Goulburn Broken CMA Strategic Levee Categorisation Project

Final Report



April 2026

Project	GBCMA Strategic Levee Categorisation Project
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Document History and Status

Rev. No.	Author	Reviewer	Distribution	Date Issued
0	T Clark	C Dwyer	Goulburn Broken CMA	5-11-2025
1	T Clark	C Dwyer	Goulburn Broken CMA	16-12-2025
2	T Clark	C Dwyer	Goulburn Broken CMA	30-4-2026

Cover photograph: Cobram Town Levee

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1 Introduction

Following the Spring 2022 floods and a subsequent government inquiry into flood response matters, the Victorian Government through the Department of Energy, Environment and Climate Action (DEECA) provided funding to the Catchment Management Authorities (CMA's) in northern Victoria for a Strategic Levee Categorisation Project.

The project aims to provide improved flood intelligence for managing strategic levees located in Victoria north of the Great Dividing Range. The four CMA's involved in the project are the Goulburn Broken CMA, North East CMA, North Central CMA and the Mallee CMA.

This report documents the project undertaken for the Goulburn Broken CMA.

The project objectives are to:

- Identify and categorise levees based on the category definitions adopted for the project.
- Further develop and document flood intelligence in relation to the identified strategic levees.
- Prepare content for inclusion in the respective municipal Flood Emergency Plans (FEPs) which provides respondents with an understanding of what is required in managing the strategic levees within each local government area (LGA) during a flood event.

2 Background

Significant widespread flooding occurred during the spring of 2022, notably across northern Victoria. The response efforts to the 2022 floods involved the management of levees during the course of the floods in an effort to minimise the impact of the floods on property damage, injury risk and loss of life risk.

In the aftermath of the floods, the Victorian Government initiated an inquiry to review the effectiveness of flood response efforts including the management of levees.

The Strategic Levee Categorisation Project has subsequently been initiated to improve flood intelligence regarding levees in northern Victoria which will benefit future flood response efforts.

The overarching objective of the project is to update the respective Municipal Flood Emergency Plans (MFEPs) regarding the management of strategic levees, to improve flood readiness, intelligence and response actions.

The content added to the MFEPs will detail:

- Those strategic levees which are formally managed and the level of protection they provide (e.g. coinciding with a particular AEP and/or the corresponding gauge height).
- Those unmanaged strategic levees which may require emergency works to be delivered to provide flood mitigation benefits which meet the investment criteria nominated within the 2016 Victorian Floodplain Management Strategy
- Other strategic levees not formally managed where there is no practical means or sufficient benefit to warrant emergency works.
- Any temporary strategic levees to provide flood mitigation benefits which can be practically put in place ahead of major flooding and are then removed post flood.

A separate project has been underway concurrent with the Strategic Levee Categorisation Project. This separate project is also updating the Municipal Flood Emergency Plans (MFEPs) and the Local Flood Guides (LFGs) within the Goulburn Broken CMA region only. The project has been initiated by the VICSES and Goulburn Broken CMA. Consultants Water Technology have been engaged to undertake the project which is focussing on an update of the terminology used within the MFEP and Local Flood Guide (LFG) documents in a consistent manner.

VICSES published a report in September 2024 documenting a review of the flood emergency works policy (VICSES, 2024). The review focuses on policies and activities specifically relating to construction, removal or alteration of levees during VICSES exercises. The review report states that:

- Municipal FEPs contain varied or nil content on levee management arrangements and related agency responsibilities.
- VICSES would benefit from issuing a guidance document relating to the use of powers for emergency works.
- The next step would be for the VICSES to revise its current processes and procedures to clarify and align with the above flood emergency guidance document.

The expectation is that:

- Emergency response efforts primarily via local government resources will focus on delivering flood emergency works to Category 2 levees during flood events which meet the investment criteria nominated by the 2016 VFMS, and where time and resources allow.
- The owners of the Category 1 levees will be responsible for overseeing any necessary flood emergency works to the levees which they own, during flood response periods.

3 Levee Category Definitions

The focus of the Goulburn Broken CMA's Levee Categorisation Project has been on strategic levees. Strategic levees for the purpose of the project have been defined as those levees that protect urban areas, large rural floodplain areas, or critical infrastructure.

The levee category definitions adopted for the purpose of this project are given in Table 1. There are three different levee category definitions, Categories 1, 2 and 3. There are three sub-category definitions for Category 2 (Types A, B and C).

'Private Levees' by their definition do not provide protection to large areas and as such have not been the focus of the Goulburn Broken CMA's project.

Although 'Significant Floodplain Features' can protect urban or large rural areas, they are not strategic levees and generally don't require specific management actions during the response to flood events. As such they have not been the focus of the Goulburn Broken CMA's project.

Table 1 Levee Categories - Project Definitions

Type	Definition
Category 1	Those levees that are formerly managed whereby the operation and maintenance of the levees are in place that protect urban centres or defined areas.
Category 2	Those levees that are not managed but provide protection to either: • Urban type centres • Rural areas where it meets the investment criteria outlined in the Victorian Flood Management Strategy (DELWP, 2016) and where it meets the VICSES threshold to act under the VICSES Act 2005 Section 32AC.
Category 2 – Type A	Levees which do not require significant work ahead of a major flood and may require periodic monitoring
Category 2 – Type B	Levees which do require significant work ahead of a major flood, or levees which have known issues (weaknesses) from past floods. Active monitoring is required during a flood event.
Category 2 – Type C	Location identified for a temporary levee ahead of a major flood. The temporary levee is removed post flood.
Category 3	Levees that provide unverified levels of flood protection to multiple property rural areas.
Private Levees	Levees which have been built by individuals solely for the protection of their own property and assets.
Significant Floodplain Features	Man made features on the floodplain, which are not levees, but will have a significant impact on flow patterns during major floods that would result in significant changes in flood behaviour (e.g. elevated roads, elevated railways, irrigation channel banks).

4 Project Approach

4.1 Overview

The Strategic Levee Categorisation project for the Goulburn Broken CMA commenced in August 2024. The project has been undertaken primarily in two stages:

- Stage 1 (August to October 2024)
  - Desktop review of available data supplied by the Goulburn Broken CMA and others.
  - Cursory site inspections of the identified urban levees.
  - Preliminary consultation with those organisations with links to levee management (Goulburn Broken CMA, Strathbogie Shire Council, Moira Shire Council, Greater Shepparton City Council, Campaspe Shire Council, VICSES, Goulburn Murray Water).
  - Assessment and assignment of preliminary categories to the levees.
  - Submission of a Stage 1 report to the Goulburn Broken CMA in November 2024.
- Stage 2 (May to December 2025)
  - Additional desktop and field assessments of levees.
  - Capture and assignment of attribute data to the GIS Spatial Data Specification (SDS) levee layer by way of assistance provided by the Goulburn Broken CMA.
  - Workshop meeting with Campaspe Shire Council in early May 2025 which covered both the North Central CMA and the Goulburn Broken CMA region projects.
  - Three separate workshop meetings with the Greater Shepparton City Council, Strathbogie Shire Council and Moira Shire Council in early August 2025.
  - Application of the Rapid Appraisal Method (RAM) for selected rural levees with the aim of identifying the economic benefits of the subject levees via means of a high-level assessment.
  - Updating of assigned levee categories considering the above task outcomes.
  - Public exhibition of the assessed strategic levees in late September / early October 2025.
  - Preparation of a draft project final report documenting the project activities, outcomes and recommendations (i.e. this report).
  - Drafting of additional levee intelligence content for inclusion in the municipal Flood Emergency Plans (FEPs).

4.2 Stage 1

Following discussions with the Goulburn Broken CMA in early August 2024, a scope of activities for Stage 1 (Work Package Plan 1) was agreed.

It was agreed that the focus for Stage 1 would be on levees protecting urban areas. This was largely influenced by the current Victorian Government policy which does not provide investment in rural levee systems unless they meet the investment criteria nominated by the Victorian Floodplain Management Strategy (DELWP, 2016).

The following data was supplied by the Goulburn Broken CMA for use during this project:

- Previous reports relevant to the project (e.g. flood studies, floodplain risk management studies, flood mapping studies, mitigation scheme design reports etc).
- Digital elevation model datasets at various locations.
- Flood depth, velocity, depth velocity product, height raster files derived from two-dimensional hydraulic modelling.
- Flood aerial imagery.

- GIS levee datasets (Spatial Data Specification (SDS) which was previously the Victorian Flood Database (VFD).

Purpose built urban levees are present at:

- Greater Shepparton City Council – Shepparton / Kialla and Murchison
- Strathbogie Shire Council – Euroa and Avenel
- Moira Shire Council – Cobram, Nathalia, Numurkah, Barmah and Wunghnu
- Campaspe Shire Council – Echuca Village (Goulburn Broken CMA region levees only)

The above urban levees were subject to cursory site inspections over two days in September2024.

All four of the above councils were contacted in September 2024. In-person meetings were subsequently held with staff from the Strathbogie Shire Council and Moira Shire Council in late September 2024. Communication with the other two councils was by way of emails / phone contact.

Consultation with the VICSES encompassed an in-person meeting with the VICSES's Hume Region Operations Officer in September2024 followed by email contact and follow up phone contacts with the following six local SES units in early October2024:

- Shepparton Search and Rescue – covers Shepparton, Kialla, Merrigum and Tallygaroopna
- Murchison SES – covers Murchison
- Euroa SES – covers Euroa, Violet Town and Avenel
- Cobram SES – covers Cobram
- Numurkah SES – covers Barmah, Nathalia, Numurkah and Wunghnu
- Echuca SES – covers Echuca Village

Goulburn Murray Water were contacted by email following phone discussions, with subsequent exchange of information by email during September / October 2024.

Notable rural levees systems are located at:

- Murray River between Cobram and Barmah. Downstream of Cobram, the Murray River levee is generally referred to as the PWD (Public Works Department) levee.
- Lower Goulburn River floodplain including the Deep Creek floodplain between the Loch Garry Regulator and the Murray River.
- Drainage / floodway corridors between the Goulburn River and Echuca, located at Beatties Depression and Warrigal Creek.
- Within the Corop Lakes area located to the west and southwest of Stanhope.

Stage 1 assessment details are provided in the following appendices to this report:

- Appendix A: Greater Shepparton City Council
- Appendix B: Strathbogie Shire Council
- Appendix C: Moira Shire Council
- Appendix D: Campaspe Shire Council

4.3 Stage 2

Consultation sessions with the following council's planning, engineering and emergency management staff were undertaken in the early part of Stage 2:

- 1 May 2025 – Campaspe Shire Council. This session was initiated by the consultant's undertaking the North Central CMA project. The Campaspe Shire Council local government area is partly located in the North Central region and partly in the Goulburn Broken region.
- 5 August 2025 – Greater Shepparton City Council.
- 6 August 2025 - Strathbogie Shire Council.
- 6 August 2025 - Moira Shire Council.

Public exhibition of the preliminary assigned levee categories took place during a 23 day period which finished on the 17th of October 2025. Public exhibition encompassed:

- Publication on the Goulburn Broken CMA's web site of a media release on the 24 September 2025 calling for feedback from the community on those levees assessed and categorised as part of the project.
- The above media release article was linked to a Strategic Levee Categorisation Project web page on the CMA's web site. The project web page provided further information about the project background, aims, mapping and categorisation definitions.
- A project mapping portal linked to the above project web page. The mapping portal provided access to view the assessed levees, including the assigned categories and levee attribute data.

Goulburn Broken CMA advised that the above media release article was assessed 44 times, the levee categorisation project page was accessed 27 times, and the mapping portal site was accessed 93 times.

Some follow up on-site and desktop investigations were undertaken in the aftermath of the above council sessions to further assess specific matters that were raised at the consultation sessions.

One of the project aims was to prepare additional levee management specific content for addition to the respective Flood Emergency Plans (FEPs). This was done towards the end of Stage 2 as follows:

- A separate project being undertaken concurrently for the Goulburn Broken CMA and the VICSES is updating the municipal FEPs and the LFGs. Consultants Water Technology are undertaking this separate project.
- Water Technology drafted the levee content for addition to the FEPs using a preliminary version of this levee categorisation report.
- Confluence Group edited the additional draft content prepared by Water Technology.

Locality type maps of the assessment levees were also prepared towards the end of the project. These maps are located in Appendix H of this report. The maps or an adapted version of the maps may be used for inclusion in the future updated FEPs.

5 Urban Levees

5.1 Overview

The assessment details for urban levees are included in the following appendices:

Appendix A Greater Shepparton City Council

Appendix B Strathbogie Shire Council

Appendix C Moira Shire Council

Appendix D Campaspe Shire Council

The following sections summarise the results of the assessments.

5.2 Greater Shepparton City Council

Details in relation to existing urban levees within the Greater Shepparton City Council LGA are summarised in Table 2, including the assigned categories. Further information in regard to urban levees located within the Greater Shepparton LGA is documented in Appendix A. Levee locality maps are located in Appendix H.

The three Shepparton levees (Princess Park Levee, Macguire Reserve Levee and the Victoria Park Levee) have been categorised as Category 2 Type A. Council at the workshop in August 2025 advised that they are not actively managed at present. All the three Shepparton levees are overtopped at flood heights well below the 1% AEP event.

The one levee at Kialla (Balmoral Estate Levee) has been categorised as Category 2 Type A. It is also overtopped well below the 1% AEP flood level, has limited strategic value and is a relatively informal non engineered levee.

The existing Shepparton / Mooroopna and Kialla FEP Flood Intelligence Card does have references to the Shepparton and Kialla levees that are listed in Table 2.

The one existing Murchison levee (Stevenson Street Levee) has also been categorised as Category 2 Type A. Its crest is elevated 0.6m above the 1% AEP flood level, although it is a relatively informal low level levee.

A temporary levee has also been identified at Murchison (Station Street Temporary Levee). This levee is classified as Category 2 Type C. This levee is documented within the existing Murchison township FEP.

Council provided a spreadsheet listing all the 'council maintained levee banks'. This list had several banks on it (e.g. at Mooroopna) which when field checked were found either not to be levee banks designed to protect against riverine flooding or were not actually present (refer to Appendix A - Section A6).

Goulburn Murray Water irrigation supply and drainage channel banks at Merrigum do provide a level of protection from flooding. These banks are not however managed by GMW with flood mitigation as an objective. The banks have been assessed to be significant floodplain features.

A temporary levee segment was identified at Tallygaroopna. This levee has been categorised as Category 2 Type C. Levees at Loch Garry which influence flooding conditions at Bunbartha have been classified as Category 1 (owned and managed by Goulburn Murray Water).

Table 2 Urban Levees - Greater Shepparton City Council

Location	Name	Description / Details	Level of Protection	Category Assigned / Map Reference
Shepparton	Princess Park Levee	• Visually in very good condition • Adjoining Goulburn River to north of Midland Highway • 1,100m long, 2-3 m high, crest is sealed bike path • Protects ovals, clubrooms and Italian Social Club	4% AEP (25 year ARI) Based on zero freeboard	• Category 2 Type A (not currently actively managed) • Upgrade to Category1 once Council actively manages • Map Reference: Appendix H – Figure H2
Shepparton	Macguire Reserve Levee	• Condition varies from good to poor • Adjoining Goulburn River to south of Midland Highway • 900m long, 2-3 m high, crest is sealed bike path • Protects Tennis Centre and Crown land used for car parking	17% AEP (6 year ARI) Based on zero freeboard	• Category 2 Type A (not currently actively managed) • Upgrade to Category1 once Council actively manages • Map Reference: Appendix H – Figure H2
Shepparton	Victoria Park Levee	• Moderate to good condition • Adjoining Goulburn River on north side GV Railway • 430m long, 0.6 to 0.8m high • Crest at 14% AEP (1in 7 year) • Protects the Victoria Lake Caravan Park	14% AEP (7 year ARI) Based on zero freeboard	• Category 2 Type A (not currently actively managed) • Upgrade to Category1 once Council actively manages • Map Reference: Appendix H – Figure H2
Shepparton / Kialla	Balmoral Estate Levee	• Poor to moderate condition • Adjoining Furphy Avenue • 300m long, 0.3 m high • Informal levee • Protects rear yards of residential properties only	17% AEP (6 year ARI) Based on zero freeboard	• Category 2 Type A • Map Reference: Appendix H – Figure H2

Location	Name	Description / Details	Level of Protection	Category Assigned / Map Reference
Murchison	Stevenson Street Levee	• 90m long, 0.6 m high • Not captured within SDS levee layer	1% AEP 0.6 m freeboard	• Category 2 Type A (not currently actively managed) • Upgrade to Category1 once Council actively manages • Map Reference: Appendix H – Figure H3
Murchison	Station Street Temporary Levee	• At location shown on page 38 of FEP • Flood Intelligence Card – sandbag at this site at gauge height 12.0 (1% AEP is 11.9m).	> 0.5% AEP	• Category 2 Type C • Map Reference: Appendix H – Figure H2
Merrigum	No name	• GMW irrigation and drainage infrastructure banks	< 10% AEP Based on zero freeboard	• Significant floodplain features • Map Reference: Appendix A – Figure A6
Tallygaroopna	Thompsons Road Temporary Levee	• Fills in the gap between the railway embankment and Channel 17 at the Thompsons Road / Goulburn Valley Highway intersection	NA – no previous modelling / flood study	• Category 2 – Type C • Map Reference: Appendix A – Figure A8
Bunbartha	Loch Garry Levee	• Levee segments to west of Bunbartha – Loch Garry reach of Goulburn River floodplain	Unknown	• Category 1 • Owned and managed by GMW • Map Reference: Appendix H – Figure H17

5.3 Strathbogie Shire Council

Details in relation to existing urban levees within the Strathbogie Shire Council LGA are summarised in Table 3, including the assigned categories.

Further information regarding urban levees located within the Strathbogie Shire LGA is documented in Appendix B. Levee locality maps are located in Appendix H.

The Castle Creek Levee at Euroa has been classified as a Category 1 levee, owned and managed by Strathbogie Shire Council. This engineered levee has 0.6 m of freeboard above the 1% AEP flood level following upgrade works completed in 2017. The Castle Creek levee does not require any significant work ahead of a major flood.

A visual inspection in November 2025 indicates that the Castle Creek levee is in need of vegetation management works along much of its route with regrowth present in the crest and batters. The Castle Creek incised waterway bed and banks, notably approximately 150 metres upstream of the Euroa Main Road, requires monitoring for any potential undermining of the levee. Some localised rock beaching was undertaken for this reach most recently in 2017.

No levees have been identified along Seven Creeks at Euroa, notwithstanding some references to 'bund' segments in the current Euroa township MFEP.

There are two levees at rural properties on the west side of Castle Creek, opposite to the Castle Creek Levee. The levee at 183 Euroa Main Road was constructed by government (local and state) in 2021 as a compensatory measure to offset the impact of the Castle Creek Levee. This levee is a formal concrete block ring levee structure protecting a house with considerable freeboard above the 1% AEP flood level. The background to a second more informal low level earth levee at 207 Euroa Main Road is not known. The levees at 183 and 207 Euroa Main Road has been classified as Private Levees.

A future levee scheme at Violet Town has not to date been implemented. The only existing levee at Violet Town is a levee on Long Gully Creek upstream of Balmattum Road, south of the Hume Freeway. The levee is referenced by the current MFEP. This levee was inspected and has been found to be no longer functional (intentionally breached).

An existing low level informal levee is present within the Scobie Street road reserve at Avenel. This levee has been categorised as Category 2 Type A. There are no actions / work required in relation to this levee ahead of a major flood. The levee is overtopped once levels exceed the 1% AEP flood level. It is noted that a detailed flood study for Avenel township is to soon commence.

Nagambie township is not impacted by Goulburn River flooding. Parts of the township are impacted by local runoff flooding. There are reported to be multiple significant floodplain features at Nagambie influencing local runoff flooding conditions (e.g. raised local roads). There are no purpose-built strategic levees present at Nagambie.

Table 3 Urban Levees - Strathbogie Shire Council

Location	Name	Description / Details	Level of Protection	Category Assigned / Map Reference
Euroa	Castle Creek Levee	• Located on east side of Castle Creek, partly in private property, partly crown land (refer to Figure B1) • 2.4km long, average height 1.25m • Upgraded in 2000 – formal engineered levee, raised in 2017	1% AEP Minimum 1% AEP freeboard is 0.6m	• Category 1 (owner Strathbogie Shire Council) • No pre flood works required • Need to monitor the waterway condition approximately 150m upstream of the Euroa Main Road for any risk of potential undermining of the levee due to stream bed and bank erosion • Map Reference: Appendix H – Figure H4
Euroa	183 Euroa Main Road Levee	• 170 m long concrete block formal ring levee on west side of Castle Creek, north of Euroa Main Road, protects house • Compensatory levee to offset impact of Castle Creek Levee	1% AEP Estimated 1% AEP freeboard is 0.5m	• Private Levee • Minor work required prior to a flood to sandbag two openings in the levee which the property owner / occupant attends to • Map Reference: Appendix H – Figure H4
Euroa	207 Euroa Main Road	• Informal earth levee • Not maintained, gap in levee	Unknown	• Private Levee • Map Reference: Appendix H – Figure H4
Avenel	Scobie Street Levee	• Located within or adjacent to road reserve • 0.3km long • Informal levee, not engineered • Not managed	1% AEP Zero freeboard	• Category 2 – Type A • Map Reference: Appendix H – Figure H5
Violet Town	Long Gully Creek Levee	• Violet Town FEP refer to informal levee on Long Gully Creek upstream of Balmattum Road • Levee inspected, no longer a functional levee (intentionally breached)	Unknown	• Category 2 – Type B • Amend FEP content to reflect existing levee condition • Map Reference: Appendix B – Figure B5

5.4 Moira Shire Council

Details in relation to existing urban levees within the Moira Shire Council LGA are summarised in Table 4, including the assigned categories.

Further information regarding urban levees located within the Moira Shire LGA is documented in Appendix C. Levee locality maps are located in Appendix H.

The Cobram Levee Scheme encompasses multiple individual levees including Dicks Levee and Cavagna's located upstream of Cobram, and Denson's Levee and the Town Levee located at Cobram. All the Cobram Levee Scheme levees have been categorised as Category 1, owned and managed by the Moira Shire Council.

Dicks Levee is an important strategic levee, which is design to allow breakout flows once Murray River flows exceed the 5% AEP event. Murray River flows have not exceeded the current adopted 5% AEP design flow since the 1917 event, with the 1975 flood equivalent to a 5 % AEP event.

A Category 1 levee scheme is also present at Nathalia. This engineered scheme was completed in 2010. The Nathalia scheme is owned and managed by Moira Shire Council. The scheme includes multiple temporary erectable panel segments for which the trigger heights are nominated by the FEP Flood Intelligence Card.

Both the Cobram and Nathalia schemes are designed to provide protection against 1% AEP flooding.

Construction of a new levee scheme at Numurkah has recently commenced which will provide 1% AEP protection. Stage 1 of the Numurkah levee scheme that protects the northern side of the township is expected to be completed by April 2026.

There are existing low-level levees at Numurkah which have been classified as Category 1. These low-level levees are maintained and owned by Moira Shire Council (Tunnock Road, Brenion Street and Gray Street). The existing Numurkah levees are overtopped below the 1% AEP flood levels.

Existing informal levees are present at Barmah township. The existing levees are not engineered urban standard levees. The levees are overtopped below the 1% AEP flood levels. The existing levees at Barmah have been categorised as Category 2 Type B. The existing levees are not currently formally managed. In advance of a flood, temporary infill levee works are required (e.g. at driveway openings) and potentially levee raising depending on the forecast flood height. A formal upgraded levee scheme for Barham has previously been developed to functional design status but has not been implemented due to the high cost. A 2023 Victorian Government grant has been secured to revisit a potential upgraded levee scheme for Barmah.

An informal levee is present at Wunghnu. This levee has been classified as Category 2 Type A. Without any previous detailed flood study having been undertaken for Wunghnu, the strategic importance of the existing levee is not well understood.

Table 4 Urban Levees – Moira Shire Council

Location	Name	Description / Details	Level of Protection	Assigned Category / Map Reference
Cobram	Cobram Levee Scheme	• Includes Dicks Levee, Cavagna's Levee, Denson's Levee and the Town Levee (refer to Figure C1) • Temporary segments required at Mookarii Street and driveway entrance at 22 River Road • Temporary levee also required on Murray Valley Highway at Collie's • Dicks Levee is designed to act as a spillway – threshold 5% AEP event	1% AEP Minimum 250 mm of freeboard Above excludes Dicks Levee	• Category 1 • Map Reference: Appendix H – Figure H6
Barmah	-	• Multiple informal levees • Proposal to upgrade levee system to formal engineered ring levee in 2013 – has not been implemented • Victorian Government grant received in 2023 to revisit levee upgrade for Barmah – project yet to commence	3% AEP (33 year ARI) Based on zero freeboard	• Category 2 – Type B • Map Reference: Appendix H – Figure H9
Nathalia	Nathalia Levee Scheme	• Levee system at Nathalia was upgraded in 2010 • Temporary segments – demountable panels – at multiple locations • March 2012 flood only 0.03m below the 1% AEP flood levels • Irrigation channel bank on south side of town (Channel 12) also act as a defacto levee. • Temporary levee nominated by Nathalia FEP at 3 Draper Street.	1% AEP (100 year ARI) Minimum 300 mm freeboard	• Category 1 • Map Reference: Appendix H – Figure H7

Location	Name	Description / Details	Level of Protection	Assigned Category / Map Reference
Numurkah	Tunnock Road, Brenion Street & Gray Street	• Three low level relatively informal levees present • Levees overwhelmed in 2012	5% to 2% AEP (20 to 50 year ARI) Based on zero freeboard	• Category 1 • Map Reference: Appendix H – Figure H8
Numurkah	Pine Street and Wattle Street	• Temporary levee segments at road crossings along the Channel 6/6 route • Temporary levees across Pine Street and Wattle Street	Unknown	• Category 2 – Type C • Map Reference: Appendix C – Figure C8
Numurkah	-	• Irrigation channel bank (Channel 6/6) on east side of town acts as a levee.	Unknown	• Significant floodplain feature • Map Reference: Appendix C – Figure C8
Numurkah	Numurkah Levee Scheme	• Stage 1 under construction in late 2025 • Culmination of all of the studies undertaken post the 2012 flood event	1% AEP 450mm of freeboard for earthen levees, 300 mm of freeboard for concrete wall levees	• Category 1
Wunghnu	-	• South side of Nine Mile Creek • 300m long • Informal levee, not managed	Unknown at present (no design flood levels available).	• Category 2 – Type A • Map Reference: Appendix H – Figure H10

5.5 Campaspe Shire Council

Details in relation to existing urban levees within the Campaspe Shire LGA / Goulburn Broken CMA region are summarised in Table 5, including the assigned categories.

Further information regarding urban levees located both within the Campaspe Shire LGA is documented in Appendix D. Levee locality maps are located in Appendix H.

Echuca is located within the North Central CMA region and is not therefore relevant to this report. The Echuca Village area east of Echuca consists of smaller 'hobby farm' type properties. The Echuca Village area is protected from flooding by a levee to the north (Murray River Levee) and a levee to the east (Beattie Depression Levee). The levees provide 5% AEP protection as identified by recent modelling undertaken as part of the Echuca Moama Torrumbarry flood study project.

The above levees protecting the Echuca Village area have been classified as Category 1 levees which are owned and managed by GMW.

There are no other purpose-built flood protection levees within that part of the Campaspe Shire LGA which is located within the Goulburn Broken CMA region.

Table 5 Urban Levees – Campaspe Shire Council

Location	Name	Description / Details	Level of Protection	Assigned Category / Map Reference
Echuca Village	Beattie Depression	• Levees on either side of the Beattie Depression corridor between the Murray Valley Highway and the Murray River floodplain	> 5% AEP (20 year ARI) Based on 2023 Echuca Moama Torrumbarry Flood Study	• Category 1 • Owned and managed by GMW • Map Reference: Appendix H – Figure H15
Echuca Village	Murray River	• Levee present for 5 km to west of the Beattie Depression.	> 5% AEP (20 year ARI) Based on 2023 Echuca Moama Torrumbarry Flood Study	• Category 1 • Owned and managed by GMW • Map Reference: Appendix H – Figure H15

6 Rural Levees

6.1 Non GMW Rural Levees

An overview of rural levees present within the Goulburn Broken CMA region is provided in Appendix E. Levee locality maps are located in Appendix H. Summary details are provided in Table 6, including the assigned categories.

Rural levees within the Goulburn Broken CMA region are notably present at:

- Murray River south side floodplain between Cobram and Barmah (116km)
- Murray River floodplain downstream of Barmah and the Lower Goulburn River floodplain downstream of Loch Garry (147 km)
- Corop Lakes area south / south west of Stanhope (approximately 70km)

The above rural levee systems have not been actively managed for several decades.

The Victorian Floodplain Management Strategy (DELWP, 2016) views rural levees as no longer consistent with best practice. The policy documented by the 2016 VFMS does not provide for Victorian state government funding of rural levee schemes for their future maintenance unless it can be demonstrated that the levees meet investment criteria nominated by the 2016 VFMS, which excludes private income benefits derived from agriculture.

The above rural levees have been captured within the GIS SDS levee layer. A relatively recent 2013 detailed conditions assessment of the Murray River and lower Goulburn River levees (Water Technology, 2013) also documents in detail the levee condition and the level of protection provided.

For the above rural levee systems to be assigned as Category 2, it has to have been demonstrated that the levees meet the 2016 VFMS investment criteria. This has not been demonstrated and therefore they cannot be assigned as Category 2.

In the case of the Murray River and lower Goulburn River levee systems, the levees are strategic levees providing benefits to a very large number of properties. The detailed condition assessment project in 2013 identified variable levels of protection. More than 50% of the Murray River levees assessed achieved a level of protection of less than 5% AEP, whilst 8% of the Goulburn River levees assessed achieved a level of protection of less than 20% AEP.

The Murray River and lower Goulburn River levees have therefore been assessed as Category 3 levees, as opposed to Category 2 or Private Levees.

The Corop Lakes area rural levees are considered in contrast to be less strategic in terms of their condition and level of protection offered, although a condition assessment similar to the 2013 Murray River / lower Goulburn River system has not been undertaken. The Corop Lakes levees have therefore been assessed as Private Levees. Their condition and level of protection provided will vary markedly.

Table 6 Rural Levees – GBCMA Region

Location	Name	Description / Details	Level of Protection	Assigned Category / Map Reference
Murray River	PWD Levee	• 58 km of levee between the Cobram Town Levee and Pirie Creek • Original constructed by government (Public Works Department)	< 5% AEP	• Category 3 • Map Ref.: Appendix H – Figure H11 & H12
Murray River	Pirie Creek to Barmah Levee Marray Levee	• 37 km of levee between Pirie Creek and Barmah township • Constructed by private landowners	< 5% AEP	• Category 3 • Map Ref.: Appendix H – Figure H13 & H14
Murray River	Murray Bend Caravan Park	• Located 2 km west of Tocumwal • 2.3 km long ring levee, encloses 34 hectares caravan park site	1% AEP	• Private • Map Reference: Appendix H – Figure H11
Lower Goulburn River	Lower Goulburn Levees	• Goulburn River downstream of Loch Garry (approximately 100 km) • Murray River levee west of Beattie Depression (4 km)	< 20% AEP	• Category 3 • Map Ref.: Appendix H – Figures H16 & H17
South / south west of Stanhope	Corop Lakes Levees	• Approx. 70 km of levees • Few details in terms of condition and level of protection	Unknown – likely to vary markedly	• Private Levees • Map Reference: Appendix H – Figure H18
Warrigal Creek	Warrigal Creek	• 10 km of levee • Owned / managed by GMW	Unknown	• Category 1 • Map Reference: Appendix H – Figure H15
Loch Garry	Loch Garry	• Approx. 10 km of levee • Owned / managed by GMW	< 5% AEP	• Category 1 • Map Reference: Appendix H – Figure H17

6.2 GMW Rural Levees

Goulburn Murray Water through various legacy circumstances are the owners of a number of rural levee banks within the Goulburn Broken region. The GMW owned banks are located at:

- Murray River levee for 4 km west of Beatties Depression. This levee protects the Echuca Village area to the south.
- Beattie Depression levees, located east of the Echuca Village area.
- Warrigal Creek levees. These levees are located to the east of the Beattie Depression. The levees protect rural areas.
- Loch Gary levee. This levee is essentially the north side Goulburn River levee for the Loch Garry reach. The levee protects rural areas and the Bunbartha village.
- Kinnairds Swamp levees. These levees are located upstream (east) of Numurkah. Theses levees are designed to manage low flows only (< 50% AEP). In large flood events, flooding reverts to natural conditions. The Kinnairds Swamp levees have for this reason not been classified.

The above levees are all located in rural areas, although some are in relatively close proximity to urban areas (e.g. Loch Garry Levee is close to Bunbartha, levees protecting the Echuca Village area).

GMW haver advised that it does not maintain any of its supply channel and rural drainage channel infrastructure with the objective of protecting urban areas from flooding (e.g. at Merrigum).

GMW advised that the Beattie Depression Levees experienced some damage during the spring 2022 floods. Maintenance addressing the 2022 flood damage and other issues (e.g. tree growth in banks) is planned by GMW pending allocation of sufficient funds.

Further details regarding the above GMW managed levees are provided in Appendix E.

6.3 Rural Levee Economic Assessment

An economic assessment of an example rural levee system is documented in Appendix G.

The levee selected for the economic assessment is a 57 km long levee located downstream of Cobram known as the PWD levee. This levee was originally constructed by government in the late 1800s. The levee protects a large area to the south of the levee from Murray River flooding.

The levee has not been maintained by government in recent decades. A government funded condition assessment study was however completed in 2013 (Water Technology, 2013) identifying that the levee provides protection up to approximately a 5% AEP event. The largest Murray River flood since 1917 occurred in 1975 which was equivalent to approximately a 5% AEP event.

The economic assessment consisted of a high-level assessment using the Rapid Appraisal Method (RAM). The assessment details are provided in Appendix G.

Key factors impacting on the results of an economic assessment of rural levees are:

- The inclusion or exclusion of agricultural benefits associated with protecting rural areas from flooding. Agricultural benefits are deemed by the 2016 VFMS to be private benefits.
- The protection of privately owned dwellings (houses) are viewed as public benefits by the 2016 VFMS. The protection of building infrastructure directly associated with agricultural production appears to be deemed by the 2016 VFMS as private benefits.
- The protection of public roads is viewed by the 2016 VFMS as public benefits.

Two scenarios were assessed as part of the high-level economic assessment. Scenario 1 coincides with the 2016 VFMS policy settings. Summary details for Scenario 1 are:

- Assumes benefits (future reduced flood damages) are confined to dwelling damages and public roadways. Agricultural benefits are excluded.
- Assumes a damage threshold of 20% AEP.
- Assumes that the PWD levee provides protection up to a 5% AEP event, with no damage reduction benefits assumed for more severe events.
- Resultant average annual damage reduction (AAD) associated with the PWD levee is $374,000/annum, with a present value of $5.3 million assuming a design life of 75 years and a discount rate of 7%.
- Present value capital and maintenance costs for the PWD levee estimated to be $25.3 million (viewed as a lower end estimate).
- Benefit cost ratio outcome of 0.21.

The second scenario assessed (Scenario 2) assumes that agricultural benefits are included and that the levee provides protection up to the 1% AEP event. This results in a more favourable benefit cost ratio of 0.45.

The economic assessment was a single high-level assessment only. It suggests that even with the inclusion of agricultural benefits, it is likely that the capital and maintenance costs associated with a rural levee system will exceed the benefits it provides.

There may be exceptions to the above. An economic assessment of a 36 km long rural levee at Tyntynder Flats downstream of Swan Hill completed as part of the North Central CMA Levee Categorisation project produced a favourable benefit cost outcome. This was influenced by a high density of dwellings within the levee protected area (429 dwellings) and the use of a lower bound capital cost rate.

6.4 Significant Floodplain Features

There are features on floodplains which are not levees, which none the less have a significant impact on flow patterns during major floods that result in significant changes to flooding conditions.

'*Significant floodplain features'* in the context of this project includes the following:

- Elevated banks associated with irrigation supply channels and rural drainage channels.
- Segments of roadway located on elevated embankments.
- Segments of railway lines located on elevated embankments.

The landscape within the GBCMA region is littered with hundreds, if not thousands of the above man-made features. The GBCMA Levee Categorisation Project has opted not to focus on significant floodplain features and has instead focused on purpose built man-made levees.

Notable significant floodplain features are described in Appendix F.

7 Summary

7.1 Project Summary

This Strategic Levee Categorisation Project undertaken for the Goulburn Broken CMA has focused on an assessment of strategic levees leading to the allocation of assigned categories to each levee based on the category definitions adopted (Table 1). The assessment has drawn on a desktop review of available data including terrain data and flood modelling output data, consultation with local government and state government agencies, and cursory site inspections of the levees.

The work has largely focused on those levees protecting urban areas. Less emphasis has been placed on rural levees. This was largely influenced by the policy around rural levee management in Victoria as put forward by the 2016 VFMS. This policy does not enable the Victorian state government funding of rural levee schemes unless it can be demonstrated that the levees meet investment criteria nominated by the 2016 Victorian Floodplain Management Strategy.

Assigned levee categories within this report are documented in the following appendices:

- Greater Shepparton City Council urban levee – refer to Table 2 and Appendix A
- Strathbogie Shire Council urban levees – refer to Table 3 and Appendix B
- Moira Shire Council urban levees - refer to Table 4 and Appendix C
- Campaspe Shire Council urban levees - refer to Table 5 and Appendix D
- Rural levees across the Goulburn Broken CMA – refer to Table 6 and Appendix E

General locality maps for the above listed levees are located in Appendix H of this report.

Additional levee management specific content has been prepared for inclusion in the respective municipal Flood Emergency Plans (FEPs) using the knowledge derived from this project. The FEPs are being updated as part of a separate concurrent project being undertaken by consultants Water Technology for the Goulburn Broken CMA.

7.2 Summary of Findings / Learnings

The management of levees should reflect their strategic function. Levees protecting community assets and urban areas offering public benefits should be managed by the relevant authorities. This will predominantly be the relevant local government and in some instances Goulburn Murray Water.

The assessments undertaken by this project found that levees owned by local government are commonly not currently subject to systematic maintenance, with few if any ‘operation and maintenance’ manuals either existing or in use. This is despite instances where levee construction funding agreements specify that the local government is responsible for future maintenance as a condition of the funding agreement.

The presence of tailored levee management manuals (LMMs) for each Category 1 levee, should lead to an uptake in activity from the levee owners in carrying out the necessary surveillance, operation and maintenance of these levees. The manuals should include where available works as executed drawings of the levee works. As an example, the construction of the levee scheme at Numurkah has recently commenced and represents a timely opportunity for a LMM covering the Numurkah scheme to be compiled to guide future levee owner obligations and direction. The same would apply to Violet Town if that levee scheme is to proceed.

This study has found via inspections and review of documentation that the condition of the urban levees varies markedly. Some levees appear visually to be in good fit for purpose condition. Examples include the Princess Park Levee at Shepparton and the Cobram Town Levee. Some urban levees have however been allowed to deteriorate in condition due in part to insufficient maintenance.

A high-level economic assessment undertaken for the Public Works Department (PWD) rural levee downstream of Cobram has identified that the capital and maintenance costs associated with a rural levee system will most likely exceed the flood damage reduction public benefits they provide. Even with the inclusion of agricultural benefits, the cost benefit ratio outcome for the PWD rural levee is below 0.5. It is noted however that an economic assessment completed as part of the North Central CMA Levee Categorisation project for a rural levee at Tyntynder Flats downstream of Swan Hill has produced a benefit cost ratio greater than 1.0.

Other notable specific levee management issues within each LGA are flagged as follows:

- Greater Shepparton CC.
    - The levees at Shepparton are not currently systematically managed and would benefit from a change in these circumstances.
    - The flood risk status of Bunbartha is currently not well understood and would benefit from further investigations.
- Strathbogie SC.
    - Levee management maintenance is currently not a focus. An increase in maintenance activity would benefit the existing Castle Creek Levee at Euroa and possible future urban levees (e.g. at Violet Town).
- Moira SC.
    - Consideration of the future status of the Category 2 levee scheme at Barmah is needed.
    - Consideration of the future need for temporary levees at 3 Draper Street, Nathalia, as referenced by the Nathalia FEP is needed.
    - Design details for a temporary levee across the Murray Valley Highway east of Cobram, as referenced by the Cobram FEP are unclear.
    - Investigations to clarify the flood risks at Wunghnu is required.

8 References

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APPENDIX A Greater Shepparton CC Levee Assessments

A1 Shepparton, Mooroopna and Kialla

Shepparton / Mooroopna is located at the confluence of the Goulburn and Broken Rivers. The confluence of Seven Creeks and the Goulburn River is located approximately 2 km further south (upstream).

2018-2028 Goulburn Broken Regional Floodplain Management Strategy

Appendix F of the 2018-2028 Goulburn Broken RFMS provides details in regards to the following levees at Shepparton / Mooroopna (refer to Figure A1):

- Princess Park Levee
    - 1,100 m long, 2-3 m in height
    - Crest is a sealed bike path
    - Protects two sporting ovals, clubrooms and recreation building
    - Overtopping threshold – 11.66 m on the Shepparton gauge
    - Excluding freeboard, the level of protection is 0.05m below the 1993 flood level, level of protection equates to 4% AEP event (25 year ARI)
    - If you include 600mm of freeboard, the level of protection reduces to 14% AEP (7 year ARI)
- Macguire Reserve Levee
    - 900m long, 2-3 m in height
    - Crest is a sealed bike path
    - Protects the Shepparton Lawn Tennis Court centre and crown land partly used for car parking
    - Levee was sandbagged in the 2010 flood to prevent marginal overtopping. Parts of tennis courts flooded near GVW's water treatment plant due to piping flows through the levee bank.
    - Overtopping threshold – 10.98 m. Begins to overtop south of Daintons Bridge.
    - Excluding freeboard, the level of protection equates to 17% AEP event (6 year ARI)
    - If you include 600mm of freeboard, the level of protection reduces to 25% AEP (4 year ARI)
- Victoria Park Levee
    - 430m long, 0.6 to 0.8 m in height
    - Protects the Victoria Lake Holiday Park camping grounds. Caravan Park not flooded in 2010 event (i.e. levee not overtopped).
    - Levee appears to be in poor condition (e.g. trees present within the bank)
    - Overtopping threshold – 11.18 m at Shepparton gauge
    - Excluding freeboard, the level of protection equates to 14% AEP event (7 year ARI
    - If you include 600mm of freeboard, the level of protection reduces to 25% AEP (4 year ARI)
    - Levee arguably not worth maintaining as it protects against nuisance type flooding impacts only. Could be argued that camping ground should rely on evacuation procedures, not levee protection.
- Balmoral Estate Levee
    - 300 m long, 0.3 m in height
    - Informal levee of ad hoc construction
    - Protects the rear backyards west of Furphy Avenue from nuisance flooding. Does not provide protection to houses which are well above the height of the levee.

- Levee is of little strategic value given the limited benefits (i.e. does not protect houses from flooding)
- Overtopping threshold 11.10 m on the Shepparton gauge
- Excluding freeboard, the level of protection equates to 17% AEP event (6 year ARI)
- If you include 600mm of freeboard, the level of protection reduces to 25% AEP (4 year ARI)

Shepparton / Mooroopna and Kialla Flood Emergency Plan (FEP)

Appendix C2 of the 2023 GSCC FEP documents a FEP specifically for Shepparton / Mooroopna and Kialla. The FEP states that:

- Catchment areas at Shepparton – Goulburn River 12,000km^2, Broken River 2,510km^2, Seven Creeks 1,550 km^2.
- Generally there is between 3 to 5 days of flood warning time available. Flash flooding can also occur within a few hours due to local runoff.
- References to flood mitigation levees within the FEP are not detailed or specific. This is limited to saying that levees are present at strategic locations, with the levees providing protection to just over the Shepparton major flood level of 11.0m.
- Comprehensive flood inundation mapping for emergency management and response purposes. Different sets of maps for Goulburn dominant and Broken / Seven Creeks dominant.

Actions associated with levees nominated in the FEP Shepparton Flood Intelligence card are:

- Gauge height 10.98m (just above 10% AEP flood level) – Macguire Reserve levee overtopped near Dainton's Bridge. Action nominated to warn property owners in Wellsford Street adjacent to Macguire Reserve of levee breach.
- Gauge height 11.10m – Balmoral Estate levee overtopped. Action nominated to consider / commence evacuation of Balmoral Estate.
- Gauge height 11.18m – Victoria Park levee overtopped. Action nominated to evacuate the Victoria Lake Holiday Park which will begin to flood.
- Gauge height 11.66m – Princess Park levee overtopped. Action nominated to warn property owners adjoining the levee.

SDS Data

In 2024, the above four levees at Shepparton were captured for inclusion in the SDS levee layer by the GBCMA.

The assigned attribute data nominates the GSCC as the owner of the Princess Park Levee, Macguire Reserve Levee and the Victoria Park Levee. No owner is assigned to the Balmoral Estate Levee. All levees attributed as being located on Crown land.

Site Inspections

The four Shepparton levees were given a cursory inspection in late August 2024. Comments arising from this inspection are as follows:

- Princess Park Levee. This levee is in visually very good condition (refer to photographs in Figure A2). The sealed crest provides a shared pathway for cyclists and pedestrians. Minimal maintenance will be required for this levee, assuming that the batters can be mowed with ride-on machinery. Worthwhile maintaining this levee, even though there are limited benefits (protects Italian Social Club, sporting clubrooms).
- Macguire Reserve Levee. This levee varies in condition (refer to photographs in Figure A2). Steep batters with a range of varying size trees growing in the river side batter will in time incur significant costs if this levee is to be maintained. The segment at the Dainton's Bridge end is arguably worthwhile maintaining. The tennis court segment is less formal.
- Victoria Park Levee. This low-level levee is in good conditions aside from a limited number of trees growing within it (refer to photographs in Figure A3). Benefits are limited, however.
- Balmoral Estate Levee. This informal levee is not an urban standard levee. It provided limited benefits. Refer to photographs in Figure A3.

Preliminary Categorisation

Council has advised at the workshop on the 5 August 2025 that the Princes Park Levee, Macguire Reserve Levee and Victoria Park Levee are not currently being actively managed. They have therefore been assigned as Category 2, Type A.

The Balmoral Estate Levee is also classified as Category 2, Type A.

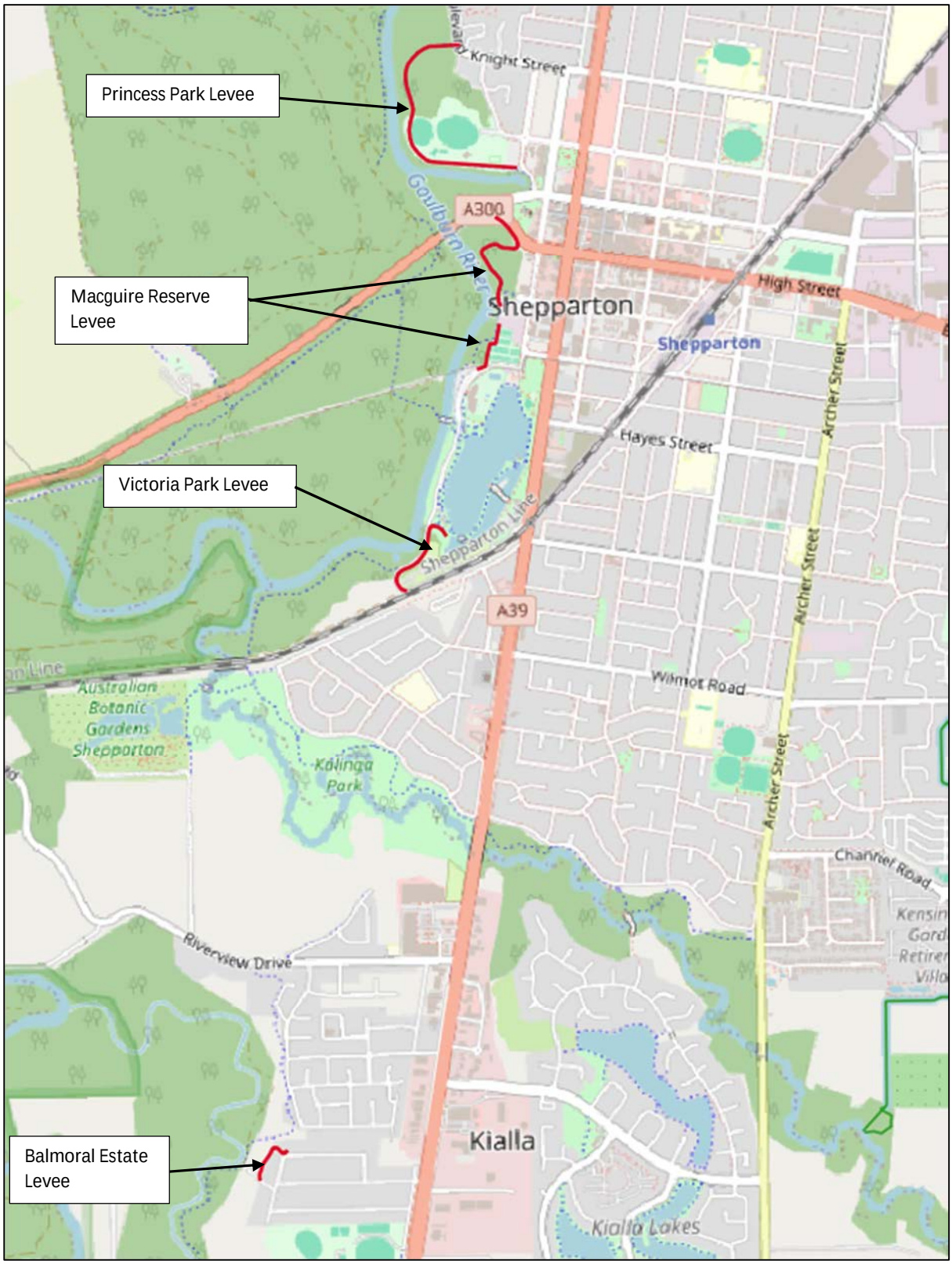


Figure A1 Shepparton Levees Locality Plan



Photo 1 – South end of the Princess Park Levee



Photo 2 – North end of the Princess Park Levee

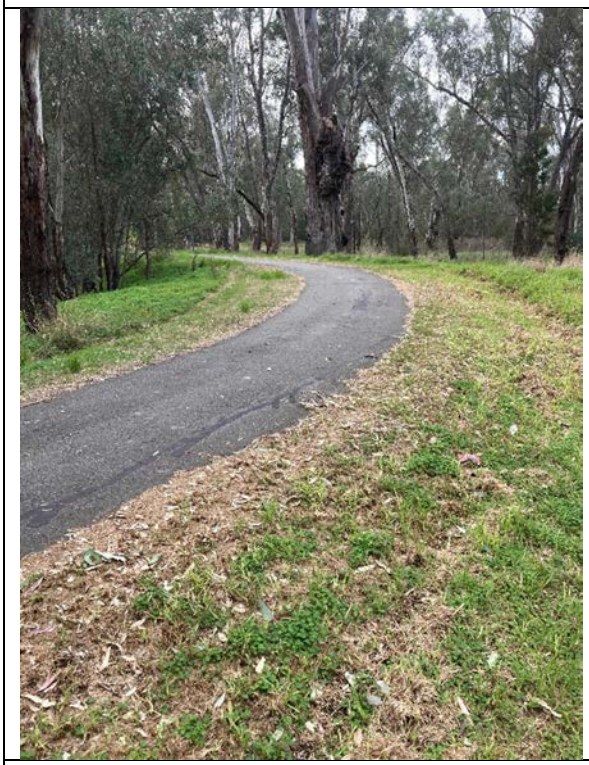


Photo 3 – Macguire Reserve Levee – north segment



Photo 4 – Macguire Reserve – segment at rear of tennis courts

Figure A2 Shepparton Levee Photographs – Princess Park and Macguire Reserve Levees

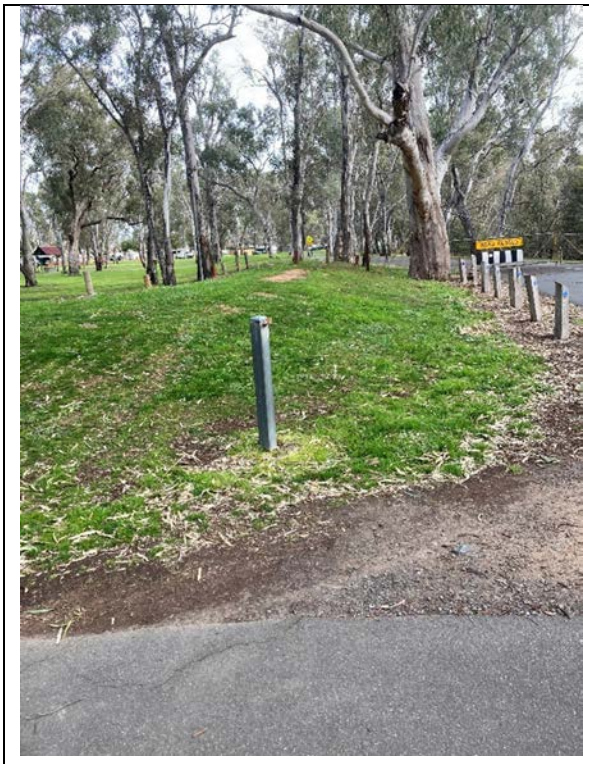


Photo 1 – North end of the Victoria Park Levee



Photo 2 – Victoria Park Levee – from wet side

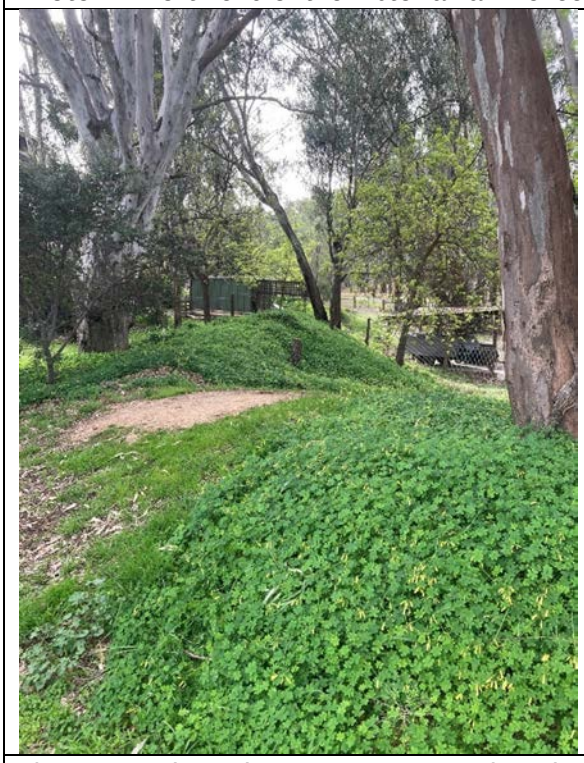


Photo 3 – Balmoral Estate Levee – north end



Photo 4 – Balmoral Estate Levee – rear of Furphy Avenue property

Figure A3 Shepparton Levee Photographs – Victoria Park and Balmoral Estate Levees

A2 Murchison

Murchison (population 900) is located on the Goulburn River. The highest flood at Murchison on record is the 1916 flood which peaked at 12.22 m.

The 2018-2028 Goulburn Broken RFMS (Appendix F) refers to a 200 m long, 0.6 m high levee located north of the Murchison-Bendigo bridge crossing on the eastern bank of the river.

Murchison Flood Mapping Study (Water Technology, 2014)

This report provides the following details for the levee located just downstream of the Bendigo-Murchison Road:

- The levee provides protection from river flooding, particularly against back flooding along the depression that runs past Stevenson Street back towards Watson Street.
- Minimum levee crest heigh is 121.04 m AHD
- 1% AEP flood level at levee is 120.43 m AHD
- 1% AEP freeboard therefore 0.61 m
- Conclusion that no upgrades to the levee are required

The 2014 report makes no reference to any other existing levees.

Murchison FEP (2020)

Appendix C1 within the 2023 GSCC FEP documents a FEP for Murchison. The FEP states that levees are located at Murchison at (refer to Figure A4):

- Along the bank of the Goulburn River, extending northwards from the Bendigo-Murchison Road to the back of the playground (200m long, 0.6m high). Freeboard 0.6 m above 1% AEP.
- Levee protecting the River Road Caravan Park. The FEP indicates that this levee is not overtopped in a repeat of the 2016 flood (i.e. 2016 flood level at gauge is 12.22 m, above the 1% AEP flood level of 11.92m).

No response actions associated with the above two levees are provided in the Murchison Flood Intelligence Card.

At gauge height of 12.0 m, just above the 1% AEP flood level of 11.9 m, sandbagging of a flow path south of Station Street between Willougby Street and Robinson Street is called for at the location shown on page 38 of the FEP (refer to Figure A4).

SDS Data

As at 2024, there were no levees at Murchison captured within the SDS levee layer.

Site Inspection

A site inspection at Murchison confirmed the presence of the levee between the playground and the Bendigo- Murchison Road (refer to Figure A5). The levee is approximately 90m in length. This levee is characteristic of a low height landscaped bund.

The site inspection identified that there is no levee present at the River Road Caravan Park.

Greater Shepparton City Council are currently installing a penstock at the Stevenson Street levee to prevent riverine floodwater entering the town, which was the issue in the 2022 flood.

The Stevenson Street levee has been classified as Category 2 Type A. The Station Street temporary levee has been classified as Category 2 Type C.



Figure A4 Murchison Levees Locality Plan

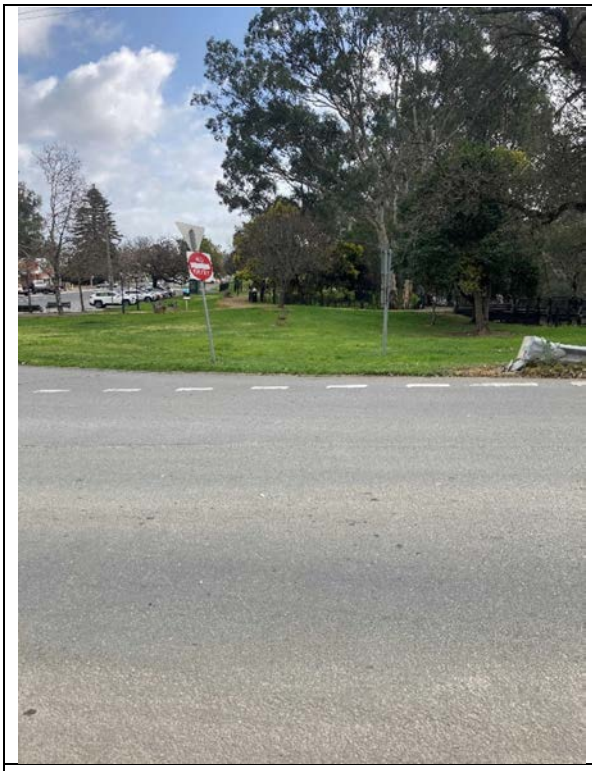


Photo 1 – View north from Bendigo-Murchison Road



Photo 2 – View south from playground

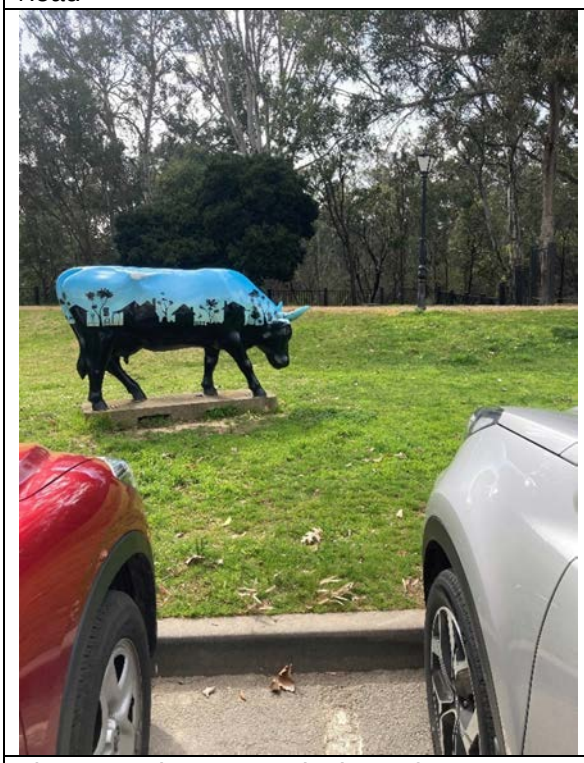


Photo 3 – View across the levee from Stevenson Street



Photo 4 – Reserve boundary of River Road Caravan Park. No levee present.

Figure A5 Murchison Levee Photographs

A3 Merrigum

Merrigum (population 470) is located 25 km west of Shepparton.

Flooding at Merrigum is associated with the Mosquito Depression. Widespread flooding at Merrigum is known to have occurred in 1974 and 1993.

A GMW engineered drain (Mosquito Main Drain) is positioned within the Mosquito Depression at Merrigum (refer to Figures A6 and A7). Banks are present on the town side of the drain to confine flows to the drain. Banks are also present adjoining the supply channel (Channel 7) located on the east side of the town.

The Merrigum FEP (Appendix C8 of the 2023 GSCC FEP) notes that an embankment was added to the Mosquito Depression floodway between Waverley Avenue and the railway embankment in 1994, with crest levels set 500 mm above the 1993 flood levels.

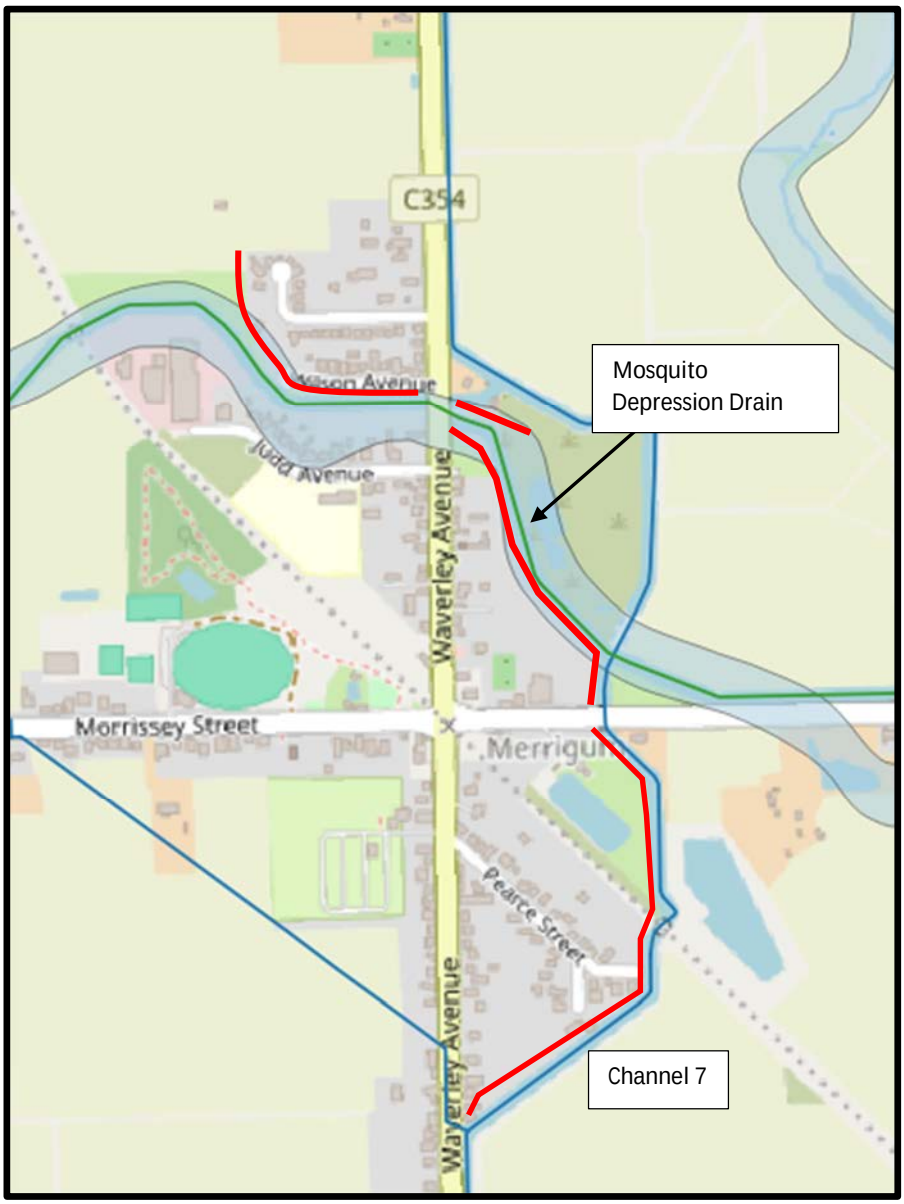


Figure A6 Merrigum Levee Locality Plan

The Merrigum Flood Study (WBM, 2005) estimates that there are 50 houses flooded to above floor level at Merrigum in a 1% AEP event. The same 2005 study produced detailed flood mapping. The study flags the use of levees as potential mitigation measure for Merrigum.

Water surface elevation raster flood modelling output files show widespread flooding at Merrigum outside the drainage and supply channel banks in a 10% AEP event. Sections of the bank are overtopped in a 10% AEP event (smallest design flood WSE available).

SDS Data

As at 2024, there were no levees at Merrigum captured within the SDS levee layer.

Preliminary Categorisation

The Mosquito Main Drain and supply Channel 7 is managed by GMW. The banks adjoining the drain and supply channel are 'Significant Floodplain Features' in the context of this project.

Management Issues

GMW has advised that they do not manage the drainage or supply channel banks at Merrigum with the aim of mitigating flooding impacts on the town. GMW advised that they are not aware of any issues arising in relation to their infrastructure banks in past floods at Merrigum.



Photo 1 – View of Mosquito Main Drain looking downstream from Waverley Av.



Photo 2 – GMW Channel 7 at Merrigum-Ardmona Road

Figure A7 Merrigum Photographs

A4 Tallygaroopna

Tallygaroopna (population 200) is located on the Goulburn Valley Highway 16 km north of Shepparton.

Congupna Creek is aligned to the east and north sides of the town. The creek is an engineered GMW open channel drain (Drain 2/11). Congupna Creek receives inflows from its local catchment. In large Broken River flood events, it can also receive breakaway flows from the river as notably occurred in 1993.

Tallygaroopna township was subject to widespread shallow inundation in March 2012. The 2012 flood is thought to be the most severe flood experienced at Tallygaroopna in living memory.

Tallygaroopna Flood Scoping Study (Confluence, 2024)

The Tallygaroopna Flood Scoping Study was completed in 2024. Notable finding from the Scoping Study are:

- Multiple man-made raised features impact on flooding conditions at Tallygaroopna. This includes:
    - Tocumwal Railway. Cross drainage through the elevated railway embankment is limited to culverts present.
    - Goulburn Valley Highway which parallels the west side of the railway is elevated with cross drainage culverts at intervals.
    - GMW and private supply channel banks, notably Channel 17 at Thompsons Road to the south of the town.
    - GMW drainage channels, notably Drain 2/11 (Congupna Creek).
- There are no purpose-built levees protecting Tallygaroopna from flooding. A low-level berm on the southern fringe of the town deflects floodwater westwards towards the railway.
- Local residents involved in flood response operations have advised that a short temporary levee was erected across the gap between the Channel 17 siphon and the railway embankment at Thompsons Road, adjoining the Goulburn Valley Highway. This temporary levee prevents local runoff from discharging northwards into Tallygaroopna.
- Local residents also advised that once flood levels in Congupna Creek / Drain 2/11 get sufficiently high to backwater / surcharge out drainage inlets, the inlets are manually closed until flood levels in the drain sufficiently recede.

SDS Data

As at 2024, there were no levees at Tallygaroopna captured within the SDS levee layer.

Preliminary Categorisation

There are no purpose-built levees at Tallygaroopna. The floodplain features acting as levees are ‘Significant Floodplain Features’ in the context of this project.

A temporary levee segment at Thompsons Road has been identified (refer to Figure A8). This levee prevents northwards flows between GMW Channel 17 and the railway line. This temporary levee is categorised as Category 2 Type C.

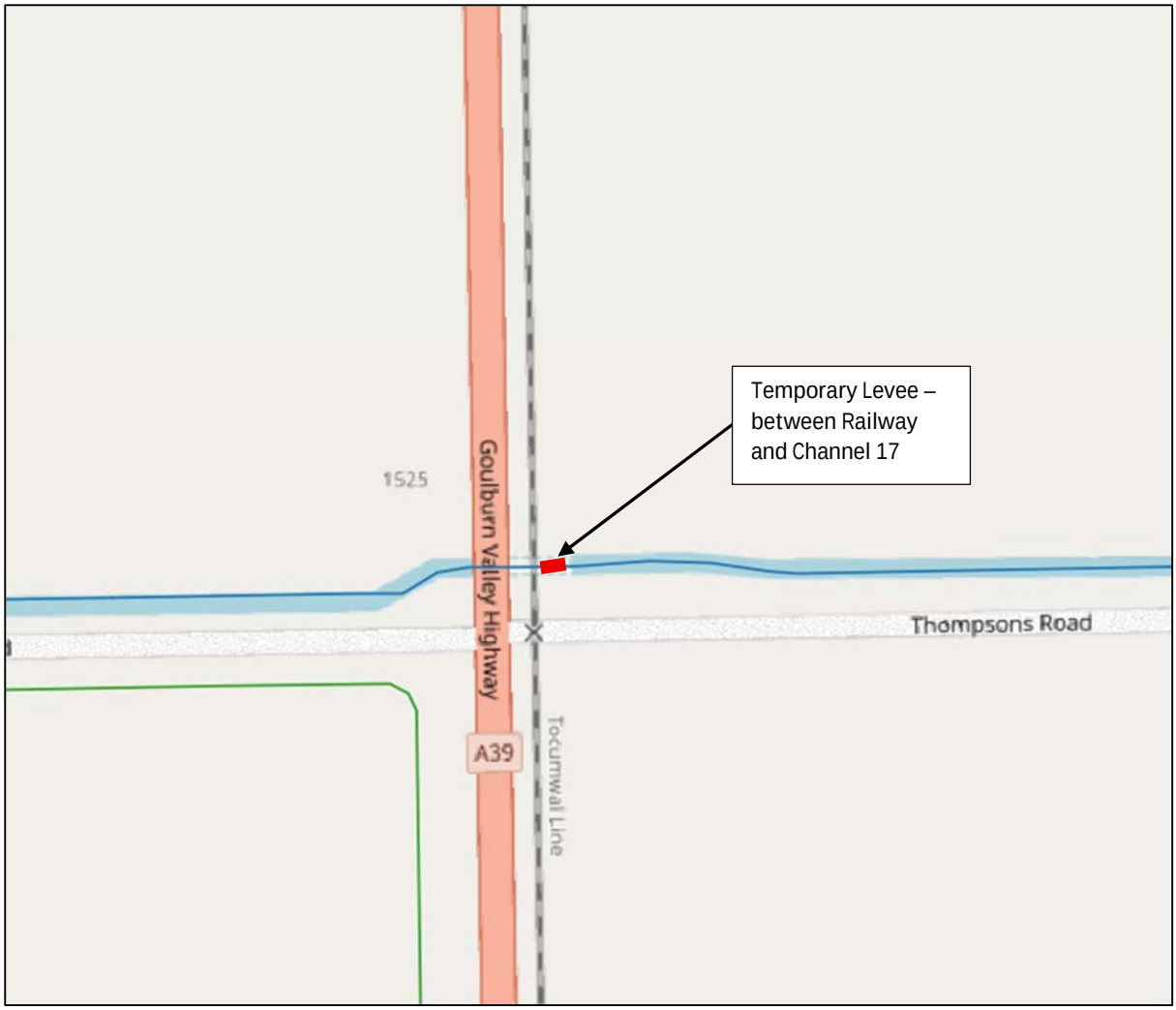


Figure A8 Tallygaroopna Thompsons Road Temporary Levee

A5 Other Towns

East Shepparton

East Shepparton (population 1,200) is located 7km east of Shepparton. Flooding is associated with runoff from the local catchment area which can lead to flash flooding.

The surrounding area is criss-crossed by a network of irrigation supply and drainage channels. Raised banks associated with this infrastructure can act to divert and/or bank up local runoff.

There are no purpose built existing levees at Shepparton East.

Congupna

Congupna (population 230) is located 8 km north of Shepparton. The town is not impacted by riverine flooding. The nearest waterway is Pine Lodge Creek located 2 km north east. Local runoff can impact on the town leading to flash flooding as notably occurred in March 2012.

The surrounding area is criss-crossed by a network of irrigation supply and drainage channels. Raised banks associated with this infrastructure can act to divert and/or bank up local runoff.

There are no purpose built existing levees at Congupna.

Katandra West

Katandra West (population 230) is located 10 km east of Tallygaroopna.

A Flood Scoping Study was completed for Katandra West in 2023 (Confluence Group, 2023). The study found that Tallygaroopna is not affected by riverine flooding. Nuisance level local runoff flooding impacts on the township, which notably occurred in March 2012.

There are no purpose-built existing levees at Katandra West.

Tatura

Tatura (population 2,500) is located 17 km south-west of Shepparton.

Flooding at Tatura is associated with the Mosquito Depression East Arm. An approximately 600 ha catchment drains into the Depression and through the town via multiple complex flow paths. Despite the relatively small catchment, flood response times are slow. Flooding can take days to peak as storages fill up along the Depression route.

A detailed study (WBM, 2006) has identified flood mapping and impacts, with 132 houses estimated to be flooded to above floor level in a 1% AEP event.

The surrounding area is criss-crossed by a network of irrigation supply and drainage channels. Raised banks associated with this infrastructure can act to divert and/or bank up local runoff.

There are no purpose-built existing levees at Tatura.

Bunbartha (Medland Road estate)

The residential estate at Bunbartha / Medland Road consists of 41 houses. Flooding risks and conditions at Bunbartha are not currently well understood. Risks would appear on the low side based on reports that the estate was not impacted by flooding in 2022. The extent to which the rural levees around Loch Garry protect Bunbartha are similarly not well understood.

The levees at Loch Garry are owned and managed by GMW. They have not been inspected or assessed as part of this project. An initial flood scoping study for Bunbartha would be desirable to provide an improved understanding of flooding risks at Bunbartha and the role that levee protection plays in influencing that risk.

A6 Council Consultation

Greater Shepparton City Council provided an email reply in October 2024 in response to a request for information as to which levees Council manages. The spreadsheet attached to the email reply nominates the following levees as being maintained by Council:

- Shepparton
    - The four levee banks shown in Figure A1 of this report (Princess Park Levee, Macguire Reserve Levee, Victoria Lake Caravan Park Levee and Balmoral Estate Levee).
    - Victoria Lake Caravan Park Levee. This is the raised ground around the perimeter of the west side of the lake (i.e. not a levee bank as such).
- Mooroopna
    - McLennan Street service road. Upon inspection, this was revealed as a short section of bank which does not link to McLennan Street (i.e. would require temporary levee works to prevent floodwater from entering the service road and surrounds).
    - Carr Crescent – between rear of Carr Crescent properties and Goulburn River. When inspected, no levee bank was found. A retaining wall is present at the rear of one of the Carr Street properties.
    - Heathmont Park – 50 m long only at western boundary. Upon inspection, this bank is across a local flow path acting as a retardation basin embankment.
    - Norton Drive sedimentation pond embankment opposite 58 Norton Drive. Upon inspection, it was confirmed that this feature is not a levee bank.
    - Bank parallel with Norton Drive adjacent to the sedimentation pond site. Upon inspection, it was identified that this bank is a retarding basin embankment, not a levee bank.
- Murchison
    - Riverbank Gardens at Murchison (as per Figure A4 of this report).
- Toolamba
    - Meadow Drive Drainage Reserve. Upon inspection, it was identified that this feature is a low-level berm in the base of the floodplain with no strategic flood protection importance.

At the workshop meeting on the 5 August 2025, Council advised that they currently do not actively manage any of the above levees. Council requested that the levees be categorised as Category 2 (unmanaged) until such time that they have set up and are undertaking formalised, scheduled and documented maintenance activities.

APPENDIX B Strathbogie Shire Council Levee Assessments

B1 Euroa

Euroa township (population 3,100 at 2021 census) is located on the north side of the Hume Freeway between Avenel and Violet Town. Seven Creeks (catchment area 337 km^2) is aligned through the centre of town. Castle Creek (catchment area 80 km^2) is aligned on the south western fringe of the town.

A levee is located on the town side of Castle Creek (Castle Creek Levee – refer to Figures B1 and B2) which protects the western side of the town from flooding. The previous levee was upgraded in the year 2000 with the aim of achieving 600 mm of freeboard above the 1% AEP flood level. The levee is 2.4 km long averaging 1.25 m in height, with a maximum height of 1.4m.

An informal levee is located on the west side of Castle Creek, immediately downstream of Clifton Street at 207 Euroa Main Road (refer to Figures B1 and B2). This rural levee appears to have previously protected what is now a semi dilapidated house, although possibly still lived in.

A further levee is located at 183 Euroa Main Road (refer to Figures B1 and B2). This levee is a ring levee protecting a house on a rural property.

Euroa Post Flood Mapping and Intelligence Project (Cardno, 2015)

This report documents the actual Castle Creek Levee freeboard. The report indicates that the 1% AEP freeboard varies from 0.31 to 0.75m. The report recommends that the southern most levee segment (approx. 400m) be raised to achieve 0.6 m of freeboard.

Euroa Levee Upgrade Works (2017)

Upgrade works to the Castle Creek Levee were completed in 2017. Two thirds of the cost of the works were funded by the Victorian State Government with Council contributing the remaining one third. The works are understood to have included the raising of the levee to achieve 600 mm of freeboard as per the recommendation made by the 2015 Cardno report. The funding agreement for the works includes a commitment from Council to maintain the levee in the future.

Euroa Flood Emergency Plan (2020)

Appendix C2 within the 2020 Strathbogie Shire Flood Emergency Plan documents a FEP for Euroa township. The FEP states that:

- Since the upgrade of the Castle Creek levee in 2000, most of the flooding problems at Euroa are caused by Seven Creeks.
- Available flood warning time is short, 10 to 20 hours from commencement of rainfall.
- Local runoff flooding also causes issues, but not as severe as the creek flooding.
- Two bund segments are reported by the FEP to be present on Seven Creeks, which are said to assist in raising the threshold of flooding, but have little influence in a 1% AEP flood.
- Above floor flooding of 150 properties in 1993 (equivalent to 2% AEP event).
- No temporary levee works actions are nominated by the Flood Intelligence Card.
- The FEP Flood Intelligence Card refers to ‘sandbagging (or evacuation) of 207 Euroa Main Road at the major flood level which is lower than the 20% AEP flood level.
- The FEP Flood Intelligence Card refers to ‘consider how to deal with 183 Euroa Main Road at the major flood level.

SDS Data

The Castle Creek levee is captured within the current levee layer of the SDS. Attribute data of note:

- Freeboard nominated as uniform 600mm
- Levee is located on private property upstream (south) of Simpsons Lane
- Levee is located on Crown land downstream (north) of Simpsons Lane
- Levee owner listed as Strathbogie Shire Council

Site Inspections – 207 Euroa Main Road

A site inspection at 207 Euroa Main Road revealed an informal low level earth levee in poor condition protecting an old house (refer to Figure B2 – Photograph 3). The house appears not to be lived in full time, or perhaps not at all. There was no one present at the time of the site inspection with no indication of recent presence.

Site Inspection – Castle Creek Levee

A site inspection of the Castle Creek Levee in November 2025 revealed:

- There is extensive vegetation regrowth within the crest and batters of the levee at many locations along the levee route. Some of this regrowth has progressed to the point where it needs removal in the short term otherwise it will become a far bigger and expensive task to address once further growth has occurred.
- Two drainage outlets were located within the levee. These are located immediately upstream of the Euroa Main Road and opposite the homestead located 800 m north of the Hume Freeway. Both are 225 mm diameter pipes fitted with flap gates on the wet side of the levee. A third pipe inlet was located on the dry side of the levee at the rear of 8 Boundary South Road, however no outlet was able to be located on the wet side of the levee, possibly due to it being buried.
- Minor superficial scratching of the levee surface was present along the levee route due to mainly rabbits.
- A fallen tree across the levee was present approximately 150 metres south of the Boundary South Road. Based on its appearance, the fallen tree appeared to have been present for some considerable period.

The Funding Agreement signed by Council for the Castle Creek Levee works undertaken in 2017 is on the basis of a stated '*commitment to ongoing maintenance from beneficiaries*'. Strathbogie Shire Council is therefore obliged to undertake the necessary ongoing maintenance required to keep the levee in a fit for purpose condition.

Site Inspection – 183 Euroa Main Road

A site inspection at 183 Euroa Main Road revealed a 170 m long formal ring levee made from large concrete blocks (refer to Figure B2 – Photograph 4). Other details based on an interview with the owner / occupant are:

- Levee construction was completed in 2021 as arranged and paid for by the GBCMA and Council, as a compensatory measure in response to the increase in flood level caused by the Castle Creek Levee.
- Levee height varies from 0.8 to 1.1 m high.
- October2022 flood peaked 0.5 m below the top of the levee.

- Two access opening in the levee (4m wide and 1.5m wide respectively) which are sandbagged by the owner / occupant when required.
- Owner advised that they do not require assistance at this point to sandbag the two openings when needed with approximately 8 hours warning time available. This may however change as they become more elderly.

Site Inspections – 207 Euroa Main Road

- A site inspection at 207 Euroa Main Road revealed an informal low level earth levee in poor condition protecting an old house (refer to Figure B2 – Photograph 3). The house appears not to be lived in full time, or perhaps not at all. There was no one present at the time of the site inspection with no indication of recent presence.

Preliminary Categorisation

Preliminary classification as follows:

- The Castle Creek Levee. Formal engineered levee with 600 mm freeboard managed by Strathbogie Shire Council. Category 1 is appropriate category.
- 183 Euro Main Road. Formal levee with considerable freeboard. Classified as a Private Levee.
- 207 Euroa Main Road. Informal low-level levee with at least one gap in levee. Classified as a Private Levee.

Management Issues

Council has advised that there is no Operation and Maintenance Manual for the Castle Creek Levee. Maintenance would therefore appear to be somewhat ad-hoc at best and more reactive than systematic scheduled maintenance. Council acknowledged that they should organise themselves to start maintaining the levee as per the 2016 grant funding agreement conditions.

The levee at 183 Euroa Main Road appears to have been constructed by government (local and state) as a compensatory measure to offset the effect of the Castle Creek Levee. Maintenance is minimal given its concrete block formation. Ongoing communication with the owner/occupier in relation to operational measures (e.g. sandbagging of openings) is recommended.

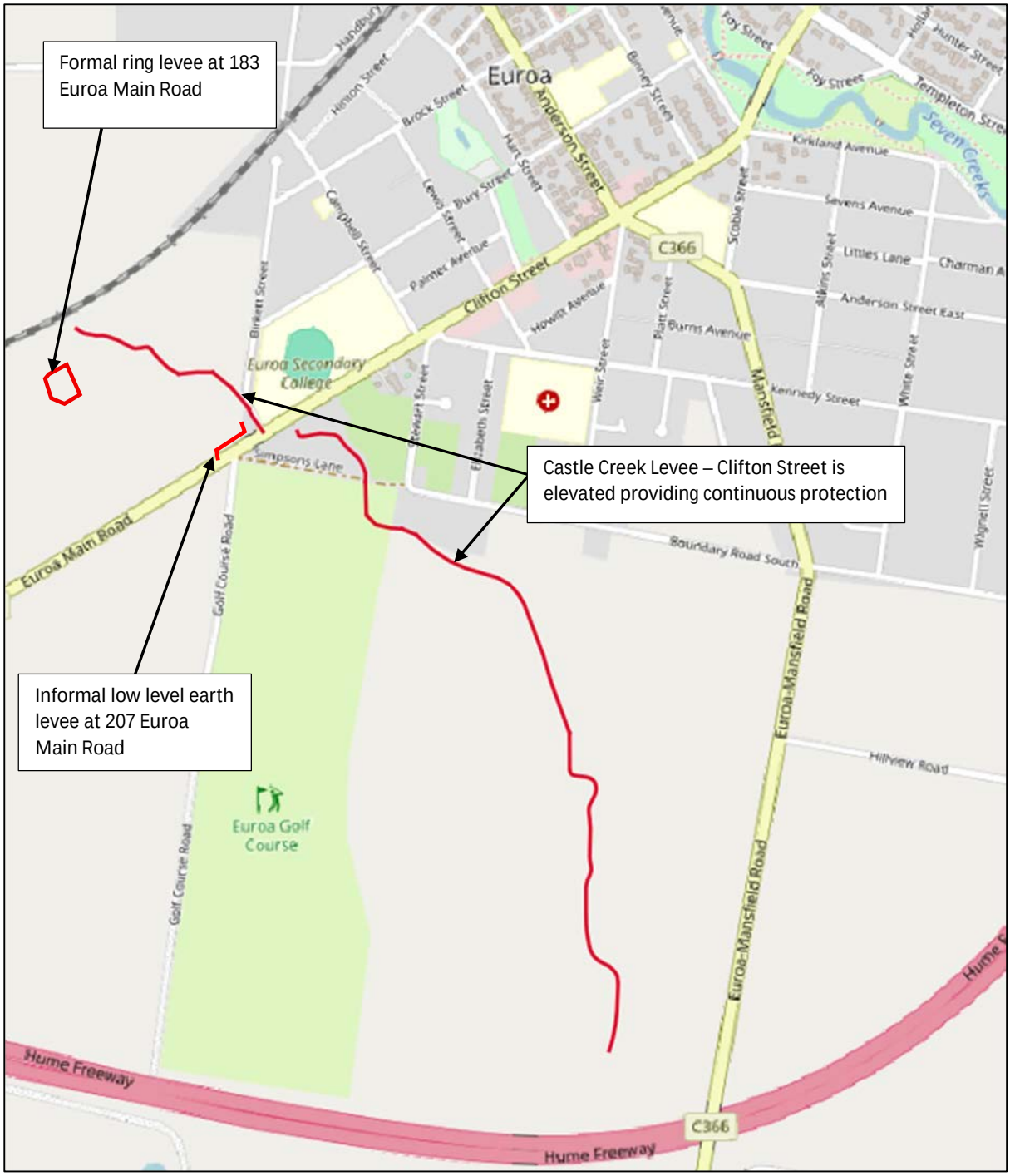


Figure B1 Euroa Levees Locality Plan



Photo 1 – Castle Creek Levee at Clifton Street crossover



Photo 2 – Castle Creek Levee – regrowth in crest



Photo 3 – Informal levee on west side Castle Creek at 207 Euroa Main Road



Photo 4 – Formal ring levee at house at 183 Euroa Main Road

Figure B2 Euroa Photographs

B2 Avenel

Avenel township (population 1,100 at 2021 census) is located on Hughes Creek (catchment area 528 km^2), 15 km north east of Seymour.

No detailed flood studies and / or mitigation studies have been undertaken previously for Avenel. A detailed flood study for Avenel is to commence in 2025/2026. The CMA's 2018-2028 Goulburn Broken RFMS does not identify any levees as being present at Avenel.

Avenel Flood Emergency Plan (2020)

Appendix C1 within the 2020 Strathbogie Shire Flood Emergency Plan documents a FEP for Avenel. The FEP states that:

- Avenel experiences localised flooding within the township
- Flooding on the east side of the creek is confined by a steep escarpment
- Flooding on the west side of the creek is not as confined
- An informal levee is present on the eastern side of Scobie Street within the road reserve (refer to plan below)

The Flood Intelligence Card within the Avenel FEP indicates that:

- Houses along Jones Street may be flooded to above floor level in a 10% AEP to 5% AE event (Jones Street is located on eastern fringe of Avenel).
- Scobie Street levee is overtopped in a 1% AEP event.

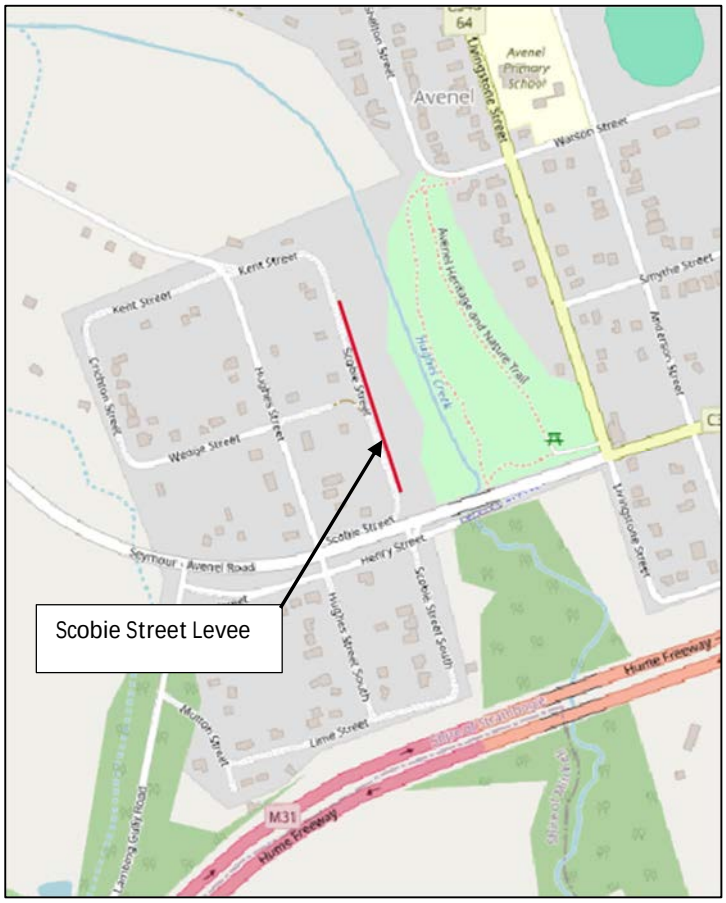


Figure B3 Avenel Levee Locality Plan



Photo 1 – Scobie Street looking north, levee within road reserve



Photo 2 – Looking west across Scobie Street, houses on west side of road

Figure B4 Avenel Photographs – Scobie Street Levee

SDS Data

The Scobie Street levee (refer to Figure B3 and B4) is captured within the current levee layer of the SDS. Attribute data of note:

- Listed as being located on Crown land managed by Strathbogie Shire Council
- No levee owner nominated

Preliminary Categorisation

The Scobie Street levee is described as:

- Informal earth levee
- No apparent owner / manager

The Scobie Street levee fits within the Category 2 – Type A categorisation.

B3 Violet Town

Violet Town township (population 930 at 2021 census). Violet Town is located on Honeysuckle Creek (catchment area 59km^2). Long Gully Creek (catchment area 11 km^2) also known as Lambing Gunyah Creek flows through the south western town fringe.

Appendix C4 within the 2020 Strathbogie Shire Flood Emergency Plan documents a FEP for Violet Town. The FEP states that:

- Violet Town was significantly impacted by flooding in October 1993 and April 1999.
- Township flooding is significantly influenced by the elevated railway embankment and the Hume Freeway embankment.
- Informal levee present on Long Gully Creek upstream of Balmattan Road (this is outside the town, south of the Hume Freeway). Anecdotal accounts suggest the levee may have been built by the then council during the mid 1950s. Levee has not been managed / maintained for a long time.
- There are no other levees at Violet Town.

The relatively small catchment above Violet Town means that the available flood warning time is too short for flood warning services and / or temporary mitigation works such as temporary levees.

A site inspection of the Long Gully Creek levee upstream of Balmattum Road was undertaken. The levee is a relatively low level, typical rural type earth levee on the east side of Long Gully Creek (refer to Figures B5). The levee has been breached towards its northern (downstream end – refer to Figure B6 – Photograph 2), possibly to allow for Long Gully Creek flows to spill into a large dam on the adjoining east side waterway. This levee has been classified as Category 2 – Type B. The breach would need to be plugged for the levee to function.

Further site inspections were carried out at Violet Town in the vicinity of the Honeysuckle Caravan Park, Marys Lane and Honeysuckle Creek upstream of the Hume Freeway. No levees or significant floodplain features were identified.

The Violet Town Floodplain Management Scheme proposes a new flood levee. Implementation of the new levee scheme has not to date occurred.



Figure B5 Violet Town Levee Locality Plan



Photo 1 – Long Gully Creek Levee



Photo 2 – breach in the Long Gully Creek Levee

Figure B6 Violet Town – Long Gully Creek Levee Photographs

B4 Nagambie

Nagambie township (population 2,000 at 2021 census) is located on the Goulburn River at Lake Nagambie. Appendix C3 within the 2020 Moira Shire Flood Emergency Plan documents a FEP for Nagambie. The FEP states that:

- Nagambie is not expected to be affected by river flooding with the exception of a small section of low lying land adjoining Lake Nagambie.
- The town is affected by local runoff / stormwater flooding.
- The Caravan Park on the south side of the town is affected by river flooding.
- No reference to any existing levees.

The 2018-2028 Goulburn Broken RFMS makes reference to a rural levee within Vickers Road and a western approach ramp to the old Chinaman's Bridge as impeding floodwaters. The removal of the levee and ramp are flagged as proposed.

The 2017 Nagambie Flood Study report (BMT WBM, 2017) makes no reference to any purpose built levees at Nagambie.

No levees at Nagambie have been captured within the SDS as at 2024.

A site inspection confirmed that the original Chinamans Road bridge and the immediate approach ramp embankments at the bridge site are still present (refer to the photographs in Figure B7). These remnant embankments would not appear to be significantly influencing flooding conditions and have not been further investigated.



Photo 1 – Chinamans Bridge – west side approach ramp at original bridge



Photo 2 – Chinamans Bridge – east side approach ramp at original bridge

Figure B7 Nagambie Photographs

B5 Consultation with Council

The Strathbogie Shire Council was contacted in regards to urban levee related matters within the GBCMA region. Officers from Council were interviewed on the 24 September 2024. Discussions revealed that:

- Council is conscious that it is the owner / manager of the Castle Creek Levee at Euroa. No formalised operation and maintenance procedures (e.g. O&M Manual) have been developed for the levee however.
- Council is also aware of the informal levee at Scobie Street, Avenel. Council undertakes routine road reserve maintenance for Scobie Street not connected with any upkeep to the levee.
- Council is not aware of any other existing levees impacting on flooding conditions at any of the other townships within the Strathbogie Shire.

Council subsequently supplied information by email on the 29 October 2024 confirming that the Castle Creek Levee was raised in 2017 to achieve 600 mm of freeboard.

At a workshop meeting on the 6 August 2025:

- Council advised that they don't undertake systematic or scheduled maintenance of the Castle Creek Levee. Subsequent to the meeting, documentation of the Castle Creek Levee upgrade funding agreement was located which specifies that beneficiaries are to commit to ongoing maintenance.
- Council advised of a significant number of raised local roads at townships (Violet Town, Avenel, Nagambie) which act as significant floodplain features.

- Council advised of several private levee management issues which are known to Council.

Following the workshop meeting, further efforts including on-site inspections were made to clarify several matters including reported rural levees south of Violet Town (refer to Section B3) and a private levee on the western fringe of Euroa(refer to Section B1).

APPENDIX C Moira Shire Council Levee Assessments

C1 Cobram

Cobram township (population 5,400 at 2021 census) is located on the Murray River, 33km west of Yarrawonga.

Cobram is protected by a levee scheme which was raised and strengthened in 2000/2001. The Cobram levee system encompasses (refer to Figure C1):

- Dicks Levee (also referred to as Dicks Spillway) located 6 km south east of Cobram. Dicks Levee is a 440m length levee which spans a gap in the adjoining sand hills, preventing the breakout of Murray River floodwaters up to the 5% AEP event. Dicks Levee functions as a spillway for Murray River floods exceeding 5% AEP.
- Cavagna's Levee located 3 km south east of Cobram. Cavagna's Levee is a 115 m length levee which prevents the breakout of Murray River floodwaters.
- Elevated allotments next to River Road commencing approximately 200 m upstream of Mookarii Street (Barooga-Cobram Road).
- Concrete wall segment referred to as Denson's Levee, approximately 200m in length, between the River Road elevated allotments and Mookarii Street.
- Temporary levee at Mookarii Street.
- Levee located downstream of Mookarii Street referred to as the Town Levee (3.9 km in length). The downstream limit of the Town Levee connects to a water storage embankment on the north side of Harris Road.

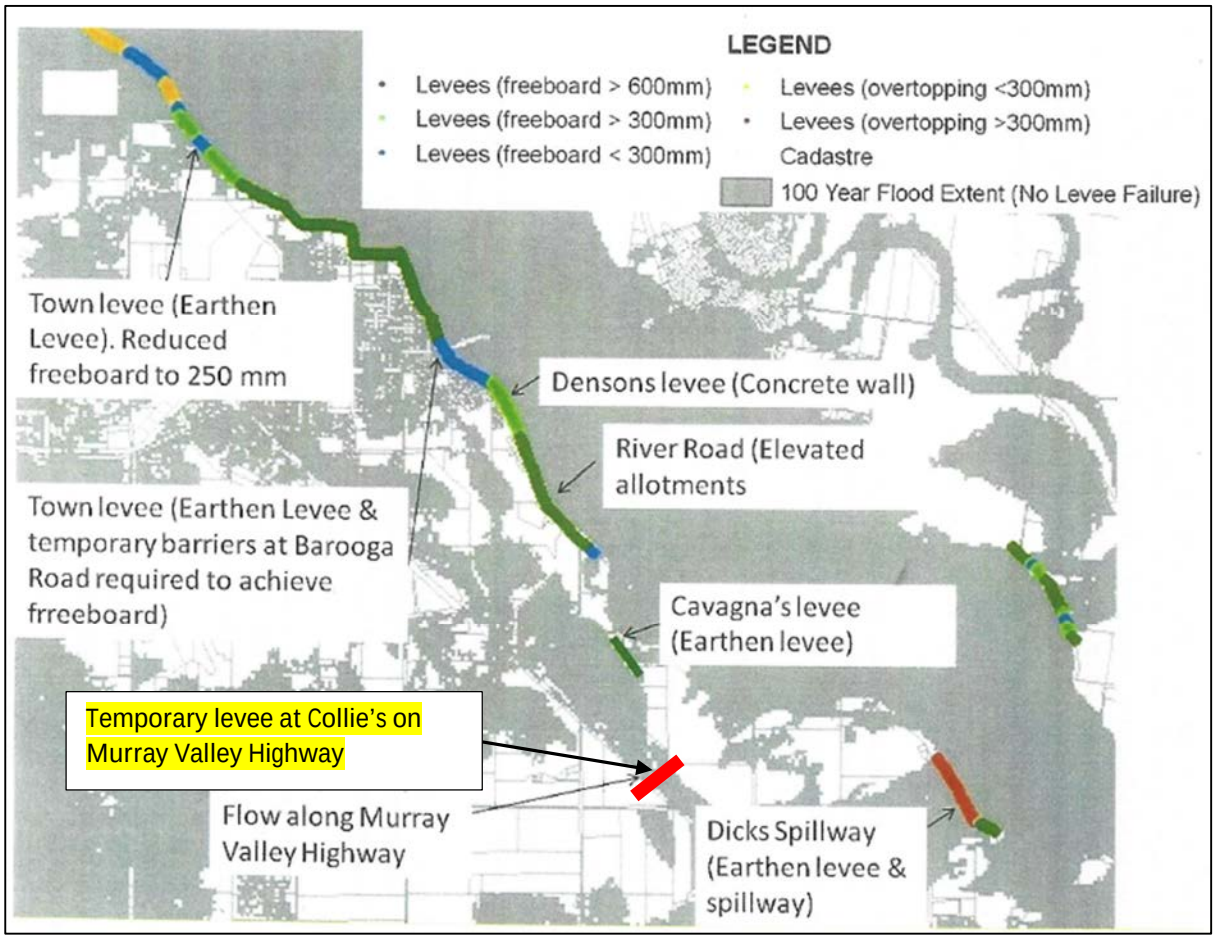


Figure C1 Cobram Levee Scheme Locality Plan

Murray River Regional Flood Study (2011)

The above levee system is described in the Murray River Regional Flood Study report (Water Technology, 2011). The levee system was upgraded to its current state following investigations in the 1980s and 1990s.

The 2011 Regional Floodplain Strategy report recommends that:

- Arrangements for the temporary structure at the Mookarii Street be defined within the Moira Shire Flood Emergency Plan.
- No other recommendations specific to Cobram township.

Dick's Levee prevents floodwater breaking away from the river channel aligned floodplain, which would result in widespread inundation of rural land to the south of Cobram, as occurred notably in 1917 and to a lesser extent 1956 and 1975. The spill level of Dicks Levee coincides with around the 5% AEP flood level. It would be possible to raise the spill level at Dick's Levee, however this would merely result in floodwater entering the southern floodplain further upstream as noted by the 2011 Regional Floodplain Strategy report. Retaining the status quo is understood to remain the current management strategy.

Urban Levees Review (SKM, 2014)

The 2014 report for the Urban Levees Review project identifies that the Cobram Town Levee downstream of Mookarii Street provides 3% AEP protection assuming 600mm of freeboard. Assuming zero freeboard, the levee provides 0.12% AEP protection (approximately 1 in 800 year ARI).

The 2014 report indicates that the Cobram Town Levee is subject to a basic inspection every six months and a detailed inspection every 12 months based on advice given by a staff member of Council.

Cobram Flood Emergency Plan (2020)

Appendix C3 within the 2020 Moira Shire Flood Emergency Plan documents a Cobram Flood Emergency Plan (FEP). Much of the content is based on the 2011 Murray River Regional Flood Study. The Flood Intelligence Card within the FEP calls for:

- Closure of various drainage structures under the Cobram levee at a Yarrawonga gauge height of 6.6 to 6.8 m (flow at 6.7 m is quoted as 98,000 ML/day – equivalent to less than 20% AEP event)
- Construction of a temporary levee across the Murray Valley Highway at 'Collie's' at a Yarrawonga 5% AEP gauge flood height of 8.5 m (251,000 ML/day). There are no details in the MFEP in regard to the precise location, width, height etc for the temporary levee.
- Install temporary barriers (e.g. sandbagging) across property access driveway at 22 River Road (gap in Denson's Wall) at Yarrawonga 2% AEP gauge height of 9.0 m (328,000 ML/day).
- Install temporary levee across Mookarii Street at Yarrawonga 1% AEP gauge flood height of 9.3 m (387,000 ML/day). Described as potentially a clay bank.

The largest flood at Yarrawonga since 1917 occurred in 1975 when floodwater peaked at 242,000 ML/day, just below the 5% AEP flood level.

Corowa, Howlong & Mulwala Flood Study (WMAwater, 2024)

This project was undertaken by Federation Council. The final report was issued in October 2024. The study adopts design flood flows at Yarrawonga based on the results of flood frequency analysis. The adopted flows are:

- 20% AEP (approximately 4.5 year ARI) – 131,000 ML/day
- 10% AEP (10 year ARI) – 189,000 ML/day (2011 study – 193,000 ML/day)
- 5% AEP (20 year ARI) – 249,000 ML/day (2011 study – 251,000 ML/day)
- 2% AEP (50 year ARI) – 333,000 ML/day (2011 study – 328,000 ML/day)
- 1% AEP (100 year ARI) – 390,000 ML/day (2011 study – 387,000 ML/day)
- 0.5% AEP (200 year ARI) – 450,000 ML/day (2011 study 448,000 ML/day)

The above flows remain practically the same as the 2011 Murray River Regional Flood Study estimates.

Tocumwal and Barooga Flood Study (WMAwater, 2025)

A flood study undertaken for Berrigan Shire Council for the reach of the Murray River between Yarrawonga and downstream of Tocumwal was completed in early 2025 (WMAwater, 2025). This study adopted the above design flow estimates at Yarrawonga.

Current Cobram East Levee Design Project

An ongoing project led by Moira Shire Council and its Steering Committee aims to upgrade the levee protection scheme east of Cobram to further protect Cobram township from flooding in the event of outflows at Dicks Spillway. This project is currently assessing options prior to progressing to design and implementation.

SDS Data

The following comments are made in relation to the SDS levee layer associated with the Cobram scheme levees as at 2024:

- Dicks Levee, Cavagna's levee captured – minimal assignment of the expanded attribute data
- Upstream of Mookarii Street – Denson's Levee captured
- Downstream of Mookarii Street – entire route captured, multiple segments, moderate assignment of expanded attribute data. Attributes not assigned include freeboard, reliability.

Preliminary Categorisation

The Cobram levee scheme, including Dicks Levee, Cavagna's Levee and the levees at Cobram upstream of Harris Road are described as:

- Varying in form – earth levee, concrete wall, temporary segments
- Varying in freeboard – minimum is 250 mm above 1% AEP (excludes Dicks Levee spillway which is designed to overtop at the 5% AEP flood level)
- Owned / managed by Moira Shire Council (levees are a declared Council asset)
- Require monitoring during flood events as do most levees
- Largely untested due to absence of major flood events since 1975 flood. The 1975 flood peaked at 242,000 ML/day. Both 2016 and 2022 peaked at 182,000 ML/day at Yarrawonga, not sufficiently high to initiate outflows at Dicks Levee.

The Cobram levees are clearly Category 1 levees given the above circumstances.

Management Issues

The current Cobram FEP would benefit from:

- Further details being provided in relation to the Murray Valley Highway temporary levee at Collie's – wherever this is (precise location, type structure, source materials, width, height etc). Current reference to Collie's in the FEP is on page 63 – second paragraph. This matter is linked to the ongoing Cobram East levee improvement project.
- Similarly further details being provided in relation to the Mookarii Street temporary levee.
- Further details in regards to temporary measures associated with closing of the access driveway at 22 River Road.
- Newly identified potential temporary levee identified as part of a current FEP update project located at Racecourse Road, just north of Harris Road at Cobram north.

There are height triggers nominated for each of the above in the Flood Intelligence Card except for the Racecourse Road site which is a newly identified action. None of the height triggers will have been reached since the 1975 flood event.

Preliminary details are as follows for three of the above four sites (refer to Figures C2 and C3). The location of the Collies temporary levee site is yet to be confirmed.

- Mookarii Street
  - 1% AEP flood level – 116.16 m AHD
  - Road crown – 115.89 m AHD
  - Temporary levee height – 116.76 m AHD (0.6 m above 1% AEP flood level)
- 22 River Road – opening in concrete wall:
  - 1% AEP flood level – 116.16 m AHD
  - Temporary levee height – 116.76 m AHD (0.6 m above 1% AEP flood level)
- Opening between lagoon embankment and channel banks at Racecourse Road site:
  - 1% AEP flood height 113.58 m AHD
  - Ground surface varies 113.1 to 113.8 m AHD
  - Temporary levee height – 114.18 m AHD (0.6 m above 1% AEP flood level)

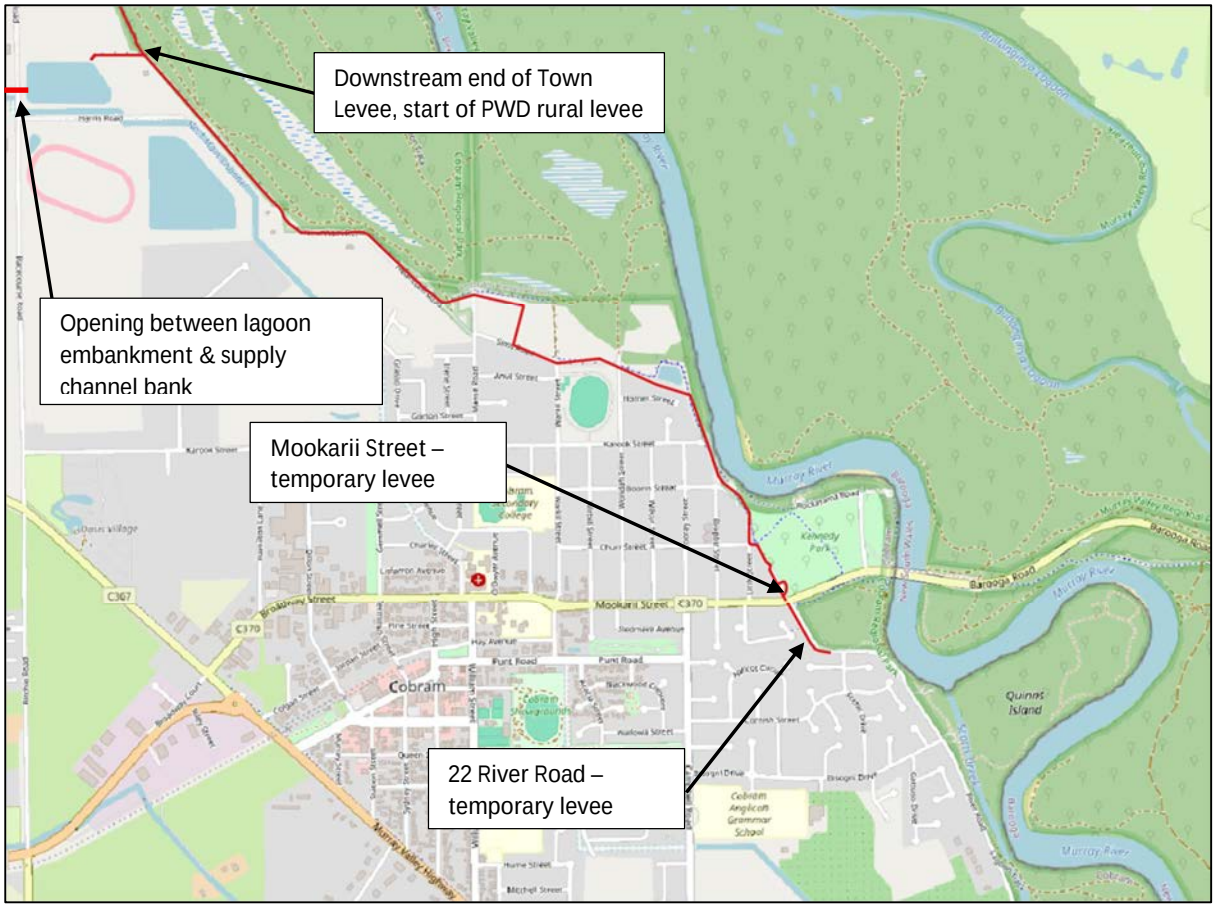


Figure C2 Cobram temporary levee segments



Photo 1 - Gap in concrete wall levee at 22 River Road



Photo 2 – Concrete Wall (Denson's) Levee north of Mookarii Street



Photo 3 – View looking north across Mookarii St, site of temporary levee



Photo 4 – Town levee on south side of town, new development on dry (right) side

Figure C3 Cobram Levee Photographs

C2 Barmah

Barmah township (population 230 at 2021 census) is located on the Murray River, 25 km upstream of the Goulburn River confluence.

Barmah township is located upstream of the Barmah Choke. Goulburn River inflows into the Murray River floodplain are located downstream of the Barmah Choke. Goulburn River overflows into the Deep Creek floodway flow into the Murray River floodplain upstream of the Barmah Choke. Large Goulburn River inflows can lead to reverse flow through the Barmah Choke.

Most, if not all of Barmah is inundated based on a 1% AEP Murray River flood level of 96.9m AHD.

An informal levee system is present at Barmah. Site inspections and examination of the LiDAR data have identified the following levees (refer to Figures C4 and C5):

- The southern most segment of the Murray River rural levee (Pirie Creek to Barmah 37 km long segment) which is aligned parallel to the river side of Moira Lakes Road. This terminates approximately 300 m north of Corry Street.
- Corry Street Levee (340m) – aligned on north side of Corry Street. Does not connect to Moira Lakes Road. Gaps at three driveway entry points. Crest height approx. 96.9 to 97.2 m AHD based on 1994 survey (RWC – 201841).
- Evans Street Levee (390m) which connects to Murray Street. Crest height varies 96.4 to 96.8 m AHD (1994 survey).
- Barmah Bridge Caravan Park Levee (190m). Crest height 96.2 to 96.4 m AHD (1994 survey).
- Riverview Drive Levee (500m) – located between the river and Riverview Drive. Crest height 96.6 to 96.7 m AHD (1994 survey).

Aside from the Murray River levee north of Barmah, none of the above levees as at 2024 had been captured for inclusion in the SDS levee layer.

Assessment of Flood Risk to Township of Barmah & Preliminary Flood Mitigation Review (SKM, 2008)

This 2008 report concludes that the then existing levees at Barmah are structurally inadequate and would need to be replaced with new levees, if a levee scheme was to be pursued. The existing levees were found be in poor condition, with large sections removed for driveway access, crests and batters scoured, inadequate tie in with high ground and no consistent standard of protection.

Barmah Township Flood Mitigation – Functional Design (Water Technology, 2013)

A proposal for a formal engineered levee at Barmah is documented in the Barmah Township Flood Mitigation Functional Design report (Water Technology, 2013). Plans of the proposed ring levee are included in the 2013 report. This proposal has not proceeded, presumably due to lack of funding / support (TBC).

Barmah Flood Emergency Plan (Moira Shire Council, 2020)

Appendix C6 within the 2020 Moira Shire Flood Emergency Plan documents a Barmah Flood Emergency Plan (FEP). The FEP states that:

- Levees at Barmah are effective at providing protection up to approximately a 3% AEP event.
- The 1993 and 1975 events were approximately equivalent to a 3% AEP event.

- Considerable efforts (sandbagging) were made during the 1993 flood to prevent Barmah from flooding.
- Protection in a 1% AEP event is not considered achievable via temporary works.
- A flood level of 7.3 m at Yarrawonga (140,000 to 150,00 ML/day) indicates that Barmah is likely to be at risk of flooding.

Future Barmah Floodplain Management Plan Project

Moira Shire Council has received a 2023 Victorian State Government grant to develop a Floodplain Management Plan for Barmah township. This will include an assessment of the potential upgrade of the levee system at Barmah. The grant was received in the aftermath of the flooding experienced in the spring of 2022. The project is yet to commence.

SDS Data

The SDS levee layer excludes any levees at Barmah, other than the Murray River levee to the north of Barmah.

Preliminary Categorisation

The Barmah informal levee system is not currently managed outside of flood response activities. They are not therefore Category 1.

Depending on the size of the forecast flood event, temporary works to the levees have been initiated in past flood events (e.g. 1993 and 2022) to prevent flooding of the town. Category 2, Type B would therefore appear to be the applicable category for the Barmah levees.

The local CFA unit is understood to have taken a lead role in flood response activities at Barmah in 2022. Moira Shire Council had minimal involvement due to limited available resources.



Figure C4 Barmah Levees Locality Plan



Photo 1 – Corry Street levee from the eastern end of the levee



Photo 2 – Riverview Drive levee from the south end of the levee



Photo 3 – Evens Street levee from the west end of the levee



Photo 4 – Rural levee north of Barmah – on river side of Moira Lakes Road

Figure C5 Barmah Levee Photographs

C3 Nathalia

Nathalia township (population 1,980 at 2021 census) is located on the Broken Creek, 22 km east of Barmah and the Murray River.

The Broken Creek receives runoff from its local catchment and can also receive breakaway inflows from the Broken River, as occurred in 1993.

Flooding at Nathalia generally peaks about 2 to 4 days after the peak at Walshs Bridge (Broken Creek gauge located upstream of Nathalia).

Flooding of properties does occur outside the levee protected zone.

Nathalia Floodplain Management Study (SMEC, 2005)

This report documents a combined flood study and floodplain risk management study for the township of Nathalia. The report recommends that the then levee be raised to protect the town from 1% AEP flooding. The levee was subsequently upgraded in 2010.

Urban Levees Review (SKM, 2014)

The 2014 report for this project documents the following level of protection:

- Levees on north side of the Broken Creek
    - Assuming zero freeboard – 0.7% AEP (142 years ARI)
    - Assuming 600 mm freeboard – 22% AEP (4.5 years ARI)
- Levees on south side of Broken Creek
    - Assuming zero freeboard – 0.13% AEP (770 years ARI)
    - Assuming 600 mm freeboard – 15% AEP (6.7 years ARI)

Nathalia Flood Emergency Plan (2020)

Appendix C12 within the 2020 Moira Shire Flood Emergency Plan documents a Nathalia Flood Emergency Plan (FEP). The FEP states that:

- Nathalia is protected from 1% AEP flooding by a levee system. The levee was upgraded in 2010. The levee freeboard ranges from 450 to 600 mm.
- The levee is predominantly earthen (permanent) except for some temporary segments:
    - Demountable aluminium panels are used at road crossings and at the foreshore area.
    - Temporary levee at 3 Draper Street (levee segments to the north and south of the house at this property).
- GMW Channel 12 acts as a levee on the south side of town (preventing the influx of Goulburn River floodwater into the Broken Creek floodplain).

The levee system at Nathalia is shown in Figures C6 and C7. Temporary actions identified by the FEP as required to prevent flooding are (trigger heights are flood heights at the Broken Creek Walshs Bridge gauge):

- 3.3 m - erect flood barriers in Weir Street (300 m segment))
- 3.35 m – erect flood barriers across Railway Street (10 m segment)
- 3.4 m – erect flood barriers across Murray Valley Highway (25 m segment)
- 3.41 m – erect flood barriers in Bromley Street (130 m segment)
- 3.5 m – two low level levee segments required at 3 Draper Street (40m and 60m)

The FEP advises that it is important that the roadway demountable levees are not erected until close to when required as they severe road access.

SDS Data

Town levee system is captured within the VFD /SDS. Owner listed as Moira Shire Council. Freeboard listed as 300mm.

Moira Shire Council has confirmed that the levees at Nathalia are a Council maintained asset.

Preliminary Categorisation

The 'Nathalia Town Levee' system is managed by Moira Shire Council. Significant work is required during a flood, to erect the temporary segments using demountable panels, once trigger heights at the Walshs Bridge Broken Creek gauge are reached.

All the Nathalia Town Levee system including the purpose-built permanent levees and the temporary demountable panel segment levees have been categorised as Category1.

The temporary levee at 3 Draper Street (two levee segments – 40 m long and 60 m long) has been categorised as a Category 2 – Type C levee.

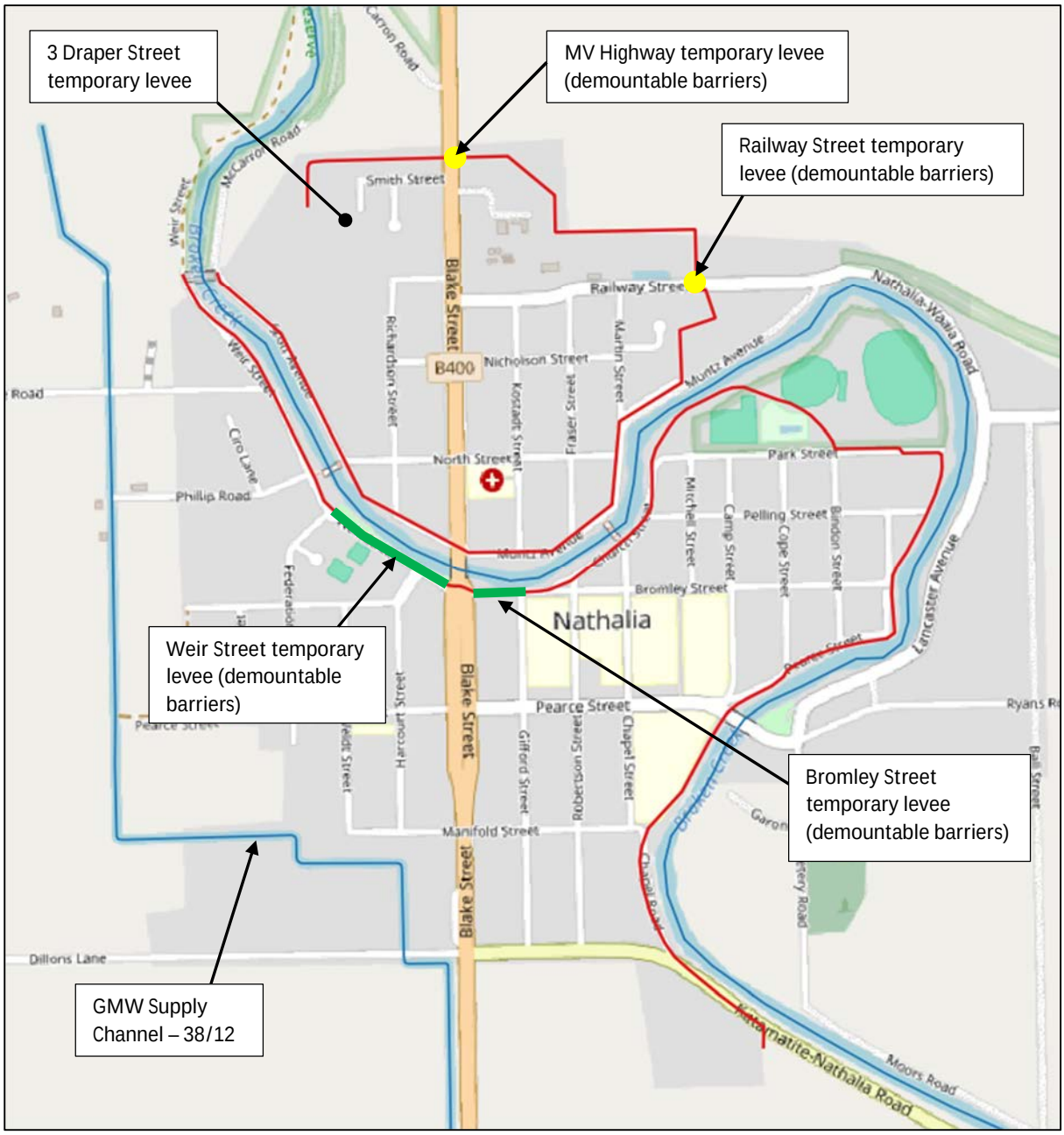


Figure C6 Nathalia Levees Locality Plan



Photo 1 – Murray Valley Highway temporary levee site



Photo 2 – Railway Street temporary levee site



Photo 3 – Weir Street – view back towards MV Highway – temporary levee site



Photo 4 – Chapel Street – typical levee arrangement at Nathalia

Figure C7 Nathalia Levee Photographs

C4 Numurkah

Numurkah township (population 3,800 at 2021 census) is located on the Broken Creek 31 km north of Shepparton.

The Broken Creek receives runoff from its local catchment and can also receive breakaway inflows from the Broken River, as occurred in 1993.

Numurkah was subject to major flooding most recently in the March 2012 event.

Numurkah Floodplain Management Study and Plan (Water Technology, 2017)

The 2017 report documents flood mitigation assessment work undertaken in the aftermath of the 2012 flood. It recommends the establishment of a levee system (Mitigation Package A). The levee system consists of a northern levee (north side of Broken Creek) and a southern ring levee (south side of Broken Creek).

The report states that permanent levees are a necessity at Numurkah due to the limited flood warning time available.

Goulburn Broken Regional Floodplain Management Strategy 2018-2028 (2018, GBCMA)

Appendix F of the 2018-2028 Strategy document refers to a series of levees, typically 300 to 450 mm in height, being put in place following the 1974 and 1993 floods. These levees were designed to protect against floodwaters entering the northern portion of the town. These low-level levees were overwhelmed in the 2012 flood.

Numurkah Flood Emergency Plan (2020)

Appendix C11 within the 2020 Moira Shire Flood Emergency Plan documents a FEP for Numurkah. The FEP states that:

- Non levee infrastructure including roads, railway line, supply channels, drainage channels. This notably includes GMW Channel 6/6 aligned parallel to Kinnairds Road on the east (upstream) side of the town. During the 2012 flood, temporary levees were placed across Pine Street and Wattle Drive to link up the Channel 6/6 banks. This provided significant protection to eastern parts of Numurkah.
- During the 2012 flood, temporary levees placed near the Lakeside Country Club and the south-eastern shore of Lake Numurkah provided significant protection to those areas.
- Flow constrictions at resent at the golf course, Melville Street bridge, railway bridge and GV Highway bridge.
- The railway line acts as a levee – backup as far as Melville Street.
- Both railway line and the GV Highway overtopped at multiple locations in 2012 flood event.
- Any constrictions downstream of Numurkah township do not impact on flooding at the town.
- 2012 flood event more severe than the 1993 event. 2012 – 77 houses and 10 businesses flooded to above floor level. Hospital inundated in 2012.
- Temporary levees not used in the 1993 flood, so there was reported to be more inundation in some areas compared to 2012 notably on north shore of Lake Numurkah.
- Warning time available – in the March 2012 flood, flood levels peaked at Numurkah only 14 hours after peaking at Katamatite, which was shorter than expected. Not much time for temporary works.
- Sandbagging flagged to protect:

- Telecommunications infrastructure
- GVW pump in Thornton Street
- Other locations as shown on page 111 of the 2020 Moira Shire FEP.

SDS Data

The SDS levee layer excludes any levees at Numurkah as of 2024.

Moira Shire Council Asset Database

The Council supplied spreadsheet showing levee assets for Council includes the following levees at Numurkah (refer to Figures C8 and C9)

- Tunnock Road Levee
  - 180 m long, 0.3 m in height
  - Informal levee located immediately adjacent to creek bank – wet side batter is continuation of creek channel bank
  - Protects local parkland
  - Overtopping threshold – 107.86 m AHD
  - Excluding freeboard, the level of protection is equal to approximately the 2% AEP flood
- Brenion Street Levee
  - 330 m long, 0.5 m in height
  - Informal levee offset from creek channel. Bund type form as opposed to engineered levee. Good condition.
  - Protects residential area to north
  - Overtopping threshold – 107.86 m AHD at Melville Street gauge
  - Excluding freeboard, the level of protection is equal to approximately a 5% AEP flood
- Gray Street Levee
  - 290 m long, up to 0.6 m in height
  - Informal levee located at the top of the creek bank. Gravel walking track crest.
  - Protects adjoining residential area and parkland
  - Overtopping threshold – 108.05 m AHD at Melville Street gauge
  - Excluding freeboard, the level of protection is equal to approximately a 2% AEP flood

Preliminary Categorisation

The above Tunnock Road, Brenion Street and Gray Street Levees are listed in Council's asset database. Council has not prepared operation and maintenance manuals for any of these levees. There is no scheduled systematic maintenance performed. The levees are low level levees which do not provide protection in large flood events such as 2012. The levees have been assigned as Category 1 levees.

The banks of GMW Channel 6/6 on the east side of Numurkah acts as a levee. A temporary levee is required at Pine Street to link the two headwalls on either side of the road (refer to Figure C10). A temporary levee is also required at Wattle Drive to link the Channel 6/6 bank on the north side to the elevated development fill on the south side. Category 2, Type C is an appropriate categorisation for these temporary levee segments.

Management Issues

An urban standard levee scheme at Numurkah is in the process of being implemented. Once construction is complete, Council will be responsible for their future maintenance (i.e. Category 1 levees).

Funding has been secured to construct the Stage 1 levees north of the Broken Creek. Construction of Stage 1 for the protection of the northern township area commenced in April 2025 and is likely to be completed by April 2026.

Funding has been secured to complete the detailed design of the Stage 2 ring levee south of the Broken Creek. The detailed design of Stage 2 is in progress as at late 2025.



Figure C8 Numurkah Levees Locality Plan

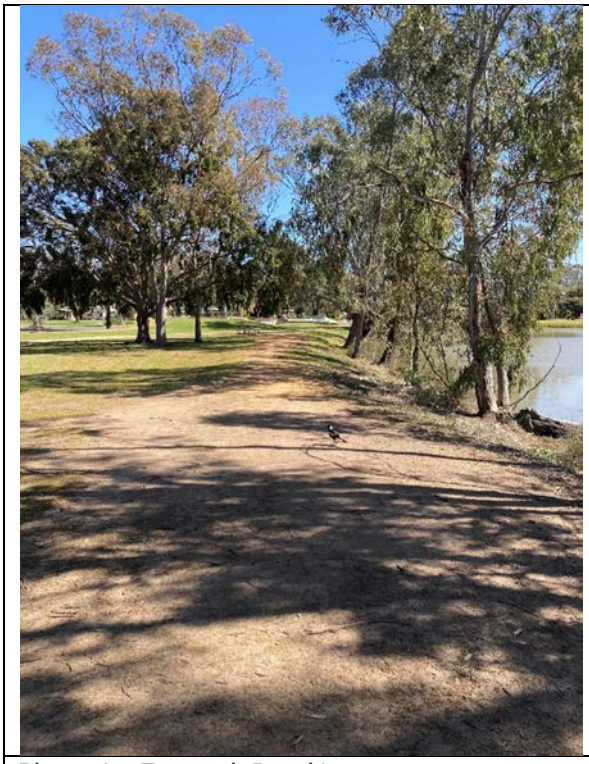


Photo 1 – Tunnock Road Levee



Photo 2 – Brenion Street Levee

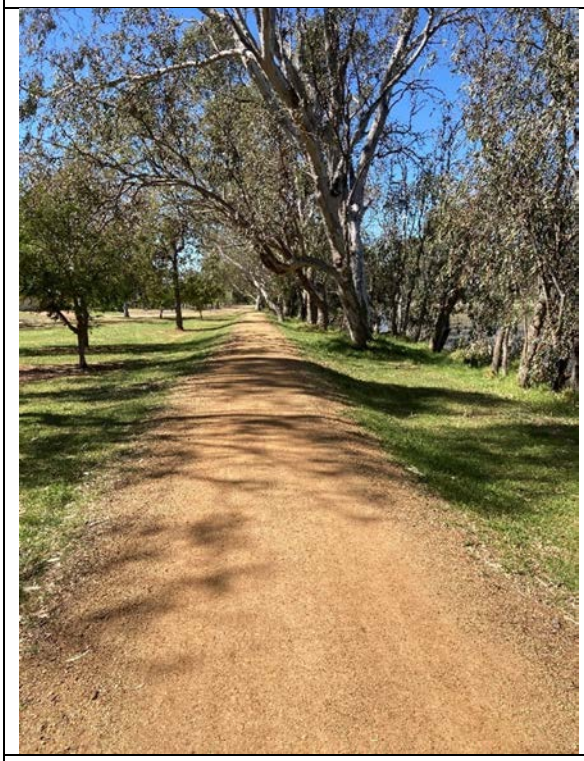


Photo 3 – Gray Street Levee



Photo 4 – Gray Street Levee

Figure C9 Numurkah Photographs

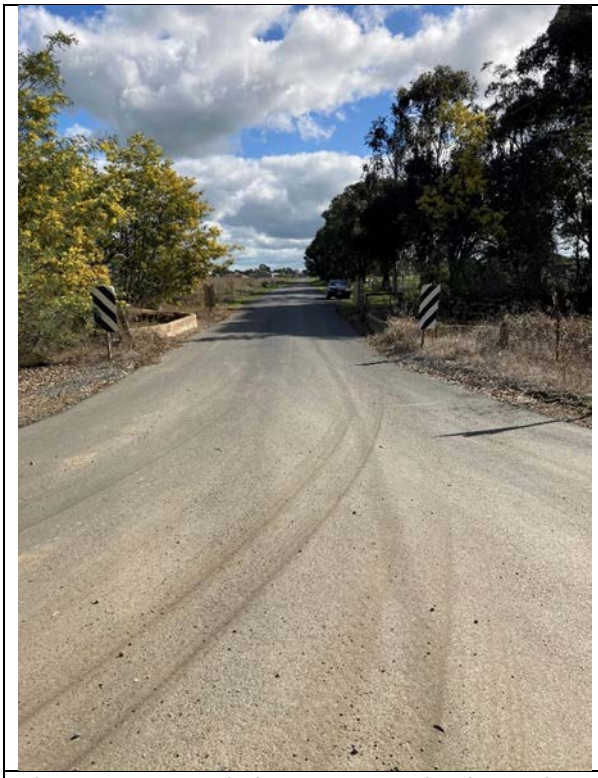


Photo 1 – Numurkah: GMW Supply Channel 6/6 at Pine Street

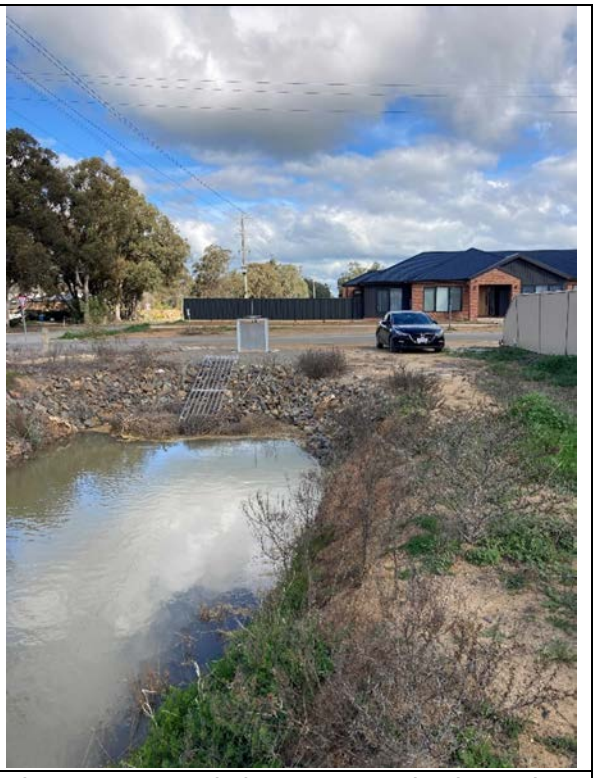


Photo 2 – Numurkah: GMW Supply Channel 6/6 at Wattle Drive

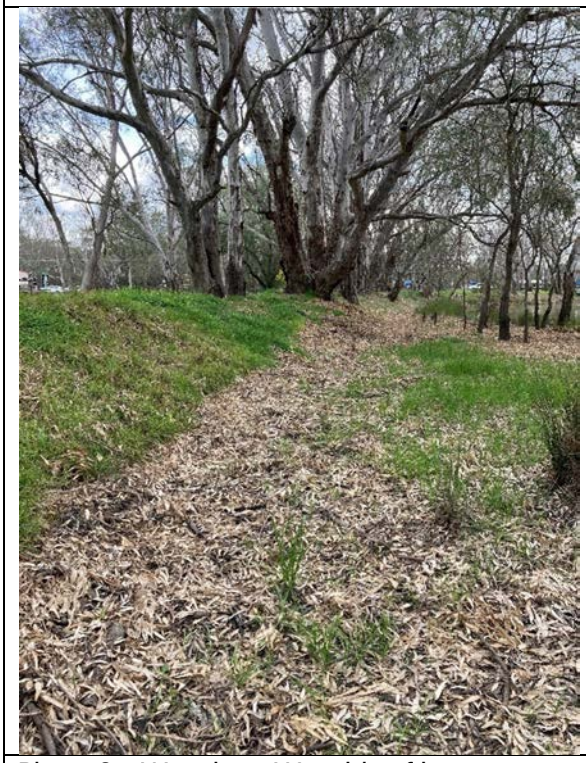


Photo 3 – Wunghnu: Wet side of levee



Photo 4 – Wunghnu: View across levee towards Nine Mile Creek

Figure C10 Numurkah and Wunghnu Photographs

C5 Wunghnu

Wunghnu township (population 320 at 2021 census) is located on the Nine Mile Creek, 6km south of Numurkah. The Goulburn Valley Highway is aligned through the centre of town.

Wunghnu Flood Emergency Plan (2020)

Appendix C11 within the 2020 Moira Shire Flood Emergency Plan documents a FEP for Wunghnu. The FEP states that:

- 11 properties were flooded to above floor level at Wunghnu during the March 2012 flood.
- The Goulburn Valley Highway was flooded to the north and south of Wunghnu, resulting in its closure.
- No previous flood studies have been undertaken for Wunghnu township.
- No references to any levees at Wunghnu.
- No flood response actions documented.

Goulburn Broken Regional Floodplain Management Strategy 2018-2028 (2018, GBCMA)

There is no reference to any existing levees at Wunghnu in the 2018-2028 Strategy document (Appendix F).

SDS Data

The SDS levee layer includes a levee on the south side of Nine Mile Creek between the Goulburn Valley Highway and the Goulburn Valley Railway. Attribute data indicates that the levee is:

- Located on Crown land
- No owner nominated
- 600 mm high earthen levee
- Medium reliability

Preliminary Categorisation

The Wunghnu levee (refer to Figures C10 and C11).is not managed. Moira Shire Council does not list it as one of their levee assets. A site inspection revealed the levee to be an informal rural levee of considerable age.

The available literature does not suggest that the levee is of any strategic importance. There has been no detailed flood study undertaken at Wunghnu to date to confirm this.

The Wunghnu levee is classified as Category 2 Type A.



Figure C11 Wungnu Levee Plan

C6 Other Towns

Yarrawonga

Yarrawonga township (population 8,600 at 2021 census) is located on the Murray River at Lake Mulwala. Appendix C2 within the 2020 Moira Shire Flood Emergency Plan documents a FEP for Yarrawonga. The FEP states that:

- In a 1% AEP Murray River flood, flooding of lawns, parkland etc at Yarrawonga could be expected. Yarrawonga Caravan Park is the only park to be affected.
- There are no existing levees at Yarrawonga.

Tungamah

Tungamah is located on the Boosey Creek, a tributary of the Broken Creek. Appendix C8 within the 2020 Moira Shire Flood Emergency Plan documents a FEP for Tungamah (population 250). The FEP states that:

- Multiple houses were flooded during the March 2012 flood event.
- In a major flood event, 10 to 20 properties are at risk of above floor flooding.
- Little or no flood warning time available.
- There are no existing levees at Tungamah.

Katamatite

Katamatite (population 200) is located on the Boosey Creek, a tributary of the Broken Creek. Appendix C9 within the 2020 Moira Shire Flood Emergency Plan documents a FEP for Katamatite. The FEP states that:

- Approximately 19 properties are flooded to above floor level in a 1% AEP flood.
- Up to 5 days of flood warning time available.
- There are no levees present.
- Sandbagging is the only measure of protecting property and infrastructure.

There are no details given in the FEP in regard to any levees which may be present at Katamatite. There are no levees captured within the VFD / SDS at Katamatite.

Other FEPs

Other non-township based FEPs included within the Moira Shire FEP are:

- Muckatah Depression. Appendix C7 documents a FEP for the Muckatah Depression. The FEP makes no reference to any existing levees which may be impacting on flooding impacts along the depression route.
- Ulupna Island. A ring type levee protects the enclosed rural area from Murray River flooding south west of Tocumwal. The ring levee is located immediately north of the PWD levee.

C7 Consultation with Council

The Moira Shire Council was contacted regarding urban levee related matters. An in-person meeting with Council was held on the 26 September 2024. Discussions at this meeting revealed that:

- Council has the following levees on its asset database:
    - Cobram levees including the Town Levee, Densons Levee, Cavagna's Levee and Dicks Levee.
    - Nathalia town levees.
    - Numurkah town levees comprising the Tunnock Road Levee, Brennion Street Levee and the Gray Street Levee.
- Council advised that they are not aware of operation and maintenance manuals for any of the above Council levees.
- A Council committee (Cobram East Levee Design Steering Committee) is progressing further assessments into possible future refinements to the Cobram Town Levee system.
- A Council Committee (Numurkah Steering Committee) is overseeing the progression of the Numurkah flood mitigation scheme.
- There is no ongoing Committee at present for the Nathalia levee scheme.
- Council is aware of the GBCMA led project to update the township FEPs within the GBCMA region.

Council advised that they do not manage any other levees aside from those associated with Cobram, Nathalia and Numurkah.

The previous Moira Shire Council Emergency Management Officer was contacted in October 2024. They advised that

- The Cobram township MFEP and the Cobram Flood Intelligence Card was relied upon by responders during the November 2022 flood event. The lack of detail in the Cobram FEP in regard to some aspects of levee management (e.g. temporary levee at Collies) would ideally be addressed.
- Flood response activities at Barmah in 2022 were mostly managed by the local CFA and residents, with minimal involvement from Moira Shire Council, due largely to lack of resources.

APPENDIX D Campaspe Shire Council Levee Assessments

D1 Echuca Village

Echuca Village is a semi-rural locality centred 5 km west of Echuca. The Echuca Village area is zoned rural, consisting of generally smaller holding 'hobby' scale farms.

Existing levees are located to the north bordering the Murray River floodplain and to the east. The levees to the areas border the Beattie Depression Drainage Scheme between the Murray Valley Highway (southern upstream end) and the Murray River floodplain (northern downstream end).

All the levees in the vicinity of the Echuca Village area are managed by GMW.

Rural Levee Assessment (Water Technology, 2013)

The Murray River levee to the north of Echuca Village was part of the 2013 Rural Levee Assessment project (Water Technology, 2013). Of the 3.5 km of levee assessed to the west of the Beattie Depression, more than 95% of the levee had a crest height at or above the 5% AEP flood level at the time of the 2013 project. Figure 3-9 of the 2013 report indicates that there are two isolated low points where the levee is overtopped in less than a 20% AEP event.

2019 Flood Emergency Plan

The 2019 FEP for the Campaspe Municipal District includes a two page MFEP specific to Wyuna, Yambuna, Kanyapella and Echuca Village. The FEP specifies that:

- The SES are to ensure that sand and sandbags are available to raise low points in levees for the protection of Echuca Village at a:
    - Shepparton gauge height of 11.6m
    - McCoys Bridge gauge height of 11.2m
- SES to notify landowners to begin patrolling levees at a McCoys Bridge gauge height of 10.23m.

Echuca Moama Flood Study (Water Technology, 2024)

Flood mapping produced as part of the 2024 Echuca Moama flood study project shows the Echuca Village area to be protected from riverine flooding up to a 5% AEP event (refer to Figure D2). In a 2% AEP event, the modelling shows the Echuca Village area to be completely flooded.

Categorisation

GMW have advised that they manage the Beattie Depression levees, Warrigal Creek levees and the Murray River levees either side of the Beattie Depression (refer to Figure D1). The levees have been assigned as Category 1 levees.

The level of protection for the Echuca Village area based on flood modelling and mapping produced as part of the 2024 Echuca Moama Flood Study would appear to be between a 5% to 2% AEP event assuming no intervention.

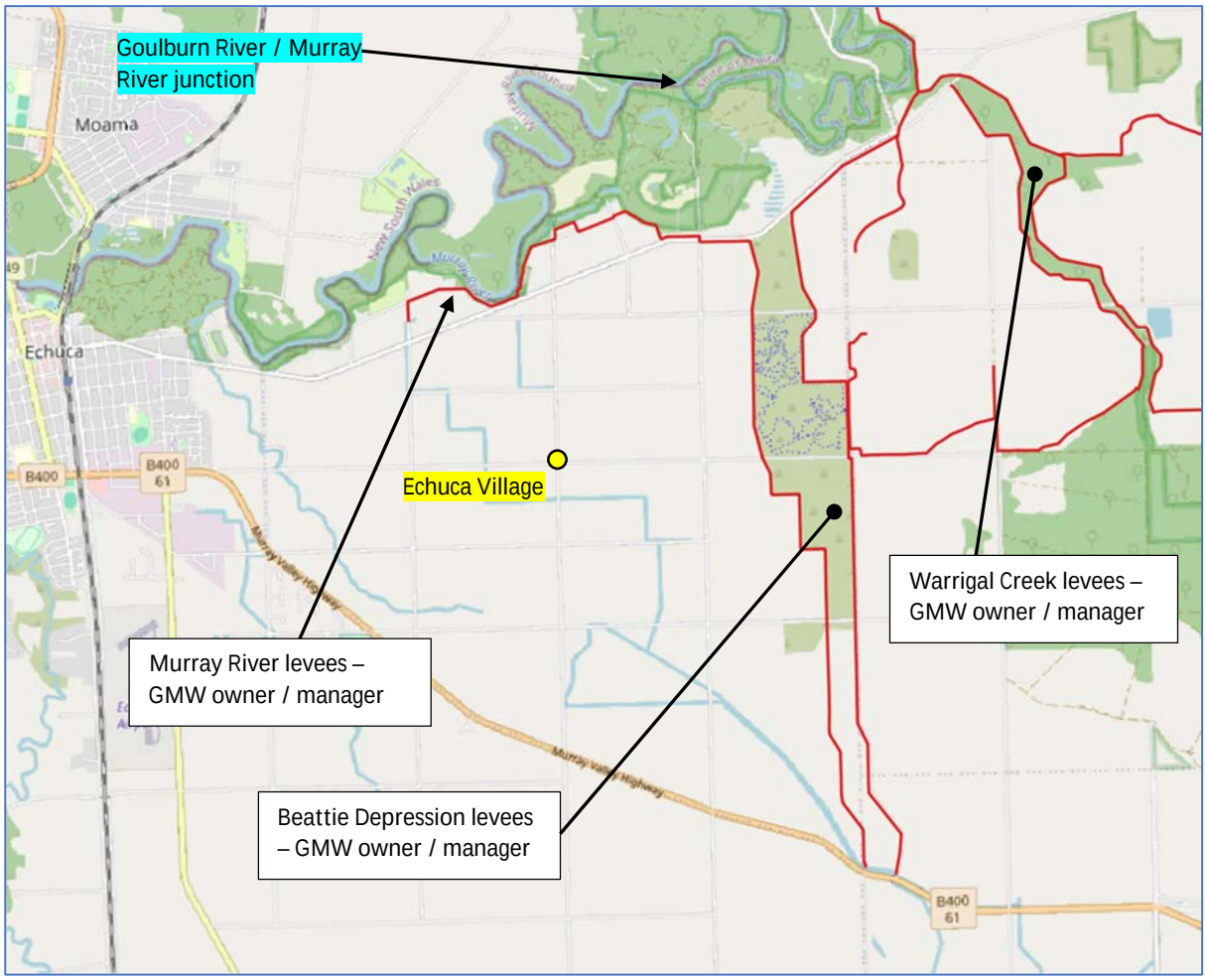


Figure D1 Echuca Village Area

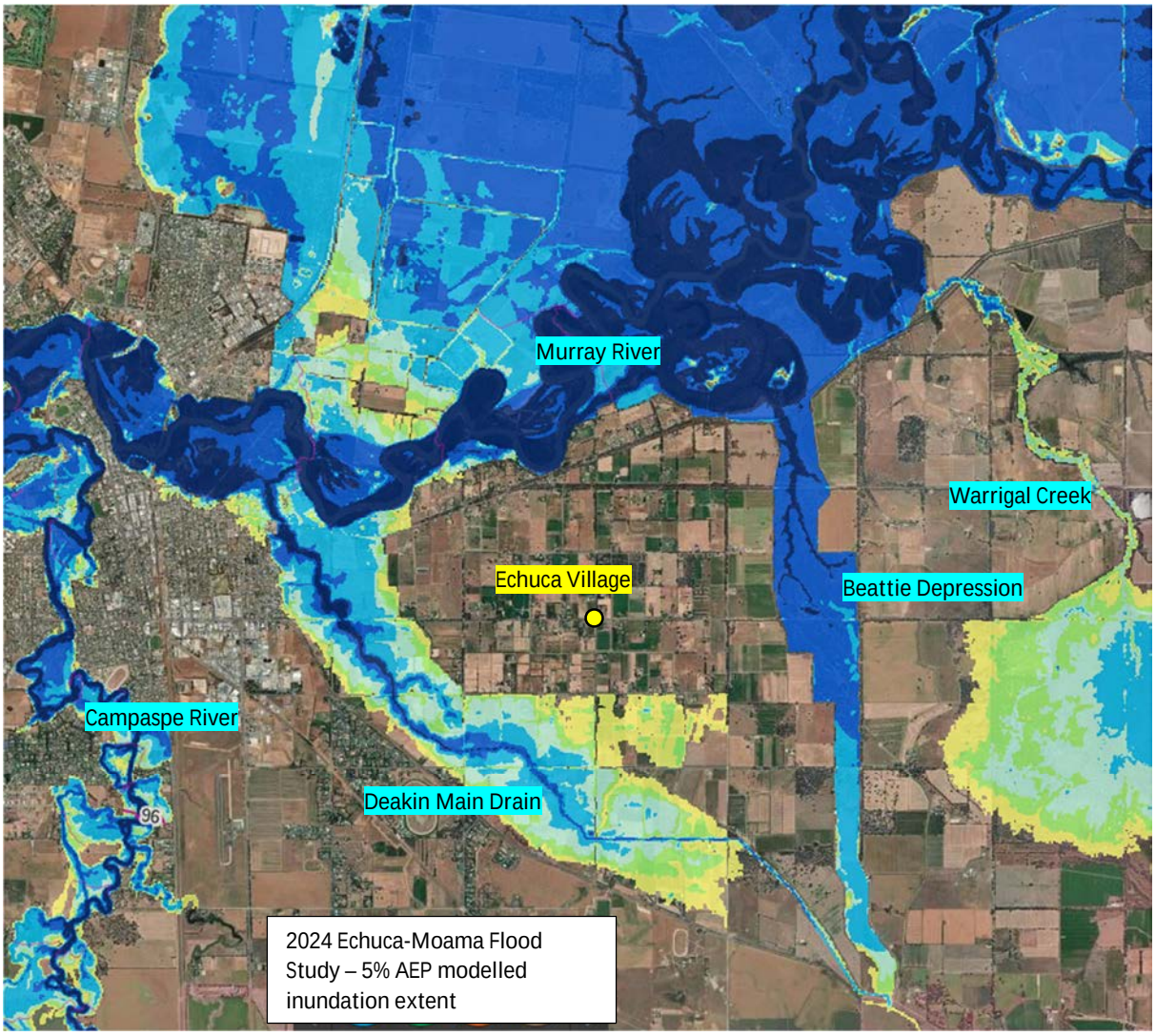


Figure D2 Echuca Village - 5% AEP Modelled Flood Extents

D2 Other Towns

Kyabram

Kyabram (population 7,400) is not positioned on a riverine waterway and is not therefore affected by riverine flooding. The town is impacted by local runoff with 26 houses reported to have been inundated in October 1993.

There are no existing levees at Kyabram.

Tongala

Tongala (population 1,300) is not positioned on a riverine waterway and is not therefore affected by riverine flooding. The town is located on a natural depression. No above floor flooding of houses is known to occur.

There are no existing levees at Tongala.

Rushworth

Rushworth (population 970) is not positioned on a riverine waterway.

There are no existing levees at Rushworth.

Colbinabbin

Colbinabbin (population 100) is located on the west side of Cornella Creek.

Floodwater from the Cornella Creek upper catchment discharges across the Waranga Western Main Channel via a siphon structure and a gated spillway structure as detailed in the Corop Lakes Flood Scoping Study (GHD, 2012). The study report comments that:

- Flooding conditions at Colbinabbin are influenced by the Waranga Western Channel, and the decommissioned railway embankment.
- Two of 70 houses at Colbinabbin are known to be subject to above floor flooding.

There are no existing levees at Colbinabbin.

Stanhope

Stanhope (population 480) is not positioned on a riverine waterway.

There are no existing levees at Stanhope.

Girgarre

Girgarre is not positioned on a riverine waterway.

There are no existing levees at Girgarre.

D3 Consultation with Council

The Campaspe Shire Council was contacted regarding urban levee related matters within the GBCMA region. Council replied that:

- Campaspe Shire Council does not currently actively manage any levees within the GBCMA region.
- Council's Flood Emergency Plan for the Campaspe Municipal District does have standalone appendices for township FEPs. The FEPs within the GBCMA region are currently under review.
- Levee protection is important for the Echuca Village area (i.e. nearby Murray and Goulburn rural levees). Flooding if the levees are breached or overtopped would likely lead to significant protracted impacts on the closely settled rural community.
- Referred to flood mapping preparing as part of the Echuca Moama Flood Study (Water Technology, 2024) which includes the Echuca Village area.

The 2024 Echuca Moama Flood Study mapping shows the surrounding levee system (i.e. Murray River levee to north and Beattie Floodway levee to the east) to be fully confining floodwaters up to a 5% AEP event. In a 2% AEP event, floodwaters are not confined with the Echuca Village area completely inundated.

APPENDIX E Rural Levees

E1 2016 Victorian Floodplain Management Strategy (VFMS)

The 2016 VFMS states that:

- Large scale rural flood mitigation systems are no longer considered best practice.
- In relation to new rural levee systems, they will not be invested in by the three tiers of government as they don't meet the community benefits nominated by Section 17.2 of the 2016 Strategy
- Most of the existing rural levee systems were not subject to planning controls or engineering standards and were built with little understanding of their ongoing maintenance needs.
- As a result, the floods of 2010-12 revealed serious deficiencies in rural levee systems.
- Given their poor construction, their potential negative impact on third parties and the environment, and the prohibitive cost of maintaining them relative to the benefits they provide, it is unlikely that many, if any, will be maintained formally into the future.
- If however, it can be demonstrated that existing government built rural levee infrastructure is providing significant benefits that meet the 2016 VFMS investment criteria (as per Section 17.2 of Strategy), then it may be possible to bring that infrastructure into formal management arrangements.
- Landowners can carry out routine maintenance works (excludes raising) of rural levees on Crown land by obtaining a permit process coordinated by the CMAs.
- Permits for maintenance on private land are subject to the planning scheme provisions.

Category 3 rural levees under the definition adopted for this project are strategic levees which provide unverifiable levels of protection to rural areas. Category 2 rural levees are not managed levees but provide flood protection to rural areas which have been shown to meet the investment criteria outlined in the 2016 VFMS.

None of the rural levees within the Goulburn Broken CMA region are currently managed. The 2016 VFMS clearly makes the case that rural levees won't be managed by state government agencies unless the 2016 VFMS investment criteria is met.

E2 Murray River Rural Levees

The constructed levee system between Cobram and Barmah is a strategic rural levee flood protection system which protects a large area to the south of the levee. This levee complex includes:

- Ex Public Works Department (PWD) levee between the Cobram Town Levee and Pirie Creek (approximately 57 km) which dates to 1895. An additional ring type levee is located north of the main levee at Ulupna Island.
- An uncoordinated constructed levee between the PWD levee at Pirie Creek and Barmah township (approximatley37 km).

The PWD levee system was breached and reinstated following major flood events in 1916, 1917, 1956 and 1975. The levee system was strengthened at multiple locations based on an audit completed in 1996/1997.

Despite lobbying by interest groups and individuals, no further government spending on maintenance has occurred in the past 20 years.

A 2013 Rural Levees Assessment (Water Technology, 2013) for the PWD and lower Goulburn rural levees was commissioned by Victorian Government agencies.

The 2013 Rural Levees Assessment report documents in detail the condition of the levees, as well as the service level / overtopping threshold along the entire levee route. The level of protection provided by the Murray River levee between Cobram and Barmah is less than 5% AEP event based on the 2013 project outcomes.

An economic assessment of the benefits of the Murray River levee system between Cobram and Barmah is not known to have been undertaken. The area south of the levee is likely to be affected by the breakout of flows upstream of Cobram at Dicks Levee. Dicks Levee is designed to be overtopped in a 5% AEP Murray River flood event.

A private ring levee is located on the Murray River floodplain at Murray Bend Caravan Park, 2km west of Tocumwal on the Victorian side of the river. The 2.3 km long ring levee encloses the 34 hectares caravan park site. The levee is up to 2 m high. The crest height varies from 0.0 to 0.8 m above the 1% AEP flood level.

E3 Lower Goulburn Rural Levees

The 147 km Lower Goulburn levee system extends from upstream of Loch Garry on the Goulburn River to north of Echuca Village on the Murray River.

The 2018-2028 GBRFMS notes that:

- The levees do not form part of any formal scheme that has an operation and maintenance authority, so the levees remain unmanaged.
- GMW is responsible for maintaining the 10 km of levee around Loch Garry.
- Government funding has previously supported studies to be undertaken in 2005 (Lower Goulburn Floodplain Rehabilitation Scheme) and 2013 (Rural Levees Assessment).
- No further government funding is planned given the 2016 VFMS policy outcomes, unless opportunities arise to integrate levee maintenance with environmental outcomes such as the 2005 rehabilitation scheme.
- The level of protection provided by the Lower Goulburn levees is less than 20% AEP (2013 Rural Levee Assessment).

E4 Beattie Depression and Warrigal Creek Levees

Both the Beattie Depression and Warrigal Creek drainage lines are bordered on each side by levees which are owned and managed by GMW.

The west side Beattie Depression levee provides protection to Echuca Village area located to the west as discussed in Appendix D – Section D1.

The total length of levee bordering the Beattie Depression is 17 km. The total length of levee bordering Warrigal Creek is 10 km.

Recent modelling undertaken as part of the Echuca Moama Flood Study (Water Technology, 2024) suggest that the Beattie Depression and Warrigal Creek levees confine floodwaters in a 5% AEP flood event (refer to Figure D2).

E5 Kinnairds Swamp Levee

Levees at Kinnairds Swamp on the east (upstream) side of Numurkah are owned and maintained by GMW. These levees are thought to have been constructed as part of the Muckatah Depression drainage scheme. The drainage scheme level of service is to provide drainage to protect against water logging in minor flood events. Flooding conditions in major flooding events revert to natural conditions via a network of levee overflow sills and culverts. The total length of levee maintained by GMW at Kinnairds Swamp is approximately 5 km.

E6 Corop Lakes Area Rural Levees

The Corop Lakes area is a rural area located west of Stanhope and Rushworth. A Flood Scoping Study has been completed for the area (2012, GHD). There are numerous private rural levees located within the Corop Lakes area. These levees have been constructed by landholders to protect their rural properties from flooding.

Corop Lakes rural levees were captured by the VFD project. There are approximately 70 km of rural levee segments in the current SDS levee layer as of 2024. Most of these levees are located:

- North of the Midland Highway in the Mansfield Swamp area (17km)
- Carag Road area south of the Midland Highway (11km)
- Between One Tree Swamp and Wallenjoe Swamp south of the Midland Highway (15 km)
- North of the Waranga Western Channel centred around the locality of Karook, 5 to 10 km north west of Rushworth (23km).

There are numerous other private levees within the Corop Lakes area which have not been captured within the SDS levee layer.

E7 Discussion

Resources do not allow for economic benefit assessments to be carried out for the above rural levee systems as part of the current Levee Categorisation project.

Maintenance measures to the existing rural levees can be carried out by landowners provided they obtain the necessary permits for work on either crown land or private land.

It is likely that the majority of the rural levee systems present do not meet the 2016 VFMS investment criteria. Maintaining in some cases close to 60 km of levee bank is very likely to prove cost prohibitive relative to the benefits they provide.

Potential exceptions could possibly include:

- Goulburn River north side levee upstream of Loch Garry which provides a level of protection to the Medland Road residential estate at Bunbartha where 41 houses are located.
- The Murray River levee and the west side Beattie Depression levee which protects the relatively small rural holding Echuca Village area.

APPENDIX F Significant Floodplain Features

F1 Overview

There are features on floodplains which are not levees, which none-the-less have a significant impact on flow patterns during major floods that result in significant changes to flooding conditions.

'*Significant floodplain features'* in the context of this project includes the following:

- Elevated banks associated with irrigation supply channels and rural drainage channels.
- Segments of roadway located on elevated embankments.
- Segments of railway lines located on elevated embankments.

The landscape within the GBCMA region is littered with the above man-made features. These features inevitably cross riverine floodplains. Cross drainage structures are generally provided within the floodplain features to cater for passing flow from the upstream side of the feature to the downstream side (e.g. bridges, culverts, weirs, subways etc).

The purpose of identifying the significant floodplain features is to alert response authorities to their presence. In some situations, these features can lead to floodwater banking up against them due to the limited capacity of the cross drainage structure present. The impacts of this can be:

- Reduced downstream peak flows due to retardation effects (i.e. positive outcome for those landowners on the downstream side of the feature).
- Inundation associated with the banking up of floodwater on the upstream side of the feature (i.e. negative outcome for those landowners on the upstream side of the feature).
- The potential if a breach or overtopping induced failure of the feature occurs, for the rapid release of a large quantity of banked up floodwater causing exacerbated downstream flooding conditions (i.e. a negative outcome for downstream landowners).

Significant floodplain features are not purpose-built engineered levee banks. Their structural integrity is therefore somewhat unpredictable. Most features through long term consolidation tend to be not susceptible to breaching through banked up water pressure. None the less, breaches may occur from time to time, if weaknesses arise (e.g. tree roots, animal burrows etc).

The following identified significant floodplain features is not a comprehensive listing of all features impacting on riverine flooding conditions. There will be hundreds, if not thousands of features scattered across the GBCMA region which affect to varying degrees flooding conditions. To capture all of these would not be possible and would not serve any useful practical purpose.

The significant natural features have been grouped within their LGA areas.

F2 Greater Shepparton City Council

F2.1 Shepparton, Mooroopna and Kialla

Notable floodplain features impacting to some degree on flooding conditions at Shepparton, Mooroopna and Kialla are described below.

Midland Highway

The Midland Highway is aligned approximately parallel to the north side of the Broken River east of Shepparton. In major Broken River flood events, breakaway flows discharge northwards across the Midland Highway into the creek system to the north which ultimately discharges into the Broken Creek downstream of Numurkah. East of Shepparton, the Midland Highway is not generally raised noticeably which reduces the extent to which Broken River floodwater is held back south of the Highway. Broken River floodwaters notably crossed the Highway in the 1993 flood leading to exacerbated flooding in the creek system to the north (i.e. O'Keefe Creek, Pine Lodge Creek, Congupna Creek).

The 3 km section of the Midland Highway between Shepparton and Mooroopna is located on an elevated causeway embankment road within the Goulburn River floodplain. There are multiple bridge cross drainage structures through the causeway.

Goulburn Valley Railway

The Goulburn Valley Railway crosses to the west side of the Goulburn River south of Toolamba, before recrossing the Goulburn River floodplain upstream of the Midland Highway between Mooroopna and Shepparton. There are multiple bridge cross drainage structures within the railway embankment.

East Goulburn Main Channel

The East Goulburn Main Channel (EGMC) is located to the south east of Shepparton. Notable waterway crossings are located at Castle Creek, Honeysuckle Creek and the Broken River. Examination of 1993 aerial flood imagery shows widespread inundation both upstream and downstream of the waterway crossings. The EGMC is not likely to be impacting significantly on peak flooding conditions at Shepparton Mooroopna except for a degree of attenuation of Broken River flows.

Other GMW Channels and Drains

Several GMW irrigation infrastructure channels are located on the northern side of Shepparton. They include notably Drain 3 and Channel 12. Banks along these channel routes impact on local flooding conditions.

F2.2 Murchison

The Goulburn Weir on-line storage will not be impacting significantly on flooding conditions at Murchison, as the storage volume is small relative to the volume of flows being discharged by the Goulburn River in major flood events.

The Bendigo-Murchison Road (High Road) is on an elevated causeway embankment on the east side approach to Murchison. Past studies have shown that floodwaters begin to overtop the road embankment as flood levels reach 11.9 m on the Murchison Goulburn River gauge (1% AEP flood level 11.92 m).

F2.3 Merrigum

GMW managed supply and drainage channels at Merrigum have the potential to significantly influence flooding conditions associated with rural runoff from the surrounding areas. This was overviewed in Section A3 of Appendix A.

Local supply channels include Channel 7 which aligned in a north-south direction on the east side of Merrigum and Channel 11/7 located to the south side of town. The Mosquito Drain bisects the town, crossing Waverley Avenue between Judd Avenue and Wilson Avenue.

Banks are typically located on either side of the GMW channels. The extent to which these banks influence flooding conditions at Merrigum is complex. Channel 7 which parallels the east side of Merrigum should be effective at preventing an influx of floodwater from the east.

It may be necessary to close drainage inlets into the Mosquito Drain if flood levels within the Drain get sufficiently high to initiate surcharge flooding out of the drainage inlets. Like all GMW rural drains, the Mosquito Drain is not designed to cater for a 1% AEP runoff event.

F2.4 Tallygaroopna

Tallygaroopna is primarily impacted by rural runoff from the surrounding areas. Tallygaroopna is subject to shallow slow-moving floodwaters in a large flood event. This notably occurred in March 2012. Floodplain features impacting on flooding conditions at Tallygaroopna include:

- GMW Supply Channel 17 to the south and west.
- Congupna Creek (Drain 2/11) to the east and north.
- Goulburn Valley Railway and Highway adjoining the west side of town.

All the above have some influence on flooding conditions. It is important that drainage inlets into Congupna Creek are well managed to prevent surcharging once creek flood levels get sufficiently high. This includes the main town drainage outlet at Congupna Creek on the east side of the Goulburn Valley Railway.

The Railway and Highway have cross drainage structures to cater for flood flows as detailed in the 2024 Tallygaroopna Flood Scoping Study. Tallygaroopna becomes subject to widespread shallow inundation in major flood events such as 2012, although impacts are generally not severe enough to induce above floor flooding. An estimated five houses at Tallygaroopna were flooded to above floor level in 2012.

F2.5 Congupna

Congupna is not affected by riverine flooding. The GMW channel network to the south east of Congupna (Drain 6/11) appears to obstruct flows being discharged by O'Keefes Creek, with the flows diverted northwards to Pine Lodge Creek as highlighted by aerial imagery of the 1993 flood event.

F2.6 Tatura

Tatura is not subject to riverine flooding. GMW's supply and / or drainage network can influence flooding conditions associated with local runoff and surrounding rural runoff by obstructing and diverting flows.

Tatura is flanked by supply channels around most of its perimeter. The Mosquito Drain is located on the east side of town.

F2.7 East Goulburn Main Channel (EGMC)

Flooding conditions within rural areas can be affected by significant floodplain features. An example of this is the corridor either side of the EGMC, both to the south and to the north of the Midland Highway.

To the sough of the Midland Highway, the EGMC crosses Seven Creek, Honeysuckle Creek and the Broken River. The EGMC is siphoned under these major waterways. Flooding is widespread on both sides of the EGMC.

To the north of the Midland Highway, the EGMC crosses O'Keefe Creek, Pine Lodge Creek and Congupna Creek. These creeks receive local catchment runoff and, in some cases, (e.g. 1993) breakaway inflows from the Broken River floodplain. The EGMC is siphoned under these waterways.

GMW are responsible for the operation of their infrastructure during flood events. This is not the responsibility of the SES or other emergency response contributors.

F2.8 Rodney Main Drain

GMW's Rodney Main Outfall Drain approaches Wells Creek and the Goulburn River floodplain from the south approximately 2 km upstream (east) of McCoys Bridge.

The Rodney Main Outfall Drain confines floodwater to the east of the Drain between Sleeth Road and Wells Creek as highlighted by aerial flood imagery of the 1993 flood event.

F3 Strathbogie Shire Council

F3.1 Road and Rail

Violet Town (Honeysuckle Creek), Euroa (Seven Creeks and Castle Creek) and Avenel Hughes Creek are all located adjoining the Hume Freeway and the Melbourne-Sydney Railway.

The waterway structures present at the waterway crossings at all three towns are generally well sized to pass the 1% AEP flow and are not thought to excessively impede the discharge of floodwaters. Flood studies completed at Euroa and Violet Town do not make any reference to capacity issues associated with the waterway crossings.

The Goulburn Valley Freeway and Shepparton Railway cross Hughes Creek south of Nagambie. No significant impacts on flooding conditions are known to result.

There are numerous other regional and local roadway crossings of waterways within the Strathbogie Shire LGA. None of these are known to have significant impacts on flooding aside from the expected localised afflux impacts.

F3.2 Irrigation and Rural Drainage Infrastructure

The Strathbogie Shire LGA is located almost entirely outside the GMW irrigation region. The East Goulburn Main Channel crosses the LGA between the Goulburn Weir and its entry point into the Greater Shepparton City Council, without crossing any significant floodplains, other than Castle Creek.

There are no known cross drainage capacity issues at the East Goulburn Main Channel Castle Creek crossing.

F4 Moira Shire Council

F4.1 Cobram

GMW supply channels are located in the area surrounding Cobram. These channels are not known to influence flooding condition at Cobram, with the key feature at Cobram being the Murray River Town Levee.

Elevated wastewater treatment lagoons are located on the north (downstream) side of Cobram. The Town Levee connects into one of the lagoon embankments. The lagoons are not known to impact on flooding conditions at Cobram.

Flood levels within the adjoining Murray River floodplain at Cobram are influenced by upstream breakout flows at Dicks Levee (Victorian side breakouts) and Seppelts Levee (NSW side breakouts).

F4.2 Barmah

Murray Street and to a lesser extent Moira Lakes Road are raised above natural ground level at Barmah. Both roads are however overtopped by floodwaters in major flood events.

The Barmah Road bridge crossing at the Murray River is not known to significantly obstruct the passage of floodwaters.

There are no GMW channels in the vicinity of Barmah.

F4.3 Nathalia

Nathalia has an urban levee complex which protects the town from riverine flooding associated with the Broken Creek system. This has rendered the surrounding GMW supply channel and drainage channels less important; however, they continue to influence local flooding conditions.

Channel 12 wraps around the south and west sides of Nathalia township. Channel 12 effectively separates the Goulburn River floodplain from the Broken Creek floodplain. Channel 12 prevents Goulburn River floodwater from impacting on Nathalia township. During the 2012 flood, Channel 12 was intentionally cut to allow confined floodwater to escape from the Nathalia side of the channel.

F4.4 Numurkah

GMW's supply and drainage channel network in the area surrounding Numurkah township influences flooding conditions. A notable influence is Channel 6/6 aligned on the east side of Numurkah. This channel obstructs approaching flood flows from the east. The existing FEP calls for temporary sandbagging at Pine Street and Wattle Street to link up the channel banks at these two road crossings.

The Goulburn Valley Railway and Goulburn Valley Highway are notable influences towards the downstream side of Numurkah. Cross drainage structure capacity is not thought to be a significant choke factor in relation to either the Railway or the Highway.

Kinnairds Wetland located on the upstream side of Numurkah does not significantly affect downstream flooding conditions, with inflows generally far more than the available active storage volume.

F4.5 Wunghnu

The Goulburn Valley Railway and Goulburn Valley Highway are aligned across the Nine Mile Creek at Wunghnu. No previous detailed flood study has been undertaken for Wunghnu.

The Railway and Highway are not thought to significantly influence flooding conditions at Wunghnu. Flooding impacts are relatively benign at Wunghnu, which is why a detailed flood study has not been commissioned to date.

F4.6 Rural Areas

GMS's supply and drainage channel network criss-crosses the Moira Shire local government area. Where these channels cross riverine and major overland flow routes, cross drainage structures are present, although some degree of afflux and bank up of floodwater results in localised impacts on flooding conditions.

GMW Channel 12 is a significant floodplain feature, effectively separating floodwaters from the Goulburn River to the south, and Broken Creek floodwaters to the north.

F5 Campaspe Shire Council

F5.1 Road and Rail

The major regional roads within the GBCMA portion of the Campaspe Shire Council are the Midland Bendigo-Murchison Road, Midland Highway and the Murray Valley Highway.

There are no known significant floodplain features associated with these roadways which has a major adverse influence on riverine flooding conditions. The Bendigo-Murchison Road is inundated in major Cornella Creek and Wanalta Creek flood events.

The Midland Highway is one of many raised embankment features in this area. There are numerous private levees both north and south of the Highway designed to confine floodwater to wetlands, rural drains and depressions.

The Murray Valley Highway crosses several rural drains, notably the Deakin Main Drain and the Wyuna Main Drain.

F5.2 Irrigation and Rural Drainage Infrastructure

The Waranga Western Channel is aligned across the Cornella Creek and Wanalta Creek catchments to the south (upstream) of the Bendigo-Murchison Road.

Cross drainage provision at the Cornella Creek is by way of a low flow siphon structure under the Waranga Western Channel and a manual operated high flow floodway structure. Cross drainage provision at the Wanalta Creek is by way of a multi gate structure at Groves Weir. Details are provided in the Corop Lakes Flood Scoping Study (GHD, 2012).

GMW are responsible for operating the Cornella Creek and Wanalta Creek Waranga Western Channel cross drainage structures during flood events.

APPENDIX G Economic Assessment – Rural Levees

G1 Introduction

The current Victorian State Government policy as set out by the Victorian Flood Management Strategy (DELWP, 2016) is that the State Government will only invest in rural levees if they meet the community benefit requirements nominated by Section 17.2 of the Strategy. The 2026 Strategy advises that if it can be demonstrated that existing government built rural levee infrastructure is providing significant benefits that meet the 2016 VFMS investment criteria, then it may be possible to bring that infrastructure into formal management arrangements.

Considering the above, an exercise has been undertaken to assess the cost benefit of a selected rural levee system within the Goulburn Broken CMA region. The assessment approach has been limited to a high-level assessment which identifies indicative benefits and costs. A more detailed assessment was not possible within the confines of the current project limited resources.

The existing rural levee located downstream of Cobram has been selected for the economic assessment. The levee between Cobram and Pirie Creek is known as the PWD levee (refer to Figures G1 and G2). This 57 km long section of rural levee was originally constructed by government in the late 1800s.

The Murray River levee between Cobram and Pirie Creek protects properties to the south of the levee. The system is not designed to achieve1% AEP flood protection. Upstream of Cobram, the crest level of Dicks Levee is set to the 5% AEP flood level. In floods exceeding a 5% AEP event, floodwater overtops Dicks Levee and spills into the floodplain to the south of Cobram and would nominally flow westwards.

The highest Murray River flood since 1917 occurred in 1975. The 1975 flood was equivalent to approximately a 5% AEP (20 year ARI) flood.

A detailed condition assessment project was completed in 2013 for the Murray River and Lower Goulburn River rural levees within the GBCMA region (Water Technology, 2013). This project confirmed that the Murray River levee between Cobram and Pirie Creek is overtopped in a 5% AEP event at multiple localised low points (refer to Figure G1).

The economic assessment comprises an assessment of benefits and costs. The reduced flood damages as a result of levee protection represent the benefits. The costs are the capital costs to construct the levee and the ongoing costs associated with maintaining the levee.



Figure G1 Murray River Levee Crest Levels (reproduced from Rural Levees Assessment (Water Technology, 2013)

G2 Estimation of Flood Damages

Flood damages can be grouped into the following categories:

- Direct tangible damages. These damages are associated with the physical impacts of the flood and include damage to building structures, the contents of buildings, agricultural damages (e.g. to crops, pasture, stock, farm infrastructure) and regional infrastructure (e.g. roads).
- Indirect tangible damages. These damages are associated with economic losses due to the disruption of normal day to day activities. The disruption can be due to resources needing to be allocated to emergency flood response, clean-up community support, or disruption associated with transport movement issues (e.g. closed roads).
- Intangible damages. These damages cannot be quantified in monetary terms. Intangible damages include increased stress levels for flood affected residents.

The assessment of flood damages has been undertaken using the Rapid Appraisal Method (RAM). Guidelines for the use of the RAM are detailed in a Victorian State Government publication – Rapid Appraisal Method (RAM) for Floodplain Management (NRE, 2000). The RAM was developed for the rapid and consistent determination of flood damages for informing flood studies and other floodplain management assessment projects.

The RAM has been used for the assessment of flood damages in both high-level studies (e.g. Corop Lakes Flood Scoping Study, GHD, 2012) and more detailed studies (e.g. Nagambie Flood Study, BMT WBM, 2017).

The RAM produces an indicative estimate of the flood damage for various size flood events. These estimates can then be used to compute the average annual damage (AAD). The RAM calculation of damages considers the following factors:

- An estimated event up to which the flood induced damage is negligible (i.e. the threshold event).
- The estimated flood damage for at least two events above the threshold event.
- The likely available warning time for the community to prepare for an impending flood and therefore take action to reduce the actual damage incurred.
- The community's levels of experience in reacting to flood warnings.
- The likely duration of flooding.

The RAM has been applied to the Murray River levee assessment as follows:

- Threshold event for flood damages. An AEP of 20% was adopted (equivalent to 4.5 year ARI).
- The two events above the threshold event were based on:
    - Flooding coinciding with the Floodway Overlay (FO) extent. An AEP of 5% was assigned to the FO extent.
    - Flooding coinciding with the combined FO and Land Subject to Inundation Overlay (LSIO) extent. An AEP of 1% was assigned to the combined FO and LSIO extent.

The FO and LSIO extents for the reach adjoining the PWD levee are shown on Figure G2. The total FO area protected by the PWD levee is 120 km^2. The total combined FO and LSIO area potentially protected by the levee is 210 km^2.

G3 Direct and Indirect Damage Calculations

Data computed for the flood damage analysis is summarised in Table G1.

G3.1 Direct Damage to Buildings

The flood overlays (FO and LSIO) were overlaid onto georeferenced aerial photography. The number of dwellings/houses within the FO and LSIO extents were subsequently identified based on a count using the aerial imagery supplied by the GBCMA. Dwelling count numbers are specified in Table G1.

The RAM is generally based on a simple count of the number of buildings within the flood extent. The RAM does not generally differentiate between buildings with flood heights above flood level and those below given that this is not generally known. For this exercise, it was assumed that all dwellings within the FO extent and the LSIO extent are subject to above floor flooding.

Damages assigned to dwellings was based on the following approach:

- Average potential damage of $43,000 per residential dwelling assumed to be subject to above floor flooding (RAM defined figure of $20,500/building factored up to allow for inflation since 2000).
- Actual damage was assumed to be 70% of the potential damage (i.e. $30,000 per dwelling) after considering that the available warning time would most likely exceed 12 hours and assuming an inexperienced community (i.e. flooding occurs infrequently due to the PWD levee having been in place for over 100 years).

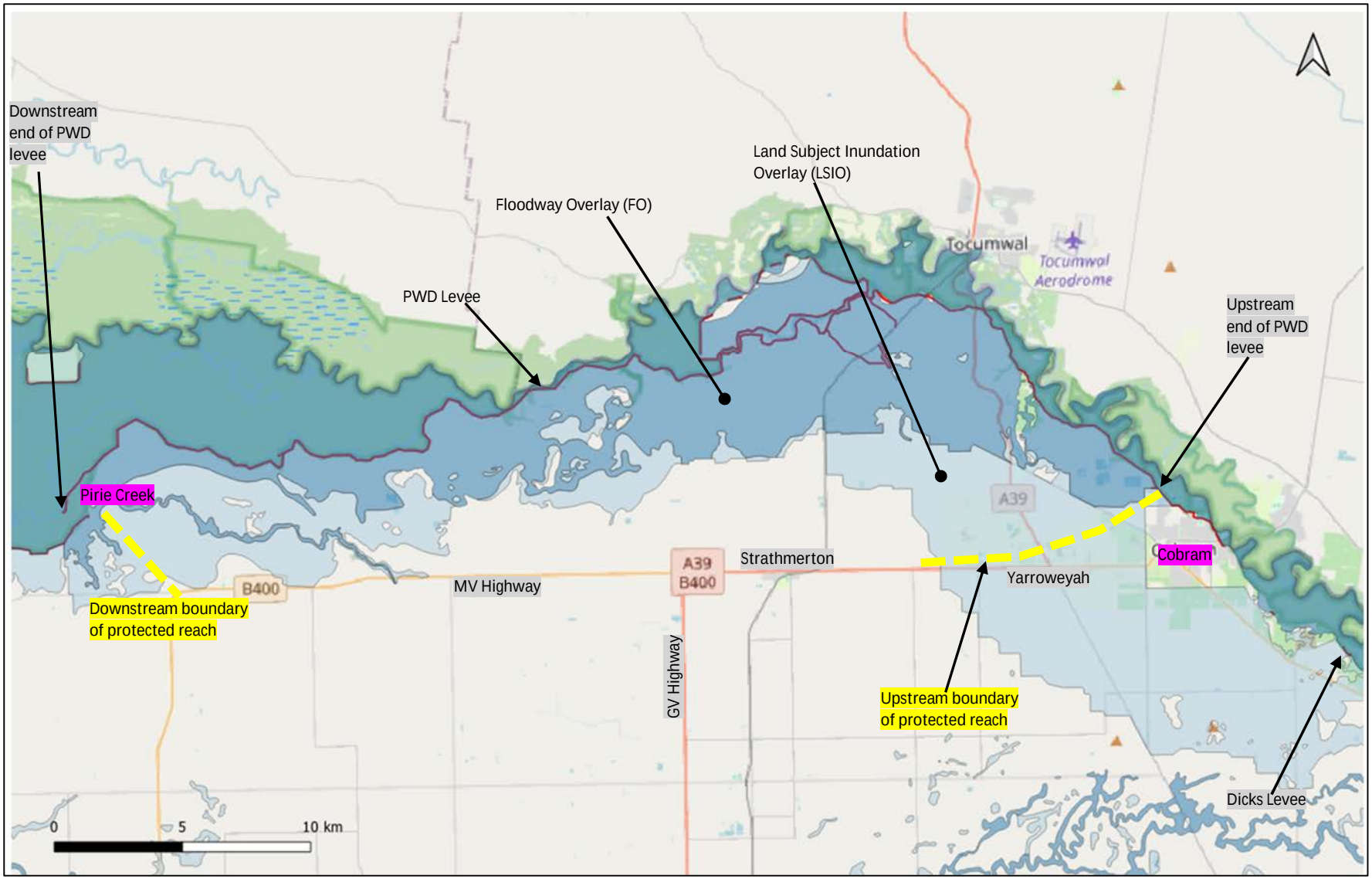


Figure G2 FO and LSIO Areas – Cobram to Pirie Creek

G3.2 Direct Damage to Agriculture

The calculated agricultural damages are based on data in the 2000 RAM publication and factored up to allow for inflation since 2000. The calculated agricultural damages include a general allowance for clean-up costs (e.g. repair of fences, erosion damage, sediment / gravel deposition etc). The applied agriculture damage rates are given below:

- Dryland pasture – $63/ha
- Dryland broadacre cropping – $302/ha
- Irrigated pasture – $188/ha
- Irrigated broadacre cropping – $607/ha

The aerial imagery and GMW's supply channel network GIS layers were interrogated to estimate the respective agricultural areas protected by the PWD levee (refer to Table G1).

G3.3 Direct Damage to Infrastructure

The RAM makes an allowance for damage to all infrastructure by applying a damage rate to the length of roads within the Flood Overlay (FO) and the combined FO/Land subject to inundation Overlay (LSIO) areas. Differing damage rates are nominated by the RAM 2000 publication for major sealed roads, minor sealed roads and unsealed roads.

Road lengths within the FO area and the combined FO / LSIO areas were estimated using the aerial imagery (refer to Table G1). The road damage figures given by the 2000 RAM publication were factored up to allow for inflation since 2000.

The applied road damage rates are given below:

- Major sealed roads - $67,000 per km
- Minor sealed roads - $21,000 per km
- Minor unsealed roads - $10,000 per km

G3.4 Indirect Damages

Indirect damages account for losses from the disruption of normal economic and social activities that arise because of the physical impact of flooding.

The RAM recommends that indirect losses be calculated as between 20 and 45% of the total actual direct damage. A rate of 30% was adopted for this exercise.

G3.5 Average Annual Damage

The RAM uses the following procedure to calculate the AAD:

- Adoption of an equivalent flood frequency coinciding with the threshold at which flood damages commence. The 20% AEP event was selected for this exercise.
- Adoption of an equivalent flood frequency coinciding with the inundation of the FO area. The 5% AEP event was selected for this exercise.
- Adoption of an equivalent food frequency coinciding with the inundation of the combined FO and LSIO areas. The 1% AEP event was selected for this exercise.

The AAD was calculated based on the above three identified damage probability points.

Table G1 Data for Flood Damage Analysis – PWD Levee - Cobram to Pirie Creek

Item	Detail	Quantity
Area protected	Floodway Area (FO)	120 km^2
	Land Subject Inundation Area (LSIO)	90 km^2
	Total FO and LSIO	210 km^2
Number of dwellings/houses	Within FO	123
	Within LSIO	107
	Total in FO & LSIO	230
Agriculture within FO	Dryland pasture	19.0 km^2
	Dryland cropping	35.0 km^2
	Irrigated pasture	5.0 km^2
	Irrigated cropping	39.0
	Total area	98.0
Agriculture within LSIO	Dryland pasture	8.0 km^2
	Dryland cropping	33.0 km^2
	Irrigated pasture	-
	Irrigated cropping	36.0 km^2
	Total area	77.0 km^2
Roads within FO	Major roads	7.6 km
	Minor sealed roads	21.3 km
	Minor unsealed roads	79.0 km
Roads within LSIO	Major roads	12.1
	Minor sealed roads	18.0 km
	Minor unsealed roads	70.0 km

Note: The above coincides with the protected reach shown on Figure G2.

G4 Estimation of Levee Costs

G4.1 Capital Costs

Indicative estimated costs for the replacement of the existing 57 km long PWD levee have been calculated as follows:

- Levee height – existing levee typically varies from 1.5 to 2.0 metres at the Cobram end of the levee as determined using 1 m grid LiDAR data. A height of 1.5 m has been adopted for this exercise.
- Crest width – existing levee crest width approximately 3 m wide at the Cobram end of the levee. Adopted 3.0 m.
- Batter slopes – have adopted 3:1.
- Material volume based on above – 11 m^3 per linear metre.
- Cost rate – assumed \$35/m^3, the actual rate will vary markedly depending on the proximity of the source and any treatment required. The assumed rate is considered to lie at the mid-point of the potential cost range.
- Total cost - \$22.2 million (based on \$35/m^3 x 11m^3/m x 57,000m)

The above equates to \$390/metre. This is a high-level indicative cost estimate only, considered to be at the mid-point of the potential range of possible costs.

G4.2 Total Costs (Capital plus Maintenance)

Levee maintenance costs have been calculated as follows:

- Future annual maintenance costs assumed to equal 1% of the estimated capital cost
- Consequently, annual maintenance cost is \$222,000 per annum
- Levee life assumed – 75 years
- Discount rate of 7% used in line with Victorian Treasury Guidelines
- Present value of 75 years of future maintenance costs at \$222,000/annum using a discount rate of 17% - \$3,100,000
- Present value of capital cost - \$22,200,000
- Present value of capital plus maintenance costs - \$25,300,000 (\$25.3 million)

G5 Benefit Cost Ratio – Scenario 1

In addition to the preceding methodology description, the following key points are pertinent to the estimation of the additional damage which would occur if the PWD levee was not present:

- The levee is overtopped at around the 5% AEP event, therefore benefits associated with any reduction in damages for events more severe than the 5% AEP event were excluded (i.e. PWD levee assumed to provide protection to the FO area only).
- Agricultural benefits are viewed by the 2016 VFMS as private benefits as opposed to public benefits (refer to Section 17.2 of the 2016 VFMS).
- Reduced damages to dwellings / houses in contrast are classed as community benefits by the 2016 VFMS.
- Public roadways are public infrastructure and are classed as community benefits by the 2016 VFMS.

The above coincides with that represented by Scenario 1. The damage estimates for Scenario 1 are given in Table G2. Scenario 1 assumes the following:

- Threshold damage event – 20% AEP
- Assumes that the levee does not reduce the flood damage for events more severe than 5% AEP
- Includes direct damages to dwellings and roadways, but excludes agricultural damages

The resultant AAD for Scenario 1 is $374,000. The present value of the AAD assuming a design life of 75 years and a discount rate of 7% is $5.31 million. The resulting benefit cost ratio is 0.31.

Table G2 Benefit Cost – Scenario 1

Item	Flood Damage ($)	
	FO (5% AEP)	LSIO (1% AEP)
Direct - Buildings / houses	3,583,000	Excluded
Direct - Agriculture	Excluded	Excluded
Direct Roads	1,746,000	Excluded
Total Direct Damages	4,329,000	Na
Indicted Damages (30%)	1,299,000	Na
Total Damage	5,628,000	Na
Total AAD	374,000	
PV future reduced flood damages (75-year life, 7% discount rate)	$5.3 million	
PV Levee Costs (capital & maintenance)	$25.3 million	
Benefit Cost Ratio	0.21	

Note: Scenario 1 assumes 20% AEP damage threshold, all houses flooded within FO and LSIO extents, agricultural damages excluded, levee protection up to 5% AEP event.

G6 Benefit Cost Ratio - Scenario 2

The cost benefit ratio for a second scenario (Scenario 2) has been quantified. Scenario 2 assumes:

- Damage threshold of 20% AEP (same as Scenario 1)
- Agricultural benefits are included
- Levee assumed to provide protection up to the 1% AEP event

The benefits (damage estimates) for Scenario 2 are summarised in Table G3.

The present value capital and maintenance costs associated with Scenario 2 assume an average levee height of 2.0 m (0.5 m higher than that adopted for Scenario 1).

The resulting benefit cost ratio of the PWD levee under Scenario 2 is 0.45.

Table G3 Benefit Cost Ratio – Scenario 2

Item	Flood Damage ($)	
	FO (5% AEP)	LSIO (1% AEP)
Direct - Buildings / houses	2,583,000	4,830,000
Direct - Agriculture	3,638,000	6,870,000
Direct Roads	1,746,000	3,635,000
Total Direct Damages	7,967,000	15,335,000
Indicted Damages (30%)	2,390,000	4,600,00
Total Damage	10,357,000	19,935,000
Total AAD	$1,294,000	
PV future reduced flood damages (75-year life, 7% discount rate)	$18.4 million	
PV Levee Costs (capital & maintenance)	$41.0 million	
Benefit Cost Ratio	0.45	

Note: Scenario 2 assumes 20% AEP damage threshold, all houses flooded within FO and LSIO extents, agricultural damages included levee protection up to 1% AEP event.

G7 Discussion

The preceding high level economic assessment suggests that it will be difficult to generate sufficient public benefits to cover the capital and maintenance costs associated with a rural levee. Even with the inclusion of agricultural benefits, the benefit cost ratio remains uneconomic at 0.45.

An economic assessment was recently completed for the Tyntynder Flats flood levee system located downstream of Swan Hill on the Murray River floodplain. The assessment was undertaken as part of the Levee Categorisation Project for the North Central CMA (by Frontier Economics as a subconsultant to Sequana Partners). The Tyntynder levee economic assessment produced a positive benefit cost ratio for the replacement of the subject 36 km levee. This was however influenced by the following factors:

- Capital cost of $7.4 million assigned to the replacement of the 36 km long levee, equating to $205/m (levee height assumed 1.5 m). This was largely influenced by the adoption of a lower bound cost rate of $18.80/m^3 for the estimation of capital costs.
- 429 residential houses protected by the 36 km long levee, which equates to one house protected for every 84 m of levee. This is an extremely high house density for a rural area. In addition, a further 16 commercial properties and 8 public buildings are protected by the levee.
- 7,635 hectares (76 km^2) of agricultural land protected. This equates to just over 2km^2 of agricultural land protected for every 1 km of levee.
- The computed levee benefits comprise:
    - Reduced residential property damage – 70% of the total benefits
    - Reduced public property damage – 10% of the total benefits
    - Other benefits -20% of the total benefits

The above details highlight that the area protected by the Tyntynder Flats levee scheme is a small holding land use area (one house per 18 hectares of protected area). The Tyntynder Flats levee economic assessment suggests that a case can be made that in these circumstances a rural levee system can provide sufficient public benefits to warrant investment from government.

APPENDIX H Levee Locality Maps

List of Maps in Appendix H

Figure H1 Index Map

Figure H2 Shepparton Township Map

Figure H3 Murchison Township Map

Figure H4 Euroa Township Map

Figure H5 Avenel Township Map

Figure H6 Cobram Township Map

Figure H7 Nathalia Township Map

Figure H8 Numurkah Township Map

Figure H9 Barmah Township Map

Figure H10 Wunghnu Township Map

Figure H11 Rural Map 1 (Sheet 1 of 8)

Figure H12 Rural Map 2 (Sheet 2 of 8)

Figure H13 Rural Map 3 (Sheet 3 of 8)

Figure H14 Rural Map 4 (Sheet 4 of 8)

Figure H15 Rural Map 5 (Sheet 5 of 8)

Figure H16 Rural Map 6 (Sheet 6 of 8)

Figure H17 Rural Map 7 (Sheet 7 of 8)

Figure H18 Rural Map 8 (Sheet 8 of 8)

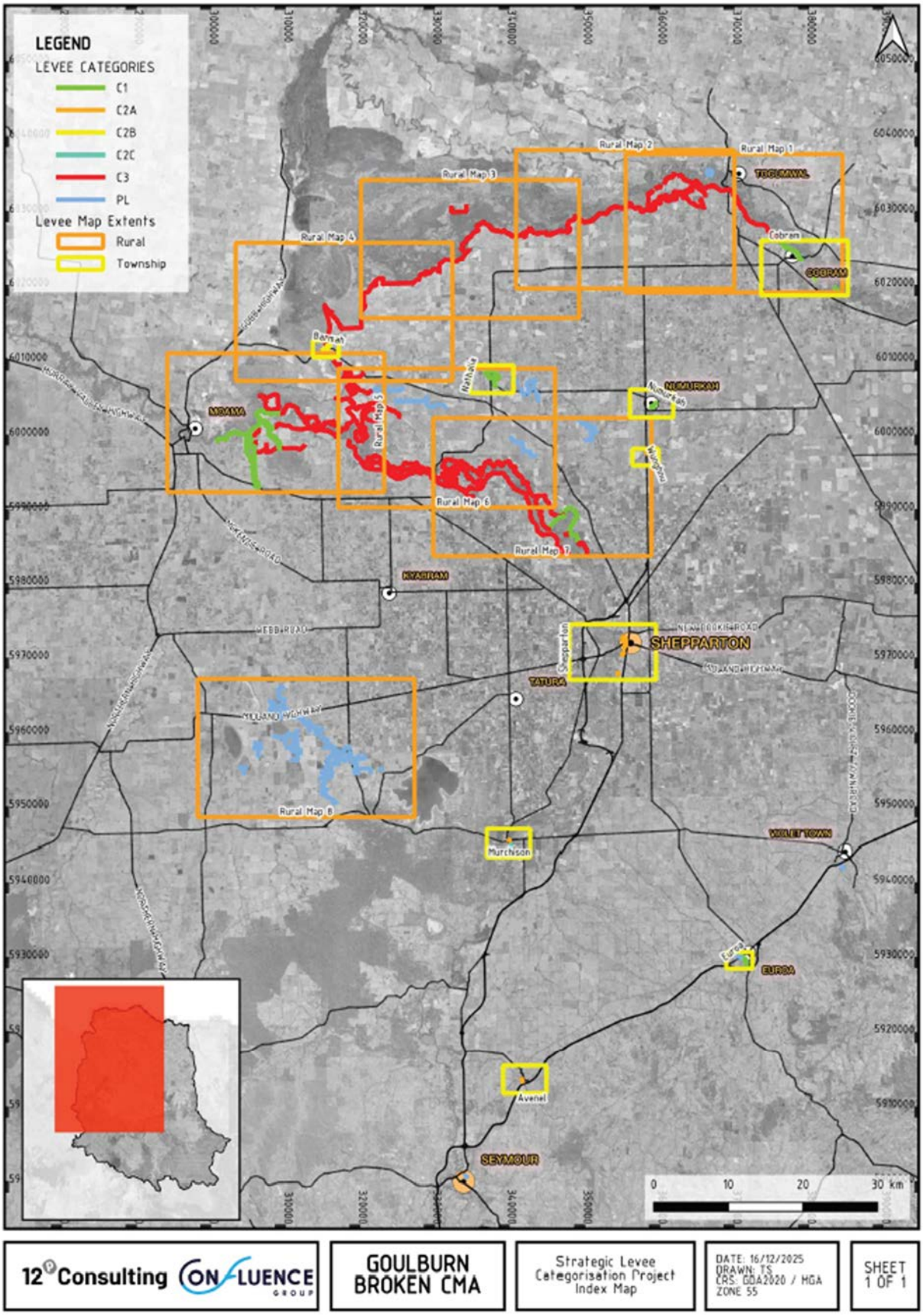


Figure H1 Index Map

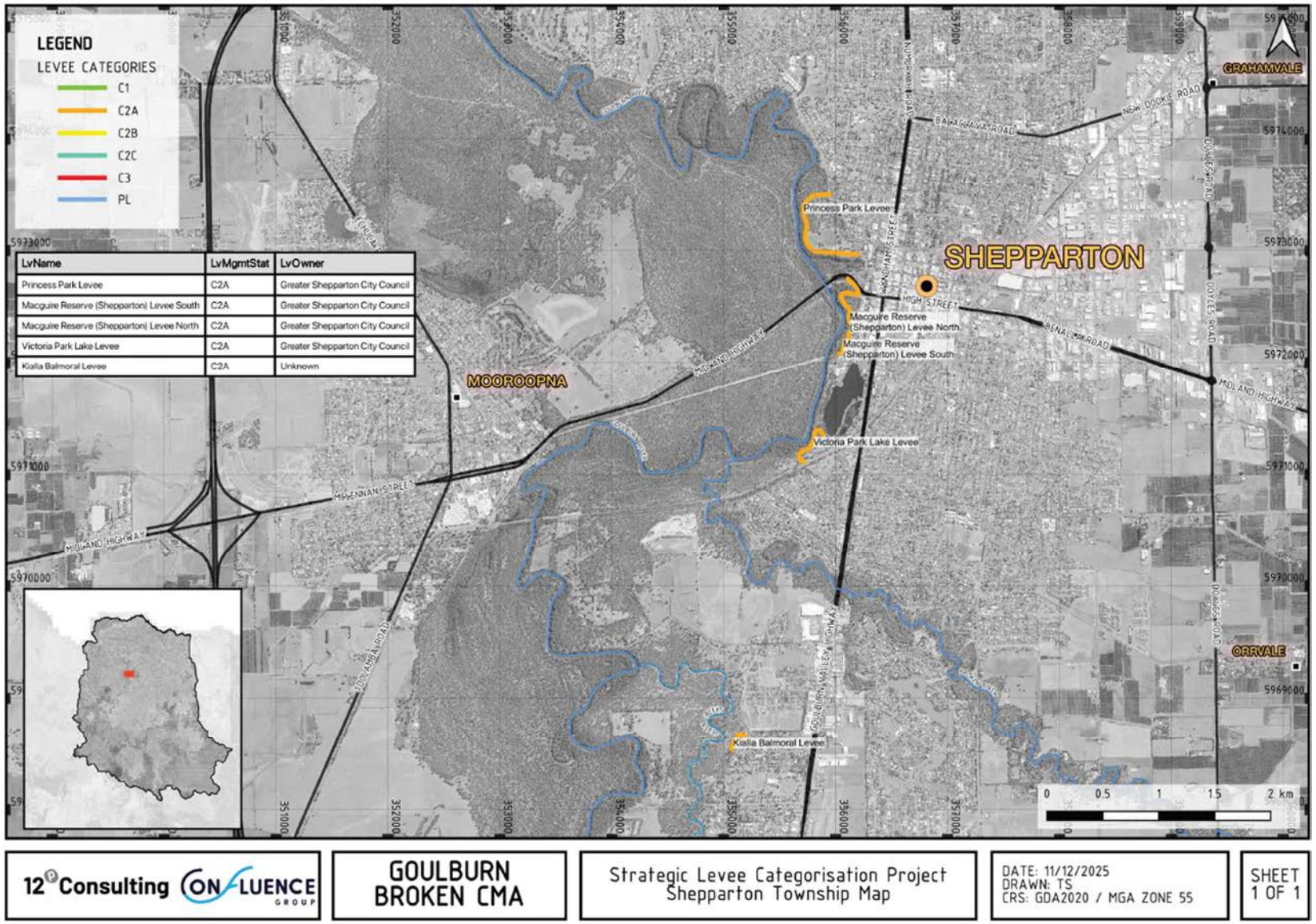


Figure H2 Shepparton Township Map

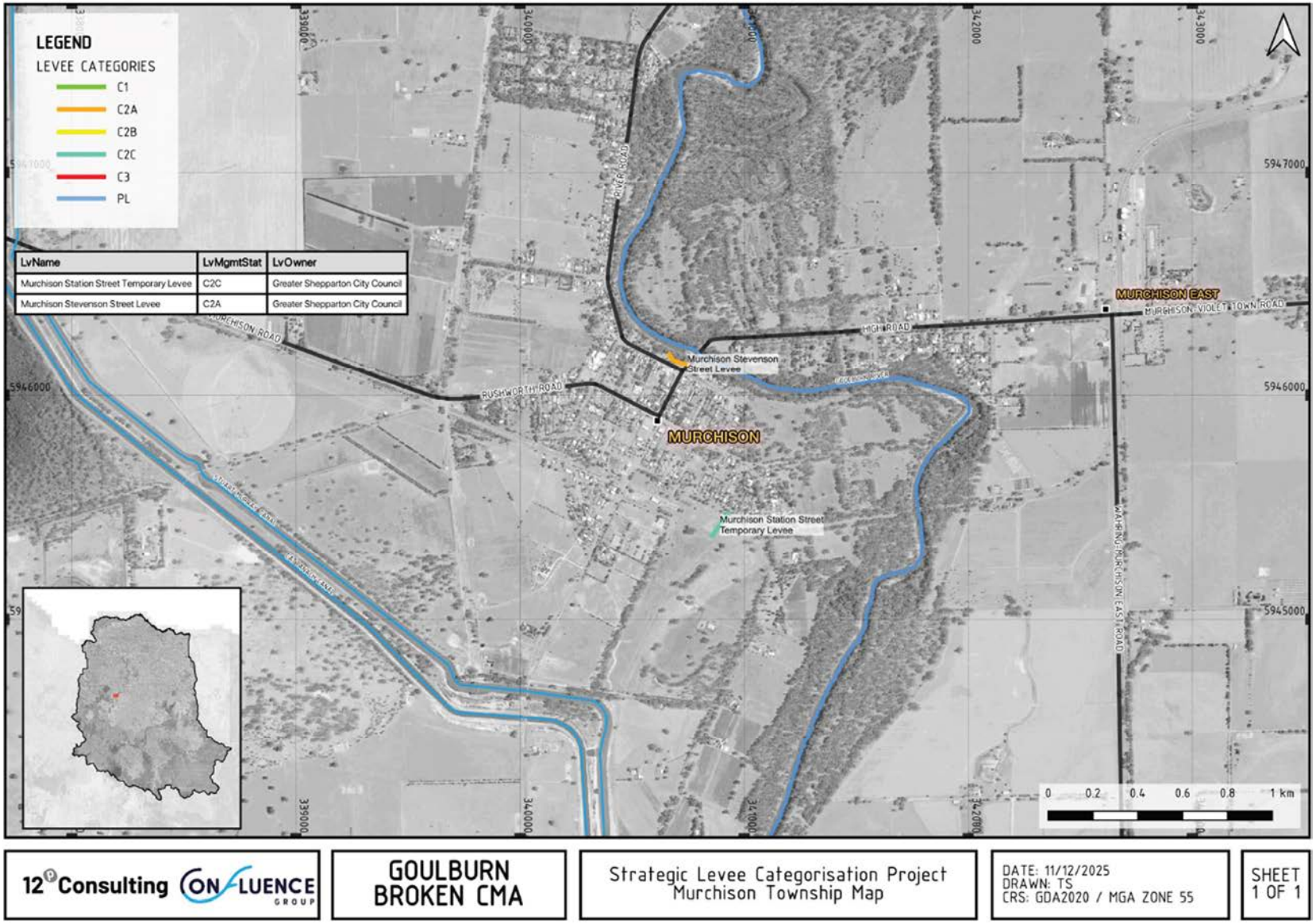


Figure H3 Murchison Township Map

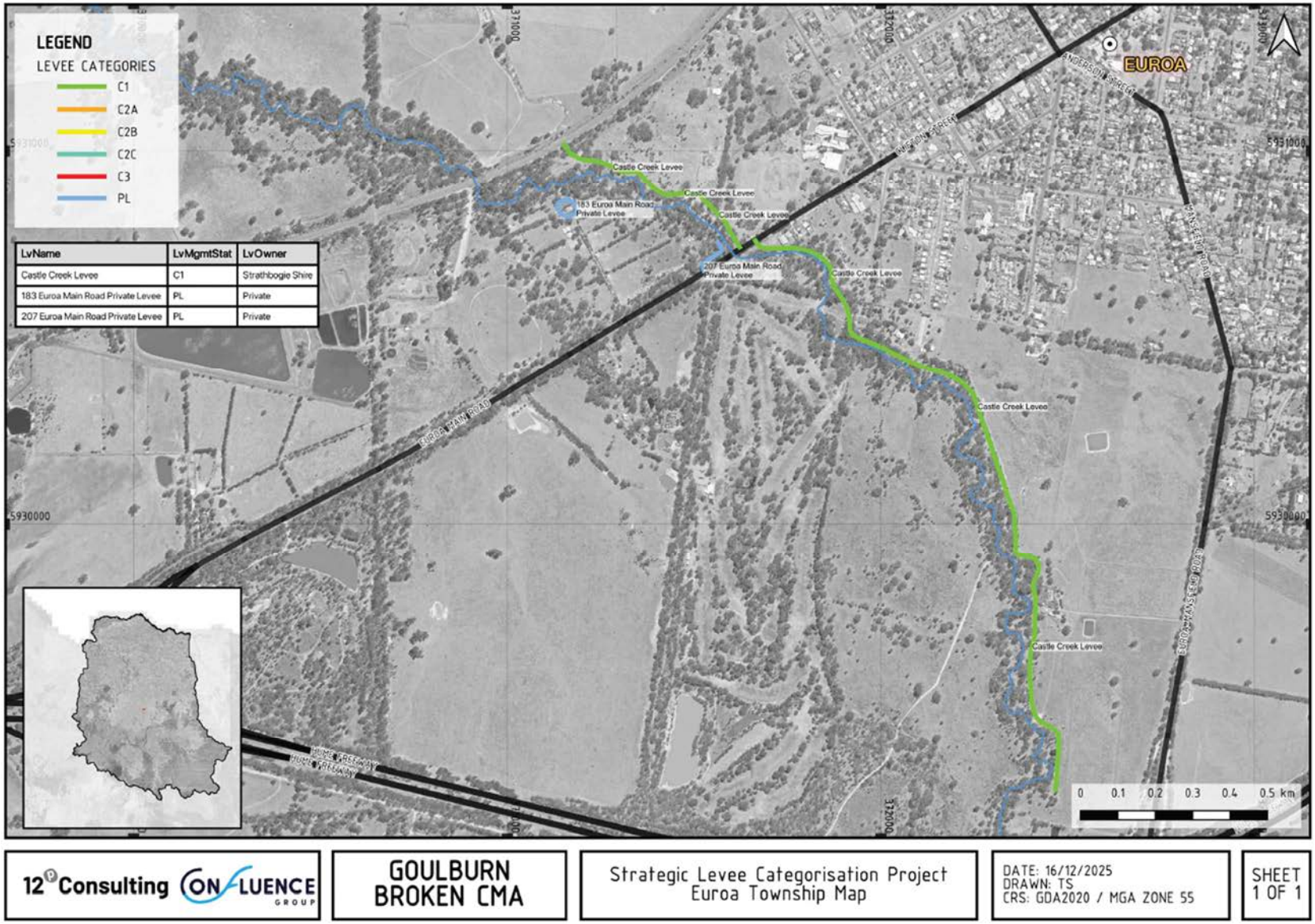


Figure H4 Euroa Township Map

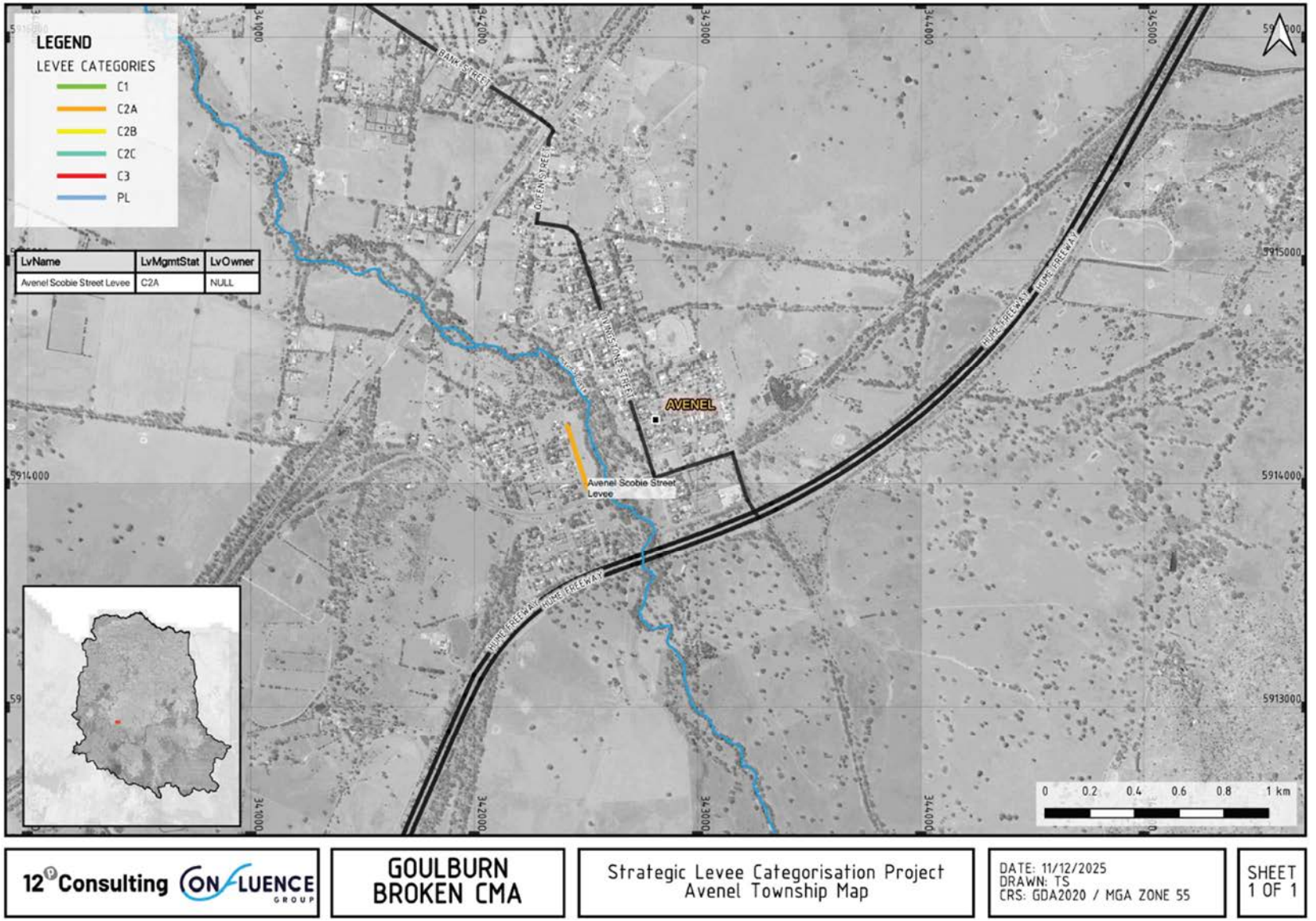
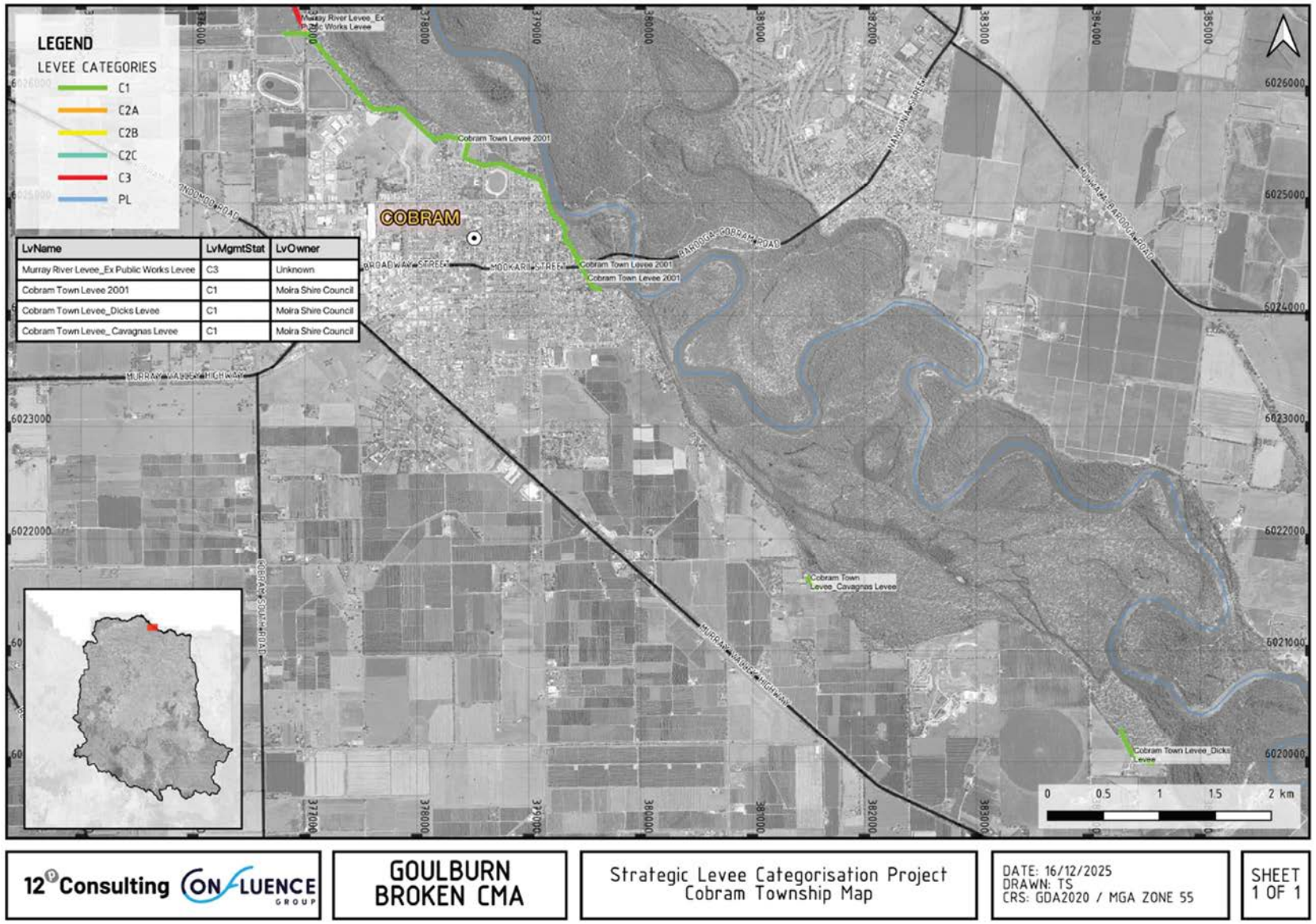


Figure H5 Avenel Township Map



LvName	LvMgmtStat	LvOwner
Murray River Levee_Ex Public Works Levee	C3	Unknown
Cobram Town Levee 2001	C1	Moira Shire Council
Cobram Town Levee_Dicks Levee	C1	Moira Shire Council
Cobram Town Levee_ Cavagnas Levee	C1	Moira Shire Council

Figure H6 Cobram Township Map

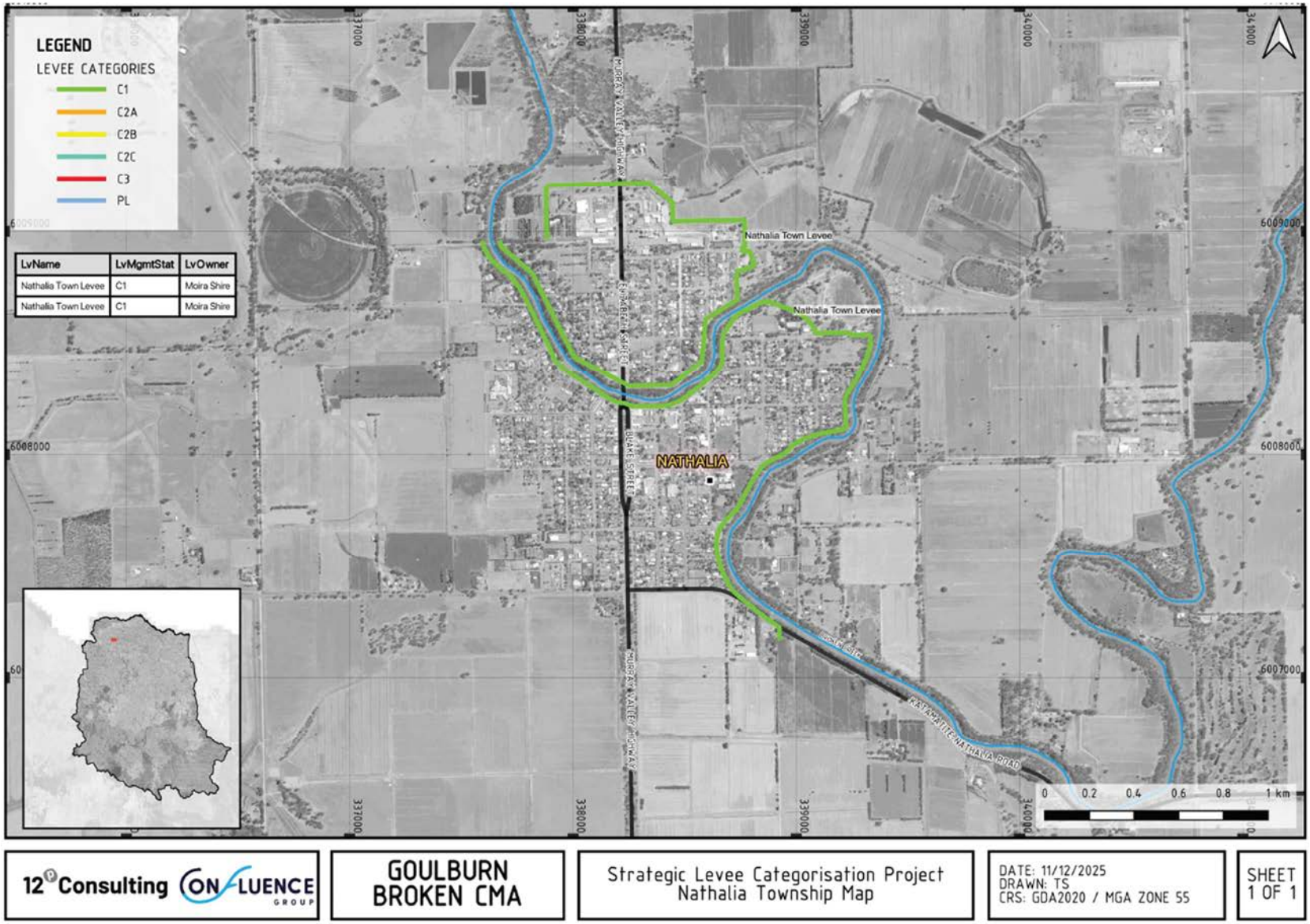


Figure H7 Nathalia Township Map

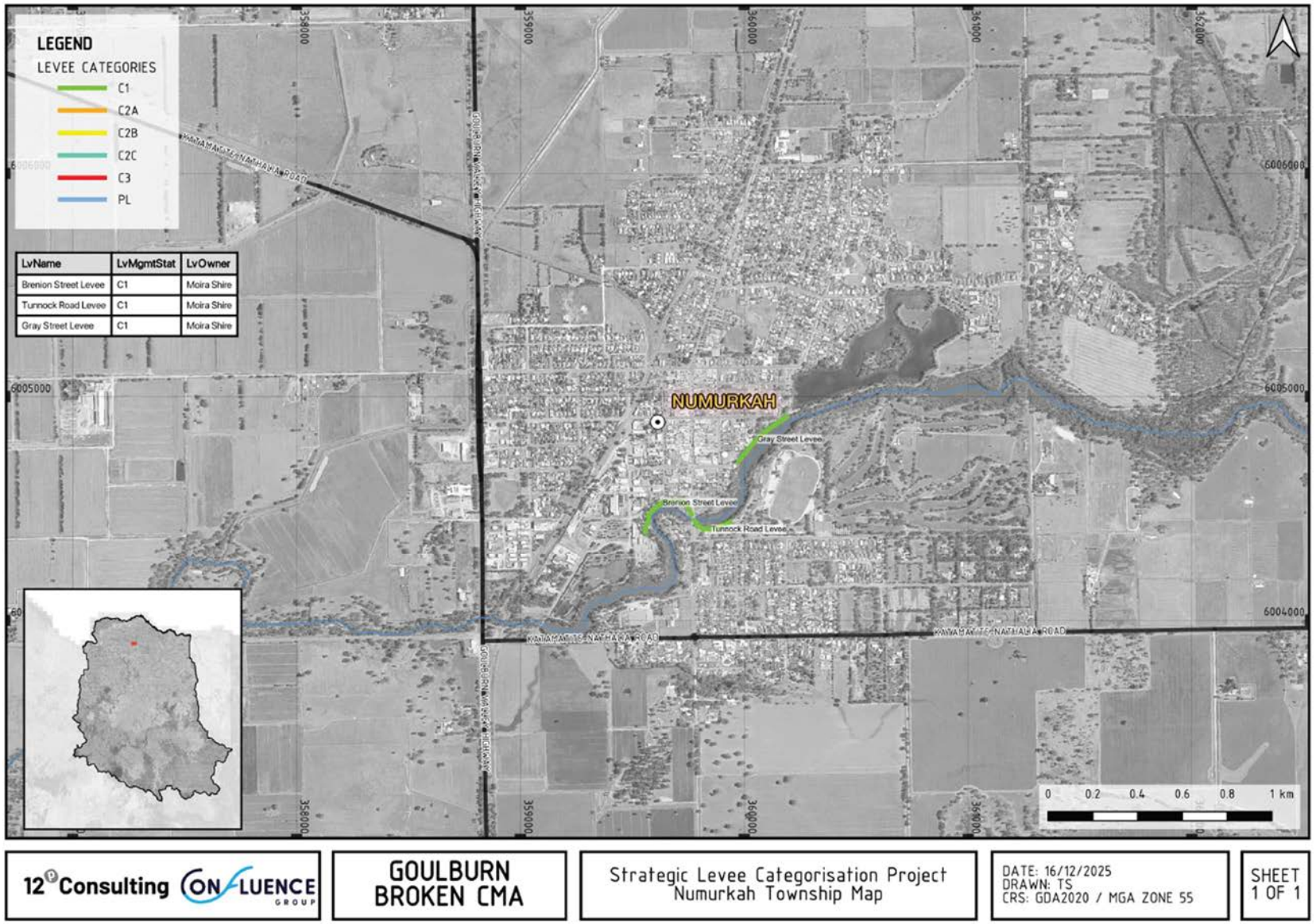


Figure H8 Numurkah Township Map

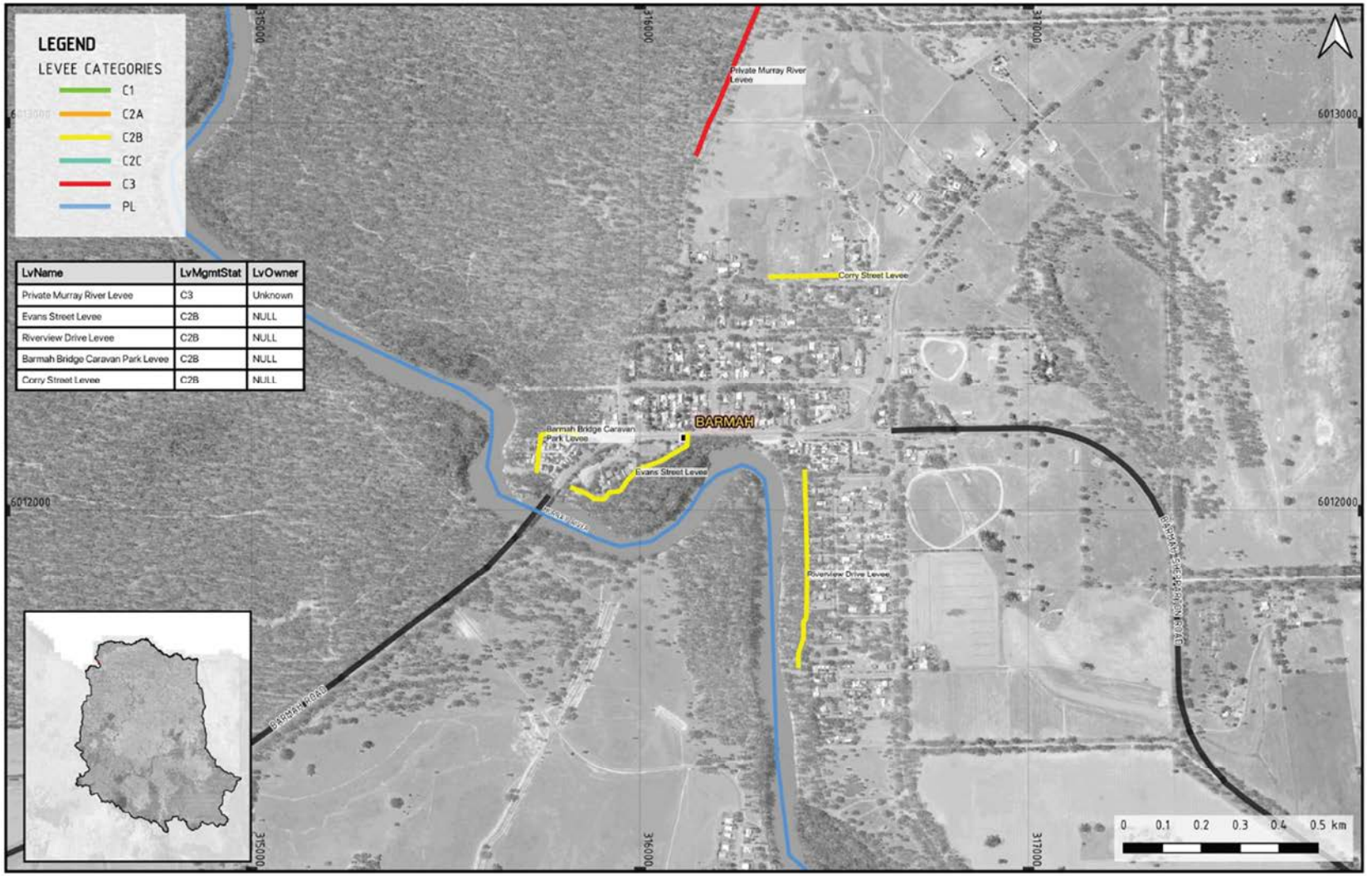


Figure H9 Barmah Township Map

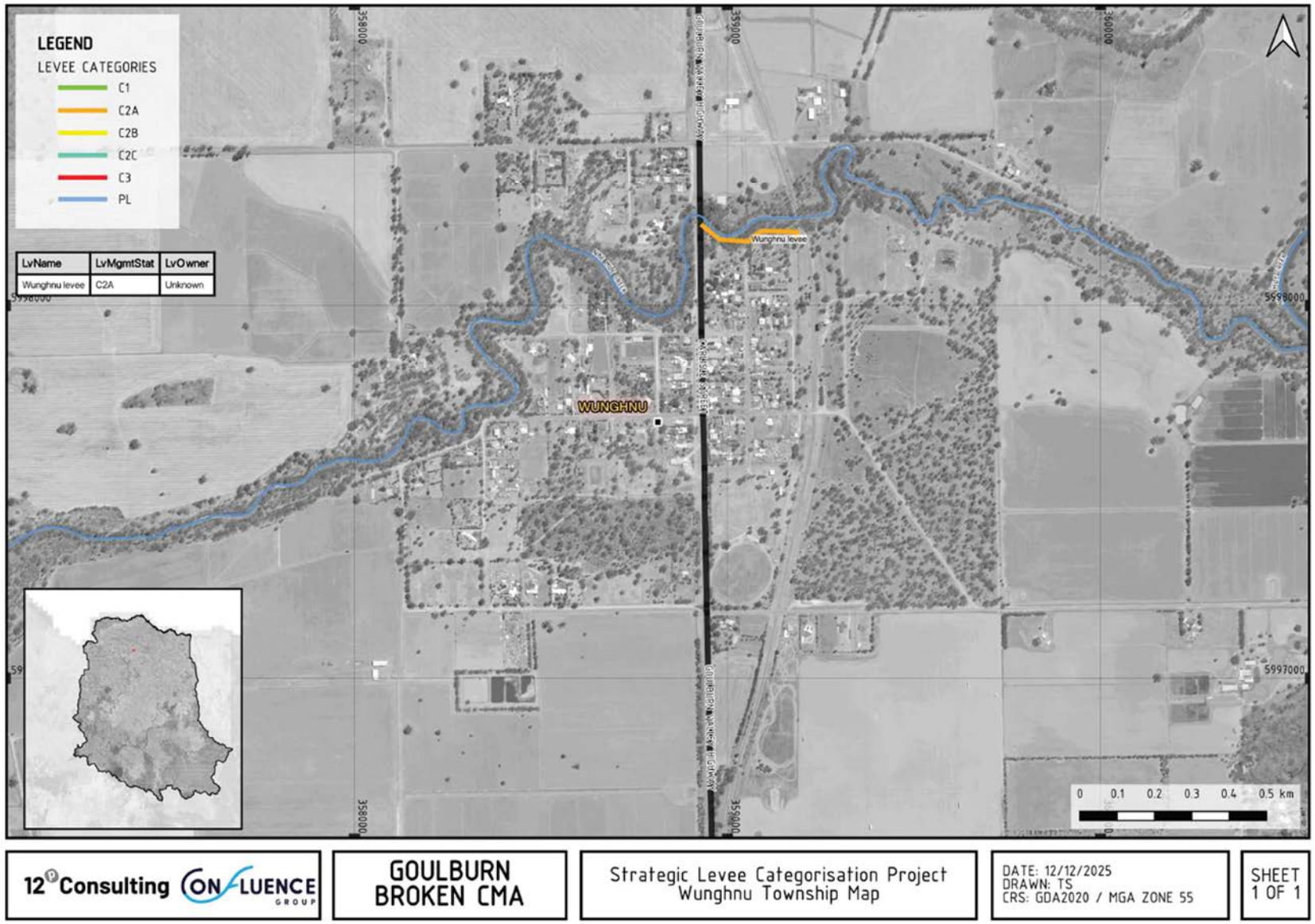


Figure H10 Wunghnu Township Map

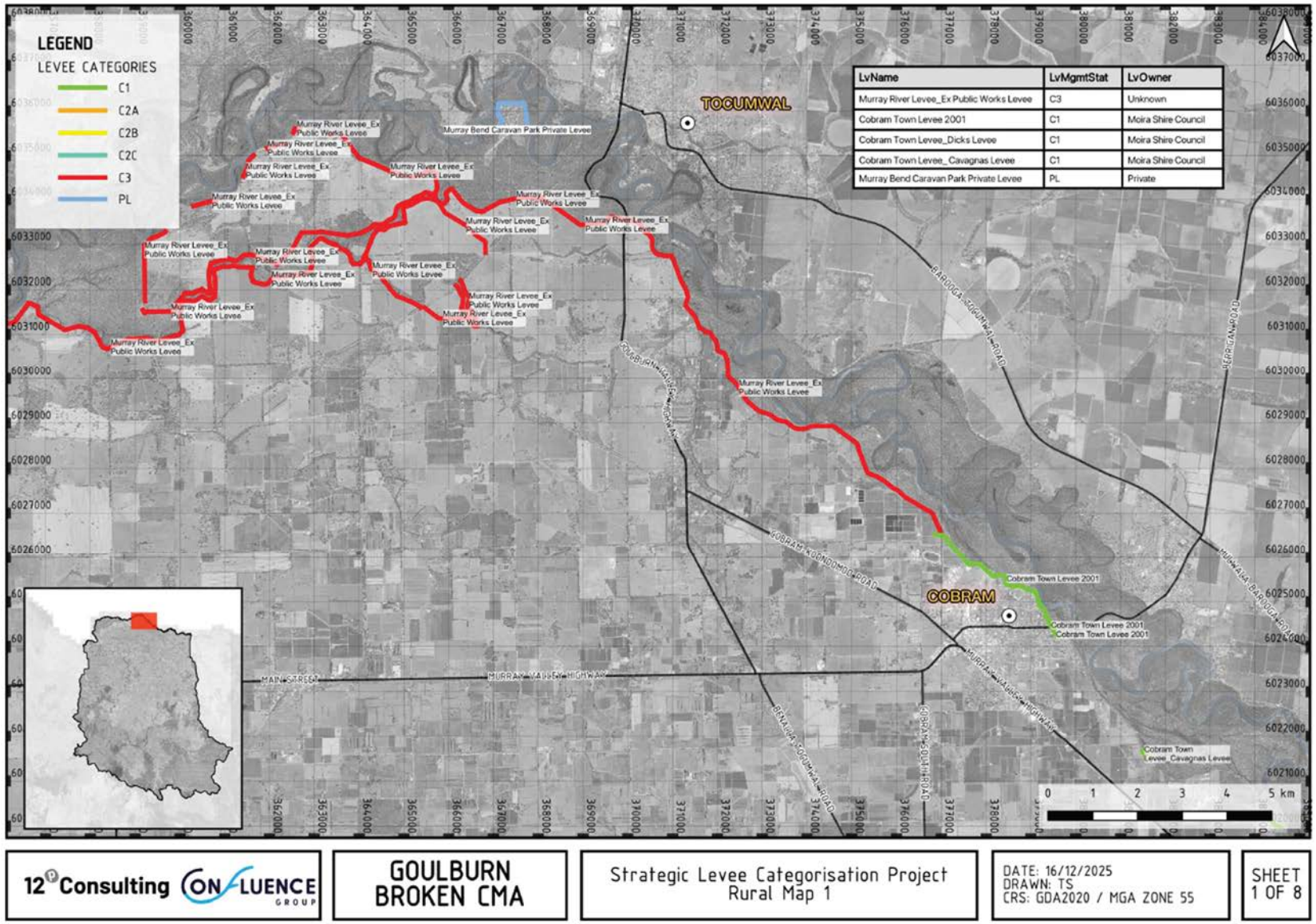


Figure H11 Rural Map 1 (Sheet 1 of 8)

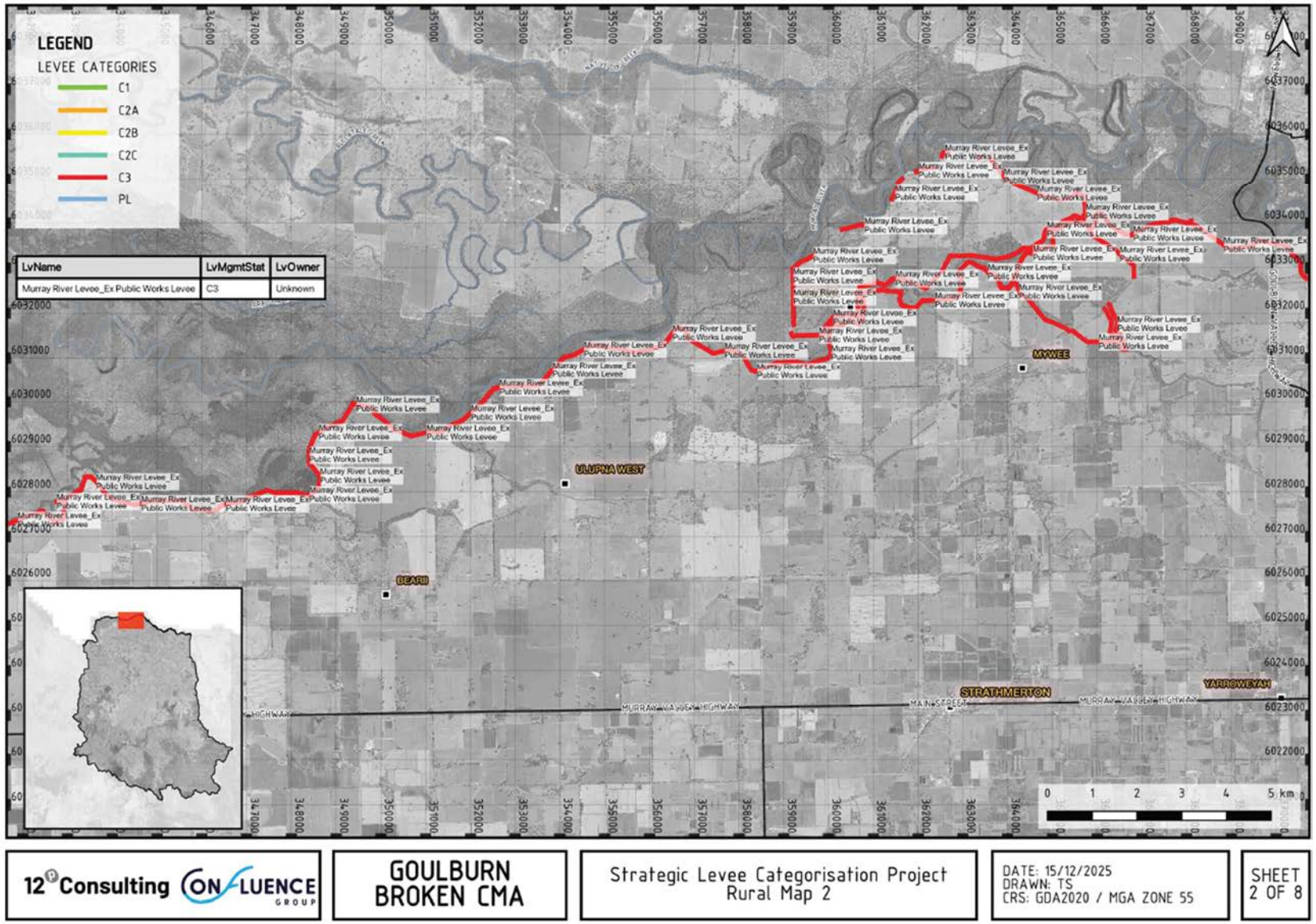


Figure H12 Rural Map 2 (Sheet 2 of 8)

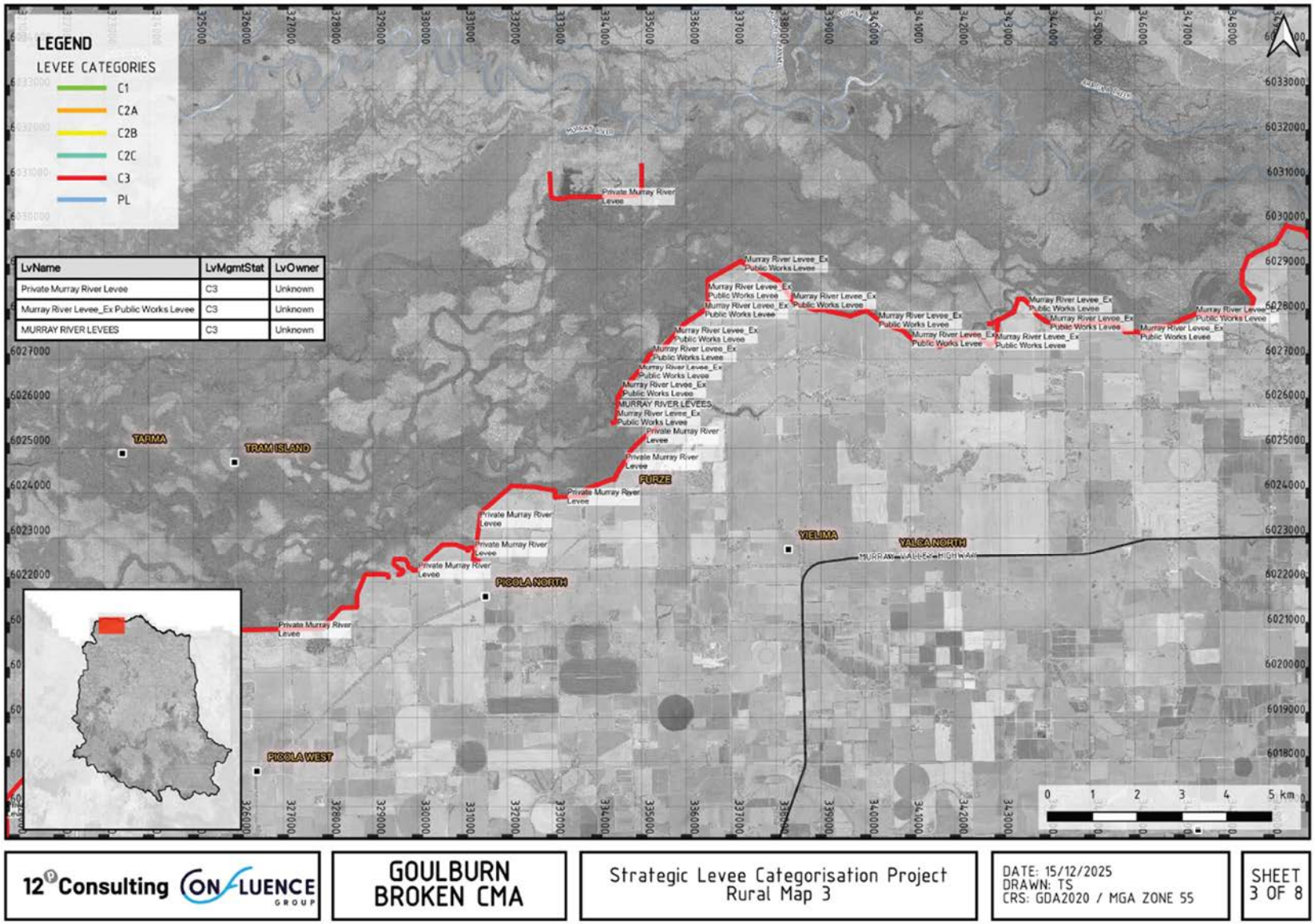


Figure H13 Rural Map 3 (Sheet 3 of 8)

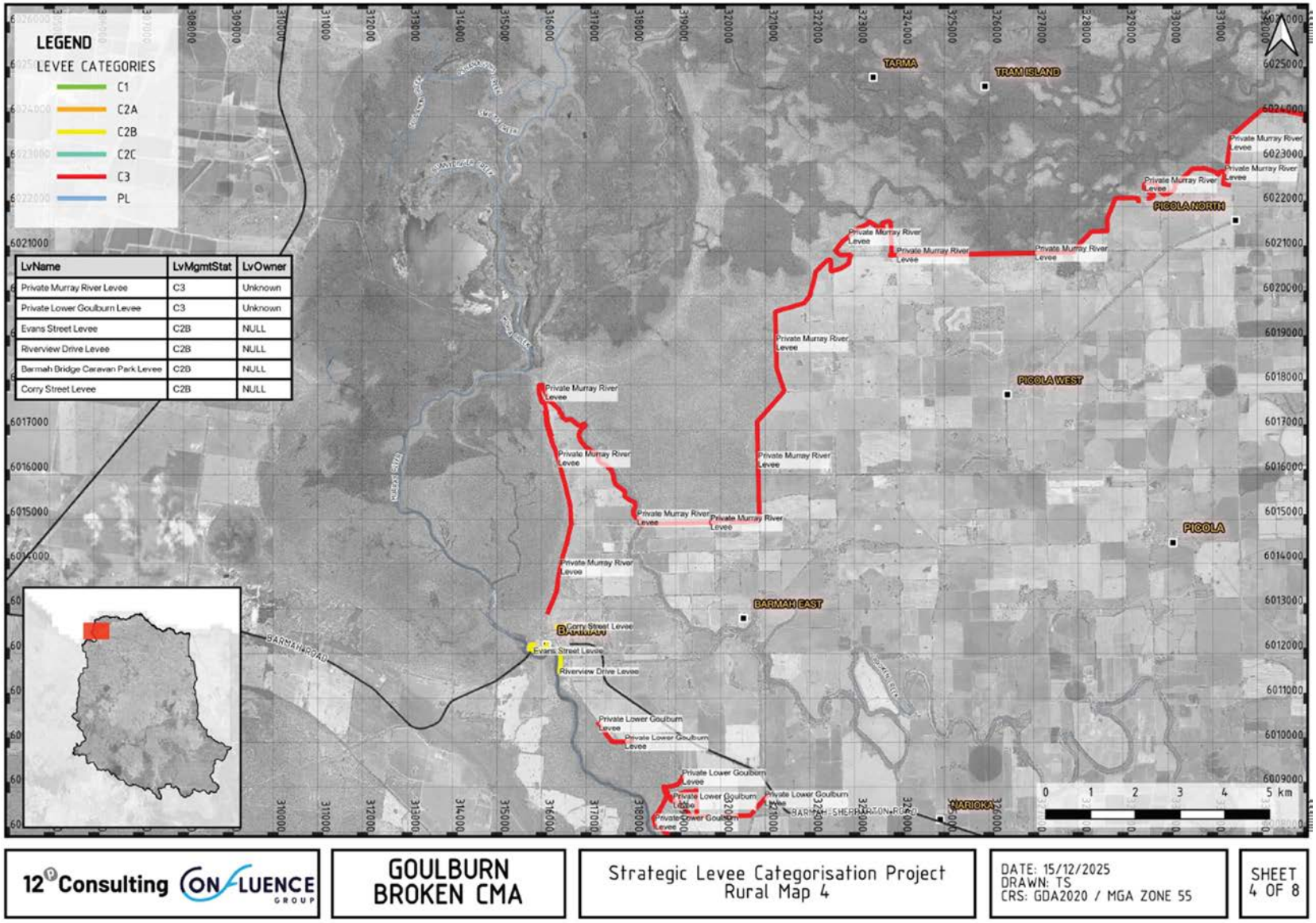


Figure H14 Rural Map 4 (Sheet 4 of 8)

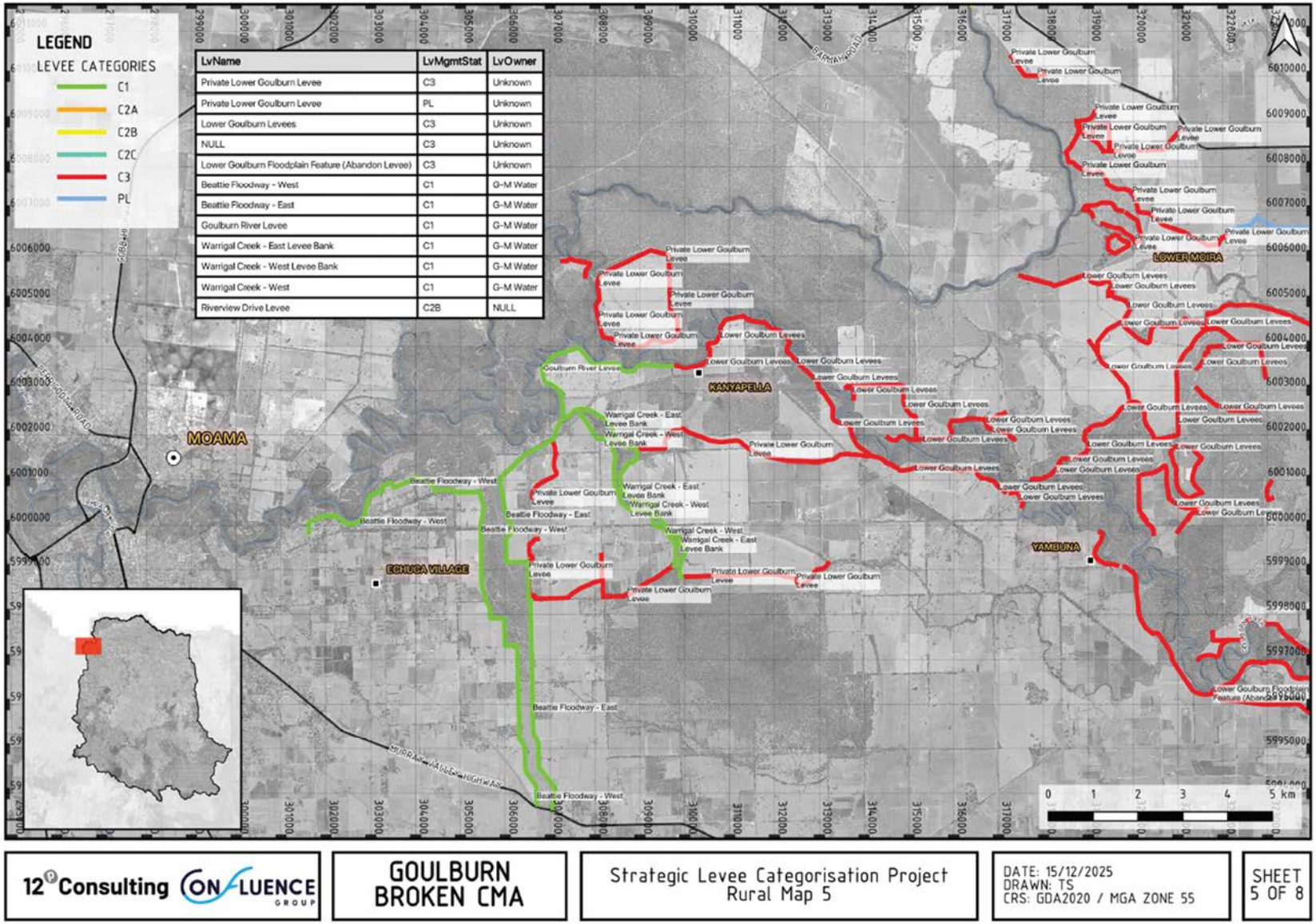


Figure H15 Rural Map 5 (Sheet 5 of 8)

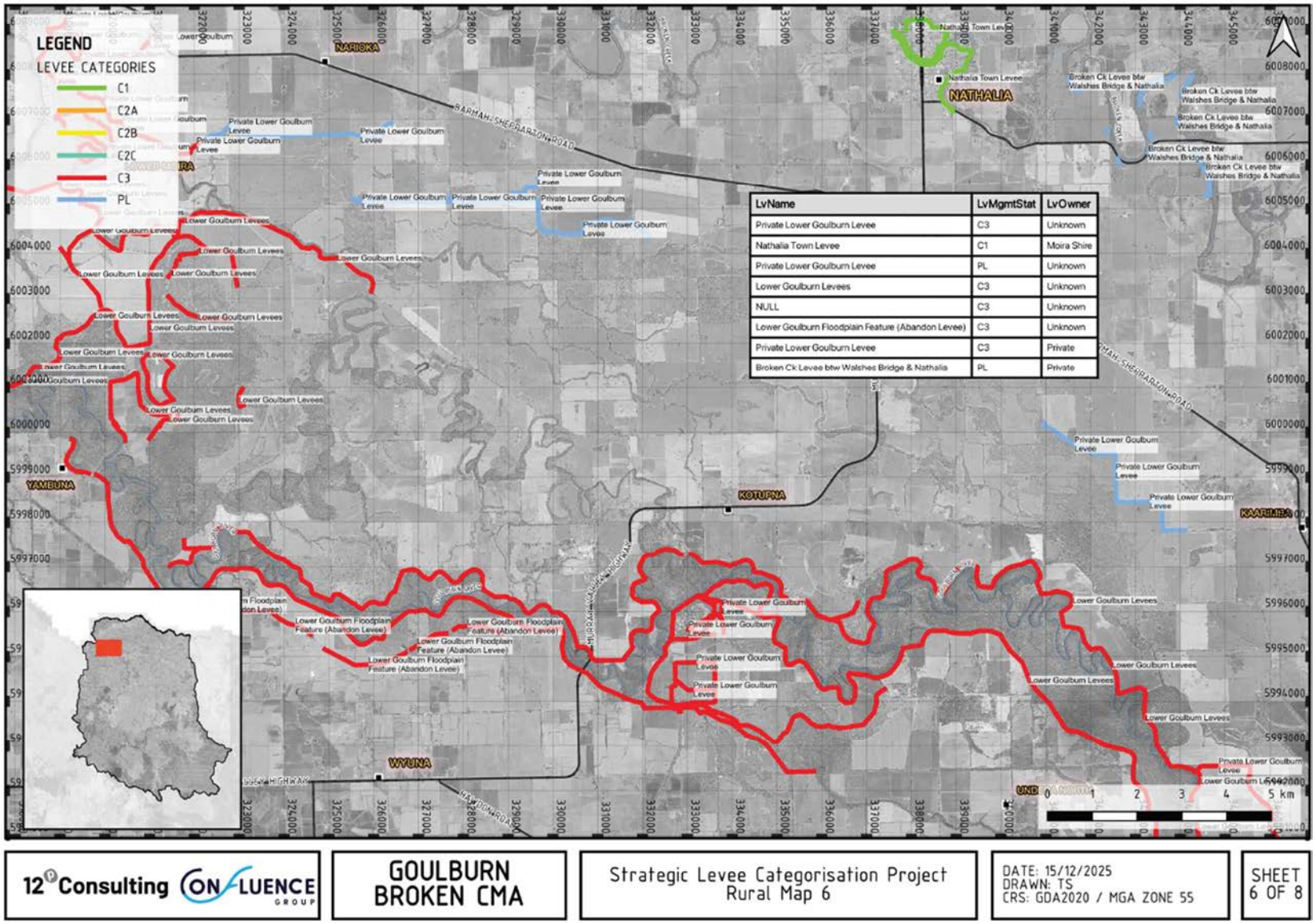


Figure H16 Rural Map 6 (Sheet 6 of 8)

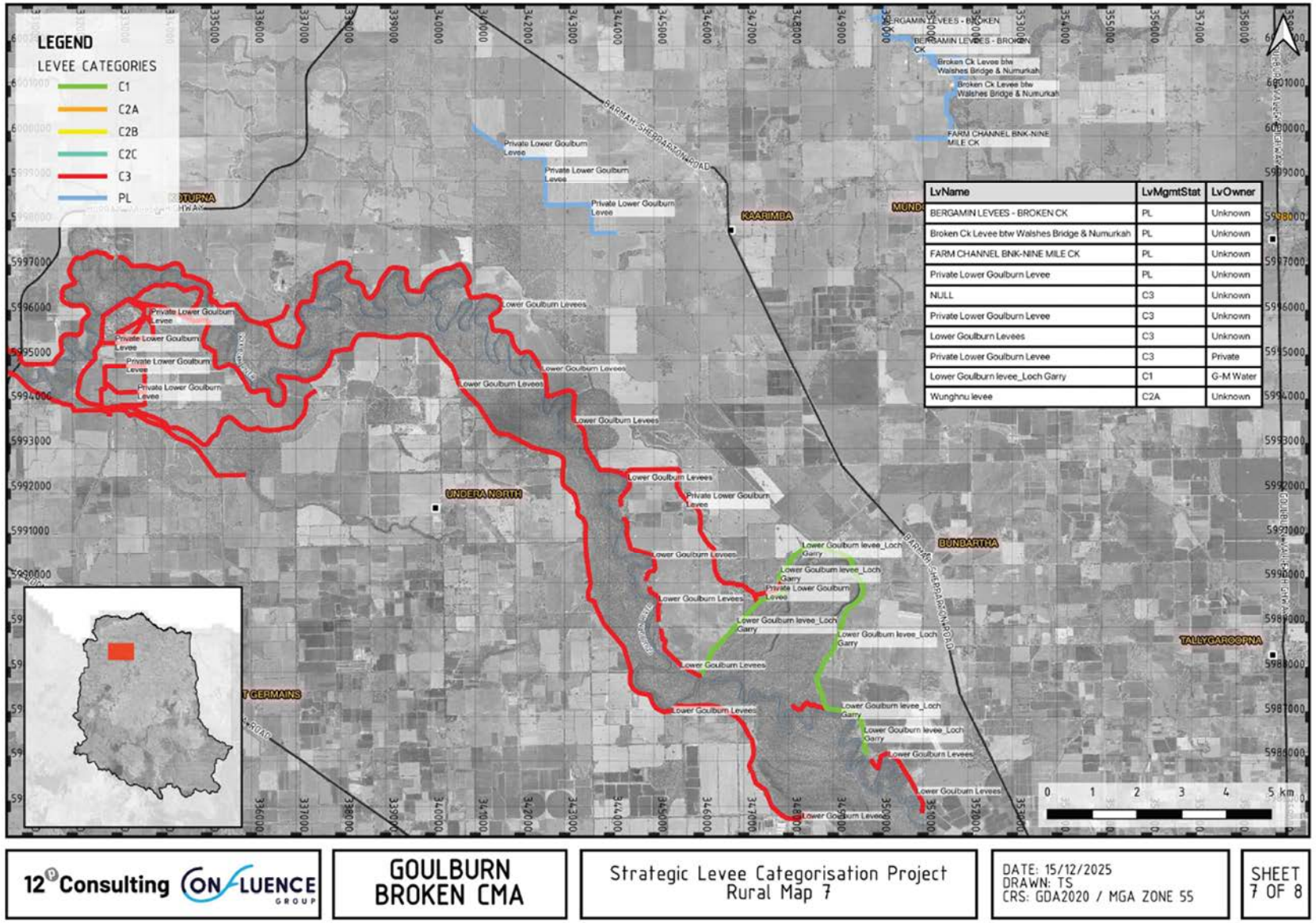


Figure H17 Rural Map 7 (Sheet 7 of 8)

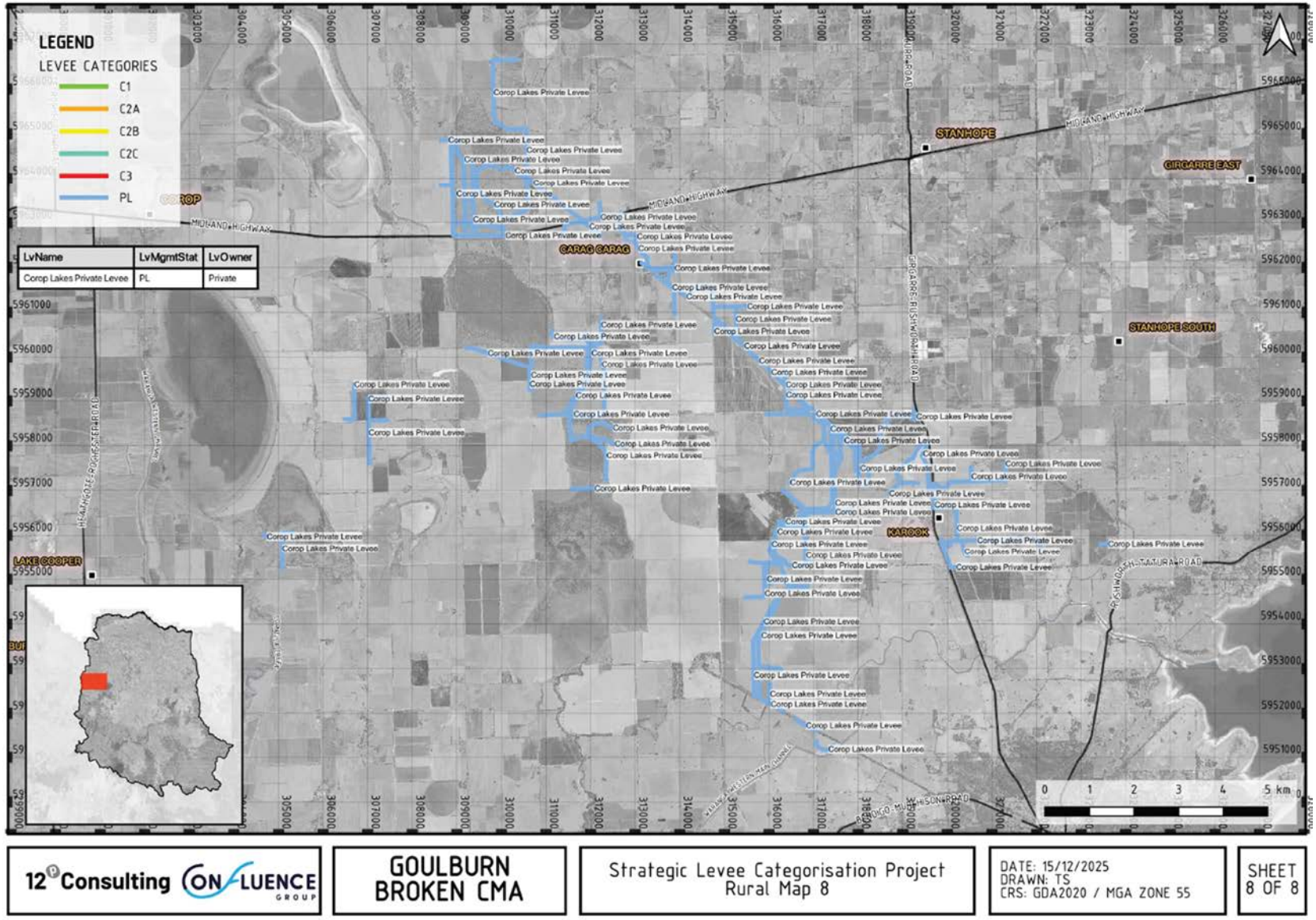


Figure H18 Rural Map 8 (Sheet 8 of 8)