

FINAL

# STRATEGIC LEVEE CATEGORISATION PROJECT - LODDON WORK PACKAGE

June 2026

STREAMOLOGY

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Source of cover image: Kerang in the 2011 Floods (NCCMA)

## Acknowledgement of Country

Streamology acknowledges and respects Traditional Owners, Aboriginal communities and organisations. The Dja Dja Wurrung people are recognised as Traditional Owners in the upper part of the Loddon catchment. The Barapa Barapa and Wamba Wemba people are Traditional Owners with connections in the lower part of the Loddon catchment.

We recognise the diversity of their cultures and the deep connections they have with Victoria's lands and waters. We pay their respects to Elders past and present, and recognise the primacy of Traditional Owners' obligations, rights and responsibilities to use and care for their traditional lands and waters.

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# 1 Introduction

In the wake of the devastating Spring floods of 2022, the Victorian Government initiated a critical project to enhance flood preparedness and response across northern Victoria. This report outlines a Strategic Levee Categorisation Assessment, funded by the Department of Energy, Environment and Climate Action (DEECA), specifically for the Loddon River catchment within the North Central Catchment Management Authority (CMA) area.

This assessment represents a proactive approach to flood management, bringing together key stakeholders including Local Government Authorities, Victoria State Emergency Service (VICSES), DEECA, and local communities. The primary objective was to develop comprehensive flood intelligence that will be integrated into Municipal Flood Emergency Plans (MFEPs) across the region.

By focusing on the research, development, and preparation of flood intelligence centred on key levees and floodplain features, this project identified practicable emergency actions. These actions will be crucial in protecting vulnerable communities and critical infrastructure during flood events.

This work package focused on comprehensively documenting the location and purpose of levees or significant floodplain features across the Loddon River catchment within the North Central CMA region (Figure 1). This report details the identification and classification of the levees and floodplain features approach.

The spatial extent of this work package included Gannawarra Shire Council, Loddon Shire Council and City of Greater Bendigo LGA areas. A small area of Campaspe Shire Council is in the Loddon Catchment, however the number and significance of levees are very small and so are not reported.

Simultaneously, levee detection and categorisation have taken place across all other catchments within the North Central Catchment Management Authority (CMA) area, which is the subject of a separate report.

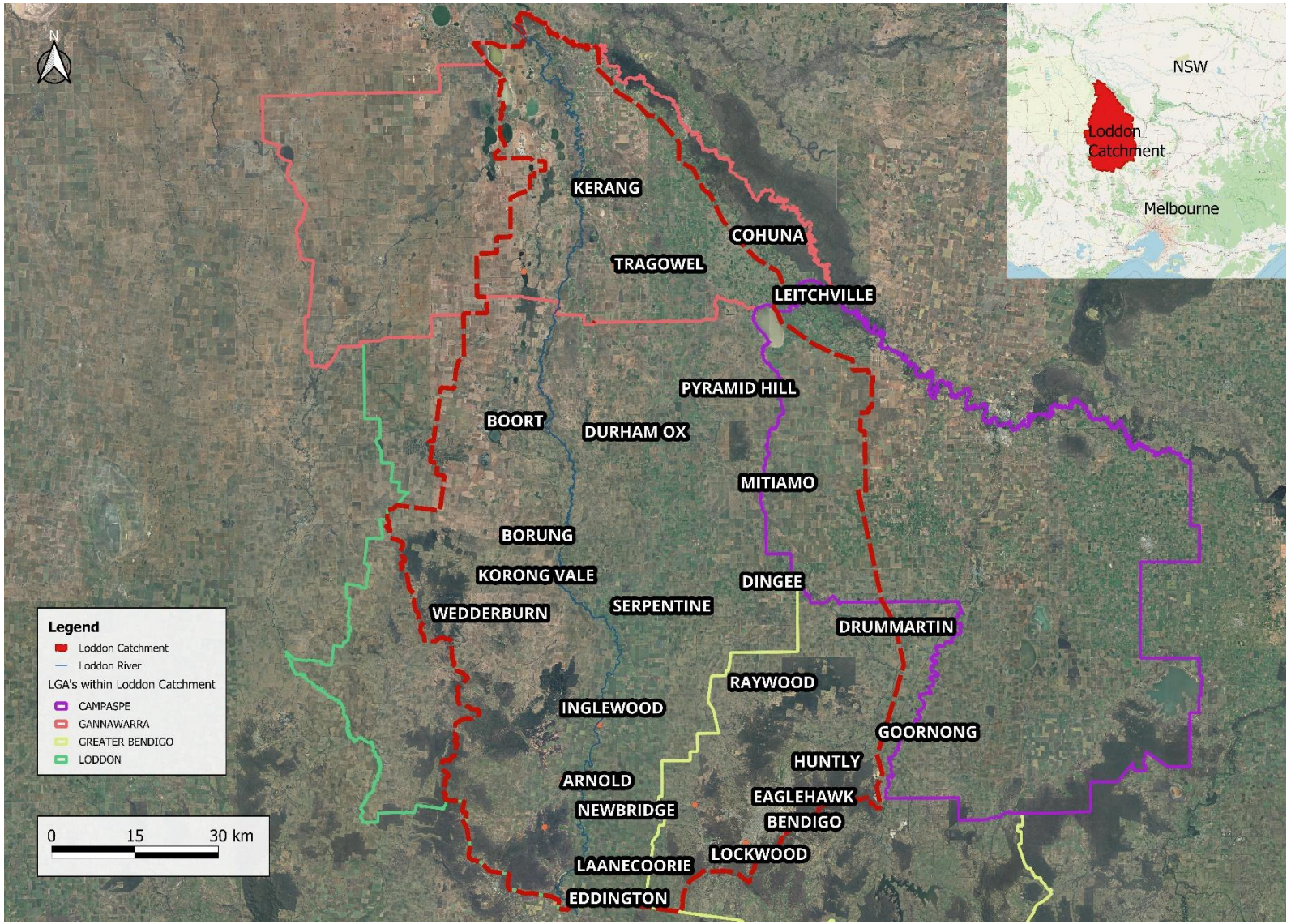



Figure 1. A Map of the Loddon Catchment (red), its location within Victoria and some key townships in the catchment.

## 1.1 Project aims

This project aimed to provide resources for understanding the importance of levees in protecting communities from the impacts of flooding. The levee assessment and this report support:

- Updating the FloodZoom levee database with a consolidated and categorised levee dataset for the Loddon catchment
- Prioritising resources to levees that provide the greatest benefit to community safety and resilience
- Identifying areas where levee performance needs improvement to reduce flood risks
- Providing information for consideration in future flood management strategies
- Making management and maintenance responsibilities clear for each levee based on categorisation level
- Community members to visualise and a give input into levee positioning and categorisation and to communicate their knowledge
- Collating institutional and community knowledge to identify issues and problem areas and suggest potential options for future levee management work or further investigations.

# 2 Methodology

To meet the projects aims a multi-stage process was undertaken, which consisted of:

1. Collating and reviewing all existing levee layers, flood management plans, lidar, flood mapping and information on significant floodplain features.
2. Creating an automated levee detection method to create an exhaustive database of potential levees
3. Amalgamating and performing data cleaning on existing levee layers and comparing with detected levee layers
4. Reviewing and agreeing upon levee categorisation definitions
5. Creating a workflow to categorise the merged and cleaned levee layers
6. Creating an additional layer using flood modelling to estimate flood effectiveness of each levee
7. Categorisations were sent to North Central CMA for expert review and comments to explain changes
8. Workshops presenting levees to relevant LGA's to identify contentious areas and change categorisation using institutional / historical knowledge
9. Uploading interactive maps of levees to an online portal and conducting community engagement sessions and field visits with landholders to evaluate categorisations
10. Accepting final changes to levee categorisations, locations and geometry and synthesising the feedback of stakeholders/ community members and knowledge provided by North Central CMA to collate issues and potential solutions for future levee management

After this exhaustive process a database of categorised levees is now available for the North Central CMA to present to stakeholders for planning and decision-making purposes and to update into the future.

The following sections (Section 2.1-2.6) provide greater detail how each step was undertaken.

## 2.1 Automated levee detection

An automatic extraction process to extract levees and floodplain features that act like levees was formulated through adaptation of Sasaki et al. (2023).

Twelve digital elevation models (DEMs) of varying coverage were provided by North Central CMA for the catchment area, captured at different time periods. The majority of the existing data was provided at one metre resolution, with two of the 12 datasets at 0.5 metre resolution. As a result, it was practicable to downscale the two higher resolution datasets to one metre using a bilinear resampling method.

The DEMs were compared for coverage and any gaps that were present were then compared to the North Central CMA provided raw LiDAR data and other publicly available data (VicMap Elevation and Depth data) as a means to create a whole catchment dataset. The data was combined to produce a merged catchment raster DEM with the most recently captured data given priority.

From the merged catchment DEM, relative elevation, slope, and curvature profiles were extracted for each raster cell. The thresholds adopted by Sasaki et al. (2023) for each parameter were initially adopted, however given the relatively flat catchment being assessed, the thresholds were then varied.

Relative elevation was determined relative to neighbouring cells for any given cell by examining the range of values within the nearest neighbourhood of cells. Relative elevation greater than 0.3 m was set as the threshold.

Through trial and error, the curvature profile from 0.02 m to 0.16 m was set as the threshold while slopes of between 5° to 17° were adopted. Ultimately, the aspect difference didn't provide any meaningful identification in automated levee detection in the Loddon. This was likely used to remove errors in Sasaki et al (2023) where mountains in the Kinu River basin in Japan were identified by their thresholds.



Figure 2. Extract of Automatic detected levee cells (pink) and CMA Levee Layer (blue).

Where a cell met all three thresholds for relative elevation, curvature profile, and slope, that raster cell fulfilled the requirements for a detected levee.

The detected levee cells were further filtered to preserve levees which were continuous, i.e. less than five metres between cells and with a minimum length of 20 metres. The remaining detected levee cells were converted to vector lines for usage in geographic information systems (GIS).

## 2.2 Levee categorisation

Categorisation definitions for all levees were agreed upon between the four participating CMAs (Mallee, North Central, Goulburn Broken, and North East), DEECA and VicSES prior to the initiation of the project. Categorisation definitions are listed in Table 1. A range of data sources were then used to initially identify and initially sort levees into categories for classification (Table 2).

Table 1. Levee categories and definitions

| Levee category | Justification |
|---|---|
| **Category 1** | Defined as those levees that are formally managed whereby the operation and maintenance are in place that protect urban centres or defined areas. |
| **Category 2 Type A** | Levees do not require significant work ahead of a major flood and may require active periodic monitoring. |
| **Category 2 Type B** | Levees require significant work ahead of major floods, or levees which have known issues (weaknesses) from past floods. Active monitoring is required during the flood event. |
| **Category 2 Type C** | Locality identified for a temporary levee ahead of a major flood and is removed post-flood. |
| **Category 3** | Defined as levees that provide unverified levels of flood protection to rural floodplain areas. |
| **Private** | Levees which have been built by individuals solely for the protection of their own property and assets. These levees to do not protect public infrastructure or assets. Examples include ring levees around homes and property. Note, Private levees (where known) should be documented (not categorised) but identified as Private Levees. |
| **Significant Floodplain Features** | Features in 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 (i.e., elevated roads, irrigation channels, railway embankments, and the like). Such features were to fail or overtop may cause downstream impacts or cause the flood to move in unexpected directions. |
| **Environmental** | Defined as an opportunistic levee that could be removed to allow for an environmental benefit or levees constructed to provide additional environmental benefit, i.e. lengthen the period of inundation |

Table 2. A list of data sources provided to identify, categorise and classify levees and explore potential management issues or options

| Data Type | Name | Description |
|---|---|---|
| **Spatial Data** | Lidar | Lidar coverage (80%). High floodplain coverage. Mix of Lidar ages. Upper catchment 2022. Mid-Lower ranges from 2011-2019. Significant portion of which was done in 2018. |
| | Flood model mapping | Raster and vectors for modelled depth and extent for AEP5, 10, 20, 50, 100, 200 and 2011 event. |
| **Levee Vectors** | CMA (NCCMA managed), VFD (Victoria Flood Database), GMW (Goulburn-Murray Water) levee layers | Shapefiles for levees. CMA layer was the most up to date and spatially accurate. VFD appeared to be drawn from aerial imagery in an automated process and was less spatially accurate. GMW for channel levees and layer had more operational information. Significant crossover for each layer. |
| **Flood study documentation** | Bridgewater Flood Management Plan (2016), Bendigo Urban Flood Study (2013), Marong Flood Study (2018), Loddon Regional Flood Study (2024), Korong Vale Flood Study (2024) | Flood studies for specific regions with the Loddon LGA area. |
| | 2013 Rural Levees Assessment | Survey commissioned by North Central CMA. |
| **Flood imagery** | Historic flood imagery | Linescan 2011, Sentinel Imagery, 2010-11 and 2016 flood aerials/photos. |
| **Municipal Flood Emergency Plans (MFEP)** | City of Greater Bendigo (2018), Gannawarra Shire Council (2019), Loddon Shire Council (2019) | VICSES lead the development of MFEPs available alongside community facing Local Flood Guides and include critical information about the risk and impacts of local flooding. |
| **Flood Management Plan** | Serpentine to Boort Flood Management Plan (2006) | Documents issues and floodplain management options. |
| | Gannawarra Flood Management Plan 2022 | Submission to Parliamentary Inquiry into 2022 floods in Victoria including recommendations for future actions. |

Due to the sheer volume of levees collated and detected during the automated process, a spatial analysis methodology was developed to classify the levees. The spatial analysis methodology to classify the levees is described below:

## Levee categorisation methodology

**1. Merged existing levee layers:**

- CMA, VFD and GMW levee layers were merged.
- CMA and VFD layer had overlapping levees (Figure 3). The CMA layer was drawn more accurately to where the elevations increased, although the layer had less info on private ownership and no ID codes for layers. When Levees overlapped CMA lines were kept. A small buffer (20 m) was created to capture overlapping layers better.
- After the layers were merged the shapefiles were manually assessed against relative elevation data and preliminary levee identification results. Anything that clearly wasn't a rise in elevation was deleted.




Figure 3. Example of CMA and VFD levee layers overlapping, with CMA layer being more accurate than VFD.

**2. Report and ring levees were created**

- All levees identified in the flood reports that had enough information in maps or descriptions were drawn in and had contextual information inputted into a shapefile.
- If the Levee was specified as Strategic, it was classified as Category 1. If it was specified as private it was labelled as such (Figure 4).




Figure 4. The west bank of the Loddon River at Benjeroop was an example of a section of levees initially identified as Category 1 (but later revised after expert review).

- Ring levees were drawn based on the ring levee points layer provided (Figure 5).
    - Not all ring levees were present in the DEM, so some levee lines were estimated based on more recent aerial imagery showing earthworks around what are likely the ring levees.




Figure 5. A ring levee drawn using aerial imagery showing flood waters being held back

### 3. Levees were merged and broken up and incremented

- Report, ring and existing levees were merged.
- Lines were split to have a maximum length of one kilometre (**Error! Reference source not found.**). This was to facilitate fairer comparisons when categorising, as some levees were long (e.g. up to several km), while others were made up of multiple smaller lines.

- A continuous number was added to each broken up section.
- Then the autoincremented number was appended to the “ID code” so the new code for each section could still be identified by the old ID code.

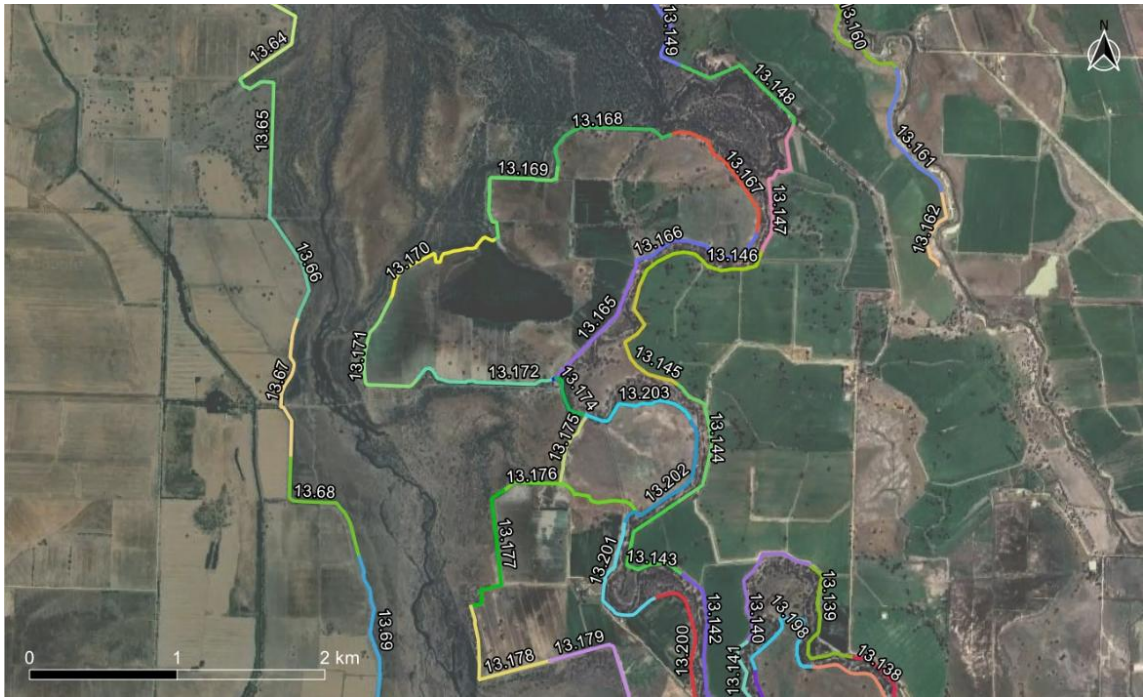



Figure 6. Example of one levee ID covering a large area (e.g. Lower Loddon near Capels Crossing) made up of multiple levees that were then broken into 1 km segments for fairer comparisons.

**4. Buffers created and levees categorised**

- A 500 m buffer was created on either side of the levees
- Columns “house_count” and “ID_count” were created, which counted how many houses (from Microsoft Building Layer) and sections of principal transport layer (key road and rail corridors) intersected the buffer
- An “Est_Cat” field was created to categorise levees based on if they intersect a certain number of houses or the principal transport network. If the buffer intersected > **20 houses** or the **principal transport layer** it was classified as Category 2. If it intersected < 20 houses and did not intersect the principal transport layer it was Category 3 (Figure 7).




Figure 7. Location: Serpentine Township. The buildings layer (pink) is used to calculate how many houses are within each 500 buffer from the levee. The white line is the principal transport layer showing the Loddon Valley Highway. The levee south of the town intersects the highway so is Cat 2. Levees around the town would be Cat 2 if they were not already identified as Strategic (Cat 1). Levees to the southeast do not intersect the principal transport network and > 20 buildings and is Cat 3.

**5. Filtering automatically detected levee polyline**

Estimated levees created from slope and relative elevation were filtered using the following steps:

- A large flood model covering the whole Loddon catchment was created in 2016, that estimated flood extents and depths at Average Recurrence Intervals (ARI) of 5, 10, 20, 50, 100 and 200 Years. Any lines that were outside the modelled ARI200 extent and extents from digitised 2011 flood imagery were also removed (Figure 8).
- The simplified levee detection method misidentified gentle slopes of dams or creeks as levees, as aspect could not be used to identify opposite slopes that are common for levees. This was because the levees were not wide enough for this method to work with the resolution of lidar provided).
- Instead, a farm dam layer from Vic Map (2019) was used to remove small dams by using a 10 m round buffer around each feature to remove as many dams misidentified as levees as possible (Figure 9).
- The lower bank next to the water's edge was also misidentified as levees so a 10 m buffer on each side of the waterway centreline was used to remove these misidentified levees (Figure 10).

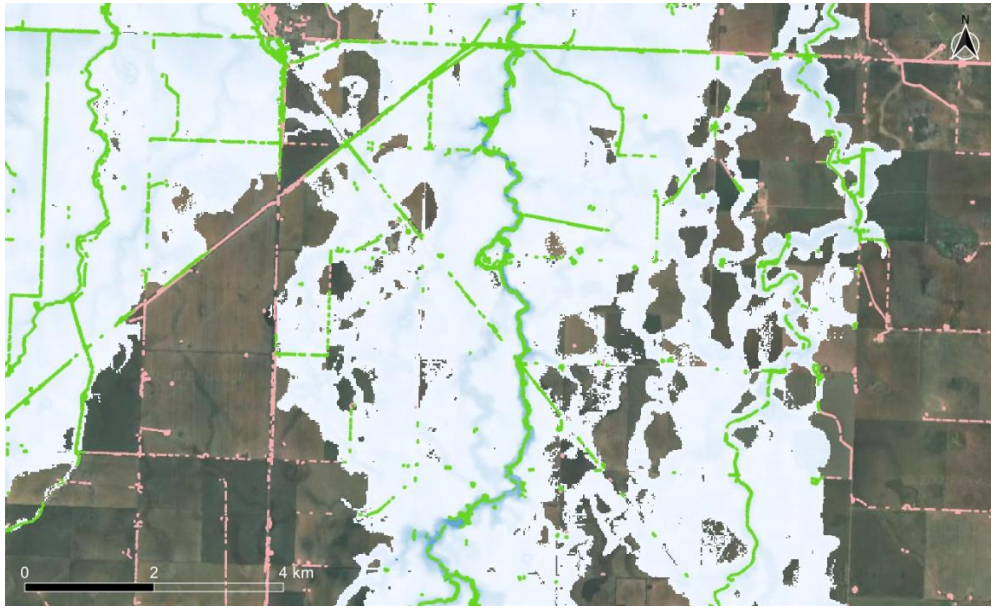



Figure 8. Any estimated levees outside of the ARI200 (pink lines) were removed to create a new filtered layer (green lines)




Figure 9. Estimate levee lines (pink) intersecting the farm dam buffer (orange) were removed

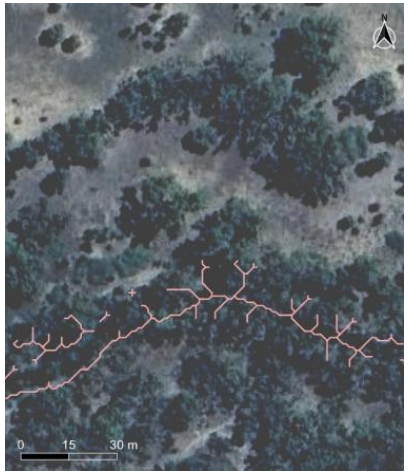



Figure 10. Banks of waterways were misidentified and removed

## 6. Created Significant floodplains features (SFF) layer

- Polylines from i) Vic map roads and ii) rail layer and iii) HY waterways (Vic map Hydro) layer (which was filtered to remove streams and rivers so only drains and channels remained) were merged into one layer (Figure 11).




Figure 11. Location: Mitiamo. Roads (purple) railways (green) and channels and drains (blue) make up significant floodplain features (SFF).




Figure 12. SFF layer (yellow) filtered by only keeping lines that intersected with estimated levee buffer (green)

- A 20 m buffer of filtered automatically detected levees was used to refine the SFF layer. If SFF layer intersected with the buffer the lines were kept, as the relative elevation of the feature is 0.3 m higher than the surrounding area and slope is within the levee range (5-17°) and therefore would act to block and redirect flow (Figure 12).

**7. Further filtering of estimated polylines**

- A 10 m buffer around significant floodplain features was used and any lines intersecting were removed (Figure 13)
- This has the potential to make it easier for users to find embankments/ levees that have not been described or previously digitised.




Figure 13. Remaining estimate levee lines (pink) are visible after being filtered by SFF layer. This layer can be used to identify roads or embankments

## Categorisation process – key outputs

- **Category 1 Levees**: Levees that are formally managed, i.e., operation and maintenance is in place to protect urban centres or defined areas.
- **Category 2 Levees**: Levees identified in reports and merged with existing levee layers. Categorisation process involved a 500 m buffer on both sides of the levee. If the buffer intersected twenty or more buildings or part of the principal transport network (key transport routes for evacuation and moving crucial goods).
- **Category 3 Levees**: Levees identified in reports and merged with existing levee layers. Categorisation process involved a 500 m buffer on both sides of the levee. If the buffer intersected less than twenty buildings and did not intersect principal transport network.
- **Significant floodplain features (SFF) (uncategorised)**: A merged shapefile using the entire Vic map roads and rail layers and hydro layer (filtered to only include channels and drains). Only lines that intersected with a 20 m buffer of the estimated levees were included so only features that had characteristics of levees (and located in important areas) were included.
- **Remaining estimated levees (uncategorised)**: Filtered results of the estimated levees process. Lines were joined if there was another cell within 5 m to filter out isolated cells but were not smoothed out. Farm dams and the middle of streams were removed, as were lines outside of ARI200 flood extents. SFF were removed so only embankments and rises in the landscape that act as levees remained. Note: some level of noise remained due to the limitations of automated filtering.

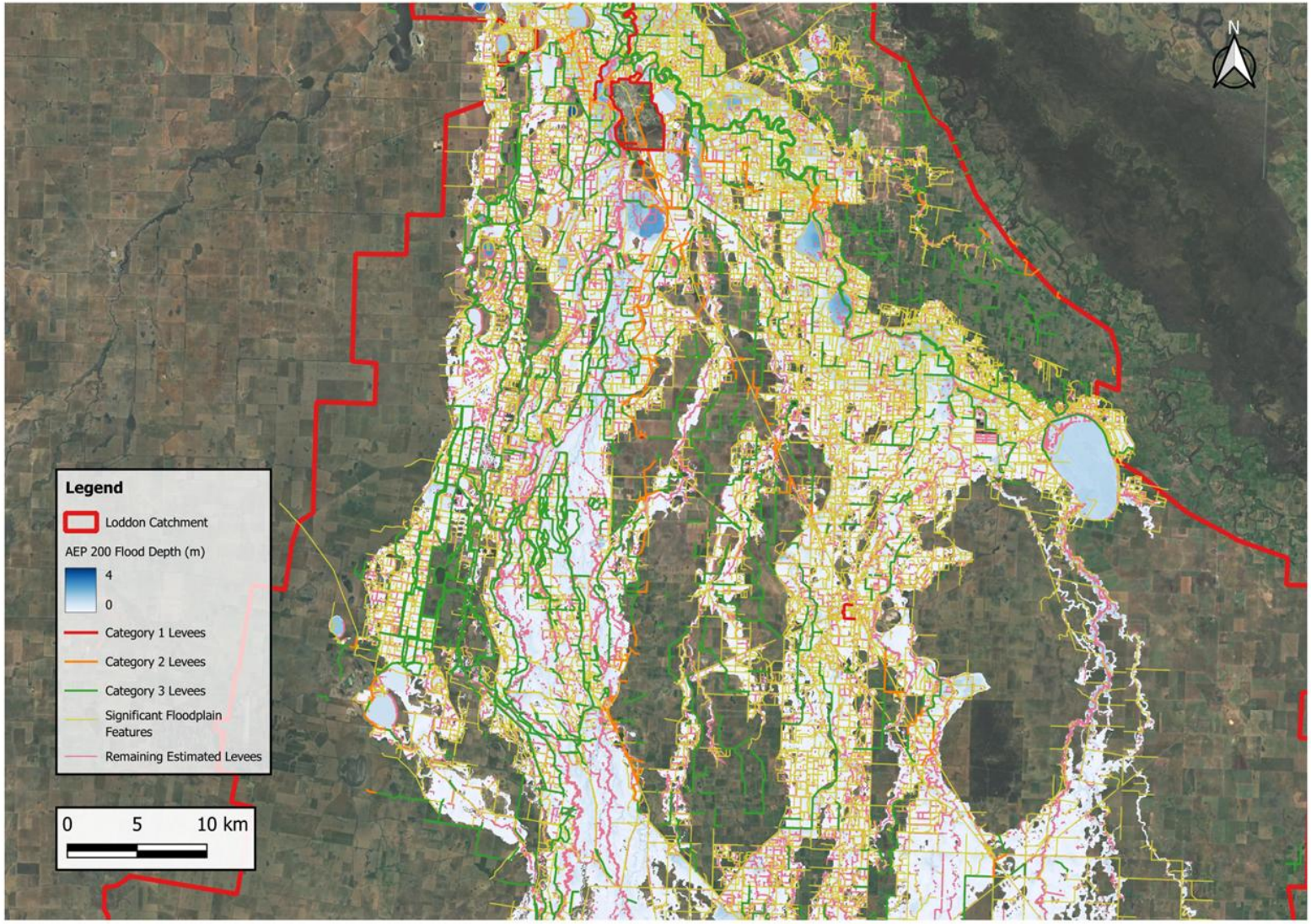



Figure 14. An overview of the large number of categorised levees and significant floodplain features

## 2.3 Flood function/effectiveness

To add additional value to the levee categorisation process, the functionality or level of flood mitigation effectiveness was determined for each levee.

Using modelled flood depth mapping outputs from a range of AEP events the flood depth that could be held back was estimated by calculating the minimum and maximum flood depths adjacent to each levee (Figure 15).

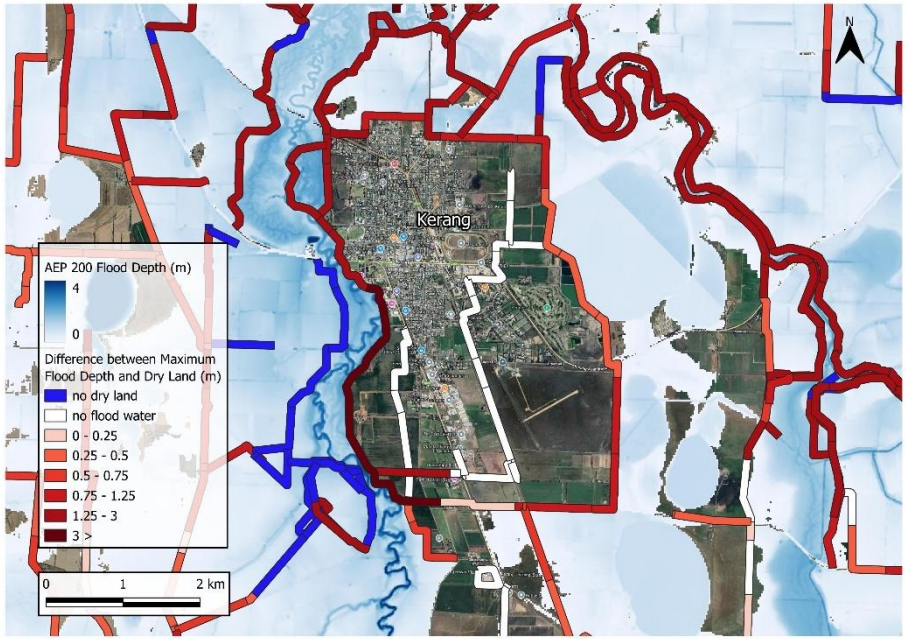



Figure 15. Effectiveness of levees calculated using flood modelling.

The methodology was as follows:

1. A small buffer was created around the levee lines, sufficient to capture the top bottom on both sides. 20 m was adopted.
2. 5%, 2% and 0.5% AEP flood depth results layer were added.
3. The range between min and max values was calculated for each depth
4. The function of the levee was categorised based on whether flooding is unaffected (unaffected – white lines), flooding is held back water to a certain depth (darker reds indicate more water held back), or the levee is breached – meaning water surrounds both sides of the levees (no dry land – blue lines).

This tool can be used to identify any important levees holding back flood waters that were not picked up in the prior categorisation process and helps vectorise flood modelling into a form that can be added to online portals to communicate levee benefits for stakeholders. However, caution must be taken as it reflects flood modelling data and relies on up-to-date data inputs.

## 2.4 North Central CMA review

All categorised levees were then reviewed by North Central CMA to identify any levees where the category from the spatially rule based categorisation process was not appropriate. North Central CMA were able to use their knowledge of flow paths and the condition and importance of the levees to determine which needed either upgrading or downgrading.

Upon review most areas intersecting the principal transport network did not warrant being Category 2 and some areas outside of key townships not directly intersecting over 20 buildings were changed to Category 1 or 2, due to their effects upstream of preventing flooding to downstream townships. Some levees identified as Category 1 due to being in flood management planning documents in the northern catchment were also downgraded based on a review of the areas protected by the given levee.

## 2.5 LGA workshop review

After review by the North Central CMA the levees within each LGA were presented to key stakeholders in an in-person workshop at Council offices to review maps and evaluate and redraw, if necessary, the specific details (length, connections) of each Category 1 and 2 levee (Figure 16).

This allowed a more refined version of the levee categorisation to be uploaded to the online portal and be provided to community members at workshops organised by North Central CMA

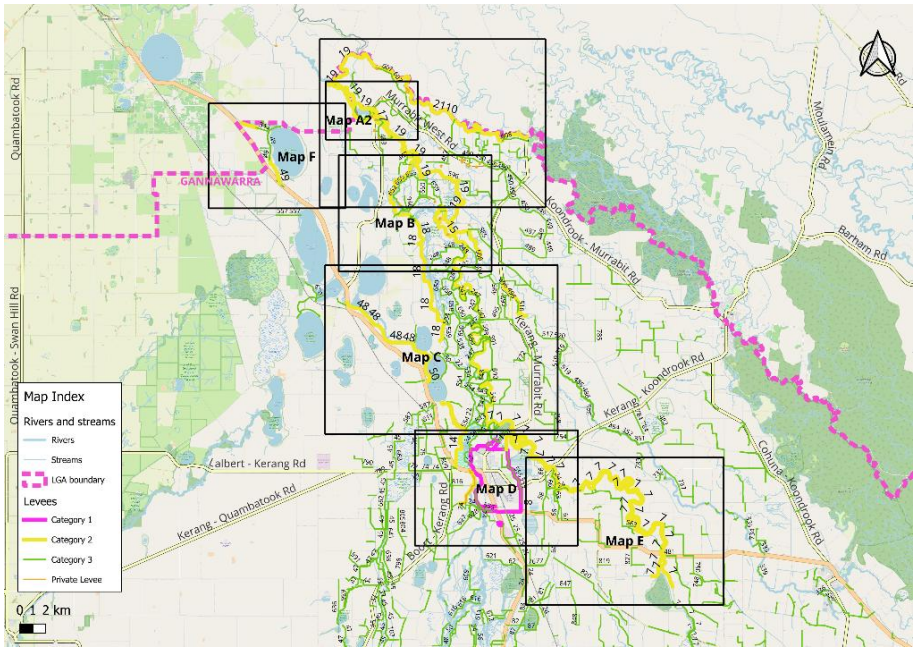



Figure 16. An overview of the 7 different finer scale maps used in the Gannawarra LGA workshop review to further refine categories and locations of present and future levees.

## 2.6 Community engagement

As part of the North Central Levee Review, community engagement played a key role in verifying mapped information, building local awareness, and identifying any additional flood mitigation infrastructure or concerns. A series of public drop-in sessions were held by North Central CMA across the region to provide opportunities for local residents to view draft levee maps, ask questions, and provide feedback.

Drop-in session locations were selected in consultation with local government representatives. Sites were prioritised based on their proximity to levee systems where local interest and past community advocacy for improved management had been noted – particularly in areas without formal levee management arrangements already in place. Rather than simply targeting larger population centres, the team focused on locations where discussions were more likely to lead to meaningful input relevant to the review.

The following community drop-in sessions were conducted:

- Bridgewater – 4 June 2025, Bridgewater Recreation Reserve
- Boort – 4 June 2025, Boort Resource and Information Centre
- Pyramid Hill – 5 June 2025, Pyramid Hill Community Centre
- Kerang – 5 June 2025, Kerang Memorial Hall (Notably, over 50 people attended this event)
- Cohuna – 26 June 2025, Cohuna Community Meeting Room
- Murrabit – 27 June 2025, Murrabit Public Hall

Representatives from North Central CMA, local Councils and VicSES were present at the sessions to support discussions and respond to questions. These sessions were advertised by North Central CMA and promoted through local council channels i.e. social media, community flood recovery contact lists. All sessions were well attended and emergency managers received valuable feedback on the strategic levee maps and many other aspects of flood emergency management.

An additional session was held with the Gannawarra Shire Council's Flood Observers Network on 1 August 2025. The Flood Observers are a group of community members with a long-standing history of involvement in local flood planning and flood event management within the framework of the Gannawarra Shire's Municipal Flood Emergency Plan. This network is a valuable source of flood history and knowledge, floodplain management ideas and actions, and community champions for the work of Council and North Central CMA. Over 50 people attended the session in Kerang which covered a range of topics including North Central CMA's levee review project.

Additional individual or small group discussions were also conducted with landowners at Tyntynder, Murrabit West, Capels Crossing, Benjeroop, Koroop, Mead, Dingwall, Tragowel, Pyramid Hill, Tandarra, Kamarooka, Raywood, Torrumbarry. These field visits and discussions with local landowners were highly valuable in assessing the value and purpose *of* levees assessed under the strategic levee review project.

# 3 Outcomes

## 3.1 Levee identification, classification and cataloguing

Several thousand kilometres of levees were able to be identified, evaluated, merged and classified into different categories (Figure 17). Significant *floodplain* features (SFF) made up the majority of the overall length (83.6%) due to the automated levee detection process. Large lengths of SFF reflect the networks of roads and irrigation infrastructure that will influence how water moves through the landscape.

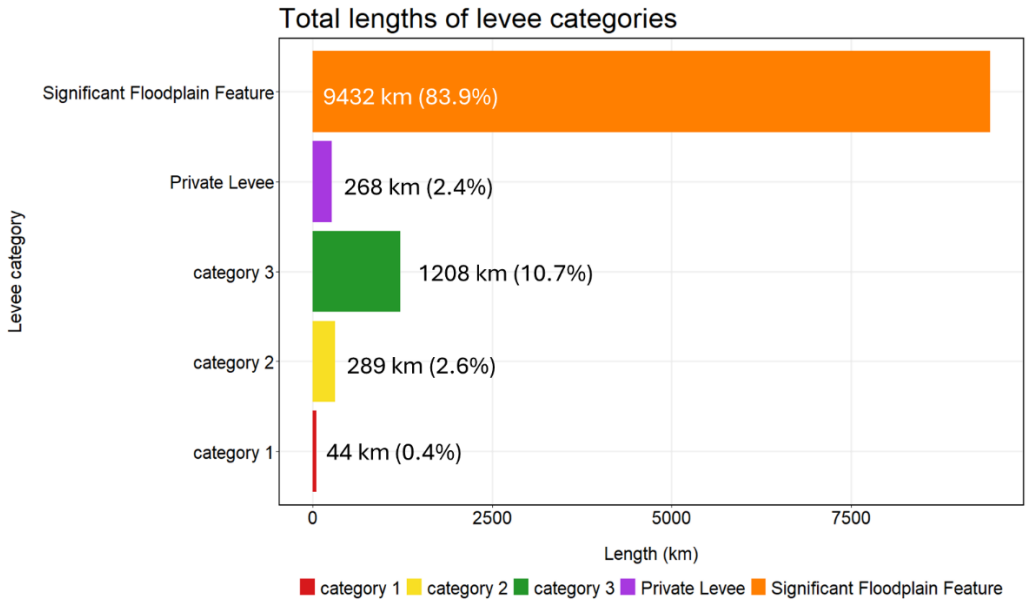



Figure 17. Breakdown of the length of levees and percentage of each category across the overall study area.

Category 3 levees were more common (10.8%) than Category 2 (2.8%) and Category 1 (0.5%) levees.

As noted by the structure of the precinct areas (Section 3.2), a larger number and length of Category 2 levees were identified in the Gannawarra Shire that need further consideration for management (Table 4). The number and total length of Category 1 levees were smaller and similar in each LGA, as these typically surrounded townships. A higher density of levees was identified in the flatter, northern areas of the Gannawarra and Loddon Shires which have experienced more widespread historical levee construction as the primary flood mitigation method.

Table 3. The total length and number of levees for each category in each LGA within the Loddon Catchment.

| LGA | Category | Length (km) | Number of levees |
|---|---|---|---|
| Gannawarra | Private Levee | 34.5 | 22 |
| | Significant Floodplain Feature | 4480.7 | 11863 |
| | Category 1 | 19.5 | 2 |
| | Category 2 | 275.6 | 21 |
| | Category 3 | 487.0 | 273 |
| Greater Bendigo | Private Levee | 2.0 | 3 |
| | Significant Floodplain Feature | 117.9 | 116 |
| | Category 1 | 9.7 | 5 |
| | Category 2 | 7.1 | 2 |
| | Category 3 | 13.7 | 20 |
| Loddon | Private Levee | 231.9 | 162 |
| | Significant Floodplain Feature | 4831.4 | 8772 |
| | Category 1 | 14.4 | 9 |
| | Category 2 | 5.9 | 10 |
| | Category 3 | 707.5 | 350 |

Importantly, an update of Municipal Flood Emergency Plans (MFEPs) intelligence cards is concurrently being undertaken by Streamology, North Central CMA and relevant LGA's. These updates catalogue key details for each Category 1 and 2 levees and management arrangements for Category 1 Levees, along with identifying gaps in the dataset that need to be filled. If more information for a particular levee is required, FloodZoom (https://www.floodzoom.vic.gov.au/) and the relevant MFEP intelligence card will have more information on the levee, including emergency management actions associated with the levee in the lead up to and during flood events.

North Central CMA have provided precinct areas for delineating large areas where local levee systems deliver a coordinated flood mitigation function. The following sections will discuss the various Category 1 and 2 levees in each focus area. For the report, precinct areas are only in the Gannawarra Shire Council LGA.

## 3.2 Focus precincts

Precinct areas were delineated by North Central CMA to group areas of levees that function together and where the effects of flooding are felt similarly (Figure 18).

Precinct areas were defined in the northern Loddon catchment only, as this is where most contiguous systems of levees exist.

North Central CMA determined which areas were designated priority. Priority areas are where discussions on categorisation and management have been centred and where decisions on future management or alternative options need to be properly investigated.

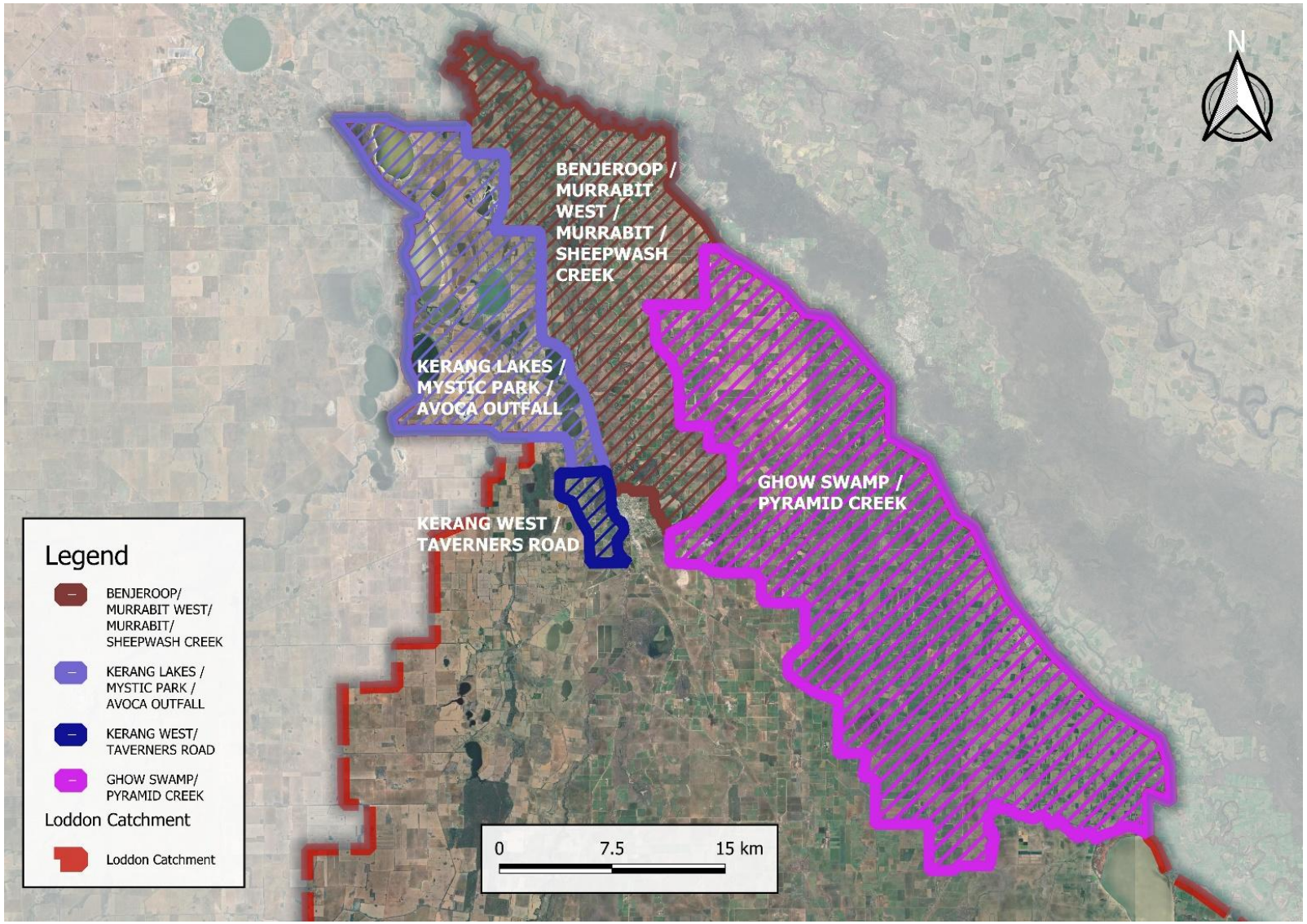



Figure 18. Overview map of the precinct areas nominated as priority by North Central CMA in the northern Loddon Catchment.

## KERANG WEST/TAVERNERS ROAD

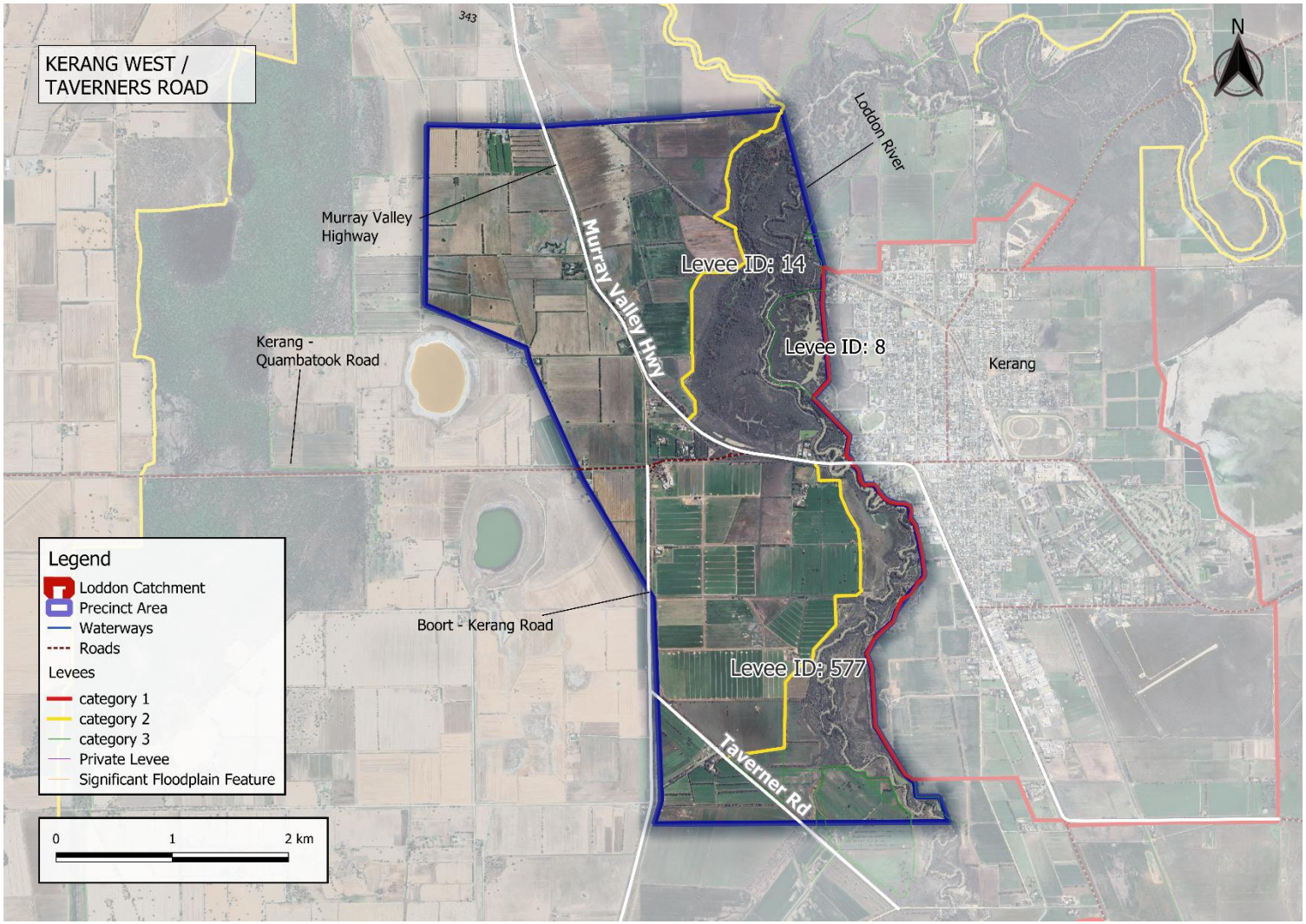



Figure 19. Precinct map for Kerang West/Taverners Road area, showing key roads, waterways and highlighting Category 1 and 2 levees.

### *Background*

This small rural area west of the Kerang township is seeking to amend or improve their flood mitigation infrastructure to achieve greater flood resilience in the face of local flood constraints. The 'Taverner Road Levee' (Levee ID = 577) commences near to the dwelling at 77 Taverner Road, Kerang, and follows an alignment generally parallel to the Loddon River until the levee connects into the raised highway embankment at the entrance to 91 Murray Valley Highway, Kerang (Figure 19). This levee provides protection to the properties to the west of it, constraining flood flows in the Loddon River between this levee and the Kerang Township levee on the east bank. The township levee is set slightly higher, so that the Taverner Road levee overtops/fails first and reduces the threat to the township. Failure of the Taverner Road levee means flood impacts occur to the properties generally bounded by the Loddon River in the east, the Murray Valley Highway in the north, Kerang-Boort Road in the west, and Taverner Road in the south.

If the levee fails, flood impacts are then exacerbated by the remainder of the intact levee, the surrounding raised roads, and the lack of capacity in drainage infrastructure to allow water to keep moving down the floodplain – effectively creating a full bathtub effect where water cannot naturally return to the river and will not commence to drain away until flood levels in the river have fully dropped. Residual flood waters can be trapped in this area for up to 2 months, causing substantial impacts to properties and community health (Figure 20).

Local community members have made a number of suggestions to improve the situation, but it is uncertain which options are most preferred, most feasible and which are likely to be effective and affordable. The primary options suggested including a third bridge under the Murray Valley Highway between the two levee systems, clearing out the floodplain downstream of the highway bridge through to the railway bridge, or the construction of levee spillways and a secondary floodway to provide for controlled peak flow management in larger flood events – as opposed to catastrophic levee failures resulting in unmanageable flow rates.

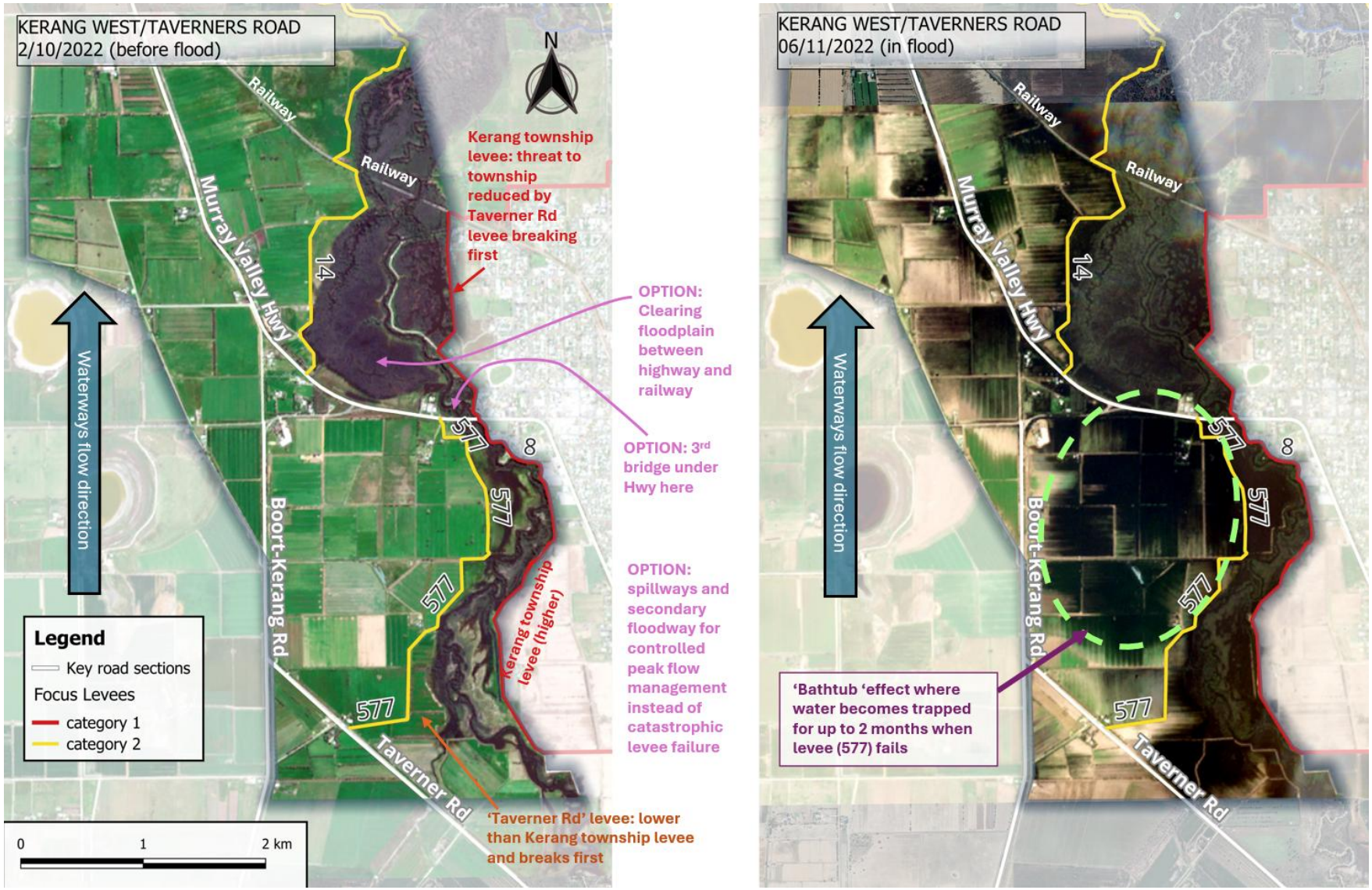



Figure 20. Diagram showing levee and flooding dynamics in the Kerang West PA

Whilst the width of the floodway between the two levees and the ability for water to flow away downstream of the highway bridge are seen as the primary local constraints, there are multiple other constraints downstream which may also be influencing flood risk in this area. These include the flow carrying capacity and regulation of the Washpen Creek, Sheepwash Creek and the Loddon River, the influence of the timing and volume of Pyramid Creek flood flows, the available storage within the Kerang Lakes at any given time, and the management of vegetation in waterways and floodways through the local area. All these matters are likely to have some impact on the ability of floodwaters arriving from the Loddon upstream of Kerang and moving past Kerang and the Taverner Road Levee system without unacceptable impacts. These constraints could be investigated further to determine possible management options to reduce pressure on the Taverner Road Levee (which would also benefit the town levee). The Lower Loddon Flood Model could be modified and utilized to test ideas locally and determine the most feasible and cost-effective options to reduce pressure on the levees.

### *Potential next steps*

Flood risk in the vicinity of the Taverner Road Levee is recognised as a pressing local issue. To build knowledge to reduce flood risk, several potential next steps have been identified, which would require funding being sought to further investigate. These include:

1. Refining the Lower Loddon flood model to replicate local flood conditions and test local flood mitigation options.
2. Assessing height and condition of the existing levees and any other relevant features required in the flood model.
3. Community engagement about potential flood mitigation options, including the existing levee system as a starting point, and possible alternative mitigation options for varying size flood events.
4. In developing the mitigation options, consider the existing levee heights and level of flood protection provided, any dwelling locations and floor heights, rural industries and places of employment, any raised roads and irrigation channels that are impacted, flood emergency fall-back positions for levee failures, and the potential for migrating levees away from the river to increase the flood carrying capacity of the river. Consideration should also be given to any impacts further downstream so as not to transfer the problem elsewhere.
5. A report on the above matters detailing the case for (or against) seeking future funding to implement preferred flood mitigation options.

## GHOW (KOW) SWAMP/PYRAMID CREEK

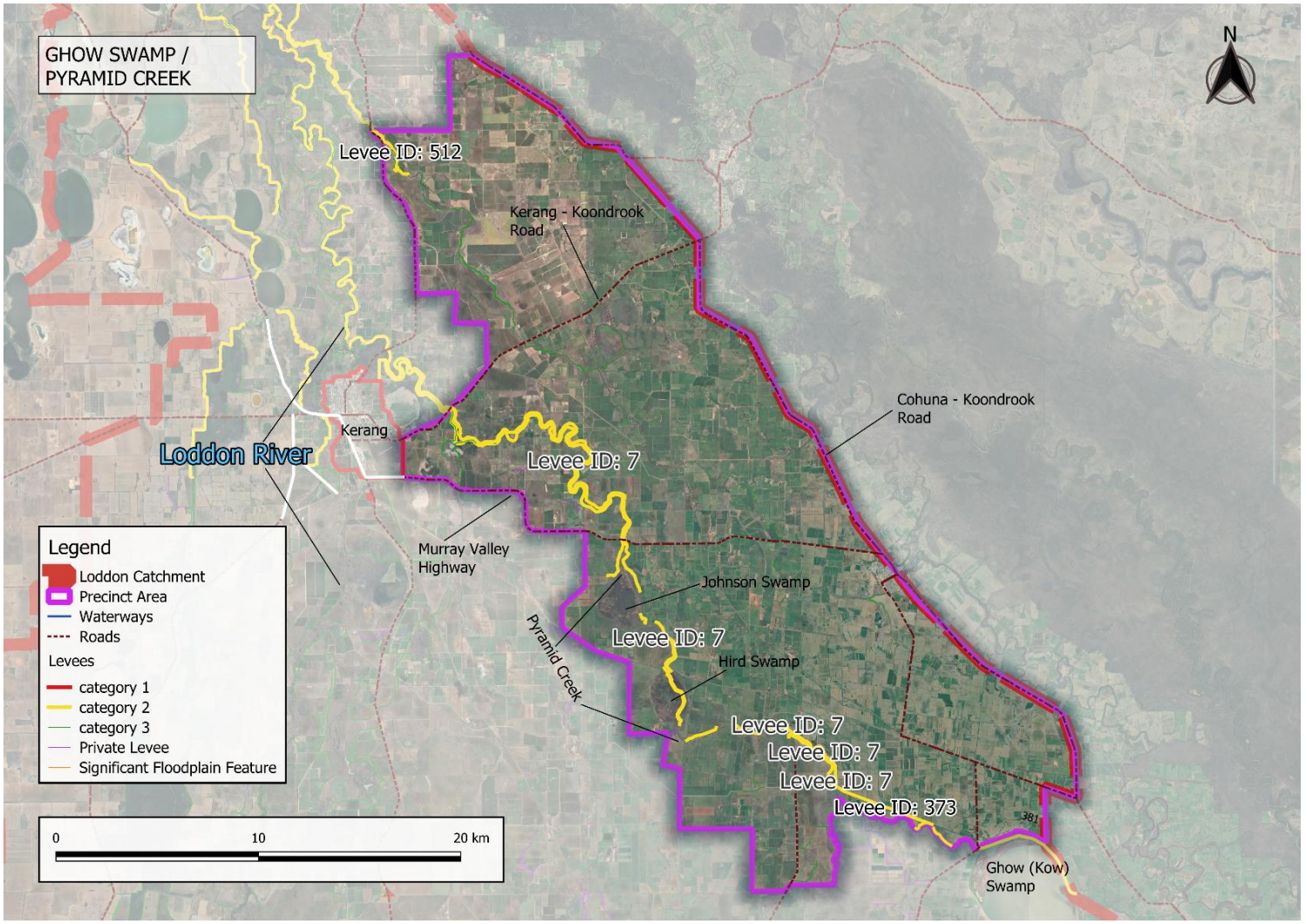



Figure 21. Precinct map for Ghow (Kow) Swamp/Pyramid Creek area, showing key roads, waterways and highlighting category 1 and 2 levees.

### *Background*

This area primarily concerns flooding issues arising from Pyramid Creek. Pyramid Creek is formed by the convergence of Bullock Creek, a natural unregulated waterway with headwaters originating south of Bendigo, and Box Creek, which receives regulated outflows from Ghow (Kow) Swamp. This confluence plays a key role in regional water delivery, drainage and floodplain dynamics, particularly during high-flow events when regulated releases from Ghow Swamp interact with catchment runoff from natural waterways. The creek receives additional flood flows from ephemeral waterways including Calivil Creek and Nine Mile Creek. Flows in the Pyramid Creek then travel to its junction with the Loddon River downstream of Kerang. Flows during floods are significantly larger than normal flows, and there are complex relationships between the timing of unregulated waterways, regulated flows from Ghow Swamp, and breakout flows coming across from the Loddon River when larger floods occur originating upstream of Laanecoorie Reservoir.

An obvious system of levees exists on both sides of the Pyramid Creek between Hird Swamp to the junction with the Loddon River. It is less clear what 'levees' exist upstream of Hird Swamp back to the Macorna Channel – with flood protection more likely to consist of areas of higher ground connected by public and private channel infrastructure as well as raised roads. The levees range from small to quite large, have uncertain or unreliable conditions and are known to breach or overtop often in larger floods. Levees also significantly constrain sections of the creek downstream of Hird Swamp with an average floodplain width of around 100 metres along its entire length – besides the large natural Hird Swamp and Johnsons Swamp themselves. These constraints would reduce the natural carrying capacity of the creek in flood events, a relationship that needs to be better understood through flood modelling and levee surveys.

Engagement with community supports there being a maximum carrying capacity within the levees and community have encouraged agencies to determine what that capacity is and whether outflows from Ghow Swamp can be managed in a way that reduces the likelihood of levees overtopping and the catastrophic blowouts of levees that occur thereafter and must then be fixed post-flood. Flow management out of Ghow Swamp is an issue that is brought up by all those landowners who live downstream of it, right through to the Loddon River's confluence with the Little Murray River. This is a key matter for further investigation to determine how best to manage floods through Pyramid Creek and help determine the appropriate flood mitigation needs of the community. It is foreseeable that the levees may only protect against limited size flood events, and that other mitigation options or emergency fall-back positions may need to be determined in collaboration with the community.

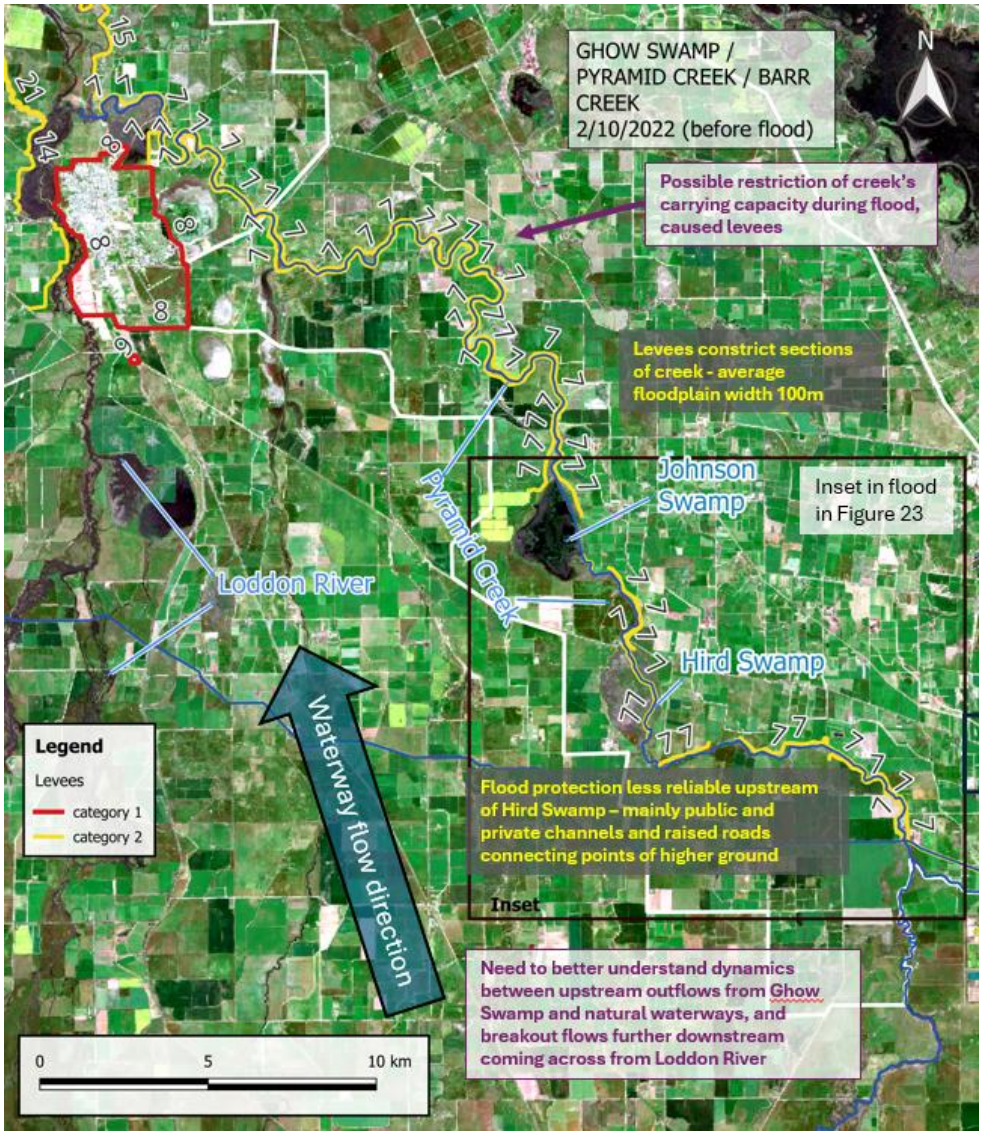



Figure 22. Diagram of levee and flow dynamics of Pyramid Creek

Community engagement also identified a lack of coordination of any flood protection strategy along the Pyramid Creek floodplain. Some landowners are actively managing and maintaining their levee sections whilst others are not – putting everyone at risk due to possible failures upstream and the location of such failures being outside the ability of those committed to a levee strategy to manage such risks on other private land. Whilst some landowners are prioritising levee protection, others are falling back to asset protection – possibly making the conclusion that the levees will fail or overtop anyway. Some believe an amended approach to flow releases out of Ghow Swamp would prevent the levees from overtopping altogether. Others believe that once Ghow Swamp flows are released then the chance of levee success diminishes significantly or is hopeless, given Bullock Creek and other unregulated flows are already threatening the top of levees.

All those that were spoken to were wanting more flood information to be available during the event to aid localised decision making. And many were concerned about the loss of access that occurs due to levee breaches, expressing that the importance of levee success extends beyond those properties immediately protected by the levees (e.g. local and major transport routes). A coordinated strategy for floodplain management along Pyramid Creek that spans Ghow Swamp to the Loddon River would identify risks and assist in developing an overarching strategy for these levees.

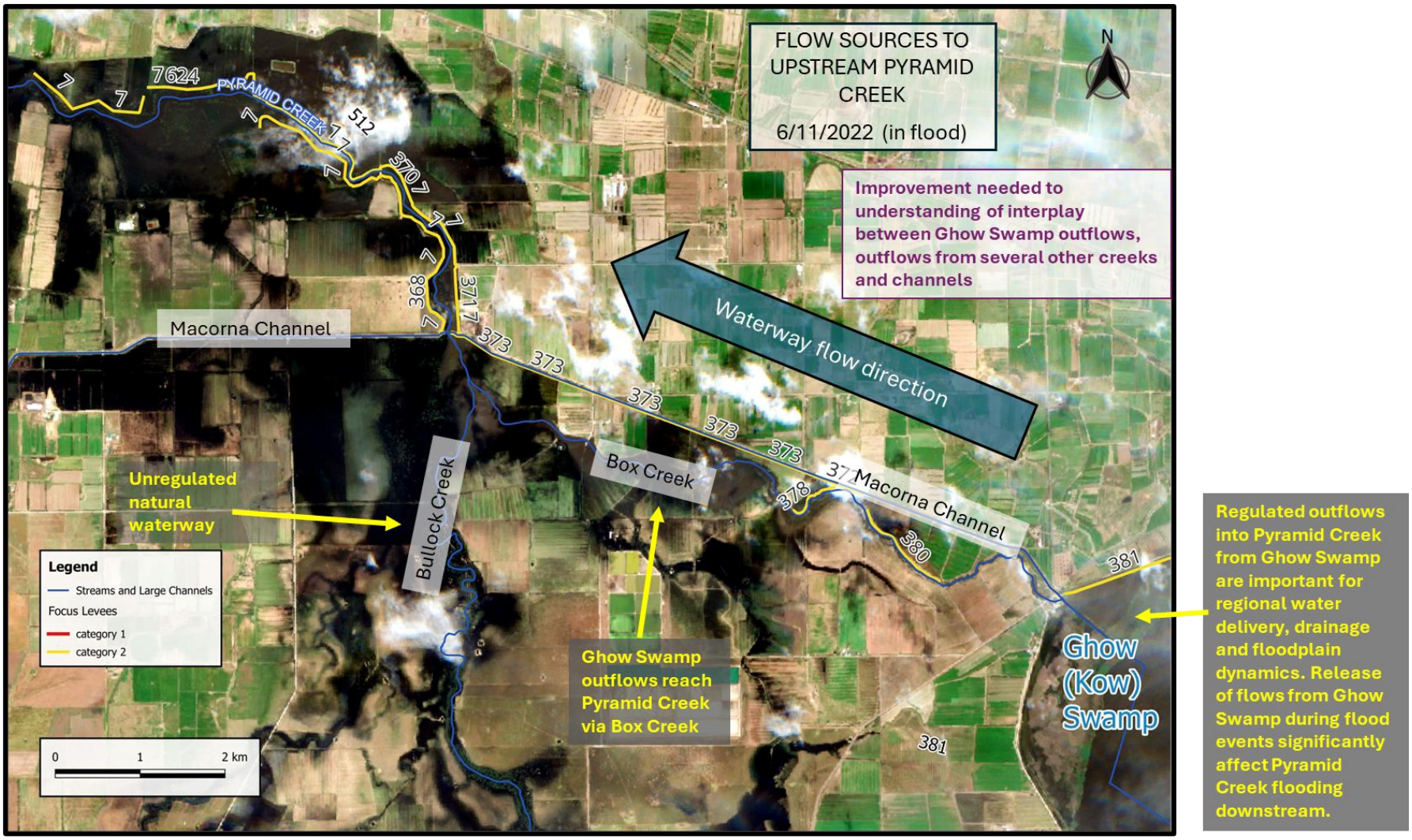



Figure 23. Inset from Figure 22 showing a zoomed confluence of several creeks converging and flooding at Macorna Channel 1 month after initial flood event

### *Potential next steps*

Developing a flood management plan for Pyramid Creek has been recognised as key need with community. To achieve this, several potential next steps have been suggested, which would require funding being sought to further investigate. These include:

1. Refining the Lower Loddon flood model to confirm flood risk along Pyramid Creek, including:
    a. Confirming the extent and likelihood of flooding along Pyramid Creek, as well as determining the influence of Ghow Swamp and climate change predictions.
    b. Investigating the flow capacity of Pyramid Creek, the relationships between flows from natural and regulated water sources, Ghow Swamp flow management options to reduce flood risks, and the investigation of potential flood mitigation options (including assessment of the effectiveness of the current levee system).
2. Assessing height and condition of the existing levees and producing a high-level concept plan of any levee upgrades/repairs/replacement that would be considered necessary for a functional levee scheme, including high-level costings for such implementation.
3. Community engagement about potential flood mitigation options, including the existing levee system as a starting point, and possible alternative mitigation options for varying size flood events. Mitigation options to include flow management of Ghow Swamp for various size flood events and considering different flood sources.
4. In developing the flood management plan, give consideration to the existing levee heights and level of flood protection provided, any dwelling locations and floor heights, rural industries and places of employment, any raised roads and irrigation channels that are impacted, flood emergency fall-back positions for levee failures, and the potential for migrating levees away from the creek to increase the flood carrying capacity of the creek. Consideration should be given to any impacts further downstream and into the Loddon River – as Pyramid Creek/Ghow Swamp flows are said to be a large influence on levee performance in the Lower Loddon River floodways as well, particularly near Capels Crossing, Benjeroop and Murrabit West.
5. A report on the above matters detailing the case for (or against) seeking future funding to implement preferred flood mitigation options.

## KERANG LAKES / MYSTIC PARK / AVOCA OUTFALL

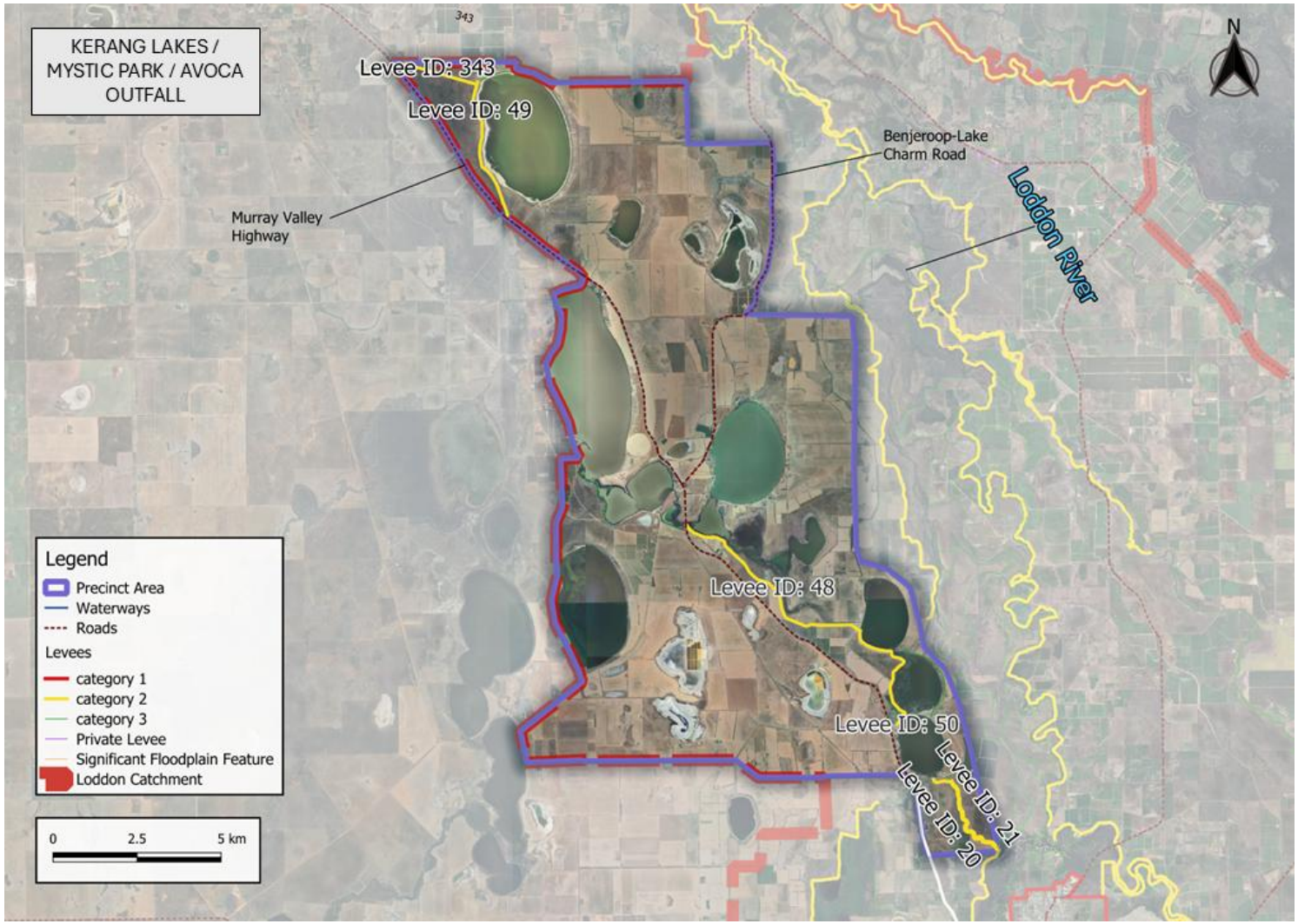



Figure 24. Precinct map for Kerang Lakes / Mystic Park / Avoca Outfall area, showing key roads, waterways and highlighting category 1 and 2 levees.

### *Background*

The Kerang Lakes are a largely regulated system that provide flood storage and an alternative pathway to regulate Loddon River flood flows through to the Little Murray River during major flood events. The effectiveness of the lakes system is dependent on the characteristics of each flood event, the flow volumes attempting to be managed and the antecedent conditions of the lakes prior to the flood event commencing. The lakes are also part of the Kerang Ramsar Wetlands group and have internationally recognised environmental values that need to be considered when operating the lakes during a flood. Any flood flows regulated into the Kerang Lakes need to ensure they can be regulated out of the system through Kangaroo Lake, Lake Boga and into the Little Murray River downstream of Lake Boga. When regulating flows into the lakes system, flood managers also need to account for any unregulated flood flows coming into the system from the Wandella Creek into Reedy/First Lake, and from the Avoca River downstream of Kangaroo Lake. There are multiple flow restrictions along the way including regulators at the Washpen Creek, the 6/7 Channel outfall from Kangaroo Lake, and the outfalls at Lake Boga into the Little Murray River.

Communities along the Lower Loddon River downstream of Kerang have raised concerns that when operational flood flows into the lakes system are ceased, their levees face an increased risk of overtopping or failure. Once the lakes system is closed off, all floodwaters from the Loddon at Kerang are forced downstream through the river channel and Sheepwash Creek alone. These floodwaters increase pressure on local levee infrastructure, particularly if Pyramid Creek is also in flood due to Ghow (Kow) Swamp flows and any unregulated flows entering it from the south e.g. Nine Mile Creek, Calivil Creek, Bullock Creek. The levees systems downstream of Kerang are very sensitive to changes in flow rates between the lakes, the river, and Pyramid Creek. This relationship needs to be better understood to ensure flood managers can manage each component optimally to best mitigate future floods. Timing of peak flows is critical, and the Lower Loddon community is concerned that flood peaks out of Ghow Swamp and through the Kerang Lakes system could be managed differently to reduce risk. Investigating the relationships between these systems or studying past events provides an opportunity to better understand the options for flood peak management in the future, which has the potential to provide widespread benefits far away from the regulating structures themselves. Further investigation on the flood carrying capacity of the multiple waterways and lakes system should also be undertaken to understand limitations in the system and whether flow management is the solution or whether floodplain modifications are required (or combinations of both).

### *Potential next steps*

Investigating the potential options for flood flow management through the Kerang Lakes System appears to be a critical need. Funding will be required to be sought to further investigate each option. Potential next steps that could be considered are:

1. Investigating and confirming the current peak flood flow capacity, flood storage volumes and historic flood peaks through the Kerang Lakes system, Kangaroo Lake, and Lake

Boga. Considering other lakes in flood storage calculations as appropriate.

2. Investigating options for greater use of the Kerang Lakes system, Kangaroo Lake, and Lake Boga for transferring more flood flows from the Loddon River to the Little Murray River. This should consider other lakes in flood storage calculations as appropriate, any synergies between flood flow management through the lakes and any potential upgrades proposed through the Victorian Mid-Murray Storage Project.
3. Investigating the relationship between management options of the lakes and any benefits or reductions in flood flow required to pass through the Lower Loddon River reach. Consideration of these benefits also needs to account for likely flood flows from Pyramid Creek and Ghow (Kow) Swamp.
4. Determining and documenting any barriers to flood flow or limitations within the system, and opportunities for improvement or upgrades. Consider new or upgraded regulators, floodways or amended flood management operations.
5. Determining and documenting plausible flood flow management scenarios into the relevant MFEP documents for consideration and use in flood emergency management control by the Incident Controller during floods.
6. Conducting community and stakeholder engagement on all aspects of the project to ensure all relevant views and historical knowledge can be captured in devising future scenario planning.

## BENJEROOP/MURRABIT WEST/MURRABIT/SHEEPWASH CREEK

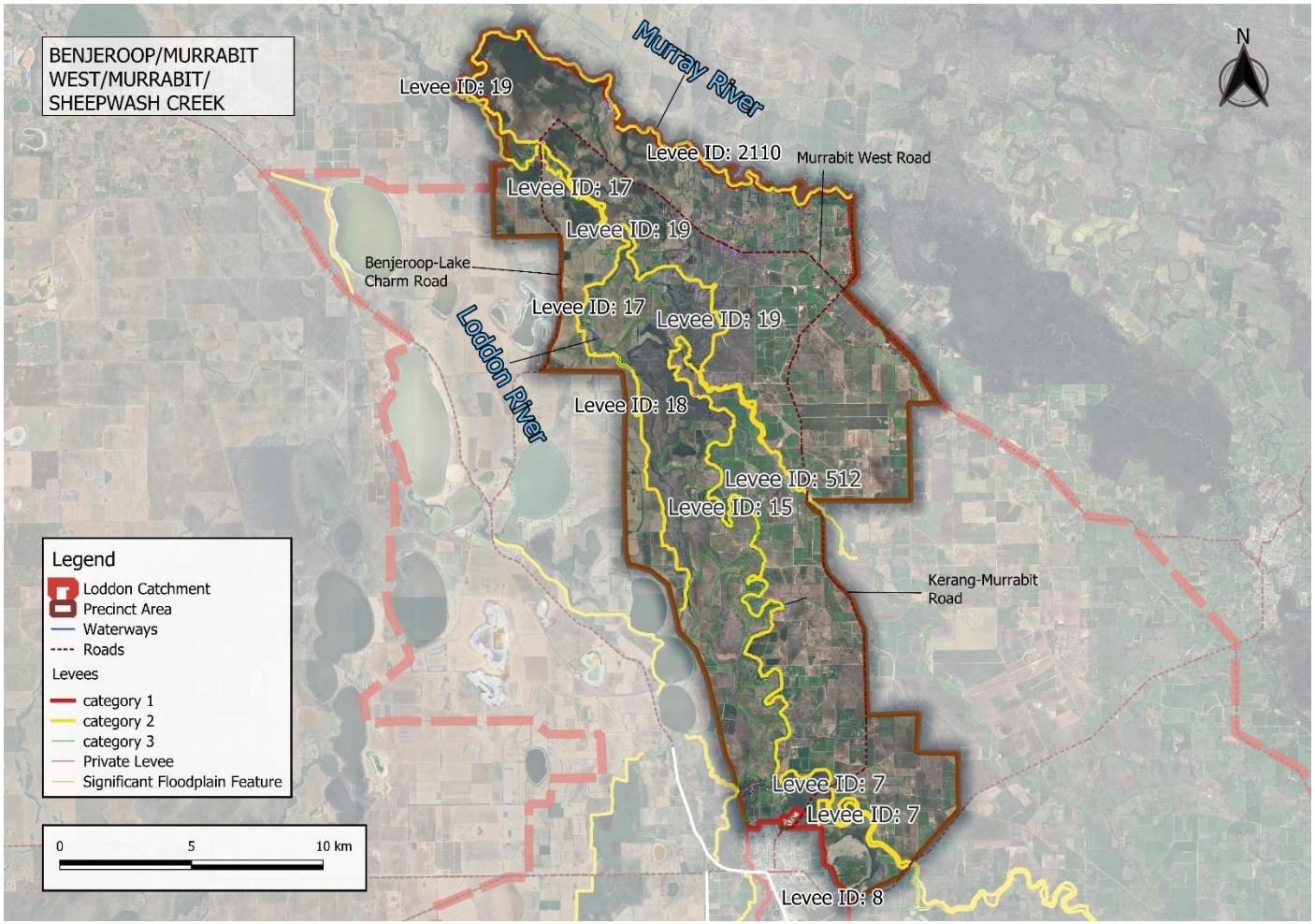



Figure 25. Precinct area map for Benjeroop/Murrabit West/Murrabit/Sheepwash Creek, showing key roads, waterways and highlighting category 1 and 2 levees.

### *Background*

This precinct is subject to a range of complex flooding mechanisms, driven by multiple sources of floodwater entering the area and by downstream river flows that back up into the precinct, delaying the passage of upstream floodwaters and local drainage. The principal waterway is the Loddon River, which conveys floodwater from its extensive upstream catchment originating near Daylesford and passing through the Cairn Curran and Laanecoorie reservoirs. While major floods on the Loddon can result from this single source, they are more commonly influenced by additional inflows from the Pyramid Creek system. Pyramid Creek receives contributions from several large upstream catchments, including Bendigo Creek, Bullock Creek, Calivil Creek, and Nine Mile Creek. Local runoff from Barr Creek can also add to flood impacts along the Lower Loddon.

Further complexity arises from flood operations through the Kerang Lakes, outflows from Ghow Swamp, and when concurrent flooding is occurring in the Murray River, which can cause water to back up the Loddon River channel and restrict the movement of flow from upstream tributaries out of the area. Flooding in this area therefore reflects a combination of natural, unimpeded flows and managed releases through the Kerang Lakes and Ghow Swamp. Community feedback indicates that this management regime has changed over time, is not well understood, and could potentially be improved to reduce impacts across the precinct. These intricate flow interactions require further investigation to inform future mitigation measures and flood emergency planning.

Significant lengths of levees exist along the Loddon River floodplain from Kerang through to the river junction with the Little Murray River at Benjeroop. These levees were originally built to contain small frequent floods on the Loddon but have since been raised higher over time and are now relied upon by communities to try to contain large floods as well – often unsuccessfully. Recent major flooding in 2011 and 2022 overwhelmed these levee systems causing overtopping and breaching near the junction of the Loddon River and Barr Creek in particular. This junction is the confluence of all water arriving from the Loddon River and its tributaries, Pyramid Creek and Barr Creek draining over 11,000km2 of land to this single point from as far away as Bendigo, Daylesford, Creswick and Maryborough. Counterintuitively, this is also the area where the levee system containing the floodplain reduces from several kilometres wide down to a much smaller 300m wide initially near the Barr Creek junction, before further reducing to less than 100m wide in places between the Barr Creek junction and where the Loddon meets the Little Murray River. Unsurprisingly, this narrow floodway cannot contain the larger flood events and levee breaches are common. Communities have also indicated that the river itself is silting up over time, further reducing flow capacity through this bottleneck at the bottom of the Loddon River catchment.

Levee breaches on the west side of the Loddon largely track alongside the river corridor. But breaches on the north side of Barr Creek can cause significant flooding behind the levees into Murrabit West and Benjeroop – as floodwaters attempt to make their way across to the larger Murray River via natural flood paths. The Murray River also has levees constructed on its immediate southern banks, meaning water becomes trapped in the Benjeroop region until river levels fall enough to enable emergency levee breaches to drain residual flood waters away. These areas are often inundated for months with some of the lower lying historic

swamp areas still holding flood waters up to 12 months after a major flood event.

Engagement with community has provided many different suggestions over a long period of time to help ease the impacts of flooding, including new ideas through this project. Multiple reports and studies exist with flood mitigation options dating back to before the establishment of CMAs. Many of the options identified have good merit behind them but may not meet contemporary floodplain management policy or government flood mitigation investment principles. These options also haven't been tested in modern flood modelling software which could now enable a proper exploration of the risks and benefits and provide the level of justification required for access to competitive fund sources. Ideas are also often local ideas for local problems only and not necessarily coordinated across the regional catchment area to include operational management of Ghow Swamp, the Kerang Lakes, and the interface with flooding in the Murray River. It is this coordination of ideas and options that could be tested in modern flood modelling software to determine if the ideas still have merit, meet government policy or whether new ideas are required. This coordination forms the basis for potential next steps to further investigate options for this area at a local and regional scale to determine the best options for future flood mitigation, the flood protection service levels provided by the levees, and whether there is need to consider fall-back options such as direct asset protection (house levees) or floodway and regulator options when flood magnitudes exceed our ability to control them. The potential next steps should be read in conjunction with precincts around this one and any synergies or learnings that could be obtained from nearby investigations.

### *Potential next steps*

Investigating the potential options for flood flow management and mitigation for the Lower Loddon has been identified as a pressing need. Funding will be required to be sought to further investigate each option. Potential next steps that could be considered are:

1. Utilising learnings from any investigations undertaken for the Kerang Lakes, Taverner Road and Ghow Swamp/Pyramid Creek focus precincts nearby.
2. Investigating and confirming the current peak flood flow capacity that can be safely conveyed through the levee system without overtopping. Knowing the maximum flow capacity or the location of any flow constraints could inform future flood flow management, strategic levee works or other mitigation options for future implementation.
3. Determining and documenting any barriers to flood flow or limitations within the system and provide recommendations for improvement or upgrades. Consideration should be given to the existing levee network, possible levee improvements, levee relocations or retreat, new or upgraded flow or drainage regulators, possible floodways for various flood scenarios or amended flood management operations from local storages. Varying forecasts of flood magnitudes may require different mitigation scenarios, and any flood management plan should be flexible to these complexities.
4. Determining and documenting plausible flood flow management scenarios and emergency mitigation actions into the relevant

MFEP documents for consideration and use in flood emergency management control by the Incident Controller during floods.

5. Conducting community and stakeholder engagement on all aspects of the project to ensure all relevant views and historical knowledge can be captured in devising future scenario planning.

## 3.3 Overview of community feedback

Community input during the North Central Levee Review highlighted both the value of local knowledge and the diversity of flood management challenges across the region. Some of the key issues emerging from the drop-in sessions included:

- **Levee performance and condition:** Many participants raised concerns about the structural integrity of levees, including erosion, past breaches, and inconsistencies in maintenance. While some levees were viewed as essential for asset protection, others were recognised as vulnerable and unlikely to provide reliable long-term defence.
- **Flood operations and water management:** The management of Ghow (Kow) Swamp and associated waterways (Loddon and Pyramid Creeks in particular) was a recurring issue. Landholders suggested that poor timing of releases exacerbated downstream flooding, and that greater transparency and coordination could reduce risk.
- **Flood duration and drainage:** A strong theme was the extended period of inundation following levee breaches. Community members emphasised the need for improved and correctly designed drainage infrastructure (culverts, siphons, regional drains) in the right locations to allow water to recede more quickly and reduce crop losses.
- **Access and recovery:** Residents stressed the importance of maintaining transport access during floods. Suggestions included upgrading roads or causeways in strategic locations to ensure supply chains and emergency services remain viable.
- **Responsibility and management arrangements:** There was uncertainty and frustration over who is responsible for levee upkeep. Participants highlighted inconsistencies between private, council, Rural water authorities, and CMA roles, with some calling for clearer frameworks or local flood management plans to guide decision-making.
- **Alternative approaches:** Many acknowledged that large-scale rural levee management may not be feasible everywhere. Instead, they suggested targeted measures such as ring levees around assets, raised livestock pads, and improved warning systems to support resilience and faster recovery.

Overall, the feedback reflected a strong willingness among landholders and communities to contribute practical knowledge and work collaboratively toward more effective and sustainable floodplain management.

The following section provides more detail on feedback for precinct areas:

### *Lower Loddon*

- Ghow Swamp management was a dominant concern. Landholders argued that poorly timed releases during the 2022 floods overtopped levees and prolonged inundation. They suggested earlier, controlled releases to create storage capacity and avoid compounding natural flood peaks.
- Levee condition and breaches were widely discussed. Some landholders suggested deliberate breaching to allow water to flow in and out more naturally and retain some control on flood direction, rather than catastrophic breaches resulting in water being trapped for months before gravity drains can be opened up to start draining water off.
- Channel erosion was raised as a threat to levee integrity – where one side of the channel bank is considered a levee. Remedial works can be difficult due to requiring native vegetation removal and subsequent offsets that incur costs, with unclear responsibility for remedial works between Rural water authorities, North Central CMA, and landholders where such channels are acting as levees.
- Boga Floodway – West banks (channel outfalls) managed by Rural water authority and should continue to do so as they are required for operational purposes. East banks are privately managed, however there is a case for an agency to formally manage those banks too if Lake Boga is going to be part of the 'Mid-Murray Storage' program. Given they will now keep the lake at high capacity all the time then the storage manager should considerer the risks for annual operational decisions that may affect natural flood flows – i.e. given reduced flood storage may be available compared to past floods, it has to be passed through Boga and into the Little Murray – to do so safely may require the levees on both sides of the floodway to function effectively. Agencies should explore the need to formally manage the east side levees as well.
- Community highlighted the need for local flood management plans in precincts where large-scale levee management may not be viable, with a shift towards recovery-focused actions such as raised roads, ring levees, and drainage infrastructure.
- Community observations that the catchment has changed since past floods. Seem to be getting big floods more often. There is no agreement to whether this is a result of bad luck or bad management or both.

### *Pyramid Creek*

- Large scale formal rural levee management may not be successful. Alternative plans may need to look for actions that support faster recovery. E.g. raised roads, ring levees, raised livestock pads, upgraded culverts.
- Concerns centred on flood duration and drainage. Landholders stressed that water should not pond for 12 weeks, pointing to culverts, roads, and Rural water authority drains as key bottlenecks.
- Ghow Swamp releases were again identified as overwhelming local levees, with landholders frustrated by poor communication and lack of warning time. Information flow is key for people to make decisions about evacuation and moving livestock or equipment to higher ground (where possible).

- Community noted that Ghow Swamp rises quickly, but also that once it hits a maximum level the flows spread out across the lake surface area and further rises are slow. Flood causing outflows downstream could potentially be lowered but northern swamp levee banks need to be able to hold and need monitoring and possible emergency repairs during future flood events.
- Lack of coordination in levee management was noted, with inconsistent approaches between private, strategic, and asset-level defences.
- Critical transport routes such as the Murray Valley Highway and Kerang-Leitchville Road were identified as priorities for upgrades to maintain access during floods.
- Calls were made to treat levees and drains as part of a single integrated flood mitigation network.

### *Tandarra*

- Feedback focused on levee works and legality, with disputes over whether certain works were enforceable, permitted, or within planning controls.
- Flood duration was the primary concern, with water remaining on crops for weeks, far beyond crop survivability thresholds. Landholders requested options to reduce duration, including drainage improvements and modelling of “all levees removed” scenarios.
- Disputes between neighbours highlighted the need for clearer governance on what works are permissible.
- Community members questioned whether blocked or modified culverts under the railway and roads were worsening flood duration.

### *Pyramid Hill / Mitiamo*

- Levee alignments at Pyramid Hill were confirmed.
- Levee alignments and benefits at Mitiamo remain uncertain.
- Interest was also expressed in flood warning improvements throughout these local areas and better coordination between local observers and incident control centres.

## 3.4 Community engagement changes to levee data

The community engagement sessions provided an important checkpoint in the levee review process (Table 4). They confirmed a general alignment between the mapped data and local knowledge, while also helping to surface a few specific issues requiring further attention. The feedback received was used to help finalise levee classifications and will help inform future communication with residents.

Table 4. Levee changes resulting from community feedback during drop-in sessions with North Central CMA. All changes were actioned.

| Recommended changes | Supporting evidence |
|---|---|
| **Wandella Forest West Bank. Change from Category 3 to Category 2 for further investigation. For extent of Wandella nature conservation reserve. West bank only.** | Community feedback from Kerang Flood Observers meeting. Review in GIS supported this change. Levees here play some role in preventing flooding moving further west to unexpected areas and could ultimately cut the Murray Valley Highway at Cranes Lake near Lake Charm. |
| **Pyramid Creek upstream of Johnsons Swamp – make Category 2 all the way back to Ghow (Kow) Swamp.** | Community feedback supports the need for a coordinated flood mitigation approach downstream of Ghow (Kow) Swamp. Levees should form the starting point for that conversation with community. Classify as Category 2. |
| **Change levees around Pyramid Hill to Category 1 and add temporary levees (2c) at gaps created by roads into town** | North Central CMA met with local community members to confirm. Levees are a mix of assets with differing owners and conditions, including levees, channels, raised railway corridor and road crossings. |
| **Continuation of Category 2 levee label along the west channel bank west of Lake Tutchewop – for completeness.** | North Central CMA review |
| **Change Lake Boort channel no. 3 Levee to Temporary Levee (2c).** | Prevents water from entering Little Lake Boort. |

## 3.5 General levee management issues

A table of the issues relating to levee management and the potential next steps to resolve these issues (Table 5) has been generated from the expert knowledge of North Central CMA and ongoing discussions with community members, local and state government, and other stakeholders. These findings can be reviewed through the North Central Regional Floodplain Management Strategy process to guide future regional planning and investment decisions. They may also assist the review of the Victorian Floodplain Management Strategy when considering future levee policy.

Table 5. A list of levee management issues in the Loddon catchment and potential next steps to address them in, broken up into 5 themes.

| Issue | Comments / Supporting evidence | Potential Next Steps |
|---|---|---|
| **Levee Data and Knowledge** | | |
| 1. Levees require final classifications | • Management responsibilities will be clarified when final classifications are decided and shared<br>• There is evidence for adopting current classifications via consultation, community feedback and lack of objections<br>• Any potential lack of adequate review during this project can be mitigated with a process for levee review after the life of the project. | i) Agree on a final set of classified levees<br>ii) Document (this report) a process to allow for review of levee categories at set intervals or after significant flood events |
| 2. In some cases, it is not known whether a levee still exists and if/when it was decommissioned | • This issue can be difficult to determine using satellite imagery, but local knowledge can provide details and historical context<br>• Consider adding field to levee layer for identifying if levee currently exists or once existed (i.e. some levees/SFF mapped have been removed physically, but it's still useful to know something was there in the past as landowners often talk about such features)<br>• North Central CMA can change field over time to keep dataset up to date. | i) Create field and populate with any known and recorded decommissioning dates<br>ii) North Central CMA could assume responsibility of managing updating |
| 3. Key Category 1 and 2 levee assets have little information on them and may need ground truthing | • Not all levees should be surveyed as there are too many levees and it will be too expensive, not targeted, | **i) Note: An update of Levee MFEP intelligence cards is concurrently being undertaken,** |

| Issue | Comments / Supporting evidence | Potential Next Steps |
|---|---|---|
| | and therefore may not be good investment without a clear forward plan<br>• Key questions to inform prioritisation could be:<br>  ○ Which levees lack condition information and understanding of the levee problem?<br>  ○ Where do the consequences of levee failure warrant short-term expenditure to understand levee condition and determine risk exposure?<br>• For example, the Tyntynder Flow tubes have been documented in the MFEP as a fall-back position should the primary Tyntynder Flats levees fail, however it is suspected that these legacy channel banks are not actually intact or contiguous anymore. Survey of the flow tubes would be a priority to inform immediate changes to the Swan Hill MFEP. | **which will help inform which levees lack information and may need targeted surveys or other information gathering**<br>ii) Establish a list of priority levees to survey<br>iii) Conduct prioritised ground-truthing surveys |
| 4. FloodZoom specifications may not allow for all desired levee metadata | • A Separate dataset may be needed, and thought will be required on how this would be done, e.g. as a separate layer in FloodZoom<br>• Emergency management function may need to be separated from historical data storing (everything) function<br>• There is a need for CMAs to be able to update information over time (levee category reviews as per mitigation described in Issue 1 above). | i) Collaborate with CMAs on a structure for separate regional asset database. |
| 5. Floor levels in high-risk areas protected by Category 2 levees need mapping | • Mapping will help inform emergency management decision making<br>• Consider a layered and prioritised approach for cost scaling/management. VicSES have valued this work to date and would likely support<br>• Possible priority order could include:<br>  ○ Highest priority - Behind unmanaged Category 2 levees (which builds the case for further investigations or emergency works) | i) Map dwelling locations (desktop assessment)<br>  a. Internal discussion that CMA approvals could build on this dataset over time (as dwellings are approved)<br>ii) Complete floor level survey (on-ground works) on a priority basis |

| Issue | Comments / Supporting evidence | Potential Next Steps |
|---|---|---|
| | ○ Lowest priority – Category 1 & 3 levee areas. | |
| 6. Levee classifications may become outdated | • Due to demographic shifts, new infrastructure being built or changes in flow regimes, the classifications of levees might change and become outdated in the system<br>• One way to counter this would be to set up a formal review cycle<br>• Reviews could include re-engagement with community. This report provides a methodology for the basis of future reviews.<br>• The data is stored in FloodZoom so it can be updated easily<br>• The method for classification is set out in this report and any levee can be reviewed using that method. | i) Establish formal review cycle with community engagement (or after a major flood event)<br>ii) Communicate to community that whilst this project has a life cycle, assessment of levee classifications does not need to be static. If a community member missed engagement this time, they can certainly raise issues with North Central CMA any other time. |
| **Levee and Flood Conveyance Works** | | |
| 7. Some temporary levee sites are frequently reinstated, which adds to flood preparedness burden | • Cost-effective permanent solutions may be possible<br>• VicSES likely support exploring promising options as it will reduce actions needing to occur during a flood. | i) Explore permanent levee options for frequently reinstated sites<br>ii) Undertake a cost-benefit analysis for frequently reinstated sites<br>iii) Prepare feasibility studies for best options. |
| 8. Promising flood conveyance and storage opportunities need further detailed investigation. Some of these include:<br>a. New floodway / plans for strategic retreat of levee banks (moving back from waterway) to increase flow conveyance and reduce flood peaks within levee systems | • The Gannawarra Community Resilience Flood Recovery Action Plan 2023-25 list options for locally supported initiatives for flood mitigation and faster recovery. This plan is evidence based and community-led, and may provide useful information when considering levee management policy options and shaping future investment that demonstates support for locally driven initiatives where they exist. Options listed in the Plan include: | i) Review and integrate actions from the Gannawarra Community Resilience Flood Recovery Action Plan 2023-25 into the North Central Regional Floodplain Management Strategy. |

| Issue | Comments / Supporting evidence | Potential Next Steps |
|---|---|---|
| b. Improving flood flow conveyance and reduce peak flow levels in the Pyramid Creek system<br>c. Flood flow conveyance and storage through the Kerang Lakes system<br>d. New low crest weir and a third bridge over the Murray Valley Highway | ○ Investigate potential for new floodway or the strategic retreat of levee banks (moving back from waterway) to increase flow conveyance and reduce flood peaks within levee systems. This is particularly relevant for the Lower Loddon, Pyramid Creek, Little Murray River and possibly Tyntynder Flats<br>○ Investigate options for improved flow conveyance and reduction of peak levels in the Pyramid Creek system. This would include the management of flows from Ghow (Kow) Swamp, and investigating options for improved conveyance of the Bullock Creek, Calivil Creek, and Nine Mile Creek flows into the Pyramid Creek. Management of flow peaks can be the difference between levees holding/not overtopping or failing/overtopping<br>○ Investigating flood flow conveyance and storage through the Kerang Lakes system, particularly addressing the limitations on outflows from Kangaroo Lake and Lake Boga. Opportunities through the Mid-Murray Storage project may arise to address these limitations<br>○ Investigate diverting floodwater from upstream of Kerang through a proposed new low crest weir and a third bridge over the Murray Valley Highway. (See Taverner road precinct plan). | |
| 9. After levee breaches occur floodwaters can remain stuck without a way of draining away | • Strategically placed regulators in rural levee banks for draining floodwaters after levee breaches have been flagged as an option to mitigate this problem<br>• Optimal placement locations still need to be identified, with options listed in the Gannawarra | i) Identify candidate sites in consultation with the community<br>ii) Model drainage benefits<br>iii) Prepare priority works program. |

| Issue | Comments / Supporting evidence | Potential Next Steps |
|---|---|---|
| | Community Resilience Flood Recovery Action Plan 2023-25 implementation<br>○ Known sites at Benjeroop for draining water into the Murray River and Little Murray River<br>○ Could investigate other sites as part of Category 2 investigation areas/precinct plans. | |
| 10. Flow migration is restricted at key regional roads | • In areas where floodplain flow migration is encouraged for environmental benefits, roads can act as a barrier or choke point<br>• Appropriate culvert capacity can improve flood flow migration. Reviewing culverts capacity on key Regional Roads is also listed in Gannawarra Community Resilience Flood Recovery Action Plan 2023-25 - including where the Wandella Creek crosses the Murray Valley Highway at Reedy Lake. (See Kerang Lakes Precinct Plan). | i) Undertake flood studies, including community engagement<br>ii) Determine highest priority sites and engage with DTP on options. |
| 11. Other infrastructure (not levees) acting as barriers to flood flows (culverts, siphons, bridges) | • Some barriers are worse than others, meaning water rushes down the catchment to one particular site and then takes a very long time for water to pass through that local area<br>• Barriers can include previous road bridges turned into culverts, larger culverts replaced with smaller ones (for managing repair costs), channel subways blocked (before or during a flood), channel siphons overgrown, cumulative impact of roadworks over time (roads raised when re-sheeted, e.g. Koroop Road, where the bridge replaced with culvert and took 12 weeks to drain water off farm). | i) Investigate key barriers and prepare options<br>ii) Engage with community and road manager<br>iii) Document possible upgrades for improved flow benefits |
| 12. Improving knowledge of strategic drain performance and coordination | • Once levees fail, local drains then become important to move water away from the floodplain and ultimately back into waterways and down the catchment<br>• Drains could be part of a layered flood defence in areas where levees are more prone to failing (e.g. Pyramid Creek). Grazing on strategic drains could be | i) Determine and map which drains are more important than others,<br>ii) Target priority drains for greater ongoing maintenance<br>iii) Enable and support community maintenance where feasible. |

| Issue | Comments / Supporting evidence | Potential Next Steps |
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| | helpful where operational and environment values align<br>• Rural water authorities provide a definition of the level of service for their drains to remove excess water within 5 days, which meets the needs for normal excess rainfall runoff from local storms. This level of service is quite low and not designed to mitigate large scale regional flood events<br>• However, landowners must often rely on the same drains (or drain pathways) to remove flood waters and are seeking a higher level of performance from the drains in certain locations. Perceived or actual barriers to drain performance is often the presence of vegetation, specifically lignum and cumbungi. Landowners are seeking more maintenance from Rural water authorities, or access/permission for them to do more works themselves. Landowners have indicated that the condition of the drains may be beyond their capacity to address, but if Rural water authorities or another organisation did the large-scale capital works first then landowners may be able to stay on top of the ongoing maintenance, if permitted to do so. | |
| **Infrastructure as Flood Mitigation** | | |
| 13. State-managed roads are not elevated high enough to remain dry during larger flooding events | • Some roads that have become flooded may only need to be raised by small amounts in certain sections to improve flood resilience and act as levees<br>• Investigating State-managed roads impacted by flooding and opportunities for raising roads could be an easy win for improving flood resilience and faster recovery – given roads are likely to need repairs after significant flooding anyway. | i) Engage with DTP to on opportunities for access improvements across their network.<br>ii) Investigate feasibility of road raising and integrate priority options into asset renewal cycles. |

| Issue | Comments / Supporting evidence | Potential Next Steps |
|---|---|---|
| 14. Some long strategic levees may be too resource (time, labour costs) intensive or undesirable to manage and maintain, particularly those on Crown Land. Consideration needed for long-term levee retreat to nearby roads or channels as the primary line of defence. | • Consideration of long-term planning for levee retreat to roads, channels or other similar raised infrastructure, where appropriate<br>• Feedback from stakeholders that falling back to assets that will be maintained anyway (as roads, channels etc.) could be a long-term solution instead of relying on and fixing levees in forests during flood emergencies<br>• Assets may need to be raised, but funding could be sought in lieu of seeking funding to maintain any existing levees and the complexities that might occur with that (Crown Land, native vegetation, cultural heritage etc.). Raising roads or reinforcing channels may be an easier option in terms of disturbed footprints and ongoing management arrangements. | i) Identify priority sites in regional floodplain management planning process<br>ii) Prepare long-term planning options for investigation. |
| 15. Where channels act as levees the responsibility for management and maintenance can be unclear | • In the past, State Rivers and Water Supply Commission was both the irrigation supply authority and the floodplain management authority, which has created management ambiguity in some locations<br>• There is a need to determine where channel infrastructure is also performing functionally as levee infrastructure and understand/determine any revised management/maintenance requirements that are needed to manage or maintain current flood risk.<br>• Acknowledge the importance of where channels function as levees and therefore maintenance is perhaps of higher importance – for coincidental flood mitigation benefit. | i) Identify and map where channels are functioning like levees<br>ii) Engage asset owners to discuss maintenance arrangements and management of flood risk. |
| 16. Channel decommissioning changes flood behaviour, so flood managers need to be aware of current and future decommissioning works | • Channel decommissioning is changing the floodplain over time. The removal of channels (or sections of them) continues to change the flood behaviour between flood events | i) Rural water authorities to continue to engage with North Central CMA when planning for any channel decommissioning<br>ii) Consider formalising an engagement protocol between |

| Issue | Comments / Supporting evidence | Potential Next Steps |
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| | • Whilst channels are not flood mitigation infrastructure, the floodplain has often been mapped and developed based on their existence and their influence on local flood behaviour<br>• Any changes to the irrigation network should consider the potential impacts on floodplain behaviour and engage with North Central CMA and those local landowners likely to be affected<br>• Simply 'leaving one bank' has not been a successful outcome in some areas, albeit a way to avoid any legal liability when decommissioning the network 'on paper'. | Rural water authorities and North Central CMA for assessing channel reconfigurations. |
| **Ring levees** | | |
| 17. There are high risk flood locations where formal levee management is not feasible or cost-effective and ring levees are likely the best localised option, but residents may not have the ability fund their own construction – particularly those already recovering from recent flood events. | • For any residual areas where no formal levee management scheme is possible or alternative proposed, consideration should be given to funding ring levees for dwellings in lieu of collective benefit strategies, on the basis of that being the cost-effective option and not leaving people behind in flood mitigation planning<br>• The Gannawarra Community Resilience Flood Recovery Action Plan 2023-25 contained a recommendation for additional government support for ring bank levees around homes for those known high risk flood locations across the floodplain. | i) Discuss options for ring levee support with DEECA<br>ii) Maintain priority dwelling list for potential ring levees |
| **Governance and Policy** | | |
| 18. Confusion about responsibility for low-priority levees | • There has been widespread confusion in community engagement about who is responsible for levees outside of assumed Category 1 levees<br>• Clarification on who can do what in terms of works/approvals was also sought | i) Collaborate with DEECA and other CMAs to produce a communications package regarding levee management, |

| Issue | Comments / Supporting evidence | Potential Next Steps |
|---|---|---|
| | • A communication product clarifying roles and regulations is likely needed. | regulations and options for landowners. |
| 19. Lack of information available to local decision makers on levee performance and managed flood flows | • Landholders / local decision makers don't have the coordinated flow release and flood estimation information required to make decisions, e.g. whether they should top up levee heights, focus on defending houses or work on strategic drainage<br>• Inter-agency mechanisms for sharing levee performance data and managed flood flow observations could improve real-time decision making and community awareness during flood events. | i) Explore options for data-sharing between VicSES, LGAs, CMA, and Rural water authorities and explore access for residents as appropriate or through MFEPs documentation and emergency response messaging. |
| 20. Private levee mangers may not feel supported / enabled | • Enabling/supporting landowners who want to continue to manage levees on private land or public land is likely to be effective considering the vast lengths of privately managed levees in the catchment<br>• Support can include resources, advice and lower fees<br>  ○ Ensure relevant resources or toolkits exist for advice and encourage seeking agency approval/consent where required.<br>  ○ Remove any unnecessary barriers to levee construction/management i.e. ~$1300 planning permit fee can be a barrier to people seeking permission and advice from LGA/CMA. Explore if levee works could be included as a VicSmart application type. This would reduce fees (~$250) and reduce approval timeframe (10 business days with prior written consent of CMA). | i) Develop guidance toolkit<br>ii) Review planning permit requirements and costs – to encourage landowners to discuss and register their works. |
| 21. Levees continue to be built without permits | • Permits are not widely enforced by LGAs for a range of reasons e.g. no notice of the works, lack of resources to enforce it, lack of evidence. | i) North Central CMA and LGAs could develop shared strategies for levee bank compliance specifically, documenting roles and responsibilities and a |

| Issue | Comments / Supporting evidence | Potential Next Steps |
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| | | commitment to greater enforcement in priority areas. |

# 4 Conclusion

This Strategic Levee Categorisation Assessment for the Loddon River catchment has delivered comprehensive, spatially consistent, and stakeholder-informed intelligence to assist in managing flood risk across the North Central CMA region. By integrating automated detection techniques, spatial rule-based categorisation, flood modelling outputs, and extensive expert and community review, the project has established a robust and transparent evidence base to support both flood emergency management and longer-term floodplain planning.

The development of a unified, cleaned, and segmented levee database has improved consistency in how levees are identified, compared, and prioritised across local government boundaries.

A key lesson learnt is that levees rarely operate in isolation. The assessment reinforced that flood risk in the Loddon catchment is driven by complex interactions between regulated and unregulated waterways, floodplain storage areas such as the Kerang Lakes and Ghow (Kow) Swamp, transport and irrigation infrastructure, and the timing and magnitude of flood peaks.

Community engagement proved critical in validating mapped information and revealing practical challenges not evident in spatial datasets alone. Local knowledge of historic flood pathways, past levee failures, prolonged inundation, and access constraints significantly enriched the assessment. Further efforts should be made to document this shared community knowledge to guide flood preparedness. A consistent theme was the need for clearer responsibility and coordination across agencies and landholders, particularly in areas where fragmented levee ownership and management arrangements increase collective risk.

Overall, the project highlights that strategic levee management in the Loddon catchment requires a coordinated, catchment-scale perspective rather than isolated, site-specific interventions. Future flood resilience will depend on aligning levee categorisation and maintenance with broader flood flow management, infrastructure planning, and emergency response frameworks. The dataset and potential options developed through this work provide a strong foundation for targeted investigations, funding prioritisation, and the integration of flood mitigation options into Municipal Flood Emergency Plans. Continued collaboration between North Central CMA, local governments, state agencies, and communities will be essential to translate this strategic intelligence into effective, sustainable flood risk reduction outcomes.

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