Street and Victoria Street
94.88	5% AEP	In addition to lesser events: Bett Street
95.3	2% AEP	In addition to lesser events: Perricoota Road, Carters Drive
95.48	1% AEP	In addition to lesser events: Lignum Road, west of Charters Drive
95.74	0.5% AEP	In addition to lesser events: Antrim Court, Kildare Avenue, Hayley Court, Odgen Court, Skye Avenue, Greytown Court,
96.1	0.2% AEP	In addition to lesser events: Echuca Street, Eddy Avenue, Hickey Drive, Lea Court, Barber Court, Nicholas Drive, Maxwell Drive, Shaw Street, Warden Street and Simms Street.
97.2	Extreme Flood	Moama entirely inundated

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Table 6-5 Roads Inundated

Event	Number of Roads	Total length of Roads Inundated – Unique Event (km)	Total length of Roads Inundated – Cumulative (km)
20% AEP	24	75.1	75.1
10% AEP	30	2.9	78.0
5% AEP	34	0.7	78.7
2% AEP	42	8.6	87.3
1% AEP	42	2.1	89.4
0.5% AEP	43	16.1	105.5
0.2% AEP	115	30.6	136.1
Extreme	119	21.4	157.5

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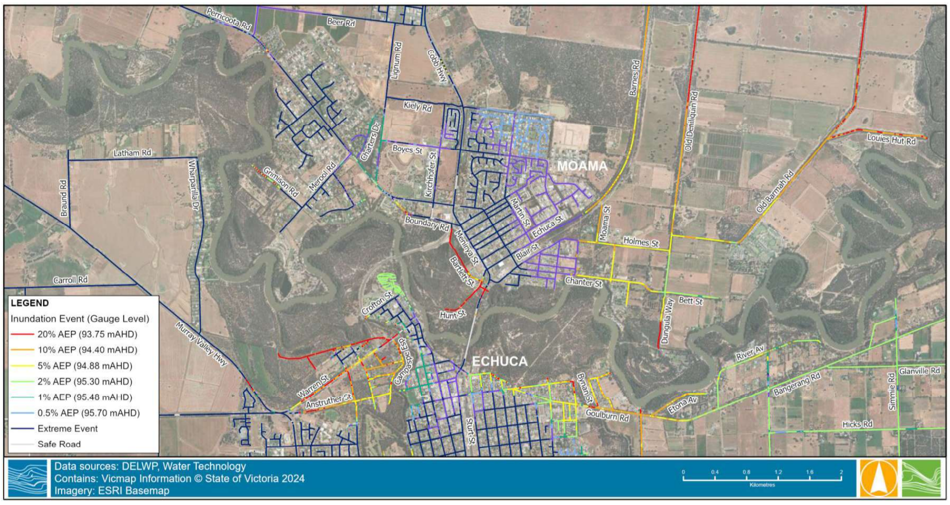

Figure 6-2 Road Closure Locations

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6.2.4 Evacuation Procedures

Peak flood levels for a range of the 20% AEP event up to the extreme flood were analysed and compared to estimated and surveyed floor levels throughout Moama township. As the level of the Murray River increases, areas of Moama become isolated and then entirely inundated. It should be noted that during the extreme flood, Moama is completely inundated and it is not safe to stay.

Consideration for different evacuation arrangements based on predicted gauge levels at Echuca Wharf are presented in Table 6-6. For flood events up to the 1% AEP portions of Moama become isolated and inundated and it is recommended to evacuate to higher ground within the township. If a flood is predicted to reach heights above the 2% AEP event, the freeboard on the Moama town levee begins to be compromised. At levels above the 1% AEP event, the levee freeboard is quite low. In events of this magnitude or greater, consideration of the likely risk of a levee breach will need to be made, and a decision made on if to evacuate the protected area behind the Moama town levee. Moama is completely inundated in the extreme flood and it is not safe to stay. Evacuation is recommended to the north via Cobb Highway to Mathoura if a peak flood event is predicted above the gauge height of 96.10 m AHD.

Table 6-6 Evacuation Recommendations

Echuca Wharf Gauge Height (m AHD)	Event	Summary	Location
94.40	Up to the 10% AEP	East Moama becomes isolated.	Properties close to the Murray River in East Moama should evacuate to higher ground.
94.40 – 95.30	Between the 10% AEP and 2% AEP Events	East Moama becomes inundated.	Consider evacuating all of East Moama to higher ground in central Moama.
95.30 – 95.48	Between 2% AEP and less than the 1% AEP Events.	The levee is breached at the low point near Kiely Road and inundates areas between Nicholas Drive and Kiely Road.	Consider evacuating properties between Nicholas Drive and Kiely Road to higher ground in central parts of Moama.
95.48 - 95.70	Above the 1% AEP and less than the 0.5% AEP Event.	The levee is breached at the low point near Kiely Road and inundates areas between Nicholas Drive and Kiely Road.	Consider evacuating properties between Nicholas Drive and Kiely Road to higher ground in central parts of Moama.
95.70 - 96.10	Above the 0.5% AEP up to the 0.2% AEP Event.	The levee is breached at multiple locations and entirely inundates the eastern section of the Moama township.	Evacuation of east portion of the Moama township within the levee to higher ground.
Above 96.10	Extreme Flood	Entirely inundates Moama township and it is not safe to shelter in place.	Evacuate all of Moama township north out of to higher ground. Consider evacuation to Mathoura via Cobb Highway

6.3 Summary of Measures

- RM01 – Flood forecasting for the Murray River at Echuca Wharf gauge be investigated for improvement.
- RM02 – A flood intelligence card for Moama has been updated. The emergency plan for Moama should be updated with information from the flood intelligence card in Appendix A.

7 PROPERTY MODIFICATION MEASURES

7.1 Land Use Planning

Land use planning is an effective measure to prevent intensification of flood risk, directing appropriate use of land in flood prone areas, commensurate with the level of flood risk. This is largely controlled by Council through the Local Environmental Plan (LEP) and Development Control Plan (DCP). The current plans in place for Moama date back to the previous Murray Shire Council.

The current LEP was published in 2011 but has been iteratively updated, and the DCP was published in 2012, with flooding controls based on the previous Moama Floodplain Risk Management Study (2001).

Within the current LEP *Sections 5.21 Flood Planning* and *5.22 Special Flood Considerations* deal with flood risk. The objectives of these sections of the existing LEP can be summarised as follows:

- To minimise flood risk to life and property.
- To allow development of land that is compatible with flood function and behaviour, including consideration of climate change.
- To avoid adverse impacts, individually and cumulatively, to flood behaviour and the environment.
- To enable safe occupation and evacuation in the event of a flood.

Section *5.22 Special Flood Considerations* of the LEP requires that flood risk be considered for development applications on land inundated by the Probable Maximum Flood (PMF), or equivalent extreme event.

The current DCP assists Council to administer the objectives as set out in the LEP. It provides the details for Council to advise on development conditions in certain areas of the floodplain and assess development applications. The DCP has had amendment over time, but it refers to outdated documents such as the *Moama Floodplain Risk Management Study (1999 version)*, and the *NSW Floodplain Development Manual (2005 version)*.

Chapter 11 Flood Prone Land of the current DCP defines three Flood Planning Areas (FPA).

- FPA1 is set as the area of the 0.5% (1 in 200) AEP inundation extent from the *Moama Floodplain Risk Management Study (1999 version)*, which corresponds to a level at the Echuca Wharf gauge of 95.60 m AHD. This was selected because it was roughly equivalent to the old 1% (1 in 100) AEP flood level at the Echuca Wharf gauge of 95.63 m AHD from an earlier flood frequency analysis by DNRE (1978), which was being used for planning purposes. The DCP suggests the Flood Planning Level at the Echuca Wharf gauge is 95.58 m AHD, which is slightly different to the 95.60 m AHD quoted in the Moama FRMS. The 95.58 m AHD level is the level from the 1D hydraulic model and the 95.60 m AHD is the adopted level from flood frequency analysis at the Echuca Wharf gauge.
- FPA2 is defined in the current DCP as land between FPA1 and the “extreme flood” as mapped in the Moama FRMS.
- FPA3 is defined as areas identified in the LEP as FPA, but not covered by the Moama FRMS, i.e. other flood prone areas of the shire outside of the Moama FRMS study area.

Table 1 Guidance and Controls Applicable to Types of Development in FPA1 of the current DCP categorises the FPA1 into four areas, high and low hazard flood storage and high and low hazard floodway. For each category the table outlines a set of guidelines and controls relevant to general development, flood control works, residential/commercial/industrial development, and caravan and tourist parks. In discussion with planners at Murray River Shire Council, it is understood that they are looking to have the Flood Planning Areas and Table 1 updated to reflect the new Echuca-Moama Flood Study (2024).

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7.1.1 Recommended Changes to Land Use Planning

Updates to the existing LEP and DCP should be made in accordance with the guidance provided in the NSW FRM Manual. It is recommended that a specialist planning consultant be engaged to review both planning instruments and update to current standards.

The NSW Flood Risk Management Guideline (FB01) states that a DCP should contain provisions that relate to areas within the floodplain where flood controls apply, and it describes different approaches for doing this. It is recommended that Council adopt the flood planning constraint category approach as it allows multiple constraints to be rolled up into a single category, offering simplicity. Four flood planning constraint categories have been recommended as described below in Section 7.1.1.2.

After discussion with a technical group of engineers and planners from Council and NSW DCCEEW, it was recommend that *Clause 5.22 Special Flood Considerations* be removed from the current LEP. Murray River Council is one of only a very small number of Councils in regional areas who elected to implement this clause and given the widespread nature of the “extreme” flood inundation which covers the entire urban area, this clause is too restrictive, encumbering all developable land surrounding the town for quite some distance. Given that there is a significantly long flood warning time (1 to 2 weeks) from riverine flooding, warning and evacuation is possible for Moama and surrounds.

7.1.1.1 Flood Planning Level and Flood Planning Area

The Flood Planning Level (FPL) in NSW is typically set using the Defined Flood Event (DFE) plus freeboard which adds an additional safety factor to be certain that the FPL will achieve the desired level of service. The standard DFE is the 1% AEP, and standard freeboard for setting the FPL is 0.5 m. The 1% AEP flood level at the Echuca Wharf gauge is 95.5 m AHD in the latest flood modelling, plus 0.5 m returns a FPL of 96 m AHD at the Echuca Wharf gauge. This is quite similar to the 96.1 m AHD of the adopted 0.2% AEP flood level.

The Flood Planning Area (FPA) is defined as the area inundated below the FPL. It is recommended that Council adopt the 0.2% AEP flood extent as the basis of the Flood Planning Area.

The 0.2% AEP flood event would overtop the current Moama town levee and inundate the protected area. We recommend that given the Moama town levee protects to the DFE with some freeboard (around 0.4 m on the earthen levee and 0.2 m on the concrete retaining wall), that we exclude the protected area behind the levee. However, if the protected area is excluded from the FPA, we strongly recommend that Council commit to upgrading the levee to provide a reasonable level of freeboard, following current NSW industry guidance. It is also recommended that Councils emergency procedures and levee owners manual be updated to reflect the now known level of freeboard available to the levee and develop clear plans for emergency temporary works to top up the levee should it be required in the near future before any upgrade works are completed.

A recommendation from this study is to investigate, design and construct levee protection works in the Tindarra Resort area, and once these works are completed, this will allow the removal of the FPA currently recommended in the area west of Moama. As these works currently do not exist, we recommend including this area in the FPA now, and that can be removed at a later date, should the works be constructed. It is also noted that the current study considers riverine inundation only, and that there is a major overland flow flood study currently underway for Moama, and it is likely that mapping from the overland study will highlight that the low depression in the west of Moama is at risk of overland stormwater inundation, which is another reason to keep this area in the FPA for now. The overland study may also identify other areas which may be considered as FPA also.

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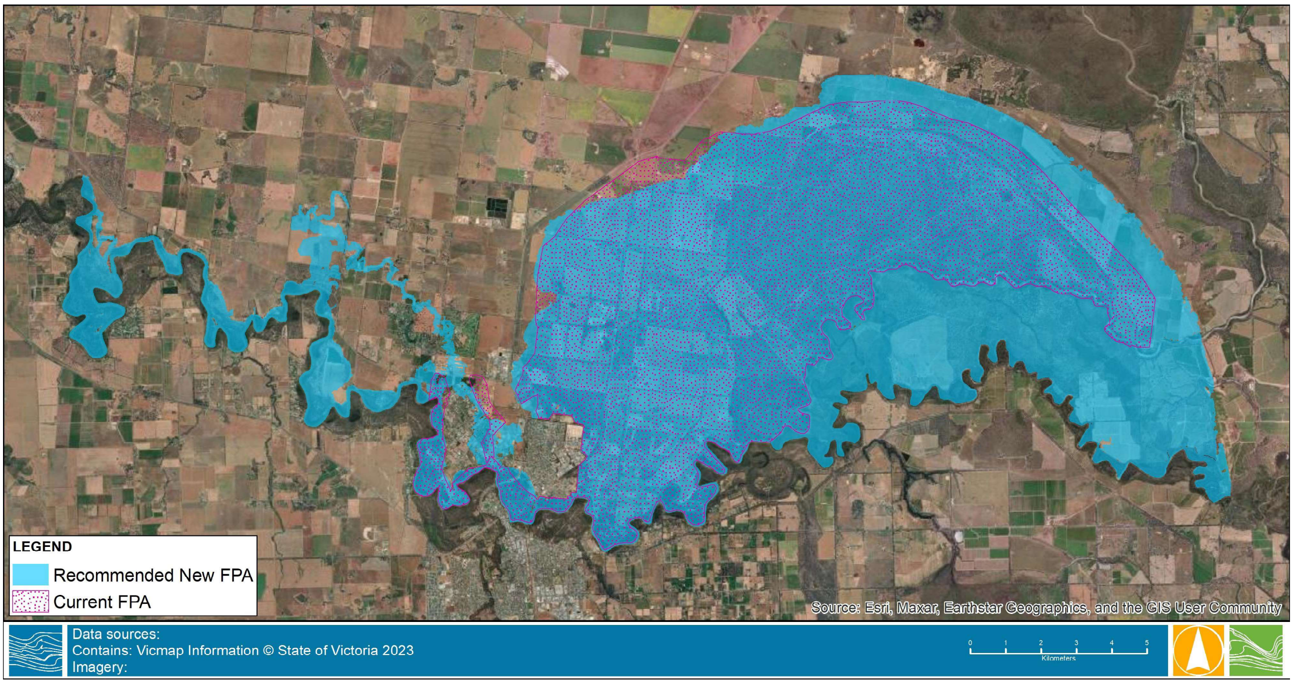

Figure 7-1 Recommended Flood Planning Area Compared to Current Flood Planning Area

7.1.1.2 Flood Planning Constraint Categories

Within the recommended FPA the flood risk profile is highly variable, with areas of high hazard and frequent inundation, to areas of low hazard and infrequent inundation. Reflecting this variation in flood risk, land within the FPA should be subject to different controls on land development. We have used Appendix A of the *Flood Risk Management Guideline (FB01) Understanding and Managing Flood Risk* (NSW DPE, 2023) in defining the Flood Planning Constraint Categories (FPCC) and describing the recommended controls for different land uses. We recommend three different FPCC as below.

- FPCC1 – includes floodway areas
- FPCC2 – includes high and moderate hazard flood storage areas
- FPCC3 – includes low hazard flood storage in flood fringe areas
- FPCC4 – includes areas outside of the FPA up to the extent of the extreme flood event

The recommended FPCC are shown in Figure 7-2, with the constraints on different land uses described at a high level in Table 7-1.

We recommend clipping the FPCC area to the Bama sandhills as the flood model in that area was only included to extend to the nearest reliable gauges to provide inflows to the , but the areas for the detailed flood mapping was downstream of the Bama sand hills .

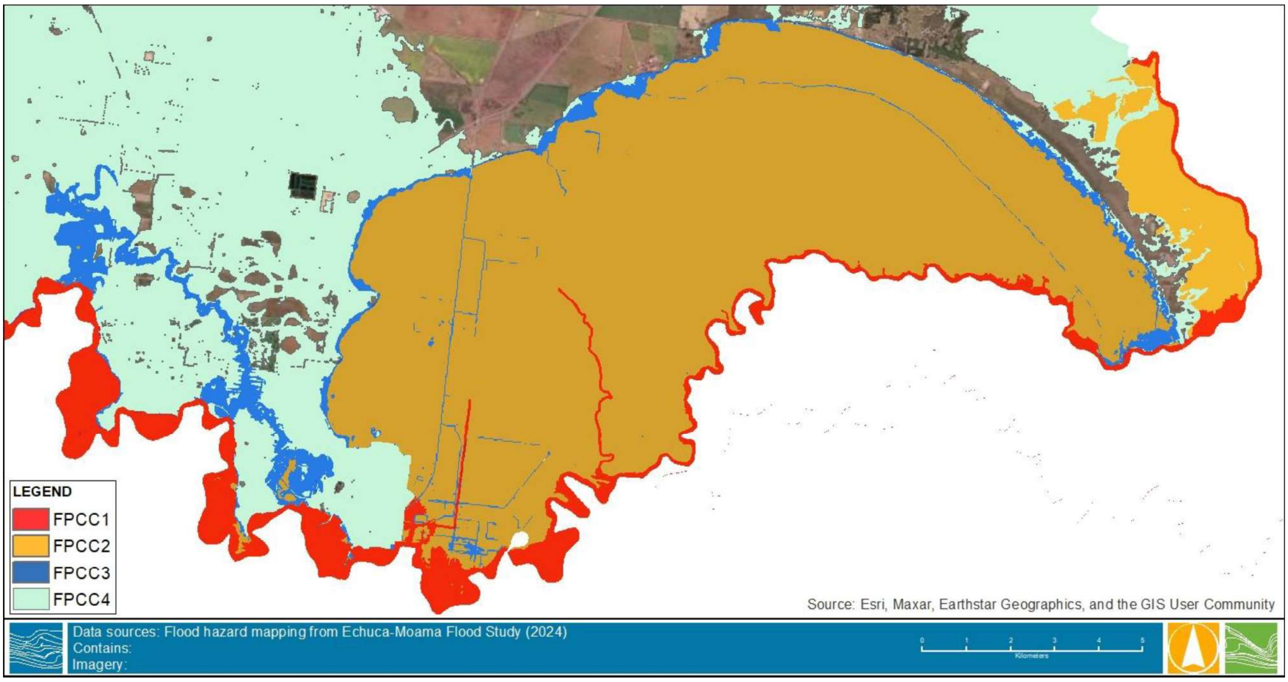

Figure 7-2 Recommended Flood Planning Constraint Categories

Table 7-1 Flood Planning Constraint Categories and Controls

Flood Planning Constraint Category Type	Constraint	Land use planning implications	Development supported with controls
Outside FPA	Areas beyond the FPA where flood risk is low, may be impacted by extreme flood (PMF)	No restrictions placed on development on the grounds of flooding	Development for vulnerable peoples, emergency services facilities, essential services facilities should be located in these areas.
FPCC1	High hazard areas of floodway, unsafe for people and vehicles, potential for damage to buildings. Development in floodways can impact flood behaviour and increase flood levels in nearby areas.	Development in these areas discouraged, with land uses which maintain flood function such agriculture better suited.	Renewal of like for like development ■ Replacement building floor levels at or above FPL ■ Replacement buildings must be constructed from flood compatible materials ■ No increase in building footprint ■ FIRA required Recreational ■ FIRA required if earthworks are proposed or above ground infrastructure proposed ■ FERP required to identify actions and responsibilities during a flood to evacuate and prepare site for flooding ■ Any infrastructure must be flood resilient Farming ■ Earthworks with changes to ground levels greater than X m requires a FIRA (X to be determined by council planning and clearly stated in updated DCP) ■ Sheds must be flood resilient and preferably open sided. Encourage racking to provide ability to temporarily store equipment above FPL during a flood.

Flood Planning Constraint Category Type	Constraint	Land use planning implications	Development supported with controls
FPCC2	High to moderate hazard flood storage areas (typically H3-H6 in the 1% AEP event), unsafe for people and vehicles.	Recommend applying this to the large storage area east of Moama, recognising the need to allow renewal of the already built environment, but not supporting intensification.	Renewal of like for like development ■ Replacement building floor levels at or above FPL ■ Replacement buildings must be constructed from flood compatible materials ■ Extensions permitted with limits (to be determined by council planning and clearly documented in updated DCP) ■ FIRA required Recreational ■ FIRA required if earthworks are proposed or above ground infrastructure proposed ■ FERP required to identify actions and responsibilities during a flood to evacuate and prepare site for flooding ■ Any infrastructure must be flood resilient Farming ■ Sheds must be flood resilient and preferably open sided. Encourage racking to provide ability to temporarily store equipment above FPL during a flood. Tourist park ■ Habitable buildings with floor levels at or above FPL ■ Any communal buildings at ground level must be flood resilient. ■ FIRA and FERP required

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Flood Planning Constraint Category Type	Constraint	Land use planning implications	Development supported with controls
FPCC3	Flood fringe areas in the 1% AEP where the hazard is low.	Development can proceed subject to conditions, with development for vulnerable communities preferred outside these areas.	Residential subdivision or single lot developments ■ Floor levels must be at or above FPL ■ Sheds/carports with floor level at or above DFE level ■ FIRA required Industrial/commercial ■ Floor levels must be at or above FPL ■ Sheds with floor level at or above DFE level ■ FIRA required Renewal of like for like development ■ Replacement building floor levels at or above FPL ■ Extensions permitted with limits (to be determined by council planning and clearly documented in updated DCP) ■ Council may require a FIRA Recreational ■ Council may require a FIRA if earthworks are proposed or above ground infrastructure proposed ■ FERP required to identify actions and responsibilities during a flood to evacuate and prepare site for flooding ■ Any infrastructure must be flood resilient Farming ■ Sheds must be flood resilient and preferably open sided. Encourage racking to provide ability to temporarily store equipment above FPL during a flood. Tourist park ■ Habitable buildings with floor levels above FPL ■ Any communal buildings at ground level must be flood resilient. ■ FERP required ■ Council may require a FIRA

Flood Planning Constraint Category Type	Constraint	Land use planning implications	Development supported with controls
FPCC4	Areas beyond the FPA where flood risk is low, may be impacted by extreme flood (PMF)	No restrictions placed on residential and commercial development on the grounds of flooding. Development controls only placed on emergency response facilities.	It is undesirable for development for vulnerable peoples, emergency services facilities and essential services facilities to be located in these areas. Should they be required however, development of emergency services facilities should require minimum floor levels set at the extreme flood level.

7.1.1.3 NSW Hydraulic Categorisation

In New South Wales flood studies, it is common to delineate hydraulic categories, describing the function of flood prone land as either floodway, flood storage and flood fringe. The New South Wales Flood Risk Management Manual (2023) defines these hydraulic categories as follows:

- **Floodways** are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas with higher velocities.
- **Flood Storage** areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of a levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
- **Flood Fringe** is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

The Flood Risk Management Manual (2023) provides qualitative descriptions of the three hydraulic categories, with some principles for how to map them, but is not prescriptive. Methods have evolved as modelling has evolved from 1D to 2D. The Department of Planning and Environment developed the Flood Function: Flood Risk Management Guideline FB02 (DPE, 2022), which provides further advice for more contemporary methods for mapping the flood function categories, and states there is no one size fits all approach.

An approach was developed that considers the specific nature of this floodplain, with its exceptionally large storage characteristics with slow velocities, and deep water. The method adopted is similar to that adopted in other large, lower catchment floodplains in NSW. The approach considered a range of different velocity and depth criteria, and through a process of iteration, defined criteria that on a visual examination appropriately defined the three flood function categories for this floodplain. The criteria was developed in conjunction with DCCEEW and are as follows:

- Floodway
  - Velocity x Depth > 0.25 m^2/s AND Velocity > 0.25 m/s
  - 10% AEP flood extent
- Flood Storage
  - Depth > 0.5 m
- Flood Fringe
  - Remaining area of flood prone land

Using the above criteria the provisional flood function hydraulic categories are shown in Figure 7-3 for the 1% AEP flood event for the Moama area.

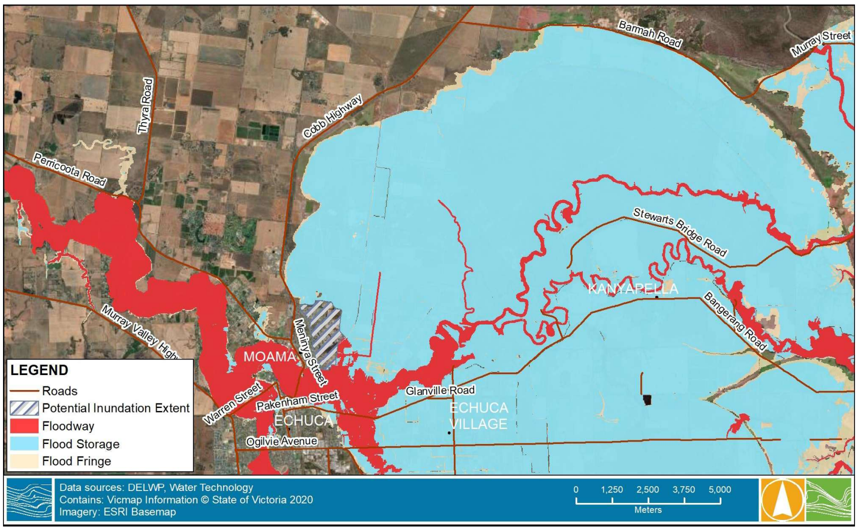

Figure 7-3 Hydraulic Categorisation

7.2 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 Council and WaterNSW regarding the construction of protection measures around their dwelling or rural shedding and its immediate curtilages. A flood work approval is required to be issued by WaterNSW before construction of any levee within the floodplain.

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. A similar result is likely for the NSW side of the floodplain. The application process will likely result in the need for a FIRA.

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. In urban areas where houses are in close proximity to each other, adverse impacts are more likely and it is strongly recommended that levee works be completed well prior to a flood event, following the correct approvals processes.

Any private levee structures constructed during a flood emergency without the required WaterNSW approval will need to be removed following the event.

7.3 Future Development in Moama

Existing Council planning growth strategies for Moama is set out in the Murray River Council Local Housing Strategy (2023). There is a draft urban growth boundary (UGB) set in the strategy that is recommended to be implemented, as per the extract in Figure 7-4. The Moama Flood Risk Management Strategy recommends that a flood planning area be applied along the depression which is inundated in the design flood event from a Murray River breakout near the Tindarra Resort. This flood planning area does include some flood controls on development.

The proposed mitigation measures recommended in Section 5, once installed, should allow development the flood planning area be removed from this depression within the UGB potentially allowing development with fewer constraints.

Given the Council has identified this area as a focus for future urban growth and is currently experiencing a large number of development applications, the proposed levee to block the flow breakout at the Tindarra Resort should be prioritised. It is recommended that Council update the Levee Operation Manual with the temporary Tindarra levee section, as was installed during the 2022 flood event, as an interim measure whilst a formal levee is investigated and constructed.

The East Moama area within the Kanyapella Basin is not appropriate for further residential development given the flood risks and proposed planning controls recommended. The exclusion of East Moama from the UGB is an appropriate approach, and it should not be included in any future potential expansion of the UGB.

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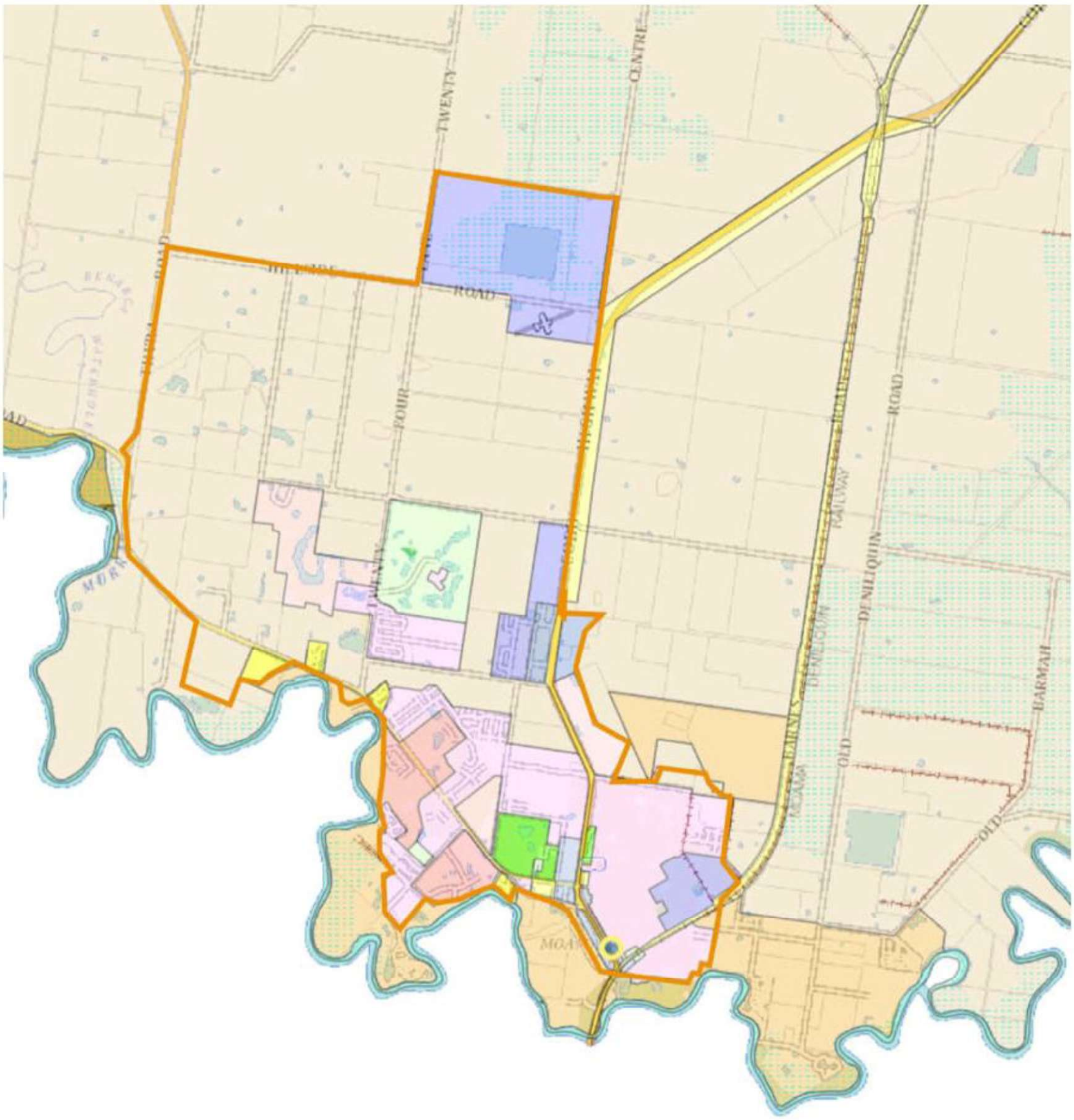

Figure 7-4 Draft Urban Growth Boundary (Local Housing Strategy, 2023)

7.4 Summary of Measures

- PM01 – The flood planning constraint categories presented in Section 7.1 of this report be implemented, to guide land use planning decisions.
- PM02 – Clause 5.22 Special Flood Considerations of the current LEP should be abandoned.
- PM03 – 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.

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8 FLOODPLAIN RISK MANAGEMENT PLAN

The Flood Risk Management Study and Plan for Moama and Echuca was developed as a collaborative effort between Councils and authorities in both New South Wales and Victoria. 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.

Table 8-1 lists the mitigation measures assessed by the Moama Flood Risk Management Study that have been recommended for implementation. The table describes each measure, responsibility, costs, funding sources and priority for implementation.

Table 8-1 Moama Floodplain Risk Management Plan

Measure ID	Description	Responsibility	Costs	Funding Sources	Benefit Cost Ratio	Priority
FM01	A new levee at Tindarra Resort. It is strongly recommended that the total flood mitigation concept plan presented in Section 5.4 be further investigated with a functional and detailed design.	Council	$1,426,000		0.35	High
FM02	Upgrade to the Moama town levee. It is strongly recommended that the total flood mitigation concept plan presented in Section 5.4 be further investigated with a functional and detailed design.	Council	$4,284,311		10.25	High
FM03	Council review the condition and adequacy of their stormwater drainage system, including pumps, and valves/gates to prevent back flooding from the rivers, this may be further investigated in the currently ongoing Moama overland flood study.	Council	Maintenance costs of up to $2,000 per pump per annum	No funding available	N/A	Medium
FM04	Installation of permanent pumps at the Chanter Street bridge	Council	$30,000	Council's own cost	N/A	Medium

Measure ID	Description	Responsibility	Costs	Funding Sources	Benefit Cost Ratio	Priority
RM01	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.	SES and BoM in co-operation	Minimal – SES and BoM work hours	No funding available	N/A	Medium
RM02	A flood intelligence card for Moama 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 emergency plan for Moama should be updated with information from the flood intelligence card in Appendix A.	SES	Minimal	No funding available	N/A	High
PM01	A specialist planning consultant be engaged to review both the DCP and the LEP and update to current standards. It is recommended that the flood planning constraint categories presented in Section 7.1 of this report be implemented, to guide land use planning decisions.	Council and DCCEEW	Consultancy fees $50,000	Council's own cost	N/A	Medium

Measure ID	Description	Responsibility	Costs	Funding Sources	Benefit Cost Ratio	Priority
PM02	Clause 5.22 Special Flood Considerations of the current LEP should be abandoned. This clause is not widely used in southern NSW and is very restrictive, encumbering all developable land surrounding the town for quite some distance.	Council and DCCEEW	Minimal	No funding available	N/A	High
PM03	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.	Council in consultation with property owners	Minimal – Council work hours	No funding available	N/A	Low

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9 REFERENCES

Flood Prone Land Policy, Department of Planning and Environment, 1984

Flood Risk Management Manual, Department of Climate Change Energy the Environment and Water, 2023

Murray Local Environmental Plan, Murray River Council, 2011

Murray Development Control Plan, Murray River Council, 2012.

Flood Risk Management Guideline (FB01) Understanding and Managing Flood Risk (NSW Department of Planning and Environment, 2023

Murray River Council Local Housing Strategy, Wakefield Planning, 2023

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APPENDIX A
FLOOD INTELLIGENCE CARD – MURRAY RIVER AT ECHUCA WHARF

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Murray River Council | 11 April 2025
Moama Flood Risk Management Study and Plan

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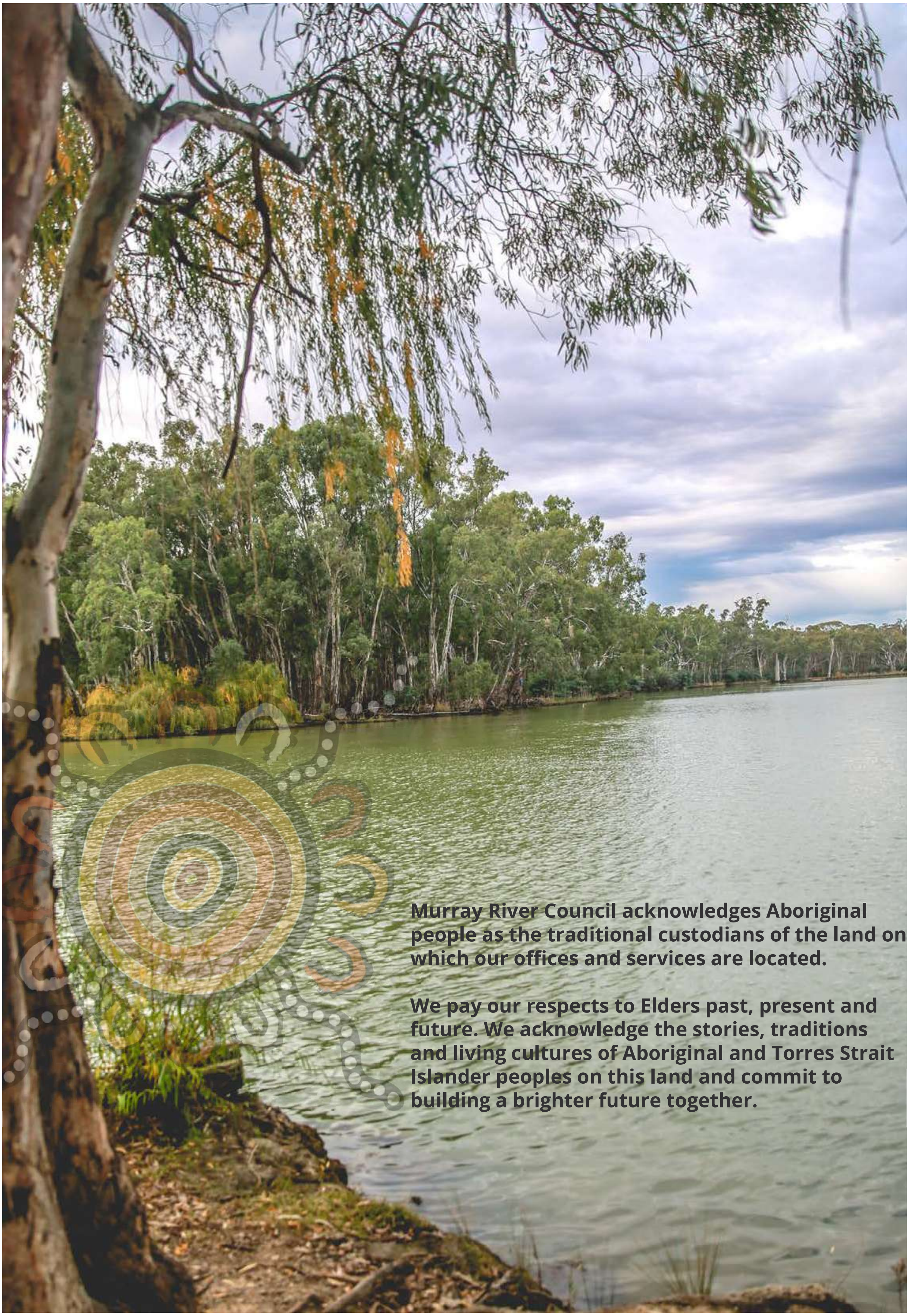
murray river council
Delivery
PROGRAM
2025-2029



Murray River Council acknowledges Aboriginal people as the traditional custodians of the land on which our offices and services are located.

We pay our respects to Elders past, present and future. We acknowledge the stories, traditions and living cultures of Aboriginal and Torres Strait Islander peoples on this land and commit to building a brighter future together.

The contents

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Our Vision

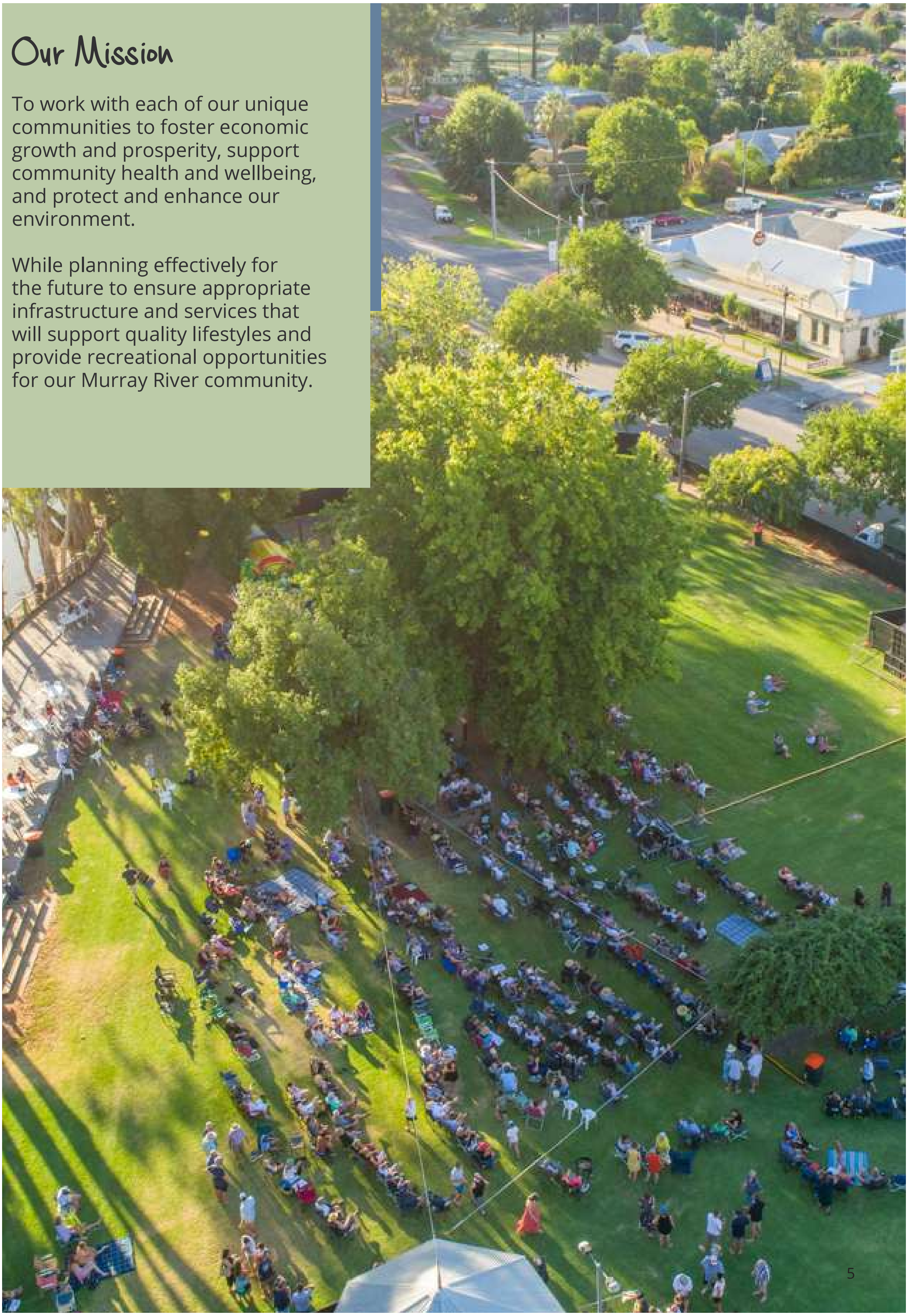
Murray River Council has vibrant, diverse and cohesive communities.
We are supported by strong local business and primary industries.
We value our beautiful waterways and natural surrounds.

4

Our Mission

To work with each of our unique communities to foster economic growth and prosperity, support community health and wellbeing, and protect and enhance our environment.

While planning effectively for the future to ensure appropriate infrastructure and services that will support quality lifestyles and provide recreational opportunities for our Murray River community.



Our Delivery Program is a statement of how Council aims to achieve the top-level goals identified in the Community Strategic Plan, and should be read in partnership with the latter.

Its life-cycle runs for the current Council term, and is reviewed and reported on at the end of this period in our State of the Region Report.

The Delivery Program is one of several planning documents that support the Integrated Planning and Reporting Framework that underpins Council's operations.

These plans come together to provide the community with a strategy that focuses on how Council can deliver services and projects that are sustainable and within the level of resources available.

The Delivery Program sits between the Community Strategic Plan and the annual Operational Plan and Budget.

Welcome.... with John Harvie

Welcome to our 2025-29 Delivery Program. This is an important multi-year planning document for Council and is the document that details the principal activities we will undertake during the current Council Term.

Developed in alignment with our Community Strategic Plan 2025-2035 (CSP), this Delivery Program translates long-term strategic goals into clear actions and initiatives. It outlines the key services, projects, and advocacy efforts that Council will undertake to enhance the liveability, sustainability, and economic vitality of our region.

Community input has been essential in shaping this program. Through consultation and collaboration when delivering our first CSP in 2022, and then the most recent updates in 2025, we have identified the priorities that matter most to our residents.

As you will see within the Delivery Program tables, there is a large focus on implementing the strategies, policies and plans we have developed over the previous Delivery Program. There is also a focus on operations, maintenance and renewals. This is to assist the community in understanding some of the 'behind-the-scenes' work council staff undertake to ensure business as usual continues.

Like most councils, resourcing is our biggest challenge. The entire local government sector in NSW is under incredible financial pressure due to increased cost shifting by state and federal governments and annual Financial Assistance Grants being cut in half since 1997.

Whilst we work towards delivering the projects and programs of works contained in this plan, we will also continue to focus on the financial sustainability of the organisation, including campaigning for significant increases in funding from both state and federal governments.

There are both challenges and opportunities in managing the growth of our region, and I believe we are well-equipped to deliver better outcomes for our communities.

So, as we work towards delivering this program through our yearly Operational Plans, we will ensure accountability and transparency remain at the core of our approach. Each year, we will report on our progress, ensuring that we remain on track and responsive to emerging challenges and opportunities.

I encourage our communities to provide feedback on whether we are delivering on our promises and getting things right. By working together, we can achieve great things!

Cr John Harvie
MAYOR

Council's Role

Although Council is the custodian of the Community Strategic Plan (CSP), it is not only our plan but that of our community too.

This means goals, projects and programs of works identified within the Community Strategic Plan, Delivery Program and Operational Plan are not always the sole responsibility of Council to deliver. In some cases, we will partner with State and Federal Government agencies or advocate on behalf of a project or program of works. The Delivery Program provides further direction in relation to those projects or programs of works where Council has a certain level of control over the outcome.

Council's role for each strategic objective within the CSP is defined by one or more of the following unique identifiers that will also flow on into the Delivery Program and Operational Plan:

DELIVER

Council delivers a range of programs and services including: waste collection, libraries, maintenance of local roads and public spaces, recreation facilities and programs, community care, special events and regulatory functions.

PARTNER

Council builds and facilitates strategic partnerships with federal and state government agencies, the private sector, and a range of other service providers whose work will contribute to delivering the Goals as identified within the Community Strategic Plan and the projects and programs of works as identified in the Delivery and Operational Plans.

ADVOCATE

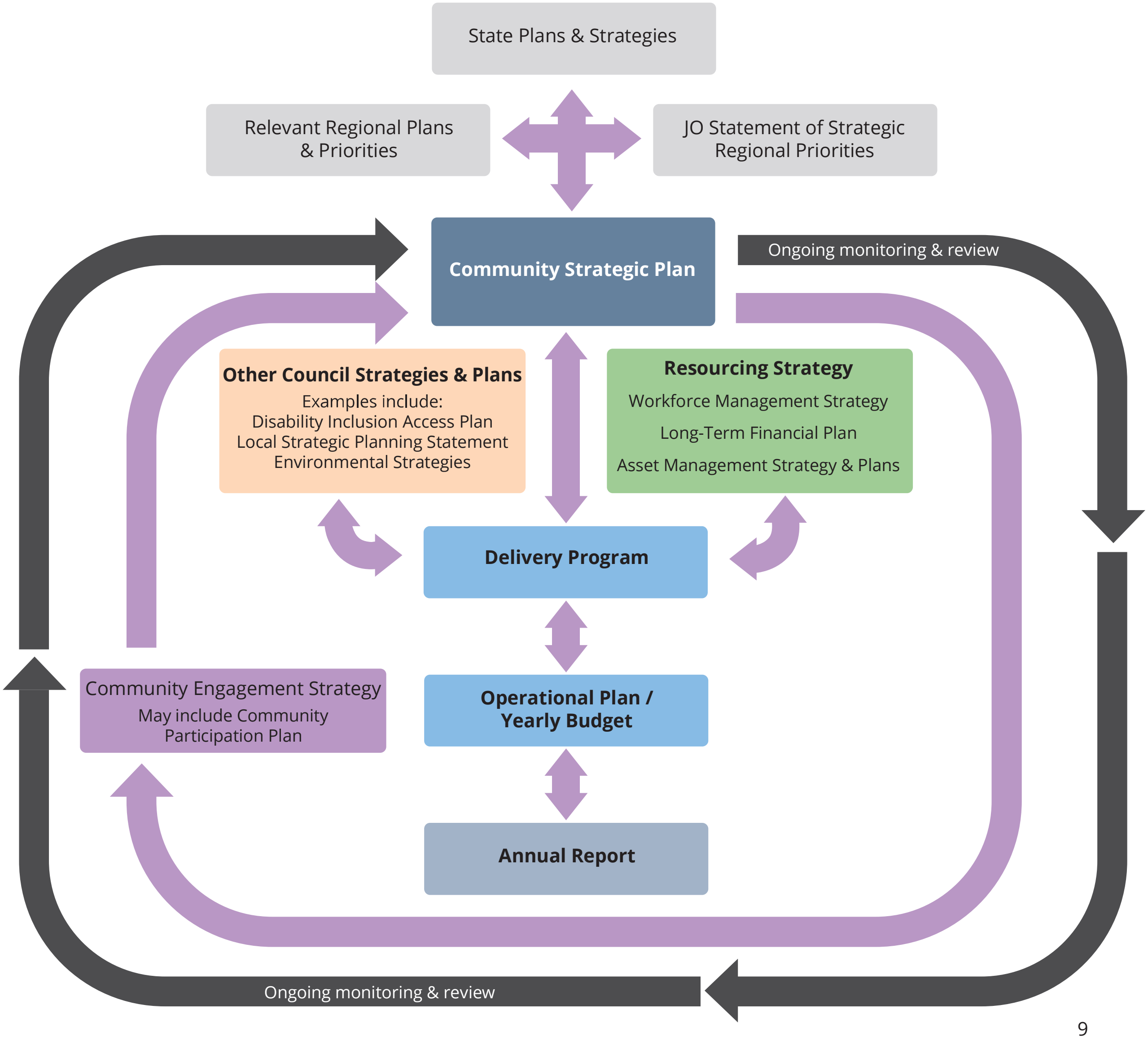
When not in direct control or partnership, Council gives voice to the needs and aspirations of the community by advocating for changes in policy and action at the relevant levels of government and industry to bring about the best outcomes for our community.

Our Framework

All NSW Councils are required to deliver their operations based on the Integrated Planning and Reporting (IP&R) framework. The framework allows Councils to draw together their various plans, strategies and reports, understand how they interact and get the maximum influence from their efforts by planning and taking a big-picture-view of the future.

The CSP must be based on the social justice principles of equity, access, participation, and rights.

Each year, Council will report to the community on the implementation of the Delivery Program and the Operational Plan and Budget. The Annual Report includes Council's Audited Report and other formal reporting as required by the *Local Government Act 1993* (the 'Act').



9

How we developed the Delivery Program.

Incorporating community feedback

The first major redevelopment of our Community Strategic Plan (CSP) commenced in late 2021 to coincide with the election cycle of 2021-2024. During this time, an extensive engagement program provided stakeholders and the community with the opportunity to have input into its development, which then informed the associated Delivery Program and Operational Plans.

Since that time, the organisation has worked to develop strategies and action plans that incorporate ideas submitted during the 2022 community consultation process. These ideas have been tested and refined along the way, and we have integrated as many as possible into our ongoing 'Business-as-Usual' processes.

Therefore, these strategies and actions plans remain at the heart of the 2025-29 Delivery Program.

Importantly, through the public exhibition stage of the draft 2025-35 CSP, feedback confirmed that the initiatives identified during the prior engagement processes still hold weight with our community. And so, like our top level CSP, this Delivery Program builds on the foundations of previous consultation efforts, ensuring continuity and alignment with ongoing community priorities.

Reviewing our 'Parking Lot'

During the 2022 consultation phase we received a lot of feedback from community members saying ideas had been previously suggested but were never actioned. These were generally some of the 'trickier ideas' that would take longer to implement. So instead of scrapping them altogether we created the 'MRC Parking Lot' which stored these extra community ideas and feedback for potential inclusion in future CSP's or Delivery Programs. Approximately 150 ideas were stored in the Parking Lot after the 2022 consultation period.

Fast forward to the development of this 2025-29 Delivery Program, we have reviewed the Parking Lot and determined more than 50% of the projects listed have either been completed or incorporated into Business as Usual, with many of the remaining items being deemed outside of Council's scope. Our Parking Lot remains, with some 40 items remaining for future investigation.

Public Exhibition of the Delivery Program - March/April 2025

Prior to final endorsement of the 2025-29 Delivery Program, the community had further opportunity to offer feedback to ensure priorities remained, or to capture any changes in community sentiment.

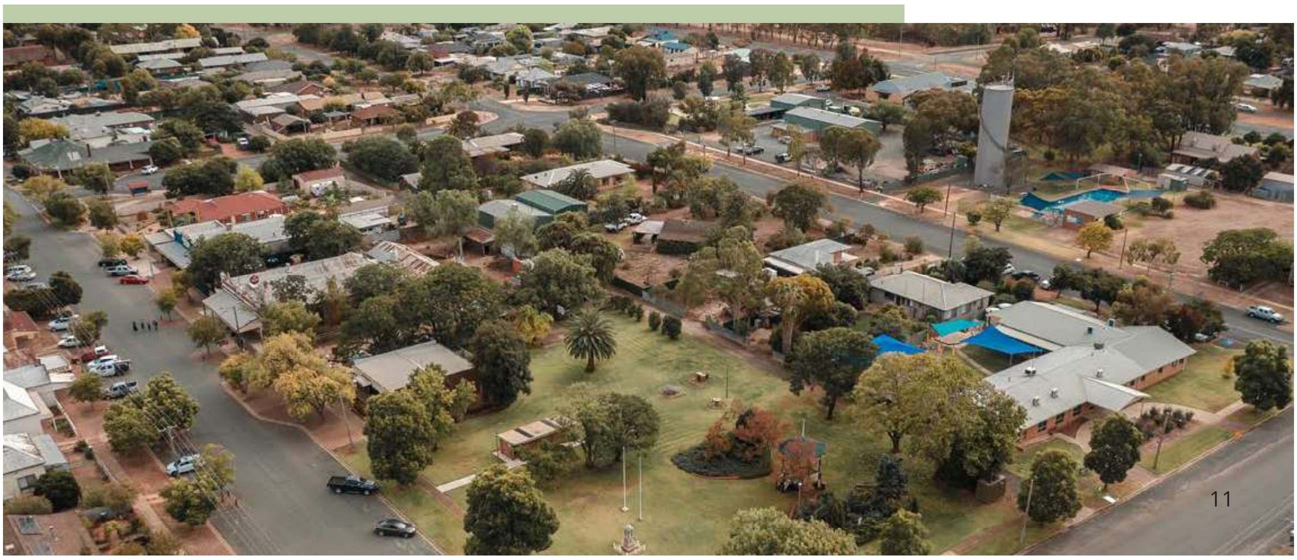
While no direct community feedback was received, several additional suggestions were provided internally by managers for consideration. The lack of further community feedback highlights general support for the priorities and direction outlined in the Delivery Program, indicating alignment with community expectations.

Major Projects.

As we look to support our community's growth into the future, many projects identified in the CSP and DP have extended timeframes or are projects which many not commence for some years.

Some projects which have been identified to be completed over the coming 10-20 years include:

- **Advocating for the upgrade / replacement of the Swan Hill Bridge**
- **A new Water Treatment Plant in Moama**
- **Reviewing and updating the Local Housing Strategy**
- **Developing and implementing an Aquatic Strategy including splash parks**
- **Financial Sustainability of Council**
- **New and updated pound facilities**
- **Updating and implementing Recreation Reserve Master Plans**
- **Placemaking Master Plans for Moulamein, Murray Downs and Mathoura**
- **Upgrades to the Barham, Murray Downs and Moama Sewer Treatment Plants**
- **Expansion of industrial land across the region**
- **Ongoing implementation and support for the South West Region Renewable Zone**



Reporting on our progress

Council is accountable for delivering and reporting on the Community Strategic Plan (CSP), Delivery Program and Operational Plans, as well as other strategies and plans adopted by Council.

Council's reporting will comply with all legislative requirements as outlined below, and we will provide other informal updates through our website, social media (Facebook account), community publications and other local print media outlets.

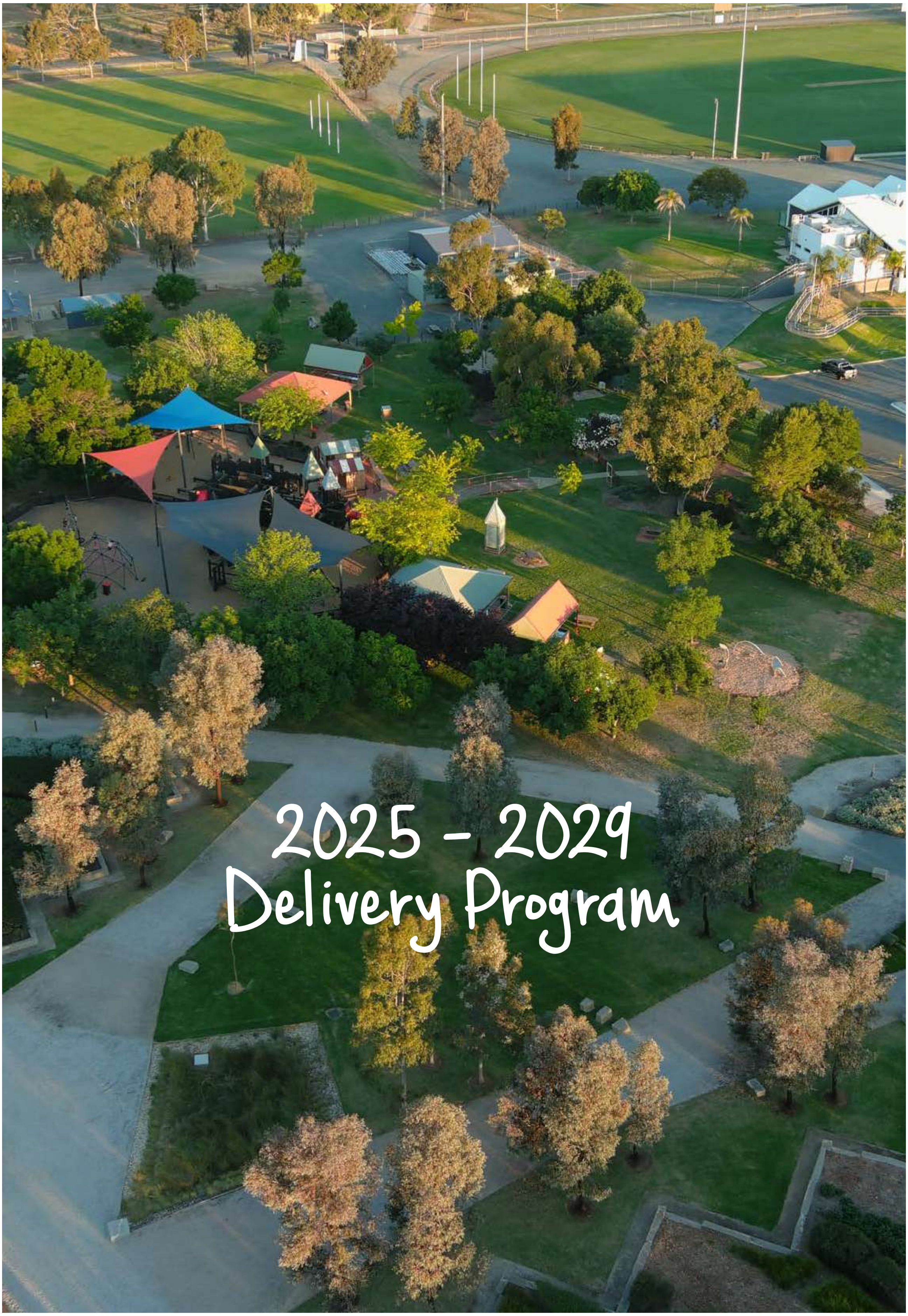
Through Council's Monthly Operational Report, Business Units will be able to continually monitor the progress of projects and programs of works identified within the Delivery Programs and the Yearly Operational Plan. These line items will directly relate to the goals outlined within the CSP. By undertaking the monthly reporting, we will ensure compliance with the monitoring requirements of the CSP and Delivery Program (section 404 of the Local Government Act – Integrated Planning and Reporting Framework).

In addition, the following reporting requirements will also be undertaken;

Annual Report - including the achievements of Council in implementing the Delivery Program, additional information required by legislation and audited Financial Statements for the financial year.

State of the Region Report – reporting on the progress of the Community Strategic Plan from one plan to the next. This report outlines how projects are tracking over a longer term – 10 years rather than just over the Council Term.

The success of the Delivery Program will be determined by a range of factors, including timeliness of delivery, budget allocation, legislative requirements, resolutions of Council and other external influences.


2025 - 2029
Delivery Program

The Delivery Program and Operational Plan are structured on the seven Themes and associated Goals identified in the Community Strategic Plan 2025-2035.

Under each Goal there are strategies, action plans, projects and programs of works which are all interconnected.

The strategies, action plans, projects and programs of works are aligned with Councils Business Units to provide accountability for each activity. Practically, most projects, programs of works or strategies will be conducted across many business units and teams.

How to read the Delivery Program

Strategic Objective - Facilitate Circular Economy

Code	Project or Programs of Works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1	Year 2	Year 3	Year 4
3.2: Develop and begin implementation of the Aquatics Strategy and action plan								
3.2.1	Develop and begin implementation of an Aquatics Strategy and action plan, to deliver a feasible level of service to the community.	Deliver	Aquatic Strategy developed and implementation has begun (in line with the Parks and Open Space Strategy).	Parks & Biosecurity.	✔	✔		

- Relates to the Theme and Goal as identified in the CSP
- Council's role in relation to the project or program of works to be delivered
- Related to the Strategic Objective identified in the CSP
- Detailed description of project or program of works to be undertaken to achieve the Strategic Objective
- What will be achieved, facilitated, or undertaken
- What year of the Delivery Program the project or program of works will commence or continue to be undertaken
- Code corresponding to Operational Budget and Monthly Operating Report to allow for ease of reporting
- Business Unit accountable for the outcome/deliverables

15

A PLACE OF ENVIRONMENTAL SENSITIVITY

Working together as a community to protect and enhance our natural and built environment for the future.

KEY PARTNERS

NSW Public Works Advisory
NSW Department of Planning and Environment
NSW Health
NSW Environment Protection Authority
NSW Department of Primary Industries
Murray Local Land Service
RAMJO / Halve Waste
Forestry NSW / NSW Parks and Wildlife
Parks Victoria
Tomra / Cleanaway
Crown Lands
Neighbouring councils
NSW Farmer's Association
Transport for NSW

Strategic Objective – Facilitate circular economy.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
1.1	**Enhance and promote waste and recycling programs in accordance with Council's Waste Strategy and compliance with EPA requirements.**							
1.1.1	Review the Waste Management Strategy.	Deliver, Partner	The current Waste Management Strategy is reviewed and a new Strategy developed with an accompanying action plan.	Waste & Compliance		✓		
1.1.2	Update and implement the items identified in the Action Plan	Deliver	Items identified in the WMS Action Plan are reviewed yearly and implemented.	Waste & Compliance	✓	✓	✓	✓
1.1.3		Deliver	Moama Waste Management Facility – Push Pit.	Waste & Compliance	✓			

Strategic Objective – Protect, enhance and sustain the natural environment.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
1.2	**Work towards creating a more Environmentally Sustainable Council.**							
1.2.1	Develop and implement an Environmental Sustainability Strategy	Deliver	Environmental Sustainability Strategy developed and implementation has begun.	Planning and Environment Directorate		✓	✓	✓
1.3	**Improve areas of natural habitat through the review and implementation of our Weed Action Plan, Weed and Vegetation Management Framework in accordance with relative legislation and funding agreements.**							
1.3.1	Weed and Vegetation Management Framework developed, and action plan implemented	Deliver	Weed and Vegetation Management Framework developed.	Parks & Biosecurity	✓			
1.3.2		Deliver	Weed and Vegetation Management Framework action plan implemented.	Parks & Biosecurity		✓	✓	✓
1.3.3		Deliver	Biosecurity - operations and maintenance.	Parks & Biosecurity	✓	✓	✓	✓
1.3.4		Deliver	Biosecurity – renewals.	Parks & Biosecurity	✓	✓	✓	✓
1.3.5		Deliver, Partner, Advocate	Work with relevant agencies to identify any natural habitat projects that Council can support and contribute to.	Parks & Biosecurity	✓	✓	✓	✓
1.3.6		Deliver, Partner, Advocate	Development and implementation of various frameworks and associated action plans, including options for seedling tree schemes to support revegetation of land previously impacted by priority weeds.	Parks & Biosecurity	✓	✓	✓	✓
1.3.7	Weed Action Plan reviewed and implemented in line with legislation and funding agreements	Deliver, Partner	Priority Weed Action Plan reviewed and future funding achieved.	Parks & Biosecurity	✓	✓	✓	✓
1.3.8		Deliver, Partner	Priority Weed Management priorities are communicated annually with the community.	Parks & Biosecurity	✓	✓	✓	✓

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
1.3.9		Deliver, Partner	Identified State Priority Weeds reducing over time.	Parks & Biosecurity	✓	✓	✓	✓
1.3.10		Deliver	Biosecurity - operations and maintenance.	Parks & Biosecurity	✓	✓	✓	✓
1.3.11		Deliver	Biosecurity – renewals.	Parks & Biosecurity	✓	✓	✓	✓
1.4	**Prioritise and rehabilitate Landfills in line with the Waste Management Strategy.**							
1.4.1	Landfills identified in the Waste Management Strategy will be rehabilitated over the next 10-year period based on budget and risk.	Deliver	Koraleigh landfill to be rehabilitated.	Waste & Compliance		✓		
1.4.2		Deliver	Moulamein landfill to be rehabilitated.	Waste & Compliance				✓

Strategic Objective - Increase awareness and education of environmental sustainability.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
1.5	**Incorporation of sustainability (ESG) criteria in Procurement Policy and Procedures**							
1.5.1	Procurement Policy to be reviewed and ESG factors incorporated into process to ensure sustainable outcomes wherever value for money is not adversely affected.	Deliver	Updated Procurement Policy and Procurement Procedure to incorporate processes to evaluate environmental, social and economic sustainability factors in all purchasing.	Legal, Property & Procurement	✓			
1.5.2		Deliver	Identification on Council's purchasing system of suppliers who meet nationally or internationally recognised sustainability standards.	Legal, Property & Procurement		✓		
1.6	**Ongoing development, review and implementation of schools, early childhood and community education programs focusing on various Council Services.**							
1.6.1	Programs developed and facilitated across the region on an as requested basis or as need arises from regulations.	Deliver	Education Program - Water efficiency and impacts on water sources.	Community Engagement	✓	✓	✓	✓
1.6.2		Deliver	Education Program - Sewer systems – The Three P's.	Community Engagement	✓	✓	✓	✓
1.6.3		Deliver, Partner	Education Program - FOGO, Waste and Recycling.	Community Engagement / Waste & Compliance	✓	✓	✓	✓
1.6.4		Deliver, Partner	Education Program - Compliance activities.	Community Engagement / Waste & Compliance	✓	✓	✓	✓
1.6.5		Deliver, Partner	Education Program - Weeds and Biosecurity.	Community Engagement / Parks & Biosecurity	✓	✓	✓	✓
1.6.6		Deliver	Education Program - Environmental Health.	Community Engagement / Waste & Compliance	✓	✓	✓	✓

A PLACE OF PROGRESSIVE LEADERSHIP

We will plan and advocate for the changing needs of our community through effective and engaging leadership.

KEY PARTNERS

Service NSW
Various business/commerce groups
Office of Local Government NSW
Marketing groups
S355 committees
Volunteers

Strategic Objective – Deliver exceptional and consistent service to our internal and external community.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
2.1	**Ensure we provide clear, concise and consistent information which is easily accessed.**							
2.1.1	Enhanced community satisfaction through improved access to information and services, with increased engagement and greater accessibility for all stakeholders, including diverse groups.	Deliver	Develop and implement a Customer Experience Strategy which focuses on the holistic Customer Journey.	Customer Service	✓	✓		
2.1.2		Deliver	Develop and implement the Customer Experience Action Plan.	Customer Service		✓	✓	✓
2.1.3		Deliver, Partner	Implement an annual customer satisfaction survey which allows for benchmarking to be achieved and reviewed to determine long term customer satisfaction (across all Council services).	Customer Service	✓	✓	✓	✓
2.1.4		Deliver, Partner	Measure and compare year-on-year performance and benchmark against other comparable councils.	Corporate Services Directorate	✓	✓	✓	✓
2.1.5		Deliver	Review and implement a Customer Service Strategy.	Customer Service	✓			
2.1.6		Deliver	Review and implement a Customer Service Action Plan (Service Delivery Plan developed, Service Level Agreements developed (Customer Service and Whole of Business).	Customer Service	✓	✓	✓	✓
2.1.7		Deliver	Review and implement a Customer Service Charter (whole of business charter) with a focus on customer enquiries, complaints and requests.	Customer Service	✓	✓		
2.1.8		Deliver	Required information and modelling outputs are presented to Councillors to enable informed decision on setting General Rates, Utility Charges and Fees.	Corporate Services Directorate / Finance	✓	✓	✓	✓
2.1.9		Deliver	Reasonable and practical budgets are prepared and adopted by Council within statutory timeframes.	Finance	✓	✓	✓	✓
2.1.10		Deliver	Comprehensive accurate and timely financial reports (audited where required) delivered on a regular basis.	Finance	✓	✓	✓	✓
2.1.11		Deliver	Required statutory reports compiled and delivered on a timely basis.	Governance & Risk / Assets	✓	✓	✓	✓
2.1.12		Deliver	Statutory information requests are responded to within required timeframes.	Governance & Risk	✓	✓	✓	✓
2.1.13		Deliver	Review and implement a Complaints Management Policy and Procedure (community-based complaints & whole of business).	Customer Service / Governance & Risk	✓	✓	✓	
2.1.14		Deliver	Fully integrated Customer Request Management System (CRMS) implemented.	Customer Service / Information Technology & Software			✓	✓

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
2.1.15		Deliver	Introduction of Customer Request and Customer Communication Journey mapping.	Customer Service		✓		
2.1.16		Deliver	Ensure Accessibility guidelines are adhered to including in but not limited to broadcast, print and social media including Councils websites.	Community Engagement	✓	✓	✓	✓
2.1.17		Deliver	Establish a Councillor Request function within the overall Customer Request Management (CRM) module incorporating a mechanism for service level measurement.	Corporate Services Directorate / Governance & Risk		✓	✓	✓
2.2	**Review Council's services to align to the 10-Year Long Term Financial Process.**							
2.2.1	Council Services reviewed and prioritisation completed	Deliver	IT Infrastructure and Security Roadmap Project developed, and implementation has begun.	Information Technology & Software	✓	✓	✓	✓
2.2.2		Deliver	Information Management Plan developed, implemented, and audited annually.	Information Technology & Software		✓	✓	✓
2.2.3		Deliver	Deployment of new enterprise software solutions completed with staff training and adoption metrics.	Information Technology & Software	✓	✓	✓	✓
2.2.4		Deliver	Conduct ongoing lifecycle replacement of ICT hardware, including servers, networking, end-user devices and delivering access to technology across council.	Information Technology & Software	✓	✓	✓	✓
2.2.5		Deliver	Options for restoration of Council's financial sustainability presented to Council and a strategy adopted by Council.	Chief Executive Office / Corporate Services Directorate	✓	✓		
2.2.6		Deliver	Internal Service Review Completed.	Chief Executive Office / Corporate Services Directorate	✓			
2.2.7		Deliver	Define Council's Operational services and develop a Service Level Strategy.	Chief Executive Office	✓	✓		
2.2.8		Deliver	Deliver internal customer service in line with Service Level Strategy.	Chief Executive Office	✓	✓	✓	✓
2.2.9		Deliver	Council Assets including yellow and grey fleet, ICT etc managed in line with Best Practise opportunities (renewals, maintenance etc).	Legal, Property, Procurement / Assets / Information Technology & Software	✓	✓	✓	✓
2.2.10		Deliver, Partner, Advocate	Review external community services such as Service NSW, Banking, V/Line, and Services Australia, weighing the costs and benefits, and exploring innovative ways to improve service efficiency.	Customer Service	✓	✓	✓	✓
2.2.11		Deliver	Council's risk appetite and Risk Management Framework reviewed. Revised as required and adopted.	Governance & Risk	✓			

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
2.2.12		Deliver	Optimal insurance policies are in place for all insurable risks.	Governance & Risk	✓	✓	✓	✓
2.3	**Review Statutory Planning & Building processes and communication material to assist with higher quality applications from customers**							
2.3.1	Statutory Planning & Building processes and communication material reviewed, and implementation has begun.	Deliver	80% Of approvals within statutory timeframes.	Development Services	✓	✓	✓	✓
2.3.2		Deliver	Update Development Services Charter.	Development Services	✓		✓	
2.3.3		Deliver	Improve education and use development forums for frequently and more meaningfully.	Development Services	✓	✓	✓	✓
2.3.4		Deliver	Develop a / review and update the policy relating to Developer Contributions (including possible concessions).	Development Services	✓	✓		
2.4	**Ensure development applications are assessed and determined within appropriate timeframes**							
2.4.1	Resource the Development Services team adequately to meet Statutory timelines.	Deliver	Budget for and develop an ongoing cadetship program.	Development Services	✓	✓	✓	✓
2.5	**Develop and begin implementation of Council's Compliance Strategy to ensure mandatory statutory obligations are met.**							
2.5.1	Develop and begin implementation of the Compliance Strategy and action plan.	Deliver	Strategy developed – with a focus on identifying Core business priorities.	Waste & Compliance	✓			
2.5.2		Deliver	Action plan developed and implementation has begun.	Waste & Compliance		✓		
2.5.3		Deliver	Compliance - operations and maintenance tasks.	Waste & Compliance	✓	✓	✓	✓
2.5.4		Deliver	Compliance – renewals.	Waste & Compliance	✓	✓	✓	✓
2.5.5		Deliver, Partner, Advocate	MOU or agreements in place with partner agencies or adjoining councils.	Planning & Environment Directorate	✓	✓	✓	✓
2.6	**Develop and begin implementation of Council's Cemeteries Management Strategy to ensure compliance with regulations**							
2.6.1	Develop and begin implementation of the Cemeteries Management Strategy and associated documents.	Deliver	Develop a Council Cemeteries Management Strategy in line with emerging legislative requirements.	Customer Service / Parks & Biosecurity		✓	✓	
2.6.2		Deliver	Develop a Service Level Agreement for cemeteries to ensure clear service expectations, enhance accountability and maintain operational efficiency and compliance.	Customer Service / Parks & Biosecurity	✓	✓	✓	✓
2.6.3		Deliver	Undertake an updated asset review of all Council cemeteries.	Customer Service / Parks & Biosecurity / Assets	✓	✓	✓	✓
2.6.4		Deliver	Cemetery - operations and maintenance.	Parks & Biosecurity / Customer Service	✓	✓	✓	✓
2.6.5		Deliver	Cemetery – renewals	Parks & Biosecurity / Project Management Office	✓	✓	✓	✓

Strategic Objective – Continue to be a trusted and ethical leader that leads by example.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
2.7	**We will strengthen our reputation across the region by building strong, positive relationships with our communities and demonstrating accountability in all our actions and decisions.**							
2.7.1	We will engage regularly with our communities through consultations and transparent communication, ensuring that feedback is valued and reflected in our decisions. By demonstrating accountability and responsiveness, we will build trust, strengthen relationships, and enhance our reputation across the region.	Partner	Projects and initiatives delivered and supported in partnership with business and community organisations.	Economic Development & Tourism	✓	✓	✓	✓
2.7.2		Deliver Partner	Progress on the implementation of the Disability Inclusion Action Plan, with key milestones achieved and stakeholder feedback collected to assess the plan's effectiveness in improving accessibility and inclusion for people with disabilities.	Economic Development & Tourism	✓	✓	✓	✓
2.8	**Review and improve our recruitment and staff retention programs**							
2.8.1	Develop and begin implementation of the People and Culture Strategy and action plan.	Deliver	Develop and begin implementation of the People and Culture Strategy and begin implementation of the action plan.	People & Culture	✓	✓	✓	✓
2.8.2		Advocate	Council's new Values are embedded into internal processes.	People & Culture	✓	✓	✓	✓
2.8.3		Deliver	Ongoing development of the Emerging Leaders program – looking at several levels of the program to be rolled out.	People & Culture	✓		✓	
2.8.4		Deliver	Development of Ascending Managers Program.	People & Culture		✓		✓
2.8.5		Advocate	Further professional development opportunities for all staff.	People & Culture	✓	✓	✓	✓
2.8.6		Deliver	Role specific mandatory training, licences and qualifications planned for and undertaken across the organisation.	People & Culture	✓	✓	✓	✓
2.8.7		Partner	Focus on successful engagement and fulfilment of cadetships and School-based apprenticeships.	People & Culture		✓		✓
2.8.8		Partner	Ongoing commitment to invest in our Community Leadership program by sponsoring one emerging community leader through the Fairley Leadership Program	People & Culture	✓	✓	✓	✓
2.8.9	Develop and begin implementation of the Work, Health and Safety Strategy and action plan	Deliver	Develop and begin implementation of the Work, Health and Safety Strategy and begin implementation of the action plan.	People & Culture	✓	✓	✓	✓
2.8.10	Develop and begin implementation of a Wellbeing Strategy and action plan	Deliver	Develop and begin implementation of a Wellbeing Strategy and begin implementation of the action plan	People & Culture	✓	✓	✓	✓

Strategic Objective – Achieve community driven results through collaboration and engagement (community and stakeholders).

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
2.9	**Improve Council and Community collaboration and interaction opportunities.**							
2.9.1	Increased opportunities for Councillor and community interaction to occur.	Deliver	Meet the Council BBQ events / Pop in sessions – Councillors and Staff to attend.	Chief Executive Office	✓	✓	✓	✓
2.9.2	Increase Council and Community collaboration and support opportunities.	Deliver, Partner, Advocate	Ongoing support of Council offered Community Grants program.	Economic Development & Tourism	✓	✓	✓	✓
2.9.3	Successful implementation of the IP&R requirements	Deliver	Development and ongoing implementation of the CSP and DP.	Community Engagement	✓	✓	✓	✓
2.9.4		Deliver	Development and ongoing implementation of the Asset Management Strategy and Plans.	Assets	✓	✓	✓	✓
2.9.5		Deliver	Development and ongoing implementation of the Workforce Plan.	People & Culture	✓	✓	✓	✓
2.9.6		Deliver	Development and ongoing implementation of the Long Term Financial Plan.	Finance	✓	✓	✓	✓
2.10	**Review and continue to improve Council's Community Engagement Framework**							
2.10.1	Review and begin implementation of the Community Engagement Framework and toolkits.	Deliver	Community Engagement embedded into Project Management Framework.	Community Engagement	✓	✓	✓	✓
2.10.2		Deliver	Community Engagement Toolkit further developed and implementation has begun.	Community Engagement	✓	✓	✓	✓
2.10.3		Deliver	Review and update the Community Engagement Strategy.	Community Engagement				✓
2.10.4		Deliver	Review and begin implementation of the Community Engagement Action Plan.	Community Engagement	✓	✓	✓	✓

A PLACE OF LIVEABLE COMMUNITIES

Well-planned, safe and accessible public spaces and facilities built with a strong sense of identity and place.

KEY PARTNERS

- NSW Department of Planning and Environment
- NSW Department of Primary Industries
- Murray Local Land Service
- NSW National Parks and Wildlife Service
- Riverina and Murray Joint Organisation (RAMJO)
- S355 Committees
- Private Developers
- Local Sporting Clubs
- Neighbouring councils
- NSW Police

Strategic Objective - Create and maintain safe and accessible community spaces that enhance healthy living and promote active lifestyles.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
3.1	**Review and begin implementation of the Parks and Open Spaces Strategy and update recreation master plans as appropriate**							
3.1.1	Review and begin implementation of the Parks and Open Space Strategy and action plan, including the review of recreation master plans as required.	Deliver	Review Parks and Open Space Strategy 2024-34	Parks & Biosecurity				✓
3.1.2		Deliver	Action plan developed and implementation has begun reflecting actions from the Strategy and the Service Delivery Plan	Parks & Biosecurity	✓	✓	✓	✓
3.1.3		Deliver	Identify and plan for Recreation Master Plans which require updates	Parks & Biosecurity	✓			
3.1.4		Deliver	Ongoing implementation of the Barham, Moama and Tooleybuc Recreation Reserve Master Plans	Parks & Biosecurity	✓	✓	✓	✓
3.1.5		Deliver	Koraleigh Recreation Master Plan	Parks & Biosecurity	✓			
3.1.6		Deliver	Buildings – Recreation Reserve buildings and other structures – renewals	Buildings & Facilities / Parks & Biosecurity	✓	✓	✓	✓
3.1.7		Deliver	Buildings – Recreation Reserve buildings and other structures – upgrades	Buildings & Facilities / Parks & Biosecurity	✓	✓		
3.1.8		Deliver	Buildings – Recreation Reserve buildings and other structures – operations and maintenance	Buildings & Facilities / Parks & Biosecurity	✓	✓	✓	✓
3.1.9		Deliver	Parks and Open Spaces - operations and maintenance	Parks & Biosecurity	✓	✓	✓	✓
3.1.10		Deliver	Sport and Recreations – operations and maintenance	Parks & Biosecurity	✓	✓	✓	✓
3.2	**Develop and begin implementation of the Aquatics Strategy and action plan**							
3.2.1	Develop and begin implementation of an Aquatics Strategy and action plan, to deliver a feasible level of service to the community.	Deliver	Aquatic Strategy developed and implementation has begun (in line with the Parks and Open Space Strategy).	Parks & Biosecurity		✓	✓	
3.2.2		Deliver	Action plan developed and implementation has begun.	Parks & Biosecurity		✓	✓	
3.2.3		Deliver	Aquatic renewals and upgrades – exiting assets.	Parks & Biosecurity	✓	✓	✓	✓
3.2.4		Deliver	Aquatic operations and maintenance – exiting assets.	Parks & Biosecurity	✓	✓	✓	✓
3.3	**Review and begin implementation of the Building Strategy.**							
3.3.1	Review and begin implementation of the Building Strategy and action plan, reflecting the delivery of a feasible level of service to the community.	Deliver	Action plan developed and implementation has begun.	Buildings & Facilities		✓		
3.3.2		Partner	Determine a feasible level of service to the community.	Buildings & Facilities		✓		
3.3.3		Deliver	Installation and management of CCTV devices as identified in the Building Strategy.	Buildings & Facilities / Information Technology & Softwear	✓	✓	✓	✓
3.3.4		Deliver	Buildings – general Council buildings – renewals.	Buildings & Facilities	✓	✓	✓	✓

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
3.3.5		Deliver	Buildings – general Council buildings – operations and maintenance.	Buildings & Facilities	✓	✓	✓	✓
3.3.6		Deliver	Buildings – Waste Facilities – renewals and upgrades.	Buildings & Facilities	✓	✓	✓	✓
3.3.7		Deliver	Buildings – Waste – operations and maintenance.	Buildings & Facilities	✓	✓	✓	✓
3.3.8		Deliver	Buildings – Water Facilities – renewals and upgrades.	Buildings & Facilities	✓	✓	✓	✓
3.3.9		Deliver	Buildings – Water – operations and maintenance.	Buildings & Facilities	✓	✓	✓	✓
3.3.10		Deliver	Buildings – Sewer Facilities – renewals and upgrades.	Buildings & Facilities		✓	✓	
3.3.11		Deliver	Buildings – Sewer – operations and maintenance.	Buildings & Facilities	✓	✓	✓	✓
3.3.12		Deliver	Building demolition and removal (across various townships).	Buildings & Facilities	✓	✓	✓	✓
3.3.13		Deliver	Building Upgrades / New buildings.	Buildings & Facilities		✓	✓	✓
3.4	**Develop and begin implementation of the Amenities Strategy.**							
3.4.1	Develop and begin implementation of the Amenities Strategy and action plan.	Deliver	Strategy and Action plan developed and implementation has begun.	Buildings & Facilities / Parks & Biosecurity	✓			
3.4.2		Deliver	Mapping and strategy to include focus on dump points and water filling locations for touring vehicles.	Buildings & Facilities / Parks & Biosecurity		✓	✓	
3.4.3		Deliver	Buildings – existing amenities building – renewals and upgrades.	Buildings & Facilities / Parks & Biosecurity	✓	✓		
3.4.4		Deliver	Buildings – existing amenities – operations and maintenance.	Buildings & Facilities / Parks & Biosecurity	✓	✓	✓	✓
3.4.5		Deliver	Buildings – new amenities building as identified in the strategy and action plan.	Buildings & Facilities / Parks & Biosecurity		✓	✓	✓
3.4.6		Deliver	Buildings – new amenities – operations and maintenance.	Buildings & Facilities / Parks & Biosecurity		✓	✓	✓
3.5	**Develop and begin implementation of a River Infrastructure Strategy**							
3.5.1	Develop and begin implementation of a documentation surrounding boat ramps, wharfs, retaining walls and pontoons	Deliver	Strategy developed for the ongoing development, maintenance and management of Wharfs and Boat ramps.	Works / Parks & Biosecurity			✓	✓
3.5.2		Deliver	Action Plan developed and implementation has begun.	Works / Parks & Biosecurity			✓	✓
3.5.3		Deliver	Asset Management Plans developed relating to the monitoring and maintenance of river infrastructure including retaining walls and pontoons.	Works / Parks & Biosecurity / Assets			✓	✓

Strategic Objective – Enable development of liveable communities.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
3.6	**Monitor, review and begin implementation of the Local Housing Strategy including considerations for affordable housing options**							
3.6.1	Review and update the Local Housing Strategy.	Deliver	Local Housing Strategy, updated and adopted by both Council and DPHI.	Development Services	✓	✓		
3.6.2	New subdivisions released in sequence and diversity of housing products considered in line with projected population growth for our LGA.	Advocate	Advocate for affordable housing options within new and existing residential releases of land.	Development Services	✓	✓	✓	✓
3.6.3		Deliver, Advocate	Consider manufactured home estates in appropriate areas	Development Services	✓	✓	✓	✓
3.6.4		Advocate	Advocate for over 55s lifestyle villages within the LGA.	Community Economic Development Directorate	✓	✓	✓	✓
3.6.5		Deliver Partner	Develop / Review a Management Plan for Council owned Caravan parks.	Community Economic Development Directorate	✓	✓	✓	✓
3.7	**Review and implementation of the various strategies which influence Council's approach to Regulatory Assurance Framework (RAF) – formally known as Integrated Water Cycle Management.**							
3.7.1	Develop and begin implementation of the Integrated Water Cycle Management Strategy and action plan.	Deliver	Integrated Water Cycle Management Strategy and Action Plan developed, and implementation has begun in line with State and Federal Government Regulations - Includes sewer, drinking water, raw water, drought management	Water & Waste water	✓	✓	✓	✓
3.7.2	Develop and begin implementation of the Regulatory Assurance Framework (to begin after IWCM is adopted)	Deliver	Regulatory Assurance Framework assessments to be undertaken yearly after the IWCM is adopted and implementation has begun, and implementation has begun.	Water & Waste water	✓	✓	✓	✓
3.7.3	Water Services (drinking water) reviewed, and action plans implemented as per the Asset Management Plans	Deliver	Water Filtration Plant upgrades investigated, actions identified and begin implementation across the network.	Water & Waste water	✓	✓	✓	✓
3.7.4		Deliver	Moama Water Treatment Plant upgrades (existing plant).	Water & Waste water	✓	✓	✓	✓
3.7.5		Deliver	Reticulation Network renewals (all infrastructure, SCADA, meters), upgrades and analysis (across various townships).	Water & Waste water	✓	✓	✓	✓
3.7.6		Deliver	New / Renewal of Building Assets.	Water & Waste wate		✓	✓	✓
3.7.7		Deliver	Water supply, treatment and distribution operations (raw and filtered).	Water & Waste water	✓	✓	✓	✓
3.7.8	Water Services (raw water) reviewed, and action plans implemented as per the Asset Management Plans	Deliver	Reticulation Network renewals (all infrastructure, SCADA, meters), upgrades and analysis (across various townships)	Water & Waste water	✓	✓	✓	✓
3.7.9		Deliver	Barham Sewer Treatment Plant upgrades and associated works.	Water & Waste water	✓	✓	✓	✓

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
3.7.10	Sewer Services reviewed and action plans implemented as per the Asset Management Plans	Deliver	Moama Sewer Treatment Plant upgrades and associated works.	Water & Waste water	✓	✓	✓	
3.7.11		Deliver	Murray Downs Sewer Treatment Plant upgrades and associated works.	Water & Waste water	✓		✓	✓
3.7.12		Deliver	Sewer Treatment Plant general renewals.	Water & Waste water	✓		✓	
3.7.13		Deliver	Sewer General Network Odour Control.	Water & Waste water	✓	✓	✓	✓
3.7.14		Deliver	Sewer General Network CCTV condition inspections.	Water & Waste water	✓	✓	✓	✓
3.7.15		Deliver	Sewer General Network SCADA upgrades.	Water & Waste water		✓	✓	✓
3.7.16		Deliver	Sewer Network - replacement / relining.	Water & Waste water	✓	✓	✓	✓
3.7.17		Deliver	Sewer Network – Pump Stations renewals.	Water & Waste water	✓	✓	✓	✓
3.7.19		Deliver	Sewer Treatment and collection – operations.	Water & Waste water	✓	✓	✓	✓
3.7.20	Stormwater Services reviewed and action plans implemented as per the Asset Management Plans	Deliver	Stormwater Services Strategy and Action Plan developed and implementation has begun	Water & Waste water / Works	✓	✓	✓	✓
3.7.21		Deliver	Moama Stormwater (Overland flood study) Study completed.	Works / Project Management Office	✓			
3.7.22		Deliver	Stormwater Basin – upgrades.	Water & Waste water	✓	✓	✓	✓
3.7.23		Deliver	Stormwater Reticulation network (pipework and pump stations).	Water & Waste water	✓	✓	✓	✓
3.7.24		Deliver	Stormwater Network operations and maintenance (across various townships).	Works / Water & Waste water	✓	✓	✓	✓
3.7.25		Deliver	Stormwater capture and reuse operations.	Water & Waste water	✓	✓	✓	✓
3.7.26	Drought Contingency and Emergency Response Plan (DCERP) developed, and action plans implemented	Deliver, Partner	Drought Contingency and Emergency Response Plan (DCERP) developed, and action plans implemented	Water & Waste water	✓	✓	✓	✓
3.7.27	Flood Management Services and Strategies reviewed, and action plans implemented	Deliver	Flood Management Strategy, Framework and Action Plan developed and implementation has begun.	Works / Project Management Office	✓	✓	✓	✓
3.7.28		Deliver	Moulamein Flood Study completed.	Works / Project Management Office	✓			
3.7.29		Deliver	Begin implementation of the Echuca Moama Torrumbarry Flood Study - development of the EMFS Risk Mitigation Plan.	Works / Project Management Office			✓	
3.7.30		Deliver	Barham Flood Study completed.	Works / Project Management Office	✓	✓		

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
3.7.31		Deliver	Mathoura and Picnic Point Flood Study completed.	Works / Project Management Office	✓	✓		
3.7.32		Deliver	Levee Bank operations and maintenance (across various townships) (notes - includes training, inspections, maintenance, general operations).	Works	✓	✓	✓	✓
3.7.33		Deliver	Levee Bank upgrades (across various townships) (note as per flood studies and flood action plan).	Works / Project Management Office	✓	✓	✓	✓

Strategic Objective – Delivery best practice and complaint waste and recycling service and infrastructure that meets community needs.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
3.8	**Review and begin implementation of the Waste Management Strategy.**							
3.8.1	Review and begin implementation of the Waste Management Strategy, in line with emerging legislation and policy changes to ensure Best Practise and compliance.	Deliver	Kerbside Collection Services – general operations, maintenance, renewals, new services.	Waste & Compliance	✓	✓	✓	✓
3.8.2		Deliver	Landfill and transfer stations – general operations, maintenance, renewals, weighbridge.	Waste & Compliance	✓	✓	✓	✓
3.8.3		Deliver	Landfill investigation and design for new sites.	Waste & Compliance	✓	✓	✓	✓
3.8.4		Deliver, Partner	Return and Earn.	Waste & Compliance	✓	✓	✓	✓
3.8.5		Deliver	Street Litter.	Waste & Compliance	✓	✓	✓	✓

Strategic Objective – Strategic planning which produces consistent, strategic, transparent outcomes.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
3.9	**Begin preparation of Master plans / Township plans for placemaking outcomes.**							
3.9.1	Master Plans and Township Plans to be created on an as needs basis.	Deliver	Priority listing to be developed to investigate and prioritise townships for placemaking, masterplans and streetscaping.	Planning & Environment Directorate				✓
3.9.2	Priority locations for placemaking and townships identified and investigation / design has begun.	Deliver	Placemaking investigation and design – Meninya Street.	Works / Project Management Office	✓	✓	✓	✓
3.9.3		Deliver	Placemaking investigation and design – Meninya Street South Precinct.	Works / Parks & Biosecurity / Economic Development & Tourism / Project Management Office / Buildings & Facilities	✓	✓	✓	✓
3.9.4		Deliver	Placemaking investigation and design – Horseshoe Lagoon Master plan implementation.	Parks & Biosecurity / Economic Development & Tourism / Project Management Office	✓	✓	✓	✓
3.9.5		Deliver	Placemaking investigation and design – Murray Downs.	Development Services	✓	✓		
3.9.6		Deliver	Placemaking investigation and design – Moulamein.	Development Services	✓	✓		
3.9.7		Deliver	Placemaking investigation and design – Mathoura.	Development Services	✓	✓	✓	
3.10	**Continue to review and monitor relevant planning instruments used for Council planning decisions including but not limited to the DCP and LEP.**							
3.10.1	Prepare new Development Control Plan and New Local Environment Plan for MRC, with the DCP being the first priority.	Deliver	Development Control Plan – review and adopt.	Development Services		✓	✓	
3.10.2		Deliver	Local Environment Plan – review and adopt.	Development Services	✓	✓	✓	✓
3.11	**Review unused land and building assets and apply a consistent and financially strategic approach to disposal or repurposing**							
3.11.1	Ongoing review of Council assets not utilised to their fullest extent with the view to repurposing or disposal of the relevant asset/s.	Deliver	All assets should be utilised to the fullest extent possible to ensure operational (and capital) expenses are balanced with a genuine need for the asset. Where that is not able to be achieved, assets should be either repurposed to that end, or disposed of in a transparent and commercial manner.	Legal, Property & Procurement / Assets			✓	

A PLACE OF INCLUSION, CULTURE & WELLBEING

A welcoming, healthy and diverse community that celebrates culture and history and is supported by accessible services.

KEY PARTNERS

Murrumbidgee Local Health Network
NSW Health
Transport for NSW
South West Arts
Local First Nation's Communities
Various Community Groups
Education providers

Strategic Objective – Develop community led strategies with a focus on social connections, social fabric and a sense of belonging.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
4.1	**Support initiatives that enhance social cohesion and a sense of belonging**							
4.1.1	Increased opportunities and engagement in community programs and events.	Deliver	Develop a Libraries Strategy.	Customer Service		✓	✓	
4.1.2		Deliver, Partner	Develop and begin implementation of a Libraries Service Level Agreement document.	Customer Service	✓	✓	✓	✓
4.1.3		Deliver	Libraries - operations and maintenance.	Customer Service / Buildings & Facilities	✓	✓	✓	✓
4.1.4		Deliver, Partner	Libraries – renewals and upgrades.	Customer Service	✓	✓	✓	✓
4.1.5		Deliver, Partner, Advocate	Continue to provide and support to various programs across all library facilities including but not limited to Book Clubs, Move and Grove, Friday Games days, Cuppa and Chat, Art Groups, School holiday programs and special event months, Tech Savvy Seniors.	Customer Service	✓	✓	✓	✓
4.1.6		Deliver, Partner	Develop and implement a Volunteer Strategy to identify ways Council can encourage and support volunteering in our community.	Local Connections / People & Culture	✓	✓	✓	✓
4.1.7		Deliver, Partner,	Volunteer groups are identified and supported. Skill sets are identified.	Local Connections / People & Culture	✓	✓	✓	✓
4.1.8		Deliver, Partner,	Volunteer groups – Risk assessments and training undertaken on an as needs basis.	Local Connections / People & Culture	✓	✓	✓	✓
4.1.9		Deliver	Supporting S355 committees to ensure they are resourced and skilled.	Local Connections	✓	✓	✓	✓
4.1.10		Deliver, Partner, Advocate	Support delivery of community programs and events (e.g. NAIDOC Week, Australia Day, Youth events and programs etc).	Economic Development & Tourism	✓	✓	✓	✓
4.1.11		Deliver	YHub at Moulamein – support delivery of Targeted Early Intervention Services to Youth.	Community Services	✓	✓	✓	✓
4.1.12		Deliver, Partner	Youth Week activities – various.	Community Services	✓	✓	✓	✓
4.1.13		Deliver, Partner	Seniors Week Activities – various.	Community Services	✓	✓	✓	✓
4.1.14		Deliver, Partner, Advocate	Strengthen relationships and partnerships with local Aboriginal organisations.	Economic Development & Tourism	✓	✓	✓	✓

Strategic Objective – Recognise and celebrate our region's rich heritage and indigenous culture (in partnership with community).

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
4.2	**Promotion and scheduling of events that celebrate heritage across the region.**							
4.2.1	Partner with communities to recognise and support initiatives and events that celebrate and promote our regional heritage.	Deliver	Deliver Museums Advisor Service.	Economic Development & Tourism	✓	✓	✓	✓
4.2.2		Deliver	Develop and implement a Heritage Strategy.	Development Services	✓	✓	✓	
4.2.3		Deliver, Partner, Advocate	Deliver Heritage Advisory Service.	Development Services	✓	✓	✓	✓
4.2.4		Deliver, Partner, Advocate	Implement Council's Arts and Culture Strategy, which includes items such as: - Support attract and deliver cultural events and programs (inc Cultural heritage interpretive trails / guided tours) - Continue to develop new cultural tourism product.	Economic Development & Tourism	✓	✓	✓	✓

Strategic Objective – Support existing and new art projects and diverse community events.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
4.3	**Review and begin implementation of Council's Arts and Culture Strategy**							
4.3.1	Review and begin implementation of the Arts and Culture Strategy and action plan, focusing on new and existing arts projects and events being undertaken.	Deliver, Partner, Advocate	Implement Council's Arts and Culture Strategy, which includes items such as: - Support, attract and deliver arts projects and events - Continue to develop new arts related tourism products.	Economic Development & Tourism	✓	✓	✓	✓
4.3.2		Partner, Advocate	Support arts organisations in their activities.	Economic Development & Tourism	✓	✓	✓	✓
4.3.3		Advocate, Partner	Advocate and support various arts and culture projects across the region.	Economic Development & Tourism	✓	✓	✓	✓

Strategic Objective – Facilitate and advocate for accessible health and wellbeing services based on local community needs.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
4.4	**Facilitate access to health and well-being services through the delivery of Commonwealth Social Support Program, Community Transport Program and Home Modification Programs across Council.**							
4.4.1	Relevant health and wellbeing services are available, with ongoing utilisation by the community.	Deliver	Continue to deliver the Commonwealth Home Support Program Services, Including • CHSP Transport • Meals on wheels • Social Support Individual • Social Support Group • Respite • Home Modifications.	Community Services	✓	✓	✓ (pending funding)	✓ (pending funding)
4.4.2		Deliver	Continue to deliver the Transport for New South Wales Transport Program – Including CHSP and CTP.	Community Services	✓	✓	✓ (pending funding)	✓ (pending funding)
4.4.3		Advocate	Promote the services available to the community including but not limited to Medicare, Legal aid, Centrelink, Doctors, Service NSW, Services Australia.	Community Economic Development Directorate / Community Services	✓	✓	✓	✓
4.5	**Identify gaps in health and wellbeing services and advocate for new, or increased services where required.**							
4.5.1	Continued advocacy for existing and attraction of new or missing health and wellbeing services as identified	Advocate	Identify gaps in services and advocate for new, or increased services where required.	Community Economic Development Directorate	✓	✓	✓	✓
4.5.2		Advocate	Investigate / Advocate for a high level health facility within the LGA	Chief Executive Office / Community Economic Development Directorate	✓	✓	✓	✓
4.5.3		Advocate Partner	Support Health Promotion strategies of relevant providers, across the region	Economic Development & Tourism	✓	✓	✓	✓

A PLACE OF PROSPERITY AND RESILIENCE

Champion business, innovation, and technology to stimulate local economic development.

KEY PARTNERS

CSIRO and other research organisations
Universities and Tafes
Murray Regional Tourism Board
Riverina Murray Destination Network
Echuca Moama Tourism
Tourism Industry Partners
S355 Committees
Community Groups
Office of Local Government NSW
Riverina and Murray Joint Organisation (RAMJO)

Strategic Objective – Encourage and support economic development across the region.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
5.1	**Promote the region as an attractive destination for Economic Development and investment.**							
5.1.1	Review and begin implementation of the Economic Development and Tourism Strategy and action plan to support economic growth across the LGA.	Deliver, Partner, Advocate	Implement Council's Economic Development and Tourism Strategy, which includes the following four strategic pillars: - Support existing businesses and communities. - Promotion and investment attraction. - Growing Tourism. - Advocacy and partnership.	Economic Development & Tourism	✓	✓	✓	✓
5.2	**Develop and promote growth opportunities in designated locations across the LGA.**							
5.2.1	Review and begin implementation of the Employment Lands Strategy to support economic growth across the LGA.	Deliver, Partner, Advocate	Develop and begin implementation of the Employment Lands Strategy.	Economic Development & Tourism / Development Services	✓	✓	✓	✓
5.2.2	Advocate to various levels of Government to promote growth opportunities across the region.	Deliver, Advocate	Develop and implement a yearly Advocacy Plan.	Chief Executive Office	✓	✓	✓	✓
5.3	**Develop a framework to support and leverage Access Rights Funding and Community Benefit Funding from renewable energy projects and programs that will deliver tangible community outcomes.**							
5.3.1	Undertake requirements as per the Commissioning Commitment to the South West Region Renewables Zone and associated projects.	Deliver, Partner, Advocate	Develop and begin implementation of the requirements of the Commissioning Commitment to the South West Region Renewable Zone and associated projects.	Chief Executive Office	✓	✓	✓	✓
5.3.2	Long term, high value community outcomes achieved through access to funding.	Deliver, Partner, Advocate	Town Action plans developed, and projects prioritised for each community.	Community Economic Development Directorate	✓	✓	✓	✓
5.3.3		Deliver, Partner, Advocate	Progress made towards clear pathways for communities to access ARF and CBF	Chief Executive Office	✓	✓	✓	✓
5.4	**Collaborate with small business to identify gaps in support services and provide tailored assistance, while advocating for support as required.**							
5.4.1	Support services available to business and utilisation of these.	Deliver	Undertake a business needs survey	Economic Development & Tourism		✓		
5.4.2		Deliver, partner, Advocate	Work closely with business groups to identify needs and solutions.	Economic Development & Tourism	✓	✓	✓	✓

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Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
5.4.3		Deliver, Partner, Advocate	Continue to support community groups delivering community capacity building activities - provision of subject matter experts to region	Local Connections	✓	✓	✓	✓

Strategic Objective – Continue to develop strong and resilient communities.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
5.5	**We will support employers in meeting their workforce needs, implement initiatives to attract new residents and workers, and actively promote the region to attract new businesses and industries.**							
5.5.1	Review and begin implementation of the *Live Work Invest in River Country* project, the Workforce Attraction Plan and other relevant initiatives to support current and potential local workforce needs.	Deliver	Review and begin implementation of the *Live Work Invest in River Country* project.	Economic Development & Tourism	✓	✓	✓	✓
5.5.2		Deliver	Review and begin implementation of the Workforce Attraction Plan.	Economic Development & Tourism / People &Culture	✓	✓	✓	✓
5.6	**Encourage upskilling and reskilling by seeking funding to establish a Country University Centre (CUC) in the region.**							
5.6.1	CUC established and/or initiatives in place to support upskilling and reskilling within the LGA.	Partner, Advocate	Partnerships created with local stakeholders such as TAFE, neighbouring Councils, Universities etc to consider initiatives to support upskilling and reskilling of our local workforce.	Economic Development & Tourism	✓	✓	✓	✓
5.6.2		Partner, Advocate	Progress made towards establishing a CUC in our region.	Economic Development & Tourism	✓	✓	✓	✓
5.7	**Communities feel more resilient and prepared for future challenges**							
5.7.1	Review and begin implementation of the Adverse Events Plan	Deliver	Review and begin implementation of the Adverse Events Plan.	Economic Development & Tourism	✓	✓	✓	✓
5.7.2	Develop Community Action Plans for each community, detailing the projects and actions that have been agreed upon and prioritised by each community, in partnership with Council (Asset Management Plan and Project Management Framework linkages must be addressed).	Deliver	Develop a methodology and criteria for prioritisation of community driven projects (in accordance with PMF and AMP).	Economic Development & Tourism / Local Connections / Development Services	✓	✓	✓	✓
5.7.3		Deliver	Community consultation to develop and prioritise Community Driven project lists.	Economic Development & Tourism / Local Connections / Community Engagement	✓	✓	✓	✓
5.7.4		Deliver Partner, Advocate	Community Driven Projects implemented or supported as per the PMF and AMP requirements.	Project Management Office / Asset owners	✓	✓	✓	✓

Strategic Objective – Promote and grow tourism across the region.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
5.8	**Promote the region as an attractive destination for tourism.**							
5.8.1	Review and begin implementation of the Economic Development and Tourism Strategy	Deliver, Partner, Advocate	Implement tourism actions from within the Economic Development and Tourism Strategy.	Economic Development & Tourism	✓	✓	✓	✓
5.8.2		Deliver, Partner, Advocate	Implement the annual Visit River Country Marketing Plan and Visit Echuca Moama Destination Marketing Plan.	Economic Development & Tourism	✓	✓	✓	✓
5.8.3		Deliver	Visitation related data monitored and reviewed.	Economic Development & Tourism	✓	✓	✓	✓
5.8.4		Deliver, Partner, Advocate	Developing, attracting, supporting and promoting local attractions and events across the region.	Economic Development & Tourism	✓	✓	✓	✓
5.8.5		Deliver, Partner, Advocate	Supporting industry to grow and develop.	Economic Development & Tourism	✓	✓	✓	✓

Strategic Objective – Partner with industry, community and government organisations to promote and nurture innovation.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
5.9	**Forge collaborative partnerships with industry, community, and government organisations to foster a culture of innovation, sharing resources, knowledge, and best practices to drive creative solutions and support sustainable development.**							
5.9.1	Innovative solutions and projects supported and developed, where opportunities arise.	Deliver, Partner, Advocate	Begin implementation of Council's Economic Development and Tourism Strategy.	Economic Development & Tourism	✓	✓	✓	✓
5.9.2		Partner, Advocate	Support Western Murray Land Improvement Group to deliver projects (e.g. biochar, agri-innovation precinct projects, advocacy for Hemp industry).	Economic Development & Tourism / Community Economic Development Directorate	✓	✓	✓	✓
5.9.3	Encourage collaboration in procurement activities by leveraging economies of scale wherever a value for money outcome can be achieved	Partner	Increased use of supplier panel contracts of other agencies or increase in the number of collaborative (joint) market approaches with other agencies	Legal, Property & Procurement				✓

CONNECTED COMMUNITIES

Enable integrated, safe and reliable transport and advocate for communications infrastructure.

KEY PARTNERS

Transport for NSW

Public Transport Victoria

Local transport companies (bus, taxi, truck etc)

NSW Health

NBN Co

Communication service providers

Strategic Objective – Advocate for and facilitate reliable communications infrastructure.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
6.1	**Collaborate on advancing digital infrastructure improvements**							
6.1.1	Improved connectivity and quality of infrastructure.	Advocate	Advocate and support relevant agencies (e.g. NBN Co and Telstra) to identify new and bring forward planned critical infrastructure projects for our region.	Community Economic Development Directorate	✓	✓	✓	✓

Strategic Objective – Develop strategies to deliver road and shared pathway infrastructure that is accessible to all.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
6.2	**Roads Strategy and associated documents to be developed and implementation has begun.**							
6.2.1	Develop and begin implementation of the Roads Strategy and associated documentation.	Deliver	Roads Strategy developed.	Works	✓	✓		
6.2.2		Deliver	Roads Action Plan implementation has begun.	Works		✓	✓	✓
6.2.3		Deliver	Review and update the Roads Policy and associated procedure.	Works	✓	✓	✓	✓
6.2.4		Deliver	Review and update the contracts and terms of reference with RMCC, TfNSW (bridge lifts, state road maintenance and ordered works) etc and determine feasibility.	Works / Infrastructure Directorate	✓			✓
6.3	**Road Asset Management to be developed to deliver a financially sustainable road network across the LGA.**							
6.3.1	Review and begin implementation of the Road Asset Management Plans taking into consideration current and emerging requirements.	Deliver	Road Asset Management Plan developed (sealed roads).	Works / Assets	✓	✓		
6.3.2		Deliver	Sealed Roads - operations and maintenance (notes – includes inspections, maintenance, general operations, condition assessments).	Works	✓	✓	✓	✓
6.3.3		Deliver	Sealed Roads – renewals and upgrades.	Works	✓	✓	✓	✓
6.3.4		Deliver	Road Asset Management Plan developed (unsealed roads).	Works / Assets	✓	✓		
6.3.5		Deliver	Unsealed Roads - operations and maintenance.	Works	✓	✓	✓	✓
6.3.6		Deliver	Unsealed Roads – renewals and upgrades.	Works	✓	✓	✓	✓
6.3.7		Deliver	Action Plans to be developed and implementation has begun.	Works		✓	✓	
6.3.8		Deliver	Service Levels identified and communicated to public.	Works			✓	✓
6.3.9		Deliver	Traffic Studies completed on an as needs basis across the road network.	Works	✓	✓	✓	✓
6.2.10		Deliver	Traffic Movement Action Plan developed, and implementation has begun.	Works	✓	✓	✓	✓
6.2.11		Deliver	Bridges and Causeways - operations and maintenance.	Works	✓	✓	✓	✓
6.2.12		Deliver	Bridges and Causeways – renewals and upgrades.	Works	✓	✓	✓	✓

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
6.2.13	Road Safety Management.	Deliver	Road Safety Infrastructure (Guard Rails, traffic islands, round-abouts, traffic and pedestrian signals, school zones, line marking etc) – operations and maintenance.	Works	✓	✓	✓	✓
6.2.14		Deliver	Road Safety Infrastructure (Guard Rails, traffic islands, round-abouts, traffic and pedestrian signals, school zones etc – renewals, upgrades and new.	Works	✓	✓	✓	✓
6.2.15		Deliver	Road Safety Engagement, Education and planning including development of the Road Safety Action Plan.	Works	✓	✓	✓	✓
6.2.16		Deliver Partner Advocate	Street Lighting - operations and maintenance.	Works	✓	✓	✓	✓
6.2.17		Deliver, Partner	Road Safety Audits (RSA) completed, and implementation of corrective actions is undertaken as needed.	Works	✓	✓	✓	✓
6.2.18	Gravel pits and Stockpile Site Management.	Deliver	Ongoing monitoring and management of the materials required to construct and maintain the road network.	Works	✓	✓	✓	✓
6.2.19		Deliver	General management of pits and stockpiles.	Works	✓	✓	✓	✓
6.2.20		Deliver	Rehabilitation of gravel pits – undertaken as needed.	Works	✓	✓	✓	✓
6.2.21		Deliver	Comply with NSW Mining regulations – relating to gravel pit management and operations.	Works	✓	✓	✓	✓
6.2.22	Feasibility of plant purchase vs hire to be carried out, looking at whole of life cost estimates, availability, suitability and other relevant factors.	Deliver	Analysis of current and proposed plant to ascertain need as well as viability of purchase as opposed to hire.	Legal, Property & Procurement		✓		
6.2.23		Deliver	Establishment of a plant hire panel of suppliers contract for up to five years via public tender.	Legal, Property & Procurement	✓			
6.3	**Pathways Plan to be developed considering sensitive design of pathways to consider environmental factors, accessibility and amenity**							
6.3.1	Develop and begin implementation of Pathways Plan that creates assets that are accessible for all.	Deliver	Develop the Pathways Plan (for all users across various townships), including a missing links plan (to connect existing pathways, crossings (walkways), School crossings.	Works	✓	✓		
6.3.2		Deliver	Develop and begin implementation of the Action Plan.	Works		✓	✓	
6.3.3	Pathways include footpaths, cycleways, shared paths, footbridges.	Deliver	Shared Pathways - operations and maintenance (across various townships).	Works	✓	✓	✓	✓
6.3.4		Deliver	Shared Pathways – renewals and upgrades (across various townships).	Works	✓	✓	✓	✓
6.3.5		Deliver Partner Advocate	New sections of shared pathways to include both expansion and missing links pathways.	Works			✓	✓
6.3.6		Deliver	New Crossings (walkways) / School crossings as identified and built as required.	Works		✓	✓	✓
6.3.7		Deliver	Asset Management Plans developed relating to the monitoring and maintenance of existing board walks and footbridges.	Works / Parks & Biosecurity / Assets			✓	✓
6.3.8		Deliver	Asset Management Plans developed relating to the monitoring and maintenance of new board walks and footbridges.	Works / Parks & Biosecurity / Assets			✓	✓

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
6.4	**Consistent, accurate and compliant signage will continue to be updated and reviewed across the region.**							
6.4.1	Develop and begin implementation of an Infrastructure Signage Plan with a focus on updating road and pathway signage across the region.	Deliver	Develop the Infrastructure Signage Plan for all road and pathway signage.	Works	✓	✓		
6.4.2		Deliver	Develop and begin implementation of the Action Plan.	Works		✓	✓	✓
6.4.3		Deliver	Road and Pathway signage - operations and maintenance.	Works	✓	✓	✓	✓
6.4.4		Deliver	Road and Pathway signage – new, renewals and upgrades.	Works	✓	✓	✓	✓
6.5	**Work with community to plan and consider long vehicle parking options.**							
6.5.1	Develop and begin implementation of a Vehicle Parking Plan ensuring feasible parking opportunities in all communities which is close to shops and town centres considering long-vehicles, trucks, cars, all access / DDA car parks and EV's.	Deliver	Develop the Vehicle Parking Plan for all users, across all townships.	Works		✓	✓	✓
6.5.2		Deliver	Develop and begin implementation of the Action Plan.	Works			✓	✓
6.5.3		Deliver	Vehicle Parking - operations and maintenance (across various townships).	Works	✓	✓	✓	✓
6.5.4		Deliver	Vehicle Parking – renewals and upgrades (across various townships).	Works	✓	✓	✓	✓
6.6	**Drainage Program reviewed to encourage sensitive design of roads which consider environmental factors, accessibility and amenity.**							
6.6.1	Develop and begin implementation of a Drainage Program of Works.	Deliver, Partner, Advocate	Studies undertaken in relating to overland flood / stormwater management.	Works / Project Management Office	✓	✓	✓	
6.6.2		Deliver, Partner, Advocate	A standard is to be developed looking at - Environmental factors, accessibility and amenity, when designing new local roads and drainage options by suitability qualified professionals– direct link and incorporated into DCP.	Works / Development Services / Parks & Biosecurity / Water & Waste water	✓	✓	✓	
6.6.3		Deliver	Culverts - operations and maintenance.	Works	✓	✓	✓	✓
6.6.4		Deliver	Culverts – new, renewals and upgrades.	Works	✓	✓	✓	✓
6.6.5		Deliver	Kerb and Gutter - operations and maintenance.	Works	✓	✓	✓	✓
6.6.6		Deliver	Kerb and Gutter – new, renewals and upgrades.	Works	✓	✓	✓	✓
6.7	**An Electric Vehicle (EV) Strategy will be developed to help plan the delivery of the public infrastructure requirements, in line with community needs (both now and into the future).**							
6.7.1	Develop and begin implementation of an Electric Vehicle (EV) Strategy to ensure sufficient infrastructure is available to service the needs of residents and visitors well into the future.	Deliver	Develop the EV Strategy and begin implementation of the Action Plan.	Economic Development & Tourism	✓	✓	✓	✓
6.7.2		Partner, Advocate	Support private operators to apply for funding to install EV infrastructure.	Economic Development & Tourism	✓	✓	✓	✓

Strategic Objective – Advocate for improved public transport.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
6.8	**Public Transport services that meet the community's needs.**							
6.8.1	Advocate for improved public transport (PT) services, as gaps are identified.	Advocate	Advocacy to local and state service providers for improved service delivery, as required.	Community Economic Development Directorate / Community Services	✓	✓	✓	✓
6.9	**Public Transport infrastructure meets the needs of the community.**							
6.9.1	Continue to improve public transport (PT) related infrastructure, as feasible.	Deliver	Program of new bus shelters installed across the region.	Works	✓	✓	✓	✓
6.9.2		Deliver	Bus Shelters - operations and maintenance (across various townships).	Works	✓	✓	✓	✓
6.9.3		Deliver	Bus Shelters – renewals and upgrades (across various townships).	Works	✓	✓	✓	✓
6.10	**Continue to deliver Community Transport options to a variety of community members.**							
6.10.1	Delivery of Council's community transport program.	Deliver, Partner	Community transport services continue to meet the needs of the community.	Community Services	✓	✓	✓	✓

Strategic Objective – Enable commercial transport and connection opportunities.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
6.11	**Continue to review and implement new and upgraded truck and heavy vehicle parking areas across the region.**							
6.11.1	New and upgraded truck and heavy vehicles parking areas developed, as feasible.	Deliver, Partner, Advocate	Develop a Strategy to review and update truck and heavy vehicle parking areas required across the region.	Works	✓			
6.11.2		Deliver, Partner, Advocate	Develop and begin implementation of the Action Plan.	Works		✓	✓	✓
6.11.3		Deliver, Partner	Future funding opportunities are being sought.	Works		✓	✓	✓
6.12	**Improve governance around heavy freight movement across the LGA.**							
6.12.1	Management of heavy freight vehicles across the region	Deliver	Develop and begin implementation of a plan to manage heavy freight movement across the region, including via the bridge network.	Infrastructure Directorate		✓		
6.12.2		Deliver	Heavy vehicles condition and weight capacity management undertaken on the road network.	Works	✓	✓	✓	✓
6.12.3		Deliver	Bridge inspection and capacity assessments undertaken.	Works	✓	✓	✓	✓

TOMORROW'S TECHNOLOGIES

Ensure the region is well placed to embrace emerging and disruptive technologies such as Artificial Intelligence and Deep Learning.

KEY PARTNERS

NSW Environment Protection Authority

NSW Department of Primary Industries

Riverina and Murray Joint Organisation (RAMJO)

NSW Department of Planning and Environment

Western Murray Land Improvement Group

CSIRO and other research organisations

Universities and Tafe

Strategic Objective - Embed a geospatial driven system into Council processes, including public interface.

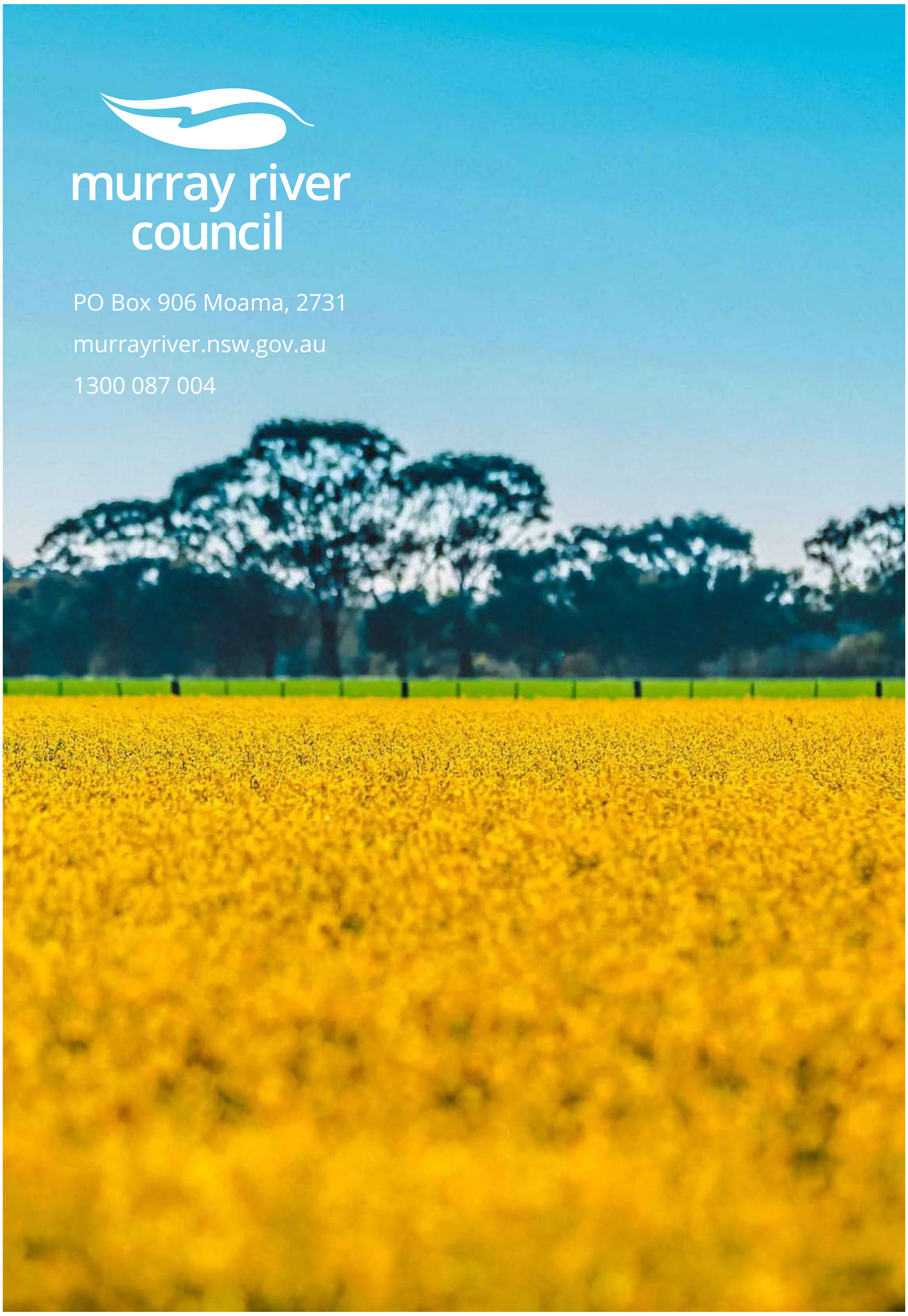
Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
7.1	**Continue development of the Council's Geospatial Information System (GIS) system.**							
7.1.1	Continue development of the Councils Geospatial Information System (GIS) system.	Deliver	GIS with Accurate asset and other data available for internal users.	Assets / Information Technology & Software	✓	✓	✓	✓
7.1.2		Deliver	Public interface is available for external users.	Assets / Community Engagement			✓	✓
7.2	**Where practicable and financially viable, integrate field based and automated data capture processes.**							
7.2.1	Increase in extent of data captured at source and through automated processes.	Deliver	Compliance, Weed Management & Meter Installation data captured using mobile devices.	Parks & Biosecurity / Waste & Compliance / Water / Information Technology & Software	✓	✓	✓	✓
7.2.2		Deliver	Internal Systems integrated with the Planning Portal to enable automated data transfers.	Information Technology & Software / Corporate Services Directorate		✓		
7.2.3		Deliver	Suppliers able to update data through an online Supplier Portal.	Information Technology & Software / Corporate Services Directorate		✓		
7.2.4		Deliver	Ratepayers can access information about their property through an online Customer Portal.	Information Technology & Software / Corporate Services Directorate			✓	
7.3	**Continue to use new technologies (including AI) to manage council operations.**							
7.3.1	Number of instances where new technologies are trialled and/or embedded to enhance the effectiveness and/or the efficiencies of Council operations.	Deliver	Building Certification System – moving fully online for dwelling inspections for our surveyors - new software used in development services to create efficiencies.	Development Services / Information Technology & Software	✓			
7.3.2		Deliver	Implement an automation/AI pilot project that is evaluated annually for operational efficiency.	Corporate Services Directorate / Information Technology & Software		✓	✓	
7.3.3		Deliver	Explore the possibility of the use of new types of technologies to access point of call for information.	Information Technology & Software / Corporate Services Directorate			✓	✓
7.3.4		Deliver	Explore the possibility to incorporate smart cities technologies.	Works / Parks & Biosecurity / Project Management Office			✓	✓

Strategic Objective – Explore technologies to forecast possible future opportunities.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
7.4	**Access various data sources and utilise the information for analysis and decision making. Share this data with stakeholders where possible. Monitor various data sources to identify emerging technologies and assess viable use cases for Council as well as the wider region.**							
7.4.1	Increase in monitoring and communication of emerging technologies to our communities and businesses.	Deliver, Partner, Advocate	Information on emerging technologies is included in community and economic development communications (e.g. newsletters) at least twice per year.	Community Economic Development Directorate	✓	✓	✓	✓
7.4.2		Deliver,	Subscriptions to relevant consumer-data gathering platforms established, with data used to inform decision-making, planning, execution, and evaluation of projects.	Community Economic Development Directorate	✓	✓	✓	✓

Strategic Objective – To encourage, educate, support and enable environmentally sustainable approaches to energy management.

Code	Project or Program of works	Deliver, Partner, Advocate	Performance Measure	Responsible Business Unit	Year 1 (2025-26)	Year 2 (2026-27)	Year 3 (2027-28)	Year 4 (2028-29)
7.5	**Council will provide support to locally generated energy projects, as they emerge**							
7.5.1	Support provided to renewable energy generation projects located within the region, as projects emerge.	Partner Advocate	Support provided to new locally generated renewable energy projects as needed.	Community Economic Development Directorate / Infrastructure Directorate / Planning & Environment Directorate	✓	✓	✓	✓
7.6	**Framework developed and in place to incorporate current and potential Biodiversity & Carbon Offset requirements.**							
7.6.1	Develop and begin implementation of a framework to manage the impending requirements of biodiversity and carbon offset requirements.	Deliver	Develop and begin implementation of the framework incorporating requirements actioned in physical planning decisions – DCP linkage.	Planning & Environment Directorate			✓	✓
7.6.2		Deliver	Methane flare pilot project outcomes investigated and where financially viable implemented.	Waste & Compliance / Planning and Environment Directorate	✓	✓		
7.6.3		Deliver	Areas identified for native vegetation biodiversity offset banking.	Planning & Environment Directorate			✓	
7.7	**Investigate and where feasible (including availability of funding) implement renewable energy generation at Council sites.**							
7.7.1	Install solar generation at identified Council sites.	Deliver	Subject to feasibility and funding availability, solar generation is installed at least 5 Council operational sites.	Corporate Services Directorate / Buildings & Facilities		✓		
7.7.2	Investigate and determine future for Energy efficiency options at Council.	Deliver	Develop an energy efficiency strategy and action plan.	Corporate Services Directorate / Buildings & Facilities			✓	✓
7.8	**Explore opportunities to include renewable energy components in Council's Power Purchase Agreements**							
7.8.1	A renewable energy component is included in Council's large site PPA	Deliver	Subject to pricing considerations incorporates at least 50% renewable energy component within the large site Power Supply Agreement (PSA).	Corporate Services Directorate / Buildings & Facilities	✓			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