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re

DRAFT Report

Cootamundra Flood Warning System Review

Cootamundra-Gundagai Regional Council

20 November 2025

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20 November 2025

Mike Brearley
Project Manager
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Via email: mike@mbaconsult.com.au

Dear Mike

Cootamundra Flood Warning System Review

This report reviews the performance of the existing Total Flood Warning System (TFWS) building blocks for the township of Cootamundra. The report includes the following:

- Assessment of the current flood warning system components for Muttama Creek and Jindalee Creek, in the light of historic events such as the September 2016 and October 2022 floods.
- Identification of possible options to improve current flood warning systems for the township.
- Findings of a multi-criteria analysis for the possible flood warning improvement options.
- Recommendations for a preferred Cootamundra TFWS configuration.

Yours Sincerely,

Neil Dufty
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EXECUTIVE SUMMARY

Cootamundra is located on the western slopes of the Great Dividing Range, in the Cootamundra-Gundagai LGA in NSW. The Cootamundra Floodplain Risk Management Study and Plan by WMAwater (2023) recommended "Improvements to Flood Warning" as a high priority (Option RM-05), described as follows:

- Undertake a review of the existing to the flood warning system for Cootamundra and identify improvements.
- Review the current flood warning system in relation to trigger levels, maintenance requirements, messaging and recipients.
- Conduct a high-level assessment of alternative flood warning systems.

This report presents the outcomes of the flood warning system review in accordance with these specifications, targeted at identifying actions which can lead to improved flood warning arrangements for Cootamundra.

The project used a comprehensive assessment methodology to examine the existing flood warning system. This involved community engagement (drop-in session in the township), discussions with Council's Technical Sub-Committee and input from the Bureau of Meteorology (BoM), NSW State Emergency Service (NSW SES) and the NSW Department of Climate Change, Energy, the Environment and Water (DCCEEW).

Several gaps were assessed in the existing flood warning system and options for improvement/expansion identified.

A multi-criteria assessment (MCA) provided a method by which the options were assessed against a range of criteria. An MCA was used in this project as a tool to support a constructive debate about the relative merits of each flood warning improvement/expansion option.

Based on the MCA, community/stakeholder consultation and data analysis, 20 opportunities for improvement (OFIs) were identified to enhance the flood warning arrangements for Cootamundra township. Each of the improvement options was assessed to provide a priority ranking to support the development of an implementation plan – the ranked shortlist of opportunities for improvement for the warning arrangements in Cootamundra township is presented in Table 6-3 in this report.

The 20 improvements were grouped into the following categories:

- Flood warning works (improvements that require physical construction and ongoing maintenance)
- Community education and engagement (improvements that involve education and engagement with stakeholders including residents, businesses and visitors)
- Emergency management planning (improvements to aspects of emergency agencies, Council, businesses and landuses housing potentially vulnerable people)
- Response (ways to help people to recover from previous floods and prepare for the next flood)
- TFWS review (reviewing components of the TFWS regularly and after floods).

The main recommended improvement to the flood warning system at Cootamundra is the development and installation of a flash flood alerting system based on rainfall and other data such as flood forecasting products, soil moisture and rain radars. The flash flood alerting system could provide at least 2 hours of extra warning lead time which can be crucial for small capacity emergency services and residents some of which may be housed in the retirement village, caravan park and early childhood facility. An early heads-up warning based on forecasted rainfall could be used 24 hours ahead of the storm, and in combination with near real time alerts of rainfall (gauged and RADAR) exceeding certain rainfall depth/intensity limits. The forecast rainfall could be used to correlate with flood maps to allow a consequence-based alerting (there are several approaches to do this), but the emphasis must be on speed of delivery of the alert given the lack of warning time.

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1 INTRODUCTION

1.1 Flood warning

Early warning systems are designed to save lives and protect property where possible. According to Mileti and Sorensen (1990, p.2), 'A warning system is a means of getting information about an impending emergency, communicating that information to those who need it, and facilitating good decisions and timely response by people in danger'.

Target G of the Sendai Framework for Disaster Risk Reduction (2015-2030) aims for inclusive, effective and multi-hazard approaches to early warning systems that enable early action.

In Australia, flood early warning systems are an important part of the flood risk management process promoted by the Australian Government. Guidance provided in the Managing the floodplain: A Guide to Best Practice in Flood Risk Management in Australia (AIDR, 2017 - p.61), shows that early warning systems are a flood response modification option and are one of 'a range of measures to reduce residual flood risk at a community scale'. In comparison with other flood risk management options, flood warning is assessed in this national guide as having a 'medium' capacity to address safety risks and a 'low' capacity to address property damage risks, both in existing and future urban developed areas (AIDR, 2017 - p.46).

The NSW Flood Risk Management Manual (DPE, 2023) acknowledges flood warning systems as an important strategic component of flood risk management in the state. The associated Flood Risk Management Guide – Support for Emergency Management Planning recognises the need to '…coordinate and improve the effectiveness of Total Flood Warning Systems (TWFS)…' to service the NSW communities.

The current arrangements for flood warning in NSW are set out in The Provision and Requirements for Flood Warning in New South Wales (NSW SES, 2019).

1.2 Australian Warning System

There have been several recent developments in flood warning systems in Australia including the Australian Warning System (AIDR, 2021). The Australian Warning System (AWS) is a new national approach to information and warnings during emergencies like bushfire, flood, storm, extreme heat and severe weather.

Prior to the introduction of the AWS, different warning systems existed for different hazard types across Australia. The Australian Warning System aims to provide a consistent warning approach to Australian communities so that people know what to do when they see a warning level.

The NSW State Emergency Service (NSW SES) started implementing the AWS in late September 2022 for warning products related to riverine flooding, storms and tsunami. Warnings for flash flooding are part of the future evolution of the project.

The AWS, adopted by NSW SES, has three core elements:

- Location + Hazard: The location and the type of hazard impacting the community (e.g. Lismore flooding).
- Action statements: For each warning level there are a range of action statements to guide protective action by the community. These statements evolve as the warning levels increase in severity. Statements range from 'stay informed' at the Advice level, to 'prepare to evacuate' at the Watch and Act level, to 'evacuate now' in the Emergency Warning level. As the situation changes and the threat is reduced, the level of warning will decrease accordingly.
- The warning level: The severity of the natural hazard event based on the consequence to the community.

For flood, the icons shown in Figure 1-1 are used:

There are three warning levels:
Advice (Yellow):
An incident has started. There is no immediate danger. Stay up to date in case the situation changes.
Watch and Act (Orange):
There is a heightened level of threat. Conditions are changing and you need to start taking action now to protect you and your family.
Emergency Warning (Red):
An Emergency Warning is the highest level of warning. You may be in danger and need to take action immediately. Any delay now puts your life at risk.

Figure 1-1 Australian Warning System national approach (AIDR, 2021)

1.3 Total Flood Warning Systems

The Australian Government provides guidance for the assessment and design of robust flood warning systems. The concept of a 'Total Flood Warning System' (TFWS) was adopted to incorporate the full range of aspects that must be addressed if flood warning services are to be provided effectively.

Guidelines for the assessment and development of a TFWS are provided by the Australian Government in its document: Application of the Total Warning System to Flood (AIDR, 2022). A schematic of the components of the TFWS promoted by this document is provided in Figure 1-2.

The NSW Flood Risk Management Guide – Support for Emergency Management Planning recommends that local councils consider in their strategic decision-making for emergency management planning that 'any warning system needs to be supported by evidence that it meets the TFWS requirements including consultation with the Bureau and the NSW SES.' (DPE, 2023 – Table 12, p.63)

Figure 1-2 Australian Components of the Total Flood Warning System (AIDR, 2022)

1.4 This project

The Cootamundra Floodplain Risk Management Study and Plan (WMAwater, 2023) recommended to 'undertake a review of the existing and identify improvements to the Flood Warning System for the Cootamundra'.

With a purpose to increase the effectiveness of the flood warning arrangements for Cootamundra and to reduce the risk to life and property within the township, the primary objectives of the project are to review the current flood warning system for Cootamundra and to identify and recommend opportunities for improvement.

The scope of work includes:

- A review of the existing system.
- Engage with the authorities and local communities and the Technical Sub-Committee (TSC) to develop an understanding of past flood experience, to map expectations of existing TFWS, and to identify gaps and opportunities for improvement.
- Assessment of the trigger levels (rainfall and water level) and warning times applicable using the existing hydrologic and hydraulic models.
- Assessment of potential benefits of installing additional rain- and/or stream gauges, including an assessment of suitable locations.
- A review of the maintenance requirements and costs, and of messaging (i.e. alerts and recipients, including vulnerable occupants).
- A review of how the existing and new information could be displayed and better communicated to the community.
- Recommendations for alternative system(s) (if any), and the benefits it would offer.

The deliverables of the project are:

- Total Flood Warning System Review Report (this report).
- Study Materials.

In line with the scope of work, this report provides the following:

- Background (including flood risk and history, community profile, flood exposure, vulnerable communities and land-uses, flood warning lead time)
- Methodology including the TFWS components analysed and community and stakeholder engagement.
- Identification of flood warning gaps and possible improvements.
- A multi-criteria analysis (MCA) to assess the short-listed possible improvements to the TFWS.
- An action plan for delivery of the TFWS improvements for the Cootamundra community setting out:
  - improvement actions
  - priorities for each improvement using scaling
  - suggested timeframes
  - responsibilities
  - indicative costs (construction and maintenance).

2 BACKGROUND

2.1 Study area

Cootamundra is located on the western slopes of the Great Dividing Range and has a population of 7,699 people (ABS, 2021). As shown in the map of the study area (Figure 2-1), Muttama Creek runs north to south through the centre of Cootamundra, Jindalee Creek approaches Cootamundra from the northwest, and Cootamundry Creek passes Cootamundra to the southwest. Jindalee Creek has a catchment area of 54 km² to its confluence with Muttama Creek upstream of Cootamundra. Cootamundry Creek joins Muttama Creek downstream of town with a catchment area of 62 km²; Muttama Creek has a catchment area of 116 km² to this confluence.

2.2 Community profile

Table 2-1 provides a brief snapshot of relevant demographic features of Cootamundra.

Table 2-1 Cootamundra - summary demographic features (ABS, 2021)

Feature	Cootamundra	NSW
Population	7,699	8,072,163
Male	49.1%	49.4%
Female	50.9%	50.6%
Median age	51 years	39 years
Average number of people per household	2.2	2.6
Only speak English at home	91.2%	67.6%
Percentage of residential properties rented	22.3%	32.6%
Same residence as 5 years ago	56%	50.7%
Percentage that did voluntary work	20.8%	13%
Percentage that needs assistance in core activities	8.9%	5.8%
Percentage that has one or more long-term health conditions	39.6%	30.9%
Percentage of Aboriginal and/or Torres Strait Islander people	7.5%	3.4%

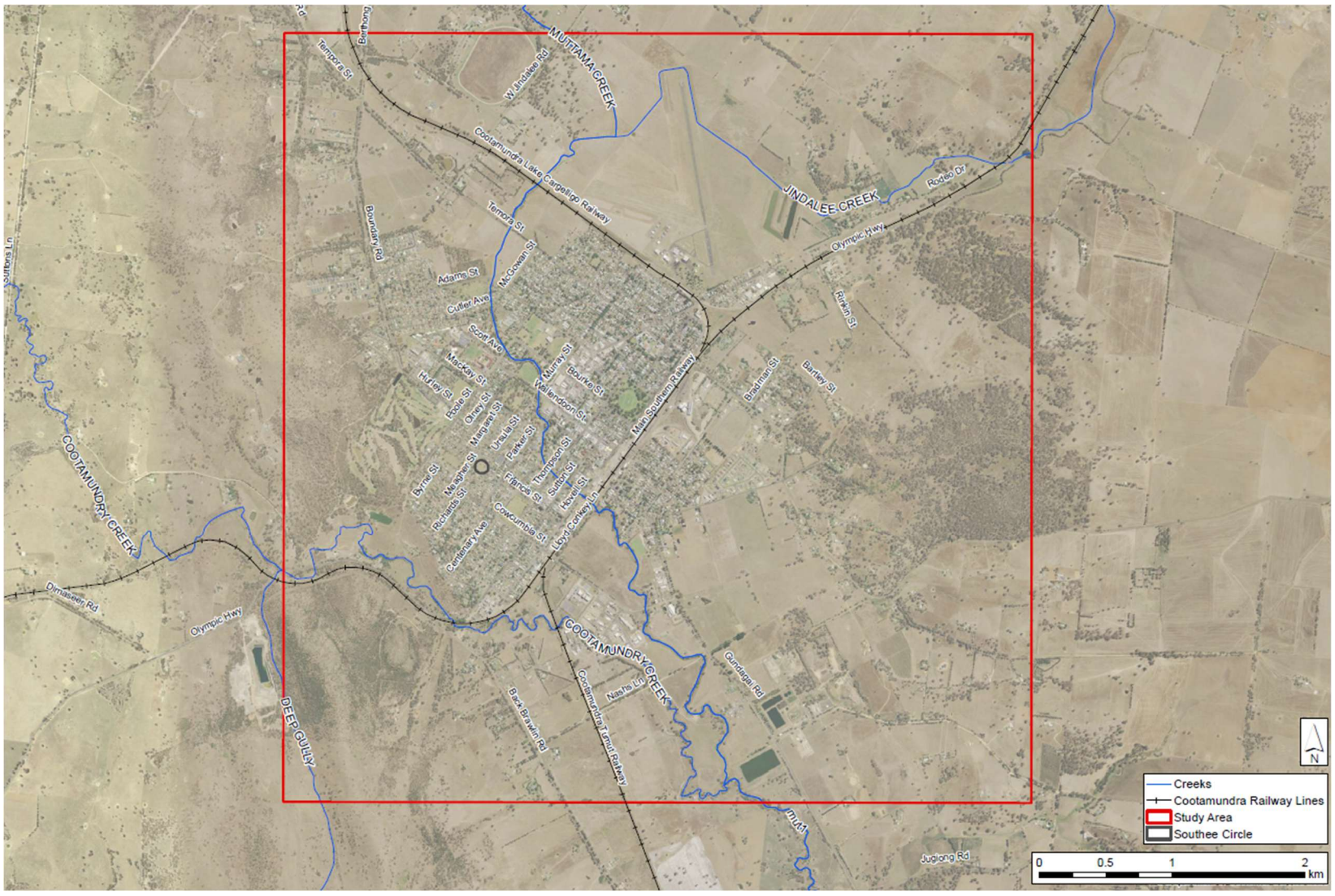


Figure 2-1 Cootamundra Study Area (WMAwater, 2023)

The data provided in Table 2-1 shows that:

- Cootamundra has a lower number of people per household than the state average. This has benefits for emergency response meaning that less people per household is involved in emergency warning response e.g. evacuation, response. This should be considered to estimate the number of people impacted by above-floor flooding of their residence as it has strong implications for emergency management planning including the extent of warning communication coverage, evacuation planning and the preparation of emergency relief centres.
- It has a higher median age than the rest of NSW. This will have implications for TFWS aspects such as warning communication methods (tendency for older people not to use social media and the internet) and response to flood warnings including managing older people and evacuation routes/emergency relief centres.
- There is a relatively high percentage of people that need assistance in core activities in this town (8.9% compared to the 5.8% NSW average). The level of those with long-term health conditions is also well above the NSW average. This will have implications for TFWS aspects such as warning communication methods (e.g. those with impaired or no eyesight) and response to flood warnings including managing potentially vulnerable people and evacuation routes/emergency relief centres.
- Fairly high rate of volunteering. The level of volunteering provides an indication of 'social capital' (trust, norms, networks) in Cootamundra. Social capital has been found to be a major contributor to community disaster resilience and enables people to support each other during emergencies.
- The proportion of people that speak only English at home, compared with the NSW average, is high. This means that English can be the main communication language for warning messages and prior community education.
- At least half the population has a five-year history in the location and there is a low level of properties rented compared to the NSW average. This implies a low transience of the population indicating that a large proportion of the community would have some experience with flooding in the area possibly including the 2016 and 2022 floods.
- There is a relatively even gender distribution in Cootamundra calling for an inclusive approach to emergency management planning.

2.3 Flood risk and history

The Cootamundra Floodplain Risk Management Study and Plan (FRMS&P) (WMAwater, 2023) assessed flood risk in the study area and identified a series of recommended options to mitigate flood risk. This FRMS&P followed on from the Cootamundra Flood Study (WMAwater, 2021) which determined the nature and extent of the flood problem in the township of Cootamundra under existing conditions. Flood behaviour has been defined across a range of event sizes and includes those which have been recorded in the past, as well as larger events which may occur in the future.

The Cootamundra FRMS&P conducted a full assessment of the existing flood risk in the study area including hydraulic hazard across the study area, above floor flooding of residential, commercial, and industrial properties, identification of known flooding issues and hotspots, and emergency response during a flood event.

The FRMS&P found that the study area experiences mainstream flooding from the creeks. Flood extents and depths across Cootamundra scale rapidly in frequent events until the 2% Annual Exceedance Probability (AEP) event. Thereafter in less probable floods, flood depths and extents increase only marginally with event rarity before a larger increase to both in the Probable Maximum Flood (PMF) event.

Flooding not only occurs due to mainstream flooding from the creeks. It is also subject to major overland flow particularly due to runoff from the elevated areas to the south and west of town e.g. from the golf course. It

should be noted that the Southee Circle area can be flooded by creek breakouts in major floods as well as from major overland flow from the upper catchment in isolation or combined.

The extent and depth of the 1% AEP flood event across the study area is provided in the map below (Figure 2-2).

2.3.1 Number of properties and people directly impacted

The Cootamundra FRMS&P estimated the number of residential and commercial properties impacted by above floor flooding at the different flood events (Table 2-2).

Table 2-2 Direct impacts of flooding (sources: WMAwater, 2023; ABS, 2021)

Event	Number of Residential Properties (above floor flooding)	Number of Commercial Properties (above floor flooding)	Total Number of Properties (above floor flooding)	Estimated Number of Residents Directly Impacted (above floor flooding)
20% AEP	17	1	18	39
10% AEP	42	7	49	92
5% AEP	70	13	83	154
2% AEP	247	48	295	543
1% AEP	375	67	442	825
0.5% AEP	443	82	525	975
0.2% AEP	492	93	585	1,082
PMF	1,400	196	1,596	3,080

As discussed in Section 1.1, the primary aim of a flood warning system is to keep people safe, with protection of property, where possible, being a secondary goal. Table 2-2 provides a good indication of the number of properties and residents directly impacted by above floor flooding in Cootamundra. The number of residents impacted by above floor flooding is estimated by multiplying the number of residential properties impacted by the average number of persons per household in Cootamundra (Table 2-1).

According to Table 2-2, there are an estimated large number of residents (825 persons) at risk of being in a property experiencing above floor flooding in a 1% AEP event. A further challenge is that these residents have little warning lead time (Section 2.4) and that there are several land-uses with potentially vulnerable persons in the floodplain (Section 2.3.3).

The significant number of commercial enterprises impacted, many of which are in the Cootamundra Central Business District (CBD), calls for each to have emergency management plans linked to business continuity planning (further discussed in Section 4). Business continuity plans are recommended by the NSW Government for business prone to disruption or potential disasters:

https://www.smallbusiness.nsw.gov.au/resources/guides/BCP

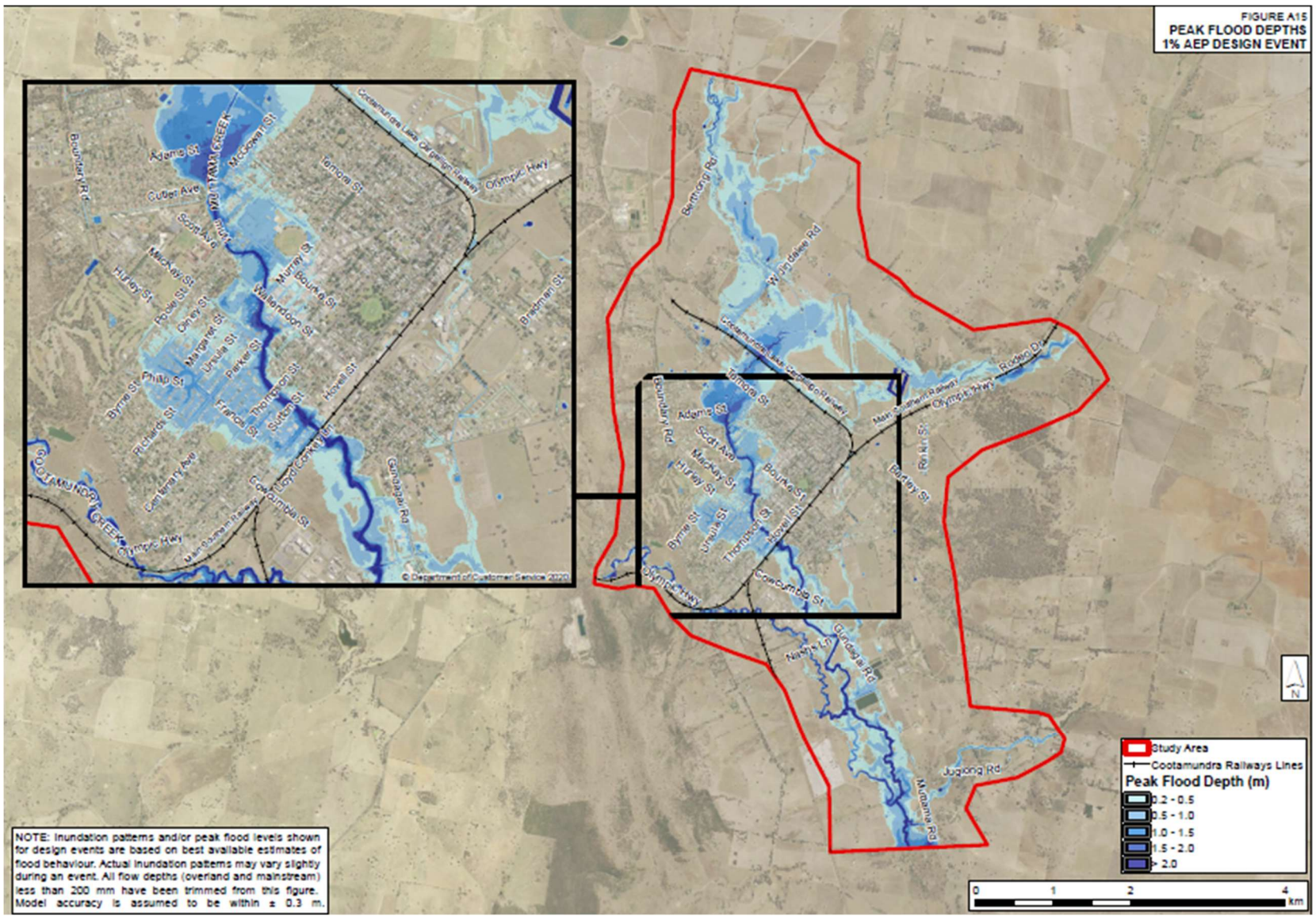


Figure 2-2 Extent and depth of the 1% AEP flood event (WMAwater, 2023)

2.3.2 Flooding Hotspots

The Cootamundra FRMS&P identified several hotspots of flood risk in Cootamundra. 'Flooding hotspots are identified as areas where there is a cluster of flood risk, this may include a number of properties which are frequently inundated (either yard or building inundation), or where high hazard flooding moves through properties, or where road trafficability is reduced due to flooding, such as at the causeways through town' ((WMAwater, 2023).

A map of the flooding hotspots is provided as Figure 2-3.

Flooding hotspots where residents and businesses are particularly at risk include:

- Cutler Avenue area. Muttama Creek enters the more developed part of Cootamundra at the Cutler Avenue causeway, which becomes inaccessible in 20% AEP events. It is noted that the flood extent is wider upstream of Cutler Avenue, and it narrows down as water funnels through the town. As water levels in Muttama Creek rise, the flood water inundates properties along Cutler Avenue and Adams Street to the east of the Creek. At this hotspot, 10 properties are impacted at the 10% AEP by above floor flooding with depths (above ground) of 0.4 m – 0.8 m at 10% AEP and 0.9 m – 1.4 m at the 1% AEP flood event.
- Poole Street and Olney Street Area. Downstream of Cutler Avenue Muttama Creek crosses the Poole Street causeway. As flood waters rise, inundation of the eastern bank across Poole and Olney Streets occurs. Design flood modelling indicates that some of the properties in this area may be flooded above floor level in events as frequent as a 20% and 10% AEP. At this hotspot, 4 properties are impacted at the 10% AEP and 8 properties at the 1% AEP by above floor flooding with depths (above ground) of 0.4 m – 0.8 m at 10% AEP and 0.8 m – 1.4 m at the 1% AEP flood event. One property first begins to be inundated above floor flooding in the 20% AEP event.
- Cootamundra CBD. The Cootamundra CBD contains a number of key services for the community and flood impacts can result in disruption for the community. There are approximately 33 commercial properties in the area, 27 of which are impacted during the 1% AEP or more frequent event. In a 10% AEP event, in addition to local overland flow, mainstream flooding from Muttama Creek impacts the area, although depths remain shallow (<0.3 m) except for the south-western area of the hotspot where depths up to 0.9 m occur due to proximity to Muttama Creek. At this hotspot, 3 properties are impacted at the 10% AEP and 27 properties at the 1% AEP level by above floor flooding. It should be noted that the Ex-Serviceman's Club, which has been used in recent flood events as an evacuation centre, is located within this area and has access issues which begin to occur around a 5% AEP event.
- Cootamundra West. The Cootamundra West hotspot contains properties that are located within the Southee Circle area and properties that are located on Cowcumbla Street, Parker Street, Cooper Lane, Centenary Avenue, Hurley Street, Francis Street, Thompson Street and Sutton Street. There are 348 properties in this hotspot area, comprising 14 commercial and 334 residential properties. In a 20% AEP event, flooding in the area occurs because of overland flow inundation. In a 10% AEP or greater event, in addition to overland flooding, mainstream flooding from Muttama Creek affects the area. At this hotspot, 4 properties are impacted at the 10% AEP and 242 properties at the 1% AEP by above floor flooding with depths (above ground) of 0.1 m – 0.4 m at 10% AEP and 0.3 m – 1.0 m at the 1% AEP flood event.

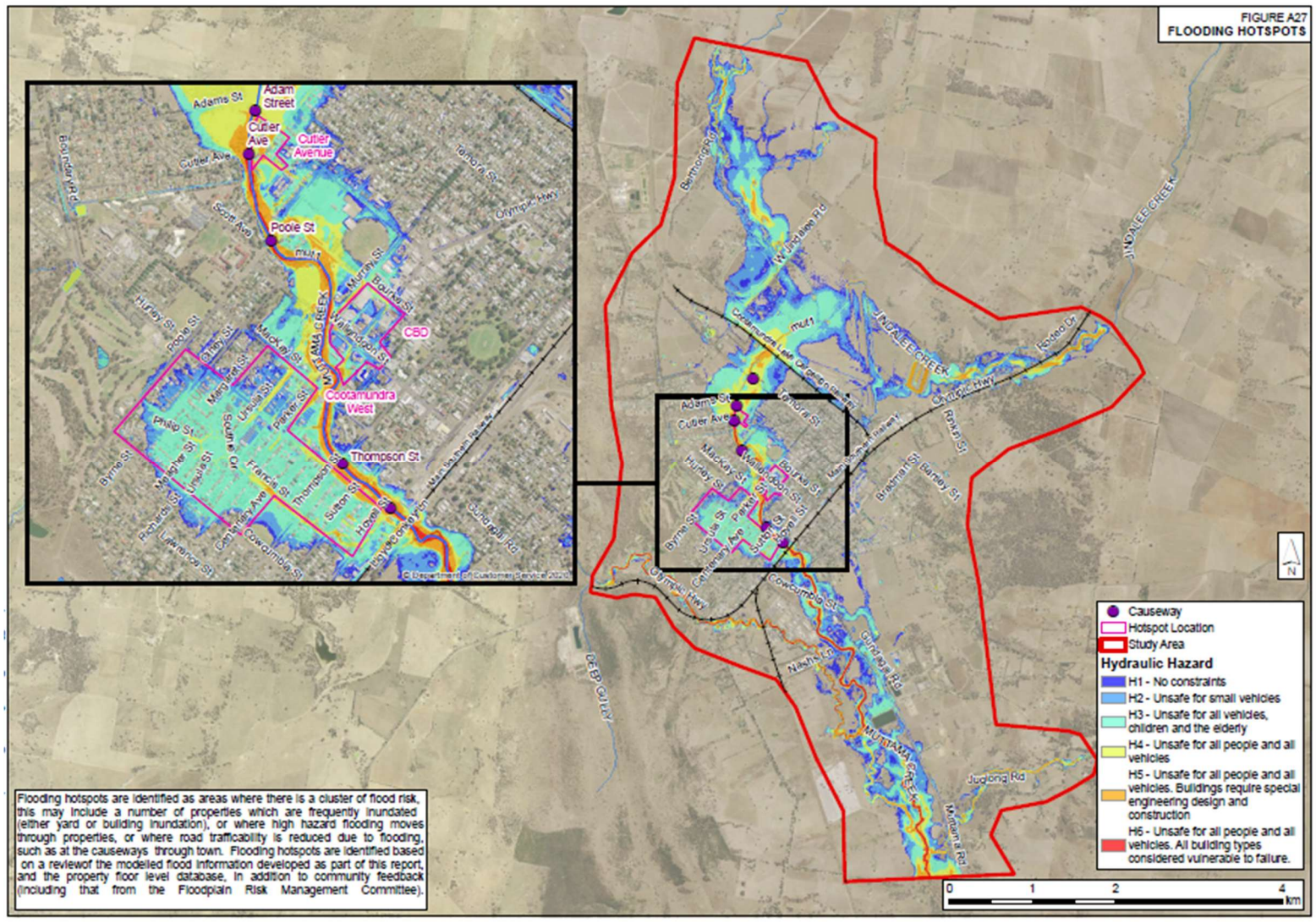


Figure 2-3 Location of flooding hotspots (WMAwater, 2023)

2.3.3 Vulnerable people and land uses

Section 2.2 indicates that there are a relatively high number of vulnerable people in Cootamundra potentially living with houses located within flooding hotspot areas. These potentially vulnerable people include older people (e.g. possible mobility, cognition issues) and people with disabilities (e.g. possible sight, hearing, cognition, mobility issues). Approximately 9% of the Cootamundra population require assistance for core activities such as walking. This has significant implications for emergency services including in evacuation assistance and possible rescue. There are also issues for the receipt and understanding of flood warning messages noting that some people may have hearing, sight and cognition issues.

Furthermore, there are several land-uses in the floodplain (and in the hotspots) that accommodate potentially vulnerable people including:

- Wattle Grove Community Lifestyle retirement village (Figure 2-4). This is located close to the Cutler Avenue hotspot with a frontage to Muttama Creek. It consists of approximately 30 single story residences. Parts of the property are impacted in the 10% AEP event with flood depths above ground of 0 m -1.0 m. From an evacuation perspective, the property becomes isolated at about the 10% AEP level. At the 1% AEP flood depths above ground are 0.5 m – 1.5 m, meaning that all residences would be significantly flooded above floor in this event. A map showing the location of the retirement village is provided as Figure 2-5.
- Creekside Kids Early Childhood Centre (Figure 2-6). This Centre has children of 6 weeks to 5 years age during weekdays. It caters for up to 48 children. The single-story Centre is located in the Poole Street flooding hotspots and would experience flooding as outlined for this hotspot in Section 2.3.2. A map showing the location of the retirement village is provided as Figure 2-7.
- Cootamundra Caravan Park. Located in the Cootamundra West hotspot between MacKay and Wallendoon Streets, the Caravan Park offers a variety of accommodation, including Motel Rooms, Ensuite Cabins and Powered and Unpowered Sites for caravanners and campers. The motel rooms and cabins are all single stories and within 300 metres of Muttama Creek. In the 10% AEP event there is up to 0.5 m of water through the Caravan Park and 0.5 m – 2.0 m in the 1% AEP event. The Caravan Park may accommodate vulnerable persons and, as tourists, would not have local flood knowledge. A map showing the location of the caravan park is provided as Figure 2-8.

Other land-uses that may house vulnerable persons but are less flood impacted include the Albion Hotel, the Cootamundra Gardens Motel and the Elm and Wren Guesthouse on Hurley Street.

Figure 2-4 Proximity of Wattle Grove Community Lifestyle Village (left) to Muttama Creek (photo: N.Dufty)

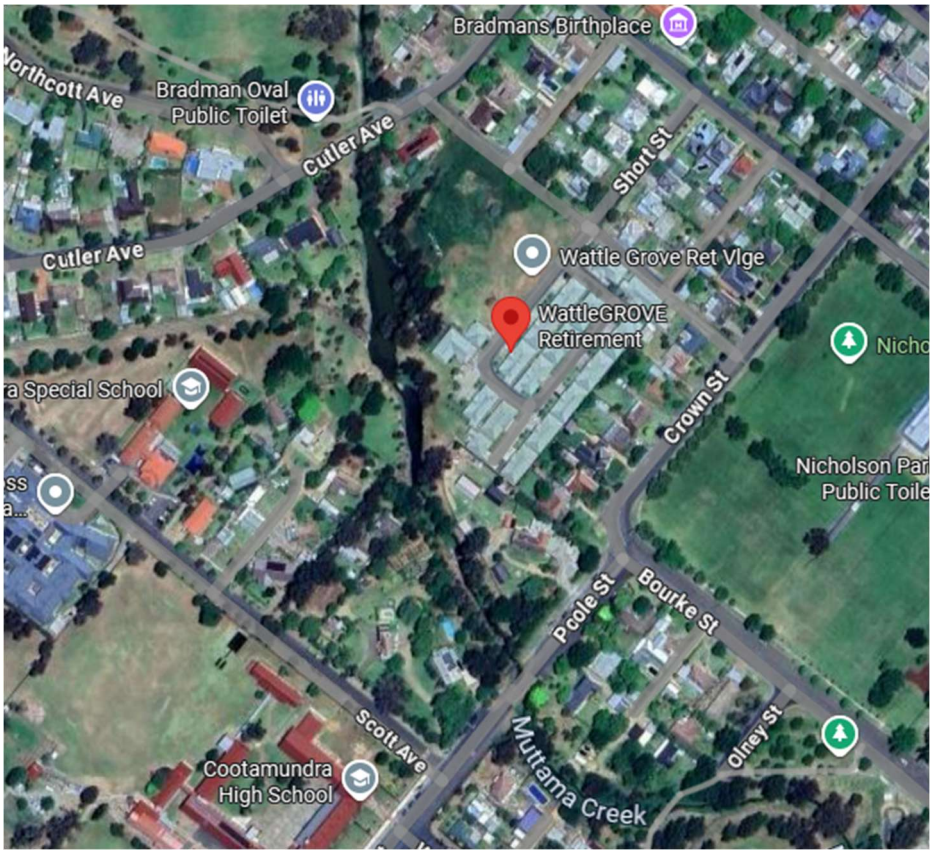


Figure 2-5 Location of the Wattle Grove Community Lifestyle Village – red marker (source: Google Earth)

Figure 2-6 Creekside Kids Centre close to Muttama Creek (photo: N.Dufty)

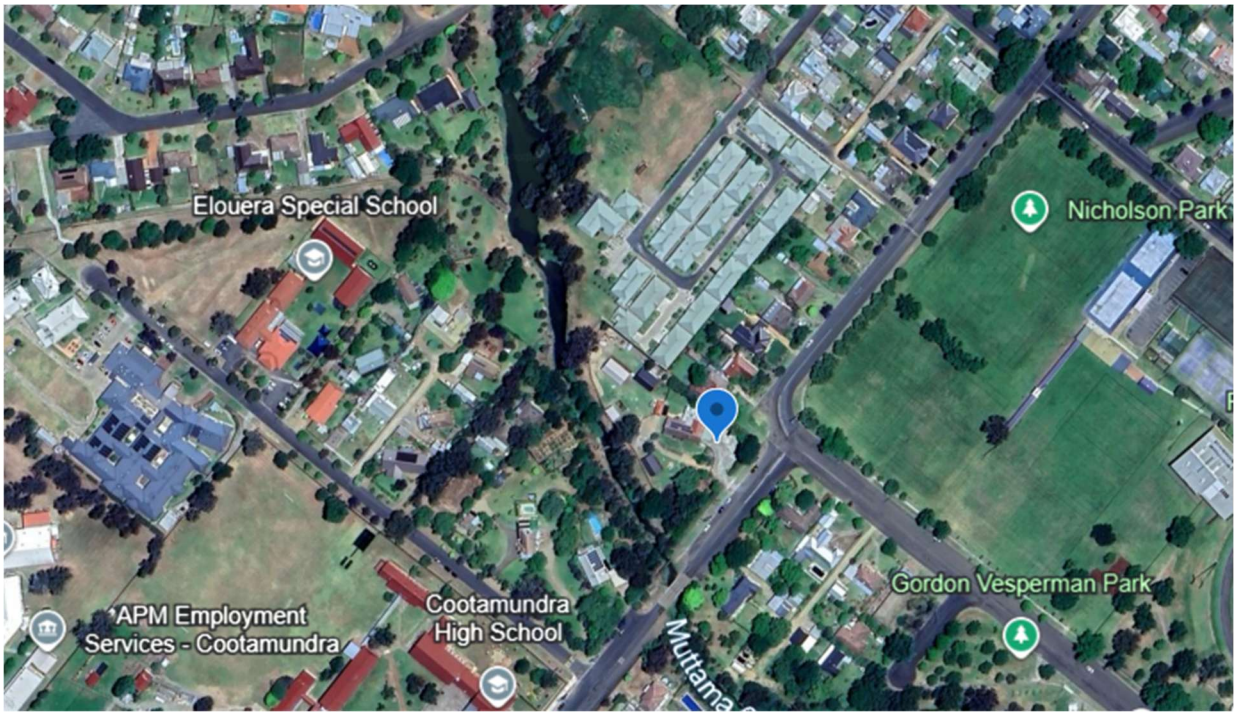


Figure 2-7 Location of the Creekside Kids Early Childhood Centre – blue marker (source: Google Earth)

Figure 2-8 Location of the Cootamundra Caravan Park – red marker (source: Google Earth)

2.3.4 Crossings

Muttama Creek bisects Cootamundra and there are 11 road crossings (bridges and causeways) of the creek. The Cootamundra FRMS&P identified the following road crossings as flooding hotspots:

- Temora Street runs between Barana Road and Hovell Street through Cootamundra and is a main thoroughfare and access route out of Cootamundra. The creek breaks out along Temora St between McGowen St and West Jindalee Rd on the western side of town. The flood depths at the crossing do not exceed 0.3m in the 20%, 10% and 5% AEP event.
- Adams Street causeway. Adams Street is inundated by mainstream flooding from Muttama Creek, cutting an access path between the eastern and western sides of town. Adams Street provides connection for properties off Adams Street and surrounding streets on either side of Muttama Creek. At the 20% AEP level, the peak flood depth is 0.75 m with a peak depth of 2.1 m in the 1% AEP event.
- Cutler Avenue causeway. Muttama Creek enters the more developed part of Cootamundra at the Cutler Avenue causeway, which becomes in inaccessible in fairly frequent events. At the 20% AEP level, the peak flood depth is 1.7 m with a peak depth of 3.1 m in the 1% AEP event.
- Poole Street causeway (Figure 2-9). Downstream of Cutler Avenue, Muttama Creek crosses the Poole Street causeway. This causeway is one of the first to be inundated during a flood event, restricting access. At the 20% AEP level, the peak flood depth is 2 m with a peak depth of 2.9 m in the 1% AEP event.
- Thompson Street causeway. Thompson Street is another frequently flooded Muttama Creek crossing within Cootamundra. Since, this causeway is flooded in frequent events with high flood depths it cannot be used to travel across Muttama Creek during a flood event. At the 20% AEP level, the peak flood depth is 1.7 m with a peak depth of 3.2 m in the 1% AEP event.
- Hovell Street causeway. The heavy vehicle route along Hovell Street is frequently inundated by mainstream flooding from Muttama Creek. High flood depths occur at this causeway across all flood events. At the 20% AEP level, the peak flood depth is 1.7 m with a peak depth of 3.5 m in the 1% AEP event. In March 2023, Council secured NSW Government funding to upgrade Hovell Street including replacing the causeway with a bridge structure.

Some bridges are also inundated frequently e.g. the Parker Street road and pedestrian bridges. Several of the causeways also have higher level pedestrian bridges adjacent that should be noted, i.e. Poole Street, Olney Street and Thompson Street. Other causeways within the town at Lloyd Conkey Avenue and Cowcumbla Street can also be cut. Figure 2-3 shows the main road crossings that can be cut.

Figure 2-9 Poole Street causeway (photo: N.Dufty)

2.3.5 Previous floods

Cootamundra has a long history of flooding since European settlement in 1847. The town was first gazetted as a municipality in 1884, and the earliest records available describe a catastrophic flood in 1885 and significant events thereafter in 1903, 1919, 1952, 1956, 1974, 1983 and 1984. A significant flood event occurred in September 2016 and more recently in October 2022.

The September 2016 flood resulted in evacuations of properties located along Muttama Creek through town. It was reported that approximately 12 properties experienced above-floor flooding during this event. The flood marks from the 2016 event were quite similar to those estimated in the 1974 flood event. Approximately 140 mm of rainfall fell during the 1974 event in comparison to less than 60 mm in the 2016 event. For a 24-hour period of rainfall, the 2016 event was considered to be a 50% AEP while the 1974 event was considered to be 1% AEP based on design rainfall (WMAwater, 2021). An analysis of the rainfall records (WMAwater, 2021) shows that conditions preceding the 1974 event were much drier and the infiltration rate likely to be higher.

A flooding event occurred in Cootamundra on 31 October 2022. Evacuation orders were issued for the properties and streets around Muttama Creek due to the possible flash flooding from 9pm that day. More than 400 properties were evacuated, and more than 100 properties and around 25 streets were reported to be impacted.

Approximately 30 properties were affected above floor level during the October 2022 flood. Temora Street was cut with approximately 600 mm depth of inundation. There was 1 m deep flood water over the Poole Street causeway and Adams Street was cut. It was reported in the media that approximately 1.5 m of flood water went through the Creekside Kids Early Learning Centre (Section 2.3.3). A truck was washed into the creek at the Hovell Street causeway (Figure 2-10). Further comments about the impacts of the October 2022 flood are provided in Figure 2-11.

The rainfall for the October 2022 event was of a rarer frequency than the September 2016 for durations similar to the critical duration of the catchment. A best estimate of the magnitude of the October 2022 event was slightly larger than a 5% AEP event (WMAwater, 2023).

Figure 2-10 Truck washes off Hovell Street causeway in October 2022 flood (photo: Timothy Dean)

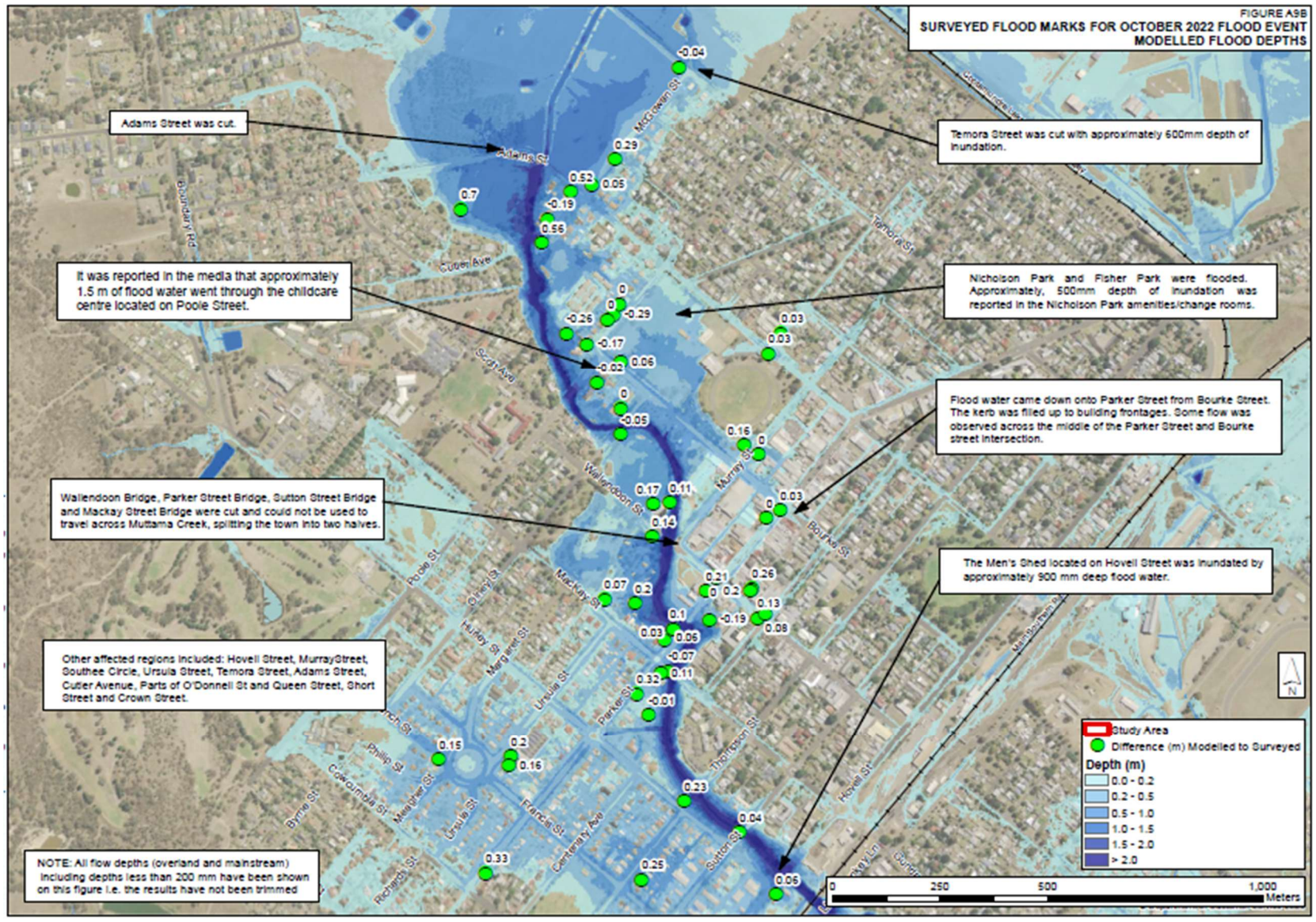


Figure 2-11 Observed impacts of the October 2022 flood (WMAwater, 2023)

2.4 Flood warning lead time

Flash flooding occurs where there is little warning time due to events such as severe storms in small catchments, dam breaks and tsunamis. It poses a significant threat to human life, because of the high flow velocities, unpredictability and rapid onset of such events (Middelmann, 2007). In Australia, a flash flood occurs where there is less than 6 hours warning time (Bureau of Meteorology, 1996).

The concept of 'flood warning lead time' is useful in flood warning research. Flood warning lead time (Figure 2-12) is the time between the issuing of a message containing a flood prediction and the time when the predicted flood height is reached (or when the stream peaks below that height) (US Army Corps of Engineers, 1994).

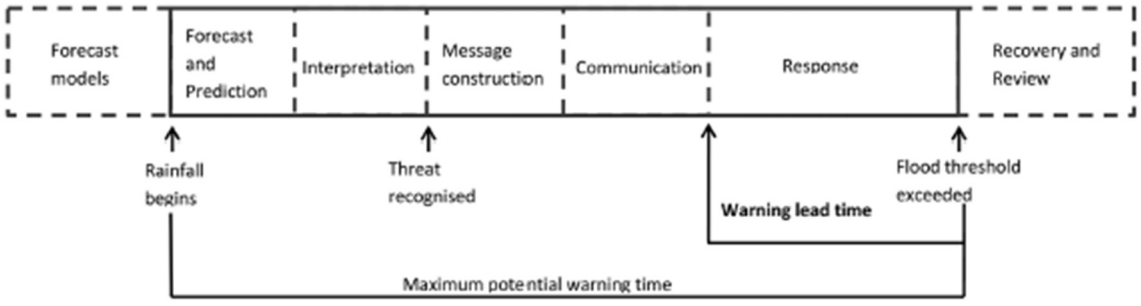


Figure 2-12 Concept of flood warning lead time (US Army Corps of Engineers, 1994)

Cootamundra is classified as a flash flooding scenario with all its flooding hotspots being impacted within 6 hours of significant heavy rain. For example, the Poole Street causeway is cut within 3.8 hours in the 10% AEP event and only 2.2 hours in the 1% AEP event. Above floor flooding can occur in the flooding hotspots well before flood peaks are reached and this can happen well within 6 hours (WMAwater, 2023).

Importantly, the flood warning lead time can be considerably less than the maximum potential flood warning time, in which case residents and emergency services may only have a few hours to respond in a safe way.

The main aim of this assessment of flood warning in Cootamundra is to **identify ways to increase flood warning lead time noting that it may be a trade off with accuracy of warning forecast information** as shown in Figure 2-13.

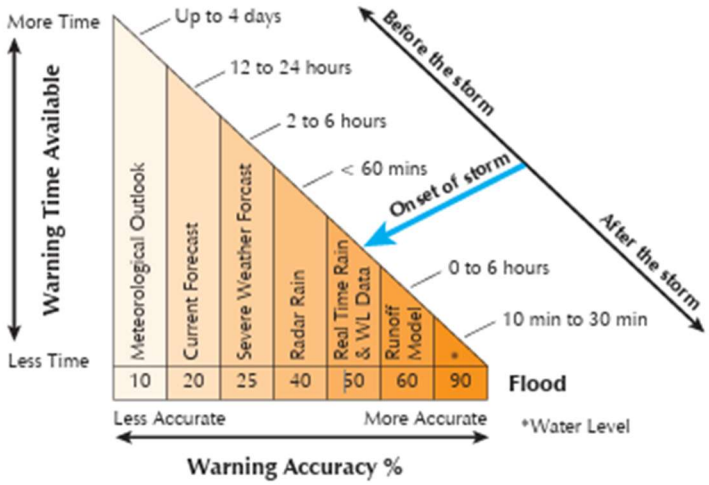


Figure 2-13 The trade-off Between Warning time and Flood Forecast accuracy for Flash Flood Situations (Attorney-General's Department, 2009)

Increased flood warning lead time helps emergency agencies to provide timely flood warning messages and mobilise their on-ground support particularly to vulnerable people. It also provides time for residents and businesses to take safe actions including evacuation.

Flood warning lead time is central to the emergency response approach used by NSW SES as shown in Figure 2-14. By increasing flood warning lead time, actual available time for evacuation is increased.

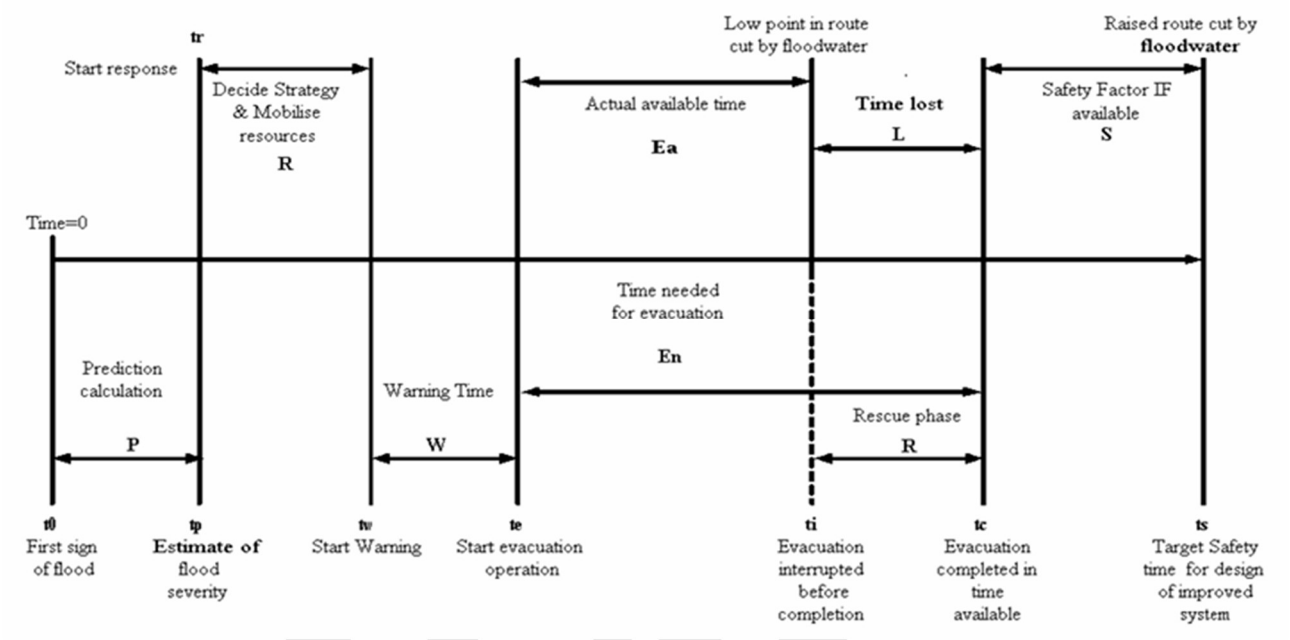


Figure 2-14 Schematic Timeline of Emergency Response for Flood Evacuation (Opper, 2004)

The mobilisation of resources for evacuation is generally outpaced by the impact of flash flooding within the community. That is also complicated by the warning lag factor, where people will try to rationalise the impacts and consequences of warnings on their lives prior to acting.

Cootamundra is a prime example of a location that the warning lag factor and the impact of flooding will occur at the same time, potentially putting people at risk during the movement phase of an evacuation. Thus, opportunities should be identified to increase warning lead time to enable more time for emergency agencies to connect with vulnerable people and for people to rationalise the impacts and consequences of warnings on their lives prior to acting.

3 METHODOLOGY

3.1 TFWS assessment framework

A TFWS assessment framework (based on Molino et al. 2011) was used to review the existing flood warning system for Cootamundra and identify improvements.

This framework builds on that promoted by the Australian Government in Handbook 7 – Flood Warning and the Public Information and Warnings handbook.

- https://knowledge.aidr.org.au/media/3521/adr-handbook-7.pdf
- https://knowledge.aidr.org.au/resources/public-information-and-warnings-handbook/

The framework enables a more holistic understanding of the TFWS and the complexity of the interactions between its components. The framework has been successfully adapted to the review of TFWS in several flood-prone Australian communities. It has been described in research articles such as https://knowledge.aidr.org.au/resources/ajem-january-2021-the-total-flood-warning-system-a-review-of-the-concept/

The framework is similar to that outlined in the Application of the Total Warning System to Flood Handbook (AIDR, 2022). The framework involves 12 components of the TFWS:

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

Figure 3-1 provides a schematic representation of the TFWS assessment framework used in this report.

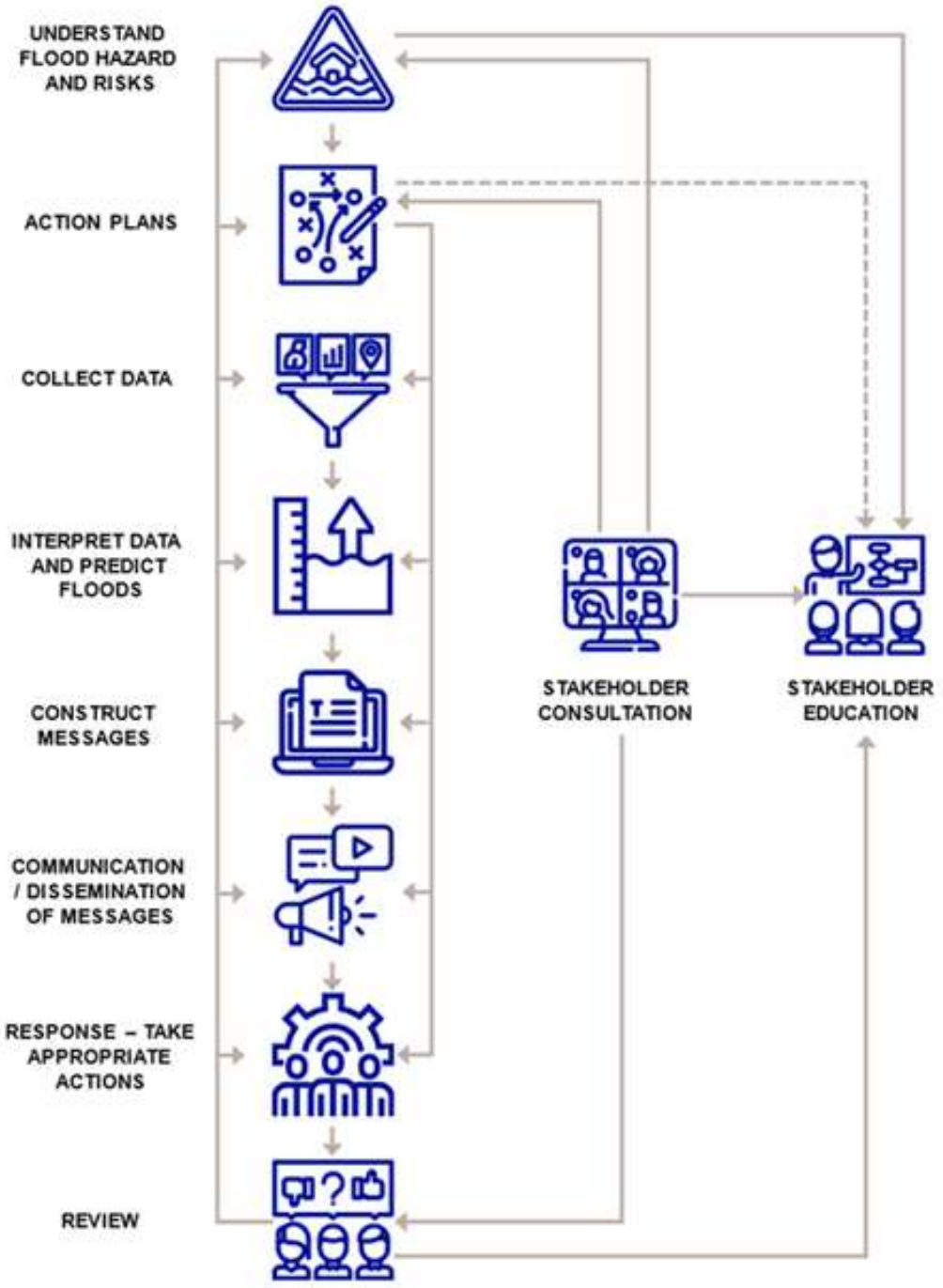


Figure 3-1 TFWS assessment framework (Molino et al. 2011)

3.2 People-centred early warning systems

Underlying the TFWS assessment framework (Section 3.1) is the recognition and understanding of the need for people-centred early warning systems as advocated by the United Nations (2025).

Being people-centred means that the early warning system (EWS) should involve at-risk communities, ensuring inclusivity for all community members. The goal of people-centred EWS is to enable individuals and communities at risk to take timely and appropriate actions, minimising the risk of injury, loss of life, and harm to property and the environment.https://www.cell.com/iscience/fulltext/S2589-0042(25)00614-5?_returnURL=https%3A%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS2589004225006145%3Fshowall%3Dtrue

'EWS become people-centred by addressing individuals' and communities' specific vulnerabilities and capacities, considering factors like gender, age, disability, mobility, language, and culture to ensure no one is left behind. By challenging the hazard-focused paradigm, this approach advocates for tailored warning systems that reduce vulnerabilities, while recognizing that root causes and systemic pressures shape access to resources and impact preparedness, response, and recovery from hazards' (Budimir et al., 2025)

Emphasising people-centred approaches is crucial for several reasons including:

- Those most affected by disasters have the most to gain from disaster risk reduction (DRR), making it a local issue.
- At risk communities are not monolithic, but consist of individuals with varying vulnerabilities and capacities, which is crucial for creating an EWS that serves everyone.
- At-risk communities possess rich traditional, local, and indigenous knowledge that informs all components of an EWS such as a TFWS.

The people-centred approach is depicted in Figure 3-2. Section 3.3 explains the community consultation and co-design tasks conducted to inform this TFWS assessment. An understanding of the Cootamundra at-risk community is included throughout and particularly in Section 2.2 and 2.3.

Figure 3-2 People-centred early warning systems (United Nations, 2025)

3.3 Community consultation

3.3.1 Community Drop-in Sessions

The project engaged in various ways with community members and stakeholders to learn about local issues regarding flood warning; to build an understanding of the local community's lived experience with flooding; and to create a sense of the collective mindset of the community.

In conjunction with Council, Water Technology facilitated an in-person meeting in the form of a drop-in session at the Cootamundra Library.

The TFWS review framework outlined in Section 3.1 was used as a basis for the community meeting discussions, and attendees were also asked to provide ideas for improvement of their existing local flood warning system.

The drop-in session was conducted on 13 August 2025 and the conversations with members of the public were structured broadly around the following questions:

- Was there enough relevant information in flood warnings?
- How were flood warnings delivered? Was this effective? Why/why not?
- Did you have enough time to respond to flood warning?
- Other suggestions for improvement?

The session was reasonably well attended by 10 members of the public. The attendees live across the Muttama Creek floodplain, and all had lived experience in the 2016 and/or 2022 flood events.

The community responses are included in Section 4 along with a technical review of the existing and proposed TFWS for Cootamundra.

3.3.2 Online Engagement Tool

To obtain general feedback from across the entire study area, a "Social Pinpoint" online mapping and comment platform was developed for the Cootamundra study area where people could submit their comments and thoughts about flood warnings for specific locations in a spatial format. This online community feedback facility was made accessible via a dedicated webpage on Council's website several weeks prior to the local drop-in sessions and kept live for several weeks after the drop-in sessions were conducted in the area. Having this additional channel for the collection of community feedback enhanced the accessibility and inclusivity of the project.

There were only 3 pins and comments provided using the online engagement tool. Input received via the online tool has been included in Section 4.

3.4 Stakeholder engagement

3.4.1 Technical Sub-committee

The project Technical Sub-Committee (TSC) includes relevant Council staff members, and representatives from NSW SES and DCCEEW. Water Technology held an in-person inception meeting with the TSC on 21 May 2025. During the meeting, possible TFWS issues in Cootamundra were discussed and the meeting was followed by a field inspection (Section 3.5) of key locations in the area. Comments related to this meeting inspection have been included in Section 4. The TSC also commented on an early draft of this report and met on 18 November 2025 to provide further guidance related to the final draft report.

3.4.2 Other stakeholder meetings

Engagement with other stakeholders was conducted in various ways, including online virtual meetings with representatives from Council, NSW SES and the BoM. In-person meetings were held in the week of the community drop-in sessions with representatives from Council and the local NSW SES unit.

3.5 Field inspections

Field inspections were carried out by Water Technology on the day of the inception meeting with the TSC and again following the community consultation drop-in session. The inspections reviewed key flood-related aspects across the Cootamundra study area. The inspections provided on-ground understanding for the analysis and evaluation for the TFWS review. Figure 3-3 shows one of the key locations visited and Figure 3-4 provides an overview of locations visited for the field inspections.

Figure 3-3 The TSC and Water Technology inspect the Berthong Road (Muttama Creek) rain and stream gauge (photo: N.Dufty)

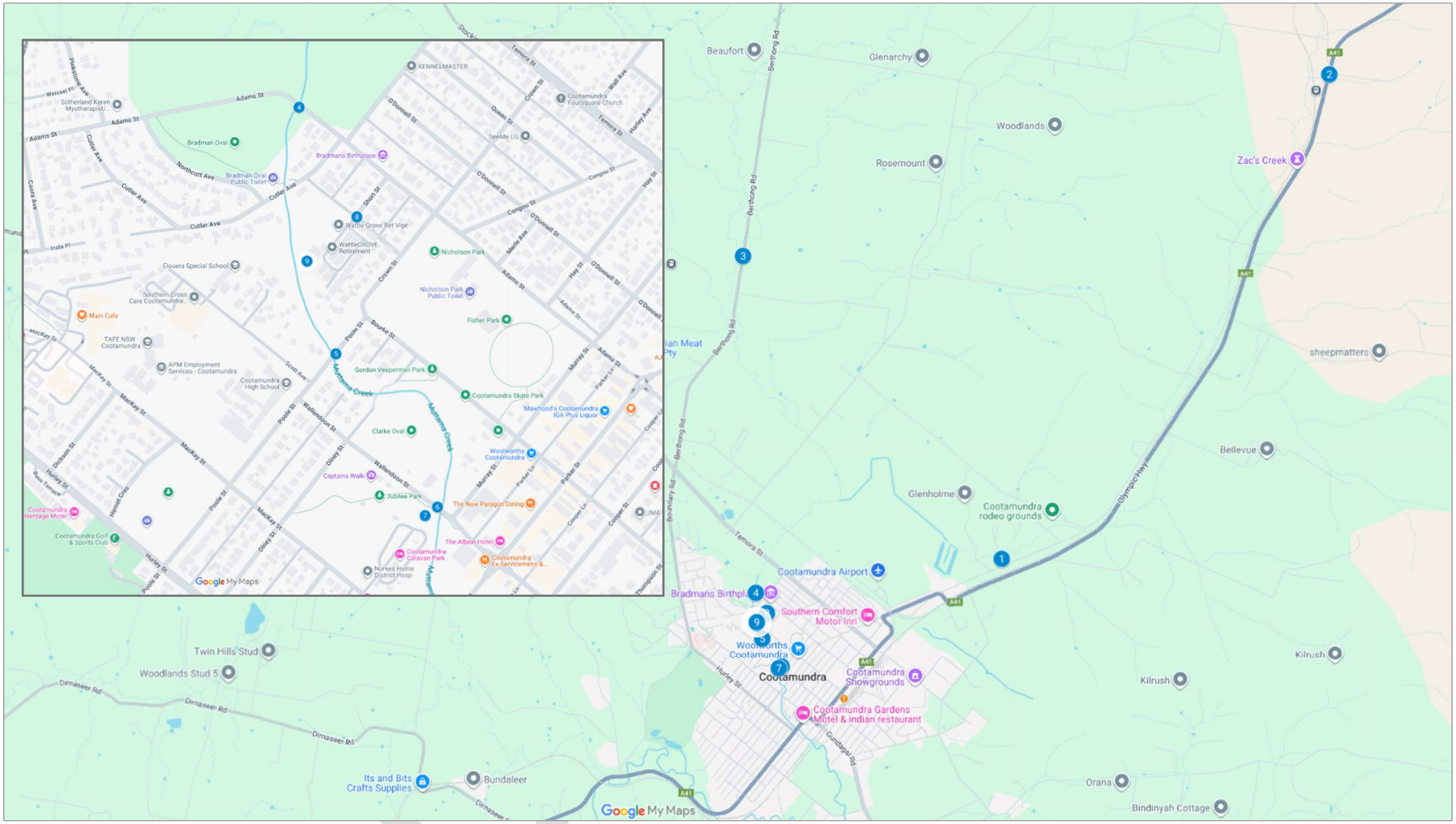


Figure 3-4 Locations (blue dots) visited in field inspections by Water Technology

4 ASSESSMENT OF THE TFWS COMPONENTS

This section of the report documents the review of each of the 12 components of the TFWS as described in Section 3.1. It identifies gaps in the Cootamundra flood warning system and possible opportunities for improvement.

4.1 Understanding flood risk

It is critical that people living and working in flood-prone communities are aware of their flood risk to increase the likelihood they will acknowledge and act on flood warnings. They should also be aware of the flood warning system services in their local community.

This section assesses whether there is adequate understanding of flood risk throughout the community and in the emergency services.

As discussed in Section 2.3, the Cootamundra Floodplain Risk Management Study and Plan (FRMS&P) (WMAwater, 2023) assessed flood risk in the study area and identified a series of recommended options to mitigate flood risk. This FRMS&P followed on from the Cootamundra Flood Study (WMAwater, 2021) which determined the nature and extent of the flood problem in the township of Cootamundra under existing conditions.

As stated in Section 1.1, the main aim of a flood warning system is to protect people. Of key interest for TFWS assessment and development is an understanding of the number of people that directly receive above floor flooding in different flood events. These potentially impacted people are the main focus of flood warnings.

The Cootamundra FRMS&P identified the number of residential and commercial properties impacted by above floor flooding at the different flood events (Table 2-2). Further analysis (Section 2.3.2) indicated that there are an estimated 825 residents at risk of being in a property experiencing above floor flooding in a 1% AEP event. Even at the 5% AEP level (similar to the October 2022 flood), there are about 154 residents that are estimated to be impacted by above floor flooding in their properties. Indications show that approximately 9% of these people require assistance for core activities (Section 2.3.3). Adding to the flood risk are 3 land-uses in the Muttama Creek floodplain that may house vulnerable persons:

- Wattle Grove Community Lifestyle retirement village
- Creekside Kids Early Childhood Centre
- Cootamundra Caravan Park.

There are also significant number of commercial enterprises impacted, many of which are in the Cootamundra Central Business District (CBD). According to Table 2-2, there are 13 businesses that receive above floor flooding in the 5% AEP event and 67 properties in the 1% AEP event.

The Cootamundra FRMS&P identified the following hotspots of flood risk in Cootamundra (Section 2.3.2):

- Cutler Avenue area. At this hotspot, 10 properties are impacted at the 10% AEP by above floor flooding with depths (above ground) of 0.4 m – 0.8 m at 10% AEP and 0.9 m – 1.4 m at the 1% AEP flood event.
- Poole Street and Olney Street Area. At this hotspot, 4 properties are impacted at the 10% AEP and 8 properties at the 1% AEP by above floor flooding with depths (above ground) of 0.4 m – 0.8 m at 10% AEP and 0.8 m – 1.4 m at the 1% AEP flood event. One property is impacted by above floor flooding in only the 20% AEP event.
- Cootamundra CBD. The Cootamundra CBD contains a number of key services for the community and flood impacts can result in disruption for the community. At this hotspot, 3 properties are impacted at the 10% AEP and 27 properties at the 1% AEP level by above floor flooding.

- Cootamundra West. At this hotspot, 4 properties are impacted at the 10% AEP and 242 properties at the 1% AEP by above floor flooding with depths (above ground) of 0.1 m – 0.4 m at 10% AEP and 0.3 m – 1.0 m at the 1% AEP flood event.

The impact of flooding on the closure of roads should also be considered in the development of the TFWS. Muttama Creek bisects Cootamundra and there are 11 road crossings (bridges and causeways) of the creek. The Cootamundra FRMS&P identified 6 of these crossings as flooding hotspots (Section 2.3.4).

Also pertinent to flood risk is an understanding of other factors including:

- Flood warning lead time (Section 2.4)
- Social vulnerability (Section 2.3.3)
- Emergency management planning (Section 4.2).

4.1.1 Gaps

Through stakeholder consultation (Section 3.4), NSW SES and Council believed that there was a good understanding of flood risk in their organisations based on the Cootamundra FRMS&P and experiences in recent flood events. However, both organisations felt that there was not a strong understanding of flood risks in the Cootamundra community. This was mainly due to misconceptions about reducing flood risk (e.g. dredging, de-snagging Muttama Creek) and the impact of floods larger than those experienced (noting that the October 2022 flood was only a 5% AEP event).

At the community meeting (Section 3.3), community members were asked about the perception of flood risk by emergency services and their communities.

Several community members felt that they were not prepared for the larger and faster event experienced in October 2022 compared with 2016. Some used local landmarks (e.g. duck crossing sign, roadside flood reference markers) for flood height reference, however use of the local landmarks for measuring the flood heights is difficult especially at nighttime.

From these responses, it appears that many people are limited in their flood risk perception by the ‘prism of experience’ - a way of understanding and interpreting the world or a situation through the lens of one's personal experiences, beliefs, and emotions. In other words, some people thought that the 2016 flood was the flood extent for them to prepare for not appreciating the possibility of larger floods such as that experienced in October 2022. There is a need for them to understand the impacts for them of all flood events up to the PMF.

Although the Cootamundra community displays relatively low transience (Section 2.2) compared to the NSW average, about half the population were not in the same residence 5 years ago and about one-fifth of the population are renters. These newcomers may have no flood experience and understanding of flood risk, and some community members interviewed identified this as an issue in safe responses to flood emergencies.

4.1.2 Opportunities for improvement

The Cootamundra FRMS&P provides an excellent assessment of flood risk which is the basis of any TFWS (Section 3.2). Whilst it appears that authorities (e.g. Council, NSW SES) have a strong understanding of flood risk across all possible flood events, this is not the case with some residents living in the Muttama Creek floodplain, even those that have had experience with the 2016 and 2022 floods. Furthermore, there are a considerable number of newcomers who probably have little or no understanding of flood risk.

Based on these gaps, the following opportunities for improvement (OFI) are identified:

OFI-1:
Regularly engage with residents, particularly in the hot spot areas, to discuss the potential flood levels and impacts to them for all flood events up to the PMF.

OFI-2:
Provide online flood risk maps and a non-technical explanation of how to read them on Council's website.

4.2 Emergency management planning

The main document to guide flood warning triggers and resultant emergency management actions is the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan (NSW SES, 2023). This is a sub-plan of the Cootamundra - Gundagai Regional Local Emergency Management Plan (EMPLAN).

The purpose of the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan (the Sub-Plan) is to cover preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding. It covers operations for all levels of flooding within the council area and clearly outlines the roles and responsibilities of all organisations including the community in relation to flood warnings and emergencies.

NSW State Emergency Service (NSW SES) is the combat agency responsible in NSW for flooding. There is a NSW SES Unit located at Cootamundra with about 10 volunteer members. It has 'good' interoperability arrangements with the NSW Rural Fire Service (RFS) which provides emergency management support in a flood as per the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan.

NSW SES (local and regional) has developed an understanding of warning triggers for its emergency response however, this intelligence requires further development into Flood Intelligence Cards to describe the impacts on the community and the commensurate actions of authorities.

The local NSW SES unit, when interviewed (Section 3.4), said that it had learned from some deployment and other issues in the 2016 flood and was much better prepared and effective in the October 2022 event based on these learnings. The Cootamundra FRMS&P provides further guidance for prioritisation of emergency response activities with particular focus on the Cutler Avenue and Poole Street/Olney Street hotspots (first impacted).

If an emergency warning is provided (or even prior to warning issuance) (Section 1.2), residents need to decide whether to shelter-in-place or to move to an evacuation centre (this being the preferred safe option). As the town is spit in two by floodwaters, it is important to have clear evacuation routes and evacuation centres on both sides of town. In 2022, the Rugby Club (approximately 30 people, mainly older – as reported) and the Showground (approximately 50 people - as reported) were used as evacuation centres, noting the former venue is located within the PMF.

All land-uses with potentially vulnerable people should have an emergency plan. The 3 land-uses in the Muttama Creek floodplain that may house vulnerable persons:

- Wattle Grove Community Lifestyle retirement village
- Creekside Kids Early Childhood Centre
- Cootamundra Caravan Park.

As noted in the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan, the Cootamundra Caravan Park should:

- Prepare a Flood Emergency Plan for the caravan park.

- Ensure that owners and occupiers of movable dwellings are aware that the caravan park is flood liable by providing a written notice to occupiers taking up residence and displaying this notice and emergency management arrangement within the park.
- Ensure that owners and occupiers of movable dwellings are aware that if they are expecting to be absent for extended periods, they should: − Provide the manager of the caravan park with a contact address and telephone number in case of an emergency. − Leave any movable dwelling in a condition allowing it to be relocated in an emergency (i.e.: should ensure that the wheels, axles and draw bar of the caravans are not removed and are maintained in proper working order).
- Ensure that occupiers are informed of Flood Information. At this time, occupiers should be advised to: − Ensure that they have spare batteries for their radios. − Listen to a local radio station for updated flood information. − Prepare for evacuation and relocation of movable dwellings (cabins).
- Ensure that owners and occupiers of caravans are aware of what they must do to facilitate evacuation and movable dwelling relocation when flooding occurs.
- Coordinate the evacuation of people and the relocation of movable dwellings when floods are rising and their return when flood waters have subsided. Movable dwellings will be relocated back to the caravan park(s) by owners or by vehicles and drivers arranged by the park managers.
- Secure any movable dwellings that are not able to be relocated to prevent floatation.
- Inform NSW SES of the progress of evacuation and/or movable dwellings relocation operations and of any need for assistance in the conduct of these tasks.

There are also requirements for early childhood centres such as Creekside Kids:

- When notified of possible flooding or isolation, childcare centres and preschools should:
  - liaise with NSW SES and arrange for the early release of children whose travel arrangements are likely to be disrupted by flooding and/or road closures; and
  - assist with coordinating the evacuation of preschools and childcare centres.

Creekside Kids and the Wattle Grove retirement village also should have emergency plans that are regularly reviewed by NSW SES.

NSW SES also recommends that each residential and commercial flood prone property has an emergency plan as part of general flood and storm preparedness - https://www.ses.nsw.gov.au/plan-and-prepare/prepare-your-home which has a dedicated section on understanding and accessing flood warnings in the emergency plan template (Figure 4-1).

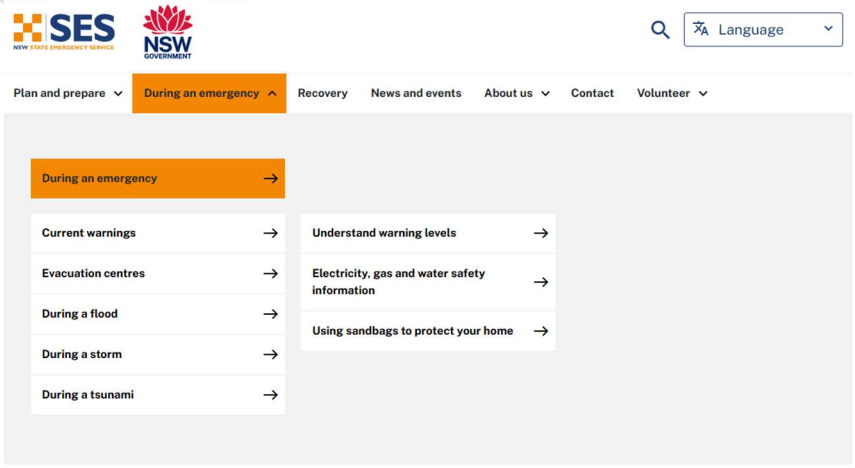


Figure 4-1 Excerpt from Flood Emergency Plan template (NSW SES)

Several community members relayed several harrowing accounts of difficulties they experienced in floods and generally supported the view that the emergency services performed better in terms of support in 2022 than 2016. However, one elderly lady in a very flood prone area had to evacuate her house in waist deep, fast flowing water and drag herself along a fence to reach safety – she received no assistance from emergency services even though this was within a well-known vulnerable (now hotspot) area.

It should be noted that the local NSW SES unit only has 10 volunteer members, while neighbouring SES units may not be able to assist in the flash flooding events experienced at Cootamundra. The local RFS Brigade provides added capacity, however it is critical that initial emergency agency focus is placed on supporting residents and businesses in the hotspot areas, with a particular focus on vulnerable people and the 3 identified vulnerable land-use locations.

4.2.1 Gaps

Whilst the Flood Emergency Sub-Plan provides general guidance, it does not provide detailed information related to Cootamundra including flood warning triggers and emergency arrangements. There is a need to update the Flood Intelligence Cards for Cootamundra and have these included in an updated Part 2 of the Sub-Plan.

It should be noted that the NSW SES Flood intelligence system is based on location specific references, i.e. gauges, and what is the consequences to the community relative to that fixed, measurable point.

Currently there are 10 Flood intelligence products within Cootamundra town, NSW SES finds that this is not viable to maintain and viable to communicate publicly against effectively. These products are based off water on ground, i.e. riverine and they are not tailored for rainfall indicators. i.e. flash flooding.

NSW SES needs direction to consistently and accurately provide an intelligence and warning product based on possible / measurable rainfall – this is further discussed particularly in Section 4.5.

Whilst NSW SES said that it had been working on emergency plans with vulnerable land-uses, regular engagement is required to regularly monitor and review emergency plans for:

- Wattle Grove Community Lifestyle retirement village
- Creekside Kids Early Childhood Centre
- Cootamundra Caravan Park.

NSW SES may engage with consultation and provide feedback on private emergency plans. However, NSW SES does not endorse or take responsibility for the implementation of private emergency plans during the response to floods.

Also, although it appears that NSW SES was more responsive in the 2022 flood, the experience of the elderly lady recounted above shows that there is room for improvement. In particular, NSW SES should have an internal register or map of the location of vulnerable people, particularly in the hot spot areas, and assistance for these people should be of the highest priority related to flood warnings. It should be noted that there are privacy issues related to official lists rather this should be an internal document based on engagement with people in flooding hotspots. NSW SES may, at some time, engage with service providers for the vulnerable community to undertake risk assessments for their clients and their recommended actions during times of flood.

The significant number of commercial enterprises impacted, many of which are in the Cootamundra Central Business District (CBD), calls for each to have emergency management plans linked to their business continuity planning. However, NSW SES does not endorse or take responsibility for the implementation of private emergency plans during the response to floods.

4.2.2 Improvements

Related to the gaps, the following opportunities for improvement are identified:

OFI-3:
Update the Flood Intelligence Cards for Cootamundra and have these included in an updated Part 2 of the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan.

OFI-4:
Regularly monitor and review emergency plans for Wattle Grove Community Lifestyle retirement village, Creekside Kids Early Childhood Centre and Cootamundra Caravan Park.

OFI-5:
Develop and maintain an internal register or map of the location of vulnerable people, particularly in the hot spot areas.

OFI-6:
Encourage all businesses in the floodplain to have an emergency plan (including related to flood) as part of their business continuity planning.

To enhance and share emergency management responsibilities with the community, it is also recommended to:

OFI-7:
Conduct regular emergency exercises with the flood-prone community in Cootamundra including safe response to flood warnings (NSW SES would need direction from the community on how to best engage and conduct these exercises).

4.3 Community flood engagement and education

Community flood engagement and flood education programs support people to prepare for and respond to floods (including to flood warnings). The prime outcome is public safety, with a secondary outcome being protection of property.

NSW SES said that they do some flood engagement work in the local community but there is little local community flood information and guidance (including for flood warning) for Cootamundra on the NSW SES website (https://www.ses.nsw.gov.au/local-information-2). The Cootamundra SES Unit has a Facebook page with over 1,600 followers which can be used for flood preparedness and warning advice (https://www.facebook.com/SESCOOTAMUNDRA/). A few community members interviewed said that they only found out that their property was flood prone after receiving advice from their insurance company.

4.3.1 Gaps

The gaps for understanding flood risk (Section 4.1.1) relate to community flood engagement and education as well and are not duplicated here. A simple fact sheet about local flood warning and safe response would help fill the gap of little local flood information provided. The Local Flood Guide template provided by VICSES for Victorian communities is a suggested approach:

https://www.ses.vic.gov.au/plan-and-stay-safe/flood-guides

The Cootamundra FRMS&P also recommended more public flood markers and information around the town to educate residents and visitors about flood risks and possible levels related to local landmarks. A historical flood marker similar to that at Gundagai, located in a prominent place such as near the Ex-Serviceman's Club and/or the Cootamundra Caravan park, would be helpful to educate the public especially visitors. It could be a

sculpture or totem pole with possible flood heights woven in to the design for community reference. Engaging the community to develop their own visual indicators and cultural tools for identifying safe locations is suggested.

4.3.2 Improvements

Related to the gaps, the following opportunity for improvement is identified:

OFI-8:
Prepare a simple fact sheet about local flood warning and safe response for the Cootamundra community.

OFI-9:

Construct a historical flood marker in a suitable location to educate residents and visitors about flood risks and possible levels related to local landmarks.

4.4 Data collection

Manual 21 – Flood Warning (Attorney-General's Department, 2009, page 15) provides guidance regarding data collection from rain and stream gauges. According to Manual 21 (Attorney-General's Department, 2009), effective routine monitoring of the potential for flooding requires '…sufficient rainfall and river flow data to provide a representative picture of what is happening over the river basin' and 'close liaison between meteorological and hydrological forecasting groups…'.

4.4.1 Rainfall data

Both pluviograph and daily rainfall records are required for hydrological analysis and flood forecasting as part of a TFWS for Cootamundra. Pluviographs record rainfall data at short time increments, indicating the temporal distribution pattern while the more common daily rainfall data provides the spatial variation over the catchments. The pluviographs are used for flood warning, whilst the daily rainfall gauges provide data for climate analysis.

Pluviograph rainfall gauges exist at both the Muttama Creek at Berthong Road and Jindalee Creek at Jindalee gauges (Figure 4-2). Berthong Road is 5 km upstream of Adams Street and represents approximately 48% (56 km²) of the catchment to where Cootamundry Creek enters Muttama Creek. Jindalee is in the eastern portion of the catchment, approximately 8 km upstream of the railway line and represents approximately 15% (14 km²) of the catchment. Both pluviograph rainfall gauges are operated by WaterNSW.

There are a number of other daily read rainfall gauges in and around the catchment. The gauge at Cootamundra Airport (Station 73142) operated by the BoM (previously located at Cootamundra Post Office 1960 - 2000) has a recording interval of 3 hours.

4.4.2 River level and streamflow data

River level and streamflow data is also required for the hydrological analysis and flood forecasting. River stream gauges in NSW are operated by several organisations including WaterNSW, Manly Hydraulics Laboratory, and in some areas, local councils.

The Muttama Creek at Berthong Road (Station 573017) and Jindalee Creek at Jindalee gauge (Station 573009) – locations shown in Figure 4-2- also record water level. Relationships of water level to flow are derived by WaterNSW based on velocity measurements during flood events and extrapolated above the highest measurement.

4.4.3 Gaps

The Cootamundra FRMS&P noted that '…a small number of rainfall gauges and two streamflow gauges exist upstream of Cootamundra, as a minimum a water level gauge (if not additional rainfall gauges also) installed in town would benefit the overall understanding of the timing of flood events…'. This view was also advocated by NSW SES during the stakeholder interviews (Section 3.4).

From analysis of the data provided by WMAWater (2021) and WMAWater (2023) including hydrographs for 2016 and 2022 and modelling outputs, it is unlikely that more telemetered stream gauges (e.g. in Cootamundra or upstream of the Berthong gauge) will provide more than a few minutes of increased warning lead time. It should be noted that this is a relatively small, high velocity flow catchment which has 63% of catchment flows already covered by existing stream gauges. However, as this may have other advantages (e.g. improved flood intelligence for future floods), the installation of an extra telemetered stream gauge in Cootamundra town is further considered in this report.

The relatively small receiving catchment area is also well covered by 2 pluviographs, a 3-hour interval rain gauge and other daily gauges. This enabled the detailed flood modelling conducted by WMAWater (2021) and helps the BoM provide a flood warning for Cootamundra based on rainfall data (Section 4.5).

However, as it was suggested by some community members and other stakeholders interviewed, installing an additional stream gauge is included for further scrutiny in the Section 5 Multi-Criteria Analysis (MCA).

Several community members interviewed (Section 3.3) and Council (Section 3.4) believed that visual (not telemetered) reference (staff) gauges in town would help community situational awareness as many use local signage (e.g. flood road markers) or other unofficial reference points (e.g. signage) in understanding real-time flood behaviour. Reference gauges are relatively low cost to erect and have little or no maintenance costs.

4.4.4 Improvements

Based on analysis of the gaps the following opportunities for improvement are identified:

OFI-10:
Design and install an extra telemetered stream gauge on Muttama Creek.

OFI-11:
Install 3 visual reference gauges at flood hot spot locations in Cootamundra.

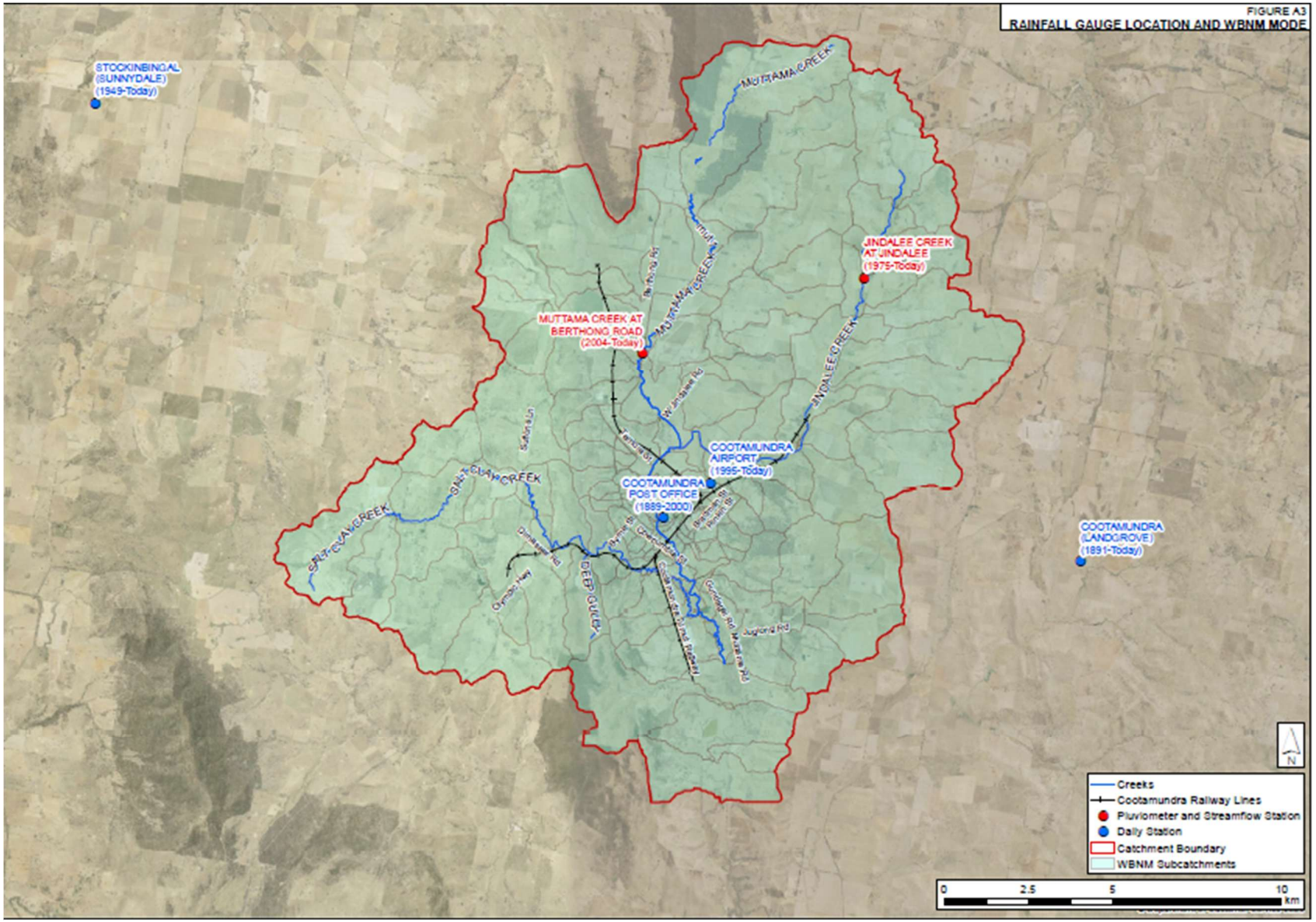


Figure 4-2 Location of pluviometer/streamflow stations and daily rainfall stations (WMAwater, 2023)

4.5 Prediction

The services that the BoM provides in NSW and ACT is outlined in 'Service Level Specification for Flood Forecasting and Warning Services for New South Wales and the Australian Capital Territory' (Bureau of Meteorology, 2024). Page 24 of this document provides flood warning detail for Cootamundra:

410 – Murrumbidgee River Valley								
n/a	n/a	Cootamundra^	No specific forecast location exists – forecast based on exceedance of a rainfall threshold as per trigger height column.	Generalised	1 hr	>50 mm in 6 hrs	n/a	n/a

The trigger for the BoM flood warning is rainfall >50mm over a 6-hour period with a target warning lead time of one hour. Using this kind of rainfall-based trigger can extend flood warning lead time for the Cootamundra community noting that the extent of time from peak rain to peak stream flow is only 1-2 hours at the 2 gauges (Figure 4-3) whilst in the first affected hotspots (Cutler Avenue, Poole/Olney Streets), the possible warning lead time is more likely in the order of 4 hours in a 10% AEP event and 3 hours in a 1% AEP event (WMAWater, 2023).

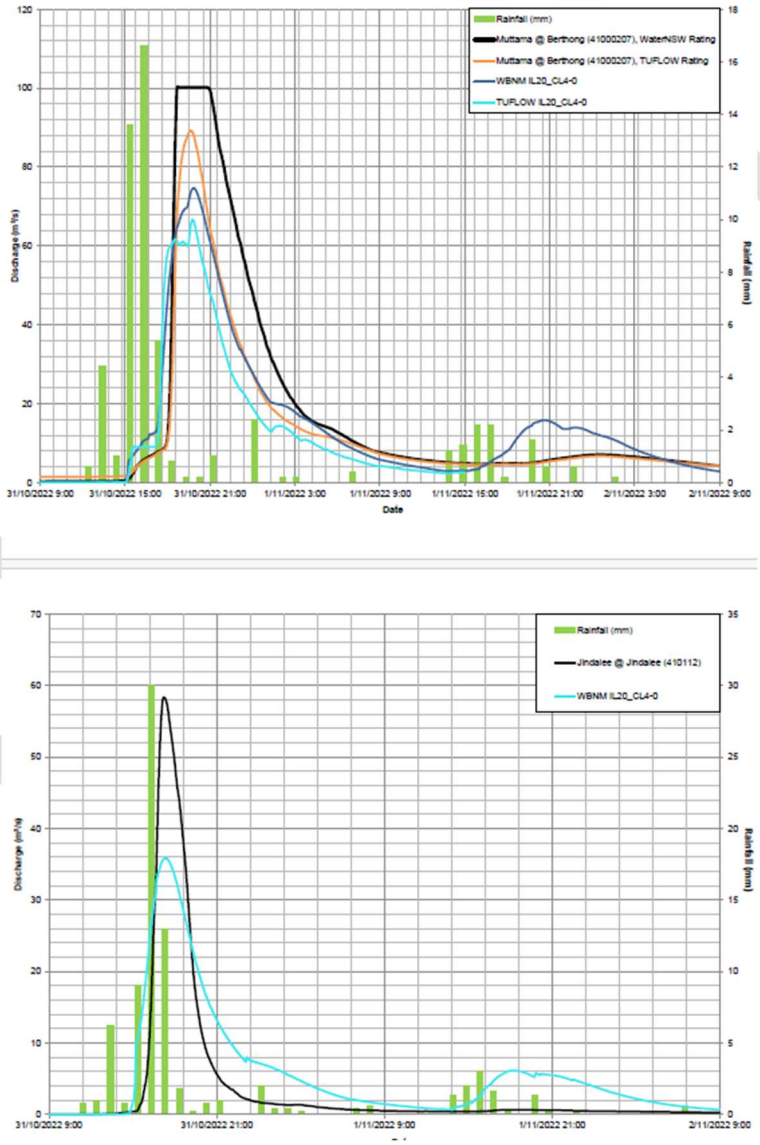


Figure 4-3 Hydrographs for the October 2022 flood event showing the time gaps between rain peaks and streamflow peaks (WMAwater, 2023)

Further to Section 4.4.1, the rainfall-based trigger provides more warning lead time value than relying on streamflow data as shown in Figure 4-3, as there is at least one hour between the peaks of rainfall and peaks of stream flow at the 2 gauges. For events less than the 5% AEP (October 2022), this warning lead time provided by the BoM flood rainfall-based flood warning would even be greater.

4.5.1 Gaps

The main problem with the BoM rainfall-based trigger is that the resultant streamflow is to a certain extent determined by catchment saturation. For example, from WMAwater (2023):

'…The flood marks from the 2016 event were quite similar to those estimated in the 1974 flood event. Approximately 140 mm of rainfall fell during the 1974 event in comparison to less than 60 mm in the 2016 event. An analysis was undertaken in the Cootamundra Flood study which found that the period preceding 1974 event received much less rainfall (less than 100 mm of rainfall over 30 days) and was much drier compared to the 2016 event (approximately 150 mm over 30 days). For a 24-hour period of rainfall, the 2016 event was considered to be a 50% AEP while the 1974 event was considered to be 1% AEP based on design rainfall...'.

It is possible that a rainfall event of <50 mm in 6 hours in a very saturated catchment could cause flooding in Cootamundra. On the other hand, rainfall of >50mm in 6 hours may not lead to a flood in a very dry catchment (e.g. drought conditions). The arbitrary trigger if not accurate may cause distrust in the community and this was supported by a few members of the community interviewed (Section 3.2).

However, soil moisture is only one factor in determining a flash flood event. A dry catchment is not exactly at lower flood risk than a wet catchment, especially for flash flooding where the runoff tends to be precipitation excess and not only tied to soil moisture levels.

Furthermore, as shown in the October 2022 flood event, there can be considerable differences in the rainfall received and related stream responses between the Muttama Creek and Jindalee Creek catchments even though the gauges are only a few kilometres apart. According to WMAwater (2023):

'…At Berthong Road, a total rainfall of 57mm fell between 11:10am 31/10/22 and 11:55PM 1/11/22, 74% (42.4 mm) fell in the 6 hours until 6pm on 31/10/22. The peak water level did not occur until 8:40pm indicating that additional rainfall had fallen in the upper parts of the catchment. At Jindalee, a total of 78.6 mm fell in a similar period, with 79% (62.6 mm) falling in the 6 hours until 6pm on the 31/10/22. The peak water level at Jindalee occurred at 6:10pm, 2.5 hours earlier than Berthong Road, at the same time levels at Berthong Road were over a metre below the later peak...'.

The BoM rainfall-based trigger may not pick up these nuances between these two catchments impacting on the timing of the warning and optimising flood warning lead time.

4.5.2 Improvements

A bespoke predictive flash flood alerting system should be considered for Cootamundra. The existing BoM flood warning, whilst it does provide more warning lead time than relying on streamflow data, is rudimentary (does not consider catchment saturation, differences between the 2 main catchments) and arbitrary (a flood could occur below the trigger level and not above it) and appears to be not favoured by the local community which tends to use more local observational and informal flood warning methods and relies on emergency services.

As WMAwater (2023) note:

'…A wide range of prediction tools are available, from basic flood information systems that use real-time rainfall triggers, to complex flash flood warning systems that run real-time hydrodynamic models informed by radar rainfall estimates. Systems such as these have high computational requirements to continuously run detailed

models, high initial and ongoing costs. When determining a suitable warning system, there is therefore a need to find an appropriate balance between model complexity (and cost), length of warning time, and accuracy of prediction…'.

The national Flash Flood Advisory Resource (FLARE) is an authoritative resource created to assist agencies with flash flood warning responsibilities, such as councils and emergency services, to design, implement and manage fit-for-purpose flash flood warning systems.

FLARE is not an operational service; rather it provides access to a wealth of information that supports local organisations to develop flash flood warning systems (Figure 4-4).

Co-ordinated by the BoM, FLARE includes a website and advisory service for registered users.

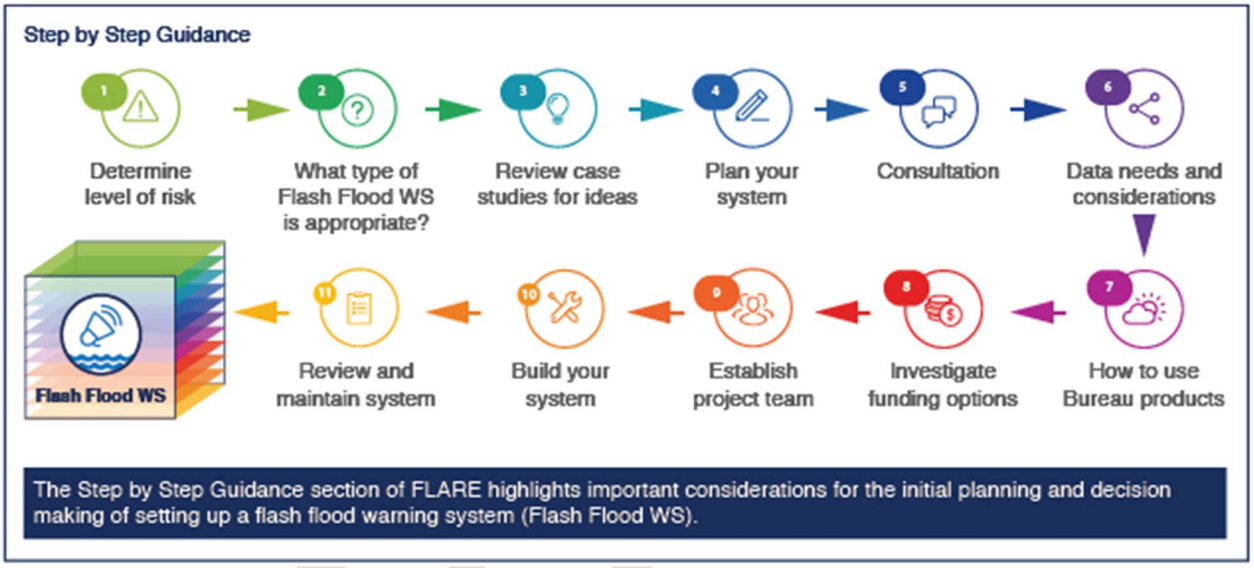


Figure 4-4 FLARE guidance for developing a flash flood warning (BoM, 2025)

The flash flood alert systems integrate meteorological and hydrological data with numerical models to provide early alerts for various types of flooding, enabling effective community and agency responses. These systems vary in complexity, cost, accuracy, and lead time depending on their design and input data sources.

- **Core components of flood systems:** Typical systems include real-time data acquisition, data management, forecasting models, workflow automation, visualization and decision support tools, alerting mechanisms, and system integration with redundancy. Costs vary widely based on system complexity and deployment choices.
- **Accuracy and lead time factors:** Prediction accuracy is primarily influenced by the quality of rainfall forecasts and observational data. Lead times differ by flood type and data availability, with river gauge-based systems offering short lead times and weather prediction-based systems providing longer but less certain warnings.
- **Types of forecasting approaches:** River gauge-based forecasting provides short lead times with high accuracy at gauge locations but limited spatial context. Rainfall-based forecasting offers medium to long lead times but depends heavily on rainfall data quality. Hydrological and hydrodynamic models range from moderate to high accuracy and costs, suitable for various urban, rural, and coastal applications.

A flash flood alerting system could have the following benefits for Cootamundra:

- Maximise flood warning lead time as it uses real-time rainfall and streamflow data.

- Provide better accuracy as it considers both soil moisture and the nuances of the contributing catchments.
- Provides direct warning messaging to local emergency services and impacted residents and vulnerable land-uses.
- Enables emergency services, Council and the community to monitor possible flooding via a website platform.

As an example, Water Technology recently developed a flash flood alerting system for certain areas in the region of Tamworth (NSW), with the following features (see also Figure 4-5):

WISER Flood Alert system:

- A customised dashboard displaying historical and real-time meteorological, hydrological and flood information in a simple, easy-to-use interface that does not require specialist expertise or experience.
- A data management system – using our WISER Water Application Programming Interface (API) as the main mechanism for data communications. This stores and/or connects to historical and real-time meteorological, hydrological and remote sensing data from various sources.
- A modelling and analysis platform that includes various open-source and commercial modelling software and analytical tools which are capable to provide real-time forecasting of flows, flood inundation and optimisation of hydraulic structures. As an example, several operational products are built on Deltares' Delft-FEWS platform, including the Bureau of Meteorology's HyFS and Melbourne Water's Flood Information Decision Support System (FIDSS). Depending on the complexity of drainage characteristics of the deployment location, the components of the WISER system can be assembled or simplified to meet any specific needs.
- Early Warning: The WISER Flood Alert system can generate and disseminate timely and accurate flood warnings to inform decision makers and the public. WISER uses a color-coded alert system to indicate the level of flood risk and the recommended actions. It can communicate the warnings through various channels, such as email, SMS, web, and social media. WISER also provides interactive maps and dashboards to visualise the flood situation and the risk assessment results.

  https://haveyoursay.tamworth.nsw.gov.au/flood-early-warning-system/

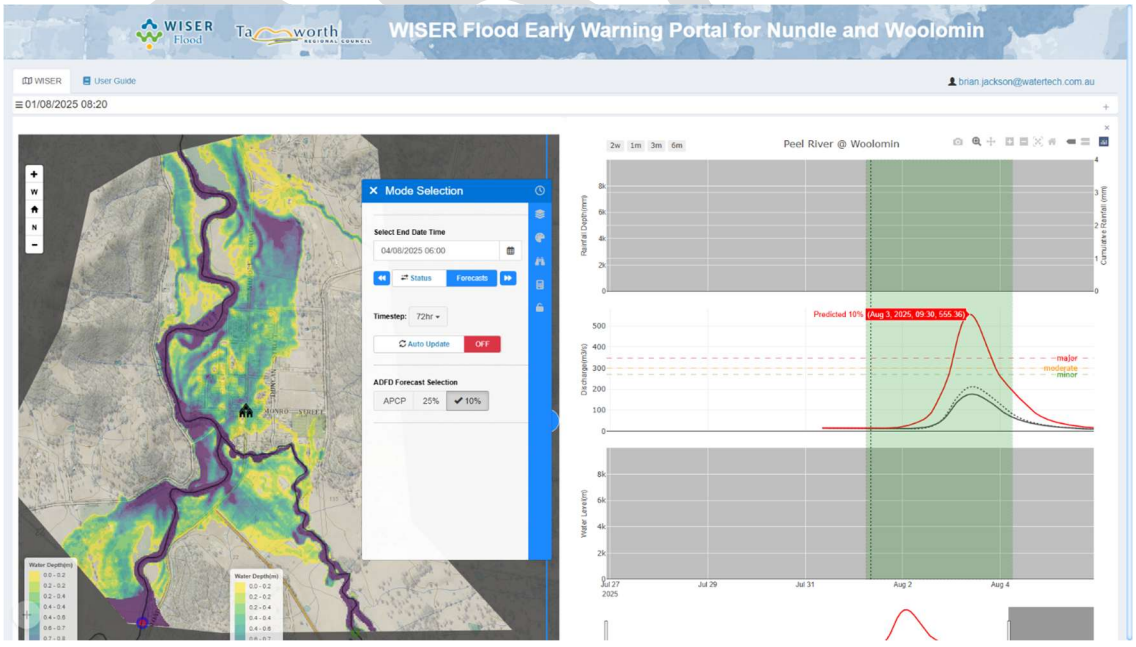


Figure 4-5 Tamworth WISER Flood Alert for the Communities of Nundle and Woolomin

Indicative costs associated with developing a bespoke flood alerting system such as WISER are in the order of magnitude of $200K, with annual maintenance costs of up to $20K.

Increasing fidelity of the radar coverage for BOM in the area might assist with estimating rainfall and super cells in the area.

Furthermore, NSW SES recommends an increased number of rainfall gauges being installed within the region, similar to the Latrobe Valley Information Network - https://www.viccouncils.asn.au/newsroom/resources/case-studies/la-trobe-valley-intelligence-network

To increase the value to Council, the network is recommended to cover a wider footprint than the current study extent for Cootamundra. This should include some of the outlying villages also impacted by flash flooding.

This could be included in a wider regional Disaster Adaptation plan to cover Harden, Young, Cootamundra and parts of Junee Shire as there would be better financial support for systems that improve warnings and resilience in wider flash flood catchments. Wallenbeen and Stockinbingal are key points of concern within the general vicinity of Cootamundra.

OFI-12:
Design and install a bespoke flash flood alerting system for Cootamundra based on FLARE guidance.

4.6 Interpretation

According to Manual 21 (Attorney-General's Department, 2009) (page 21), '…operational coordination and communication are essential between the prediction agency and the lead response agency involved in the reception and interpretation of predictions. Onsite reports provide valuable feedback to the prediction agency on the impacts of flooding and on the accuracy of the predictions. Information on forecast accuracy can be used to adjust hydrological prediction models so future forecasts can be made more accurate…'.

According to Manual 21 (Attorney-General's Department, 2009) (page 36), '…when a flood prediction is received, a primary task of the response agency (usually the local council, local SES or catchment management authority) should be to link the predicted conditions to potential impacts within the local area. This will then determine and direct response and recovery operations and the messages communicated to the community. As flood effects ultimately impact on the community itself, it is worthwhile for response agencies to develop knowledge of the local conditions and potential reactions, both within the physical and social environments…'.

With very little warning lead time, there is no time to set up the regional Incident Control Centre (ICC) and local emergency managers have to interpret the flood situation based on the BoM flood warning, flood study, local knowledge (e.g. 2016 and 2022 floods) and data from a range of sources e.g. local flood reference points.

4.6.1 Gaps and improvements

There were no specific gaps and improvements identified for the 'Interpretation' component of the TFWS system, noting that the preceding discussion in Section 4 is relevant to improving Interpretation.

4.7 Warning message construction

According to Manual 21 (Attorney-General's Department, 2009), '…the warning message is the critical link between flood prediction and interpretation on the one hand, and the taking of protective action on the other. It must be "user friendly", it should explain what is happening and what will happen, where and how the flood will affect the recipient of the message and what he or she can do about it. The message must come from a credible source, be informative and persuasive and be clearly understood by those receiving it. The message may be either in written form or communicated verbally…'.

As noted previously, the BOM issues Severe Weather Warnings and Severe Thunderstorm Warnings, Flood Watches and Flood Warnings. NSW SES releases messages to the communities at risk as per the Australian Warning System (see Section 1.2). These warnings provide details of the likely impacts on communities and what people should do. Emergency messages could also be sent specifically to those residents in danger.

Message construction is carried out by NSW SES based on best-practice community-based research using the Australian Warning System.

Due to the little warning lead time, there may not be time to construct warning messages through official channels (e.g. Emergency Alert) rather the messaging should at least be delivered locally by phone or in person directly to those particularly in the flood hotspot areas. The recommended bespoke alerting system could provide more warning lead time to enable NSW SES to construct accurate messages for Cootamundra.

4.7.1 Gaps

A few of those community members interviewed (Section 3.4) felt that flood warning messages (e.g. BoM flood warnings, text messages) should be more tailored to the local impacts on the Cootamundra flood-affected areas including the flooding hotspots.

4.7.2 Improvements

The following improvement is recommended:

OFI-13:
Tailor flood warning messages to the local impacts on the Cootamundra flood-affected areas including the flooding hotspots.

4.8 Warning message communication

According to Manual 21 (Attorney-General's Department, 2009) (page 50), '…the best predictions, the best interpretive material and the best warning messages are of little value if they have no impact on damages or safety. Failure is guaranteed if warning messages based on flood predictions and interpretations of them are not conveyed effectively to those expected to respond. In essence, a warning which is not communicated effectively is no warning at all if it is not heard or heeded…'.

Manual 21 (Attorney-General's Department, 2009) (page 51) identifies two different types of message communication based on the target audience:

1. General warnings are disseminated ('broadcast') to whole communities or regions.
2. Specific warnings are intended for individuals or parts of communities and reflect the need for 'narrowcasting' to specific audiences who may have specific characteristics or be at different kinds of risk.

NSW SES delivers flood warning information directly to the public in addition to utilising the media. A combination of the following warning methods may be utilised:

- Mobile and fixed public address systems
- Internet - including authorised social media and the official NSW SES website.
- Two-way radio
- Social media
- Hazards Near Me app https://www.nsw.gov.au/emergency/hazards-near-me-app
- Emergency Alert
- Telephone/fax

- Doorknocking
- Mobile and fixed sirens
- Variable message signs
- Community notices in identified hubs
- Distribution through established community liaison networks/partnerships

Emergency Alert is a national telephony-based alert system used by emergency service agencies to send voice messages and short message service (SMS) to landline/mobile telephones in times of emergency. Where appropriate and usually in conjunction with other warning messages, Emergency Alert is used to send SMS/voice alerts to landline and mobile telephones in a specified geographic area. The short warning times associated with flash flooding precludes the use of emergency alert in that instance. The emergency alert system should be used in conjunction with the three levels of flood warning (Australian Warning System) used by NSW SES (Figure 1-1).

Some of the above methods may not have been available due to the extent of the storm front's crossing and short warning lead times, of only a few hours.

Communities are warned through a mix of those communication methods listed above. The 'bush telegraph' (talking to neighbours, friends, vulnerable people) is used in Cootamundra according to the community members interviewed (Section 3.3).

4.8.1 Gaps

There is a need to use as many methods as possible to warn at-risk people. Several of those community members interviewed received no warning messaging during the floods. A few received Emergency Alerts, although these were received when the flood was close to peaking.

Some of the recounts of lack of warning messages from the authorities in the October 2022 flood include:

> *No warnings were given. My neighbour warned me the flood was coming higher and faster at 9.30 pm and to get my car out. No warning or assistance was provided by any person in authority. I managed to get myself out with great difficulty, having to wade out through knee deep and waist deep water, and with the current.*
>
> *No warnings, only became aware of "something wrong" about 10.45 pm when one of my cats started getting flustered at back window and when I opened back door saw 2 feet of water rushing on to my property, chaos, garbage bins floating by etc. I was last person in the area to be helped by SES, for which I am grateful, however my immediate neighbours, who had already been evacuated by SES, also had no warning till SES banged on front door about 10.30-10.45. Same story with friend in Crown Street (unaware & getting ready for bed when at about 10.30 SES banged on front door), same also for friends 100 metres away who were telephoned by family about 10.30 &, upon opening their front door, were confronted with 2-3 feet of fast flowing water about to enter their house.*
>
> *Her husband was at home, totally unaware of flooding until their someone called, and he looked outside to see water which was already in the garage. Husband never got an alert.*

Apparently, the mobile phone towers were down in this flood event and thus there is a need to look at alternative warning methods if this happens. This could include use of sirens, social media, flood wardens/flood observers and the alerting system recommended in section 4.5.2 which would give real-time online alerts. With some older and vulnerable people living in flood hot spots, it is critical to understand how they wish to receive flood warning messages and to use the strong community linkages e.g. friends, family, neighbours ('social

capital') to ensure their safety noting the relatively small capacity of emergency services in the town. It should be noted that the Wattle Grove retirement village was evacuated during the October 2022 event.

4.8.2 Improvements

There is a need to tailor flood warning messaging to the needs and capabilities of local at-risk residents and the 3 vulnerable land-uses (a 'bottom-up' rather than 'top-down' approach). A muti-modal warning approach is required that is not dependent on mobile phone operations.

OFI-14:
Liaise with at-risk residents and vulnerable land-uses to develop a local flood warning messaging approach for Cootamundra.

4.9 Response

Community response to warnings is a crucial component of the TFWS and ultimate indicator of success – if people do not hear and act on warnings the prior work is essentially meaningless.

Vulnerable people are of particular interest for flood warning response in Cootamundra (Section 2.3.3). Vulnerable people can include elderly people and those that require assistance for core activities (people with disabilities).

As described in section 2.2, the median age for residents in Cootamundra is well above the NSW average. Approximately 9% of the population require assistance for core activities such as walking, a rate almost twice the NSW average

On the other hand, Cootamundra has significantly higher levels of volunteerism than the NSW average indicating the strong social capital (networks, bonds) which has been found to be a major inherent resilience asset for communities. Several community members interviewed (Section 3.3) said that there was evidence of family, friends, neighbours and others in the town helping the response and recovery in the 2016 and 2022 floods.

Generally, there was a shared view from those interviewed that the response to the 2022 floods was better than in 2016. Emergency services were better coordinated and responsive, and the community learnt from the 2016 experience to improve its response including early evacuation in some cases. However, there were still warning response issues in the October 2022 event including with message communication and lack of emergency service support to some vulnerable people (Section 4.8).

According to those interviewed, there is still a high level of anxiety and possible Post Traumatic Stress Disorder (PTSD) in the town related to the flood events, particularly in October 2022. Comments included:

> *I am affected by PTSD when it rains. Flood damage leaves a lot to worry about long after the event, which is very stressful.*
>
> *My husband gets very worried about cars, shed, furniture etc. when it rains.*

Apparently, psychological support has been provided for flood impacted people although a few have not moved back into their premises some 3 years after the October 2022 flood.

The management of road crossings is another important response to flood warnings. With 11 main road crossings in town, it is important to close roads early with barriers and clear signage. There apparently were some motorists that drove around barriers, and a truck was marooned in Muttama Creek in the October 2022 flood (Figure 2-6). The management of pedestrian bridges is important as well. There are reports of people trying to cross these bridges when they are close to or are flooded. They are also magnets for sightseers

during floods that present a risk to community. Some of these bridges have been washed away or severely damaged in past floods.

4.9.1 Gaps

There is a need to continue psychological and readiness interventions in the town in addition to flood preparedness education (Section 4.3). This will help minimise flood anxiety and help coping appraisal and self-efficacy both of which are needed to help people respond themselves in future floods. All of the suggested improvements previously identified in this chapter will assist with this future psychological response to floods.

With the relatively low capacity of emergency services in the town and a flash flood situation it is important to encourage existing social networks (e.g. places of worship, clubs) to assist emergency services with response and recovery as required.

The management of road crossings and pedestrian crossings should be reviewed regularly based on improvements such as those recommended in the mitigation actions in the Cootamundra FRMS&P. Furthermore, the early closure of roads should be related to the crossing hotspots as detailed in the Cootamundra FRMS&P.

4.9.2 Improvements

The following improvements are recommended based on the gaps:

OFI-15:
Continue psychological and readiness interventions in the town in addition to flood preparedness education.

OFI-16:
Liaise with existing social networks (e.g. places of worship, clubs) in Cootamundra particularly to assist emergency services with response and recovery as required.

OFI-17:
Review the safety and management of road crossings and pedestrian crossings regularly based on improvements such as those recommended in the mitigation actions in the Cootamundra FRMS&P.

4.10 Review

According to Manual 21 (Attorney-General's Department, 2009) (page 67), '…flood warning systems need regular attention to ensure they will function as intended and to continue to improve their performance…'. The manual adds that review should be conducted both at the strategic and operational level.

4.10.1 Gaps

There was no evidence that the existing flood warning system for Cootamundra was being reviewed regularly (e.g. through a system monitoring and evaluation process).

Review of the TFWS should result in the Local Flood Plan and NSW SES Flood Intelligence Cards being updated based on learnings from the recent flood event and any new data obtained or changes to flood risk (e.g. new mitigation works) between flood events.

4.10.2 Improvements

The following improvement is recommended based on the gaps:

OFI-18:
Conduct an annual review of the flood warning system for Cootamundra.

4.11 Community participation

Manual 21 (Attorney-General's Department, 2009) (page 68) stresses, '…a key point about the review process is that all relevant agencies should be involved to ensure organisational changes can be implemented. Similarly, the process must be open to input from the flood-affected community, members of which are likely to have ideas about how warning systems and services can be more effectively implemented. The views of community members are essential to improving warning systems, and people should be actively encouraged to put forward their opinions on system performance and ways to improve it…'.

An important way of attaining shared responsibility is through community participation in disaster management. There is a growing body of evidence to show that community participation is critical in the development of effective early warning systems. For example, the United Nations International Strategy for Disaster Reduction provides a checklist for developing early warning systems (ISDR, 2006). It states that '…(community) should be actively involved in all aspects of the establishment and operation of early warning systems; be aware of the hazards and potential impacts to which they are exposed; and be able to take actions to minimize the threat of loss or damage…'.

Volunteers from the community form the Cootamundra NSW SES Unit and RFS Brigade which make emergency management decisions in the town.

4.11.1 Gaps

From the community consultation (Section 3.3) there generally was support for emergency services in the town, however, there was little opportunity for the community to be involved in emergency management including related to flood warning. A few people interviewed conceded that they did not understand the roles of emergency services and Council pertaining to flood warnings.

4.11.2 Improvements

In addition to opportunities for improvement recommended previously (e.g. community involvement in flood exercises), the following is recommended:

OFI-19:
Hold regular events (e.g. Open Days, field days) for the Cootamundra community to interact with emergency services and learn more about their roles and responsibilities particularly related to flood warning.

4.12 Integration of the TFWS components

Manual 21 (Attorney-General's Department, 2009) stresses the need for integration of the components of the TFWS: '…For a flood warning system to work effectively, these components must all be present, and they must be integrated rather than operating in isolation from each other. The view that any one component of the system represents all of it, or is an end in itself, impairs the system's effectiveness…'.

4.12.1 Gaps

There was no evidence found (e.g. in the Local Flood Plan) that the linkages across the components of the TFWS were well understood or regularly reviewed for Cootamundra.

4.12.2 Improvements

OFI-20:
Regularly monitor the integration of all components of the flood warning system for Cootamundra.

4.13 Summary – opportunities for improvement

Table 4-1 summarises all opportunities for improvement identified for the flood warning arrangements for Cootamundra township. These opportunities for improvement will be further evaluated through the MCA process outlined in Section 5.

Table 4-1 Opportunities to improve the flood warning system for Cootamundra

TFWS Component	Opportunity for Improvement
Understanding flood risk	Regularly engage with residents, particularly in the hot spot areas, to discuss the potential flood levels and impacts to them for all flood events up to the PMF. (**OFI-1**) Provide online flood risk maps and a non-technical explanation of how to read them on Council's website. (**OFI-2**)
Emergency management planning	Update the Flood Intelligence Cards for Cootamundra and have these included in an updated Part 2 of the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan. (**OFI-3**) Regularly monitor and review emergency plans for Wattle Grove Community Lifestyle retirement village, Creekside Kids Early Childhood Centre and Cootamundra Caravan Park. (**OFI-4**) Develop and maintain an internal register or map of the location of vulnerable people, particularly in the hot spot areas. (**OFI-5**) Encourage all businesses in the floodplain to have an emergency plan (including related to flood) as part of their business continuity planning. (**OFI-6**) Conduct regular emergency exercises with the flood-prone community in Cootamundra including safe response to flood warnings. (**OFI-7**)
Community flood engagement and education	Prepare a simple fact sheet about local flood warning and safe response for the Cootamundra community. (**OFI-8**) Construct a historical flood marker in a suitable location to educate residents and visitors about flood risks and possible levels related to local landmarks. (**OFI-9**)
Data collection	Design and install an extra telemetered stream gauge on Muttama Creek. (**OFI-10**) Install 3 visual reference gauges at flood hotspot locations in Cootamundra. (**OFI-11**)
Prediction	Design and install a bespoke flash flood alerting system for Cootamundra based on FLARE guidance. (**OFI-12**)
Interpretation	None – opportunities for improvement covered by some other OFIs.
Warning message construction	Tailor flood warning messages to the local impacts on the Cootamundra flood-affected areas including the flooding hotspots. (**OFI-13**)

TFWS Component	Opportunity for Improvement
Warning message communication	Liaise with at-risk residents and vulnerable land-uses to develop a local flood warning messaging approach for Cootamundra. (**OFI-14**)
Response	Continue psychological and readiness interventions in the town in addition to flood preparedness education. (**OFI-15**) Liaise with existing social networks (e.g. places of worship, clubs) in Cootamundra particularly to assist emergency services with response and recovery as required. (**OFI-16**) Review the safety and management of road crossings and pedestrian crossings regularly based on improvements such as those recommended in the mitigation actions in the Cootamundra FRMS&P. (**OFI-17**)
Review	Conduct an annual review of the flood warning system for Cootamundra. (**OFI-18**)
Community participation	Hold regular events (e.g. Open Days, field days) for the Cootamundra community to interact with emergency services and learn more about their roles and responsibilities particularly related to flood warning. (**OFI-19)**
Integration of the TFWS components	Regularly monitor the integration of all components of the flood warning system for Cootamundra. (**OFI-20**)

5 MULTI-CRITERIA ANALYSIS

5.1 Background

A multi-criteria assessment (MCA) provides a method by which options can be assessed against a range of criteria and offers a greater breadth of assessment than is available by considering only the reduction in flood risk or economic damages, for example. Such additional criteria may include social, political and environmental considerations and intangible flood impacts that cannot be quantified or included in a Cost-Benefit Analysis (CBA). It should be noted that the assessment of the suitability of floodplain mitigation options is a complex matter, and an MCA will not give a definitive 'right' answer but will provide a tool to debate the relative merits of each option.

5.2 Methodology

The MCA framework was developed to test the main attributes of the potential flood warning improvement/expansion options set out in section 4.13. The development of the MCA framework was based on guidance from the Australian Government for MCAs in infrastructure projects (IAUS, 2021). For the TFWS Review process, the following 6 criteria and rating scales have been defined:

IMPROVEMENT POTENTIAL ("Societal Impact" – Infrastructure Australia, 2021)

This rates how much improvement an option could be expected to deliver to a particular community. In the case of the Total Flood Warning System review this factor is split into two separate criteria, as follows:

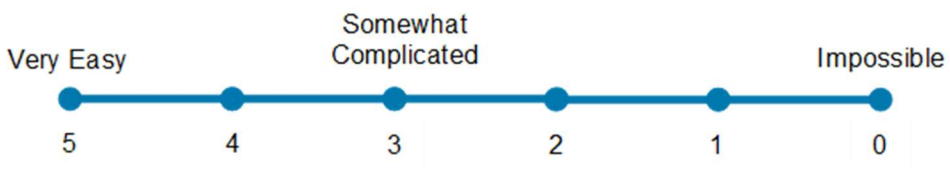
Criteria 1 = Increased Warning Lead Time

Criteria 2 = Increased Warning Accuracy

EASE OF IMPLEMENTATION ("Deliverability" – Infrastructure Australia, 2021)

This rates how simple – or complicated – it would be to implement a specific option in/for a particular community:

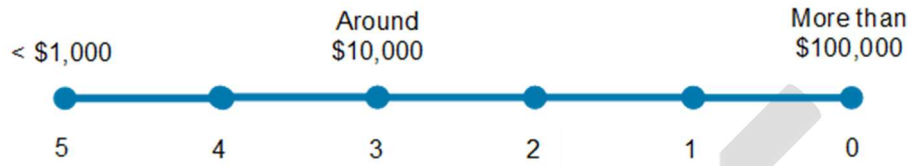
Criteria 3 = Ease of Implementation



ESTIMATED COST

This rates how costly, in Australian Dollars, it would be to implement a specific option in/for a particular community:

Criteria 4 = Estimated Cost



ACCEPTANCE FACTOR

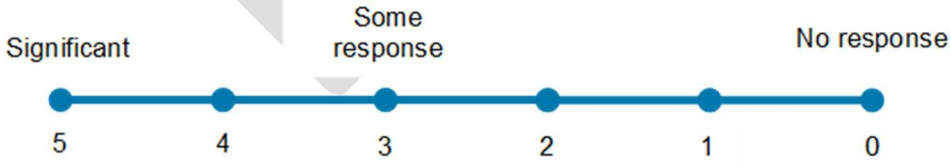
This rates how well the community is expected to accept a specific option:

Criteria 5 = Acceptance Factor

COMMUNITY RESPONSE

This rates the anticipated improvement in community response to flood warnings as a result of the specific option:

Criteria 6 = Community Response



5.3 Stakeholder input

Based on the analysis in this report including community and stakeholder consultation, a draft MCA was developed by Water Technology and presented to representatives of the BoM, DCCEEW, NSW SES and members of the TSC in the course of October 2025. The outcomes of the MCA have been refined based on the discussions with these key stakeholders.

5.4 MCA results

Table 5-1 summarises the MCA spreadsheet analysis of all flood warning improvement/expansion options identified in chapter 4, and summarised in Section 4.13.

Table 5-1 Overall Multi-Criteria Analysis (MCA) scores of TFWS Opportunities for Improvement (OFI) – sorted by highest score.

TFWS Component	Opportunity For Improvement (OFI)	Overall MCA Score	Assessment Rationale
Prediction	Design and install a bespoke flash flood alerting system for Cootamundra based on FLARE guidance. (**OFI-12**)	22	Significantly increase flood warning lead time and accuracy. Improve emergency agency intelligence and community situational awareness. High cost – construction & maintenance.
Emergency Management Planning	Update the Flood Intelligence Cards for Cootamundra and have these included in an updated Part 2 of the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan. (**OFI-3**)	18	No improvement to flood warning lead time and accuracy. Easy to implement, low cost. Use warning triggers and flood levels to target flooding hotspots and vulnerable people and landuses.
Emergency Management Planning	Regularly monitor and review emergency plans for Wattle Grove Community Lifestyle retirement village, Creekside Kids Early Childhood Centre and Cootamundra Caravan Park. (**OFI-4**)	18	No improvement to flood warning lead time and accuracy. Relatively easy to implement, low cost. Will help ensure that these landuses take appropriate safe actions particularly for vulnerable people.
Emergency Management Planning	Develop and maintain an internal register or map of the location of vulnerable people, particularly in the hot spot areas. (**OFI-5**)	18	No improvement to flood warning lead time and accuracy. Easy to implement, low cost. Will help ensure that vulnerable people are targeted by emergency services in a flood.

TFWS Component	Opportunity For Improvement (OFI)	Overall MCA Score	Assessment Rationale
Data Collection	Install 3 visual reference gauges at flood hotspot locations in Cootamundra. (**OFI-11)**	18	No improvement to flood warning lead time but some improvement in accuracy through situational awareness. Easy to install, medium cost.
Message Construction	Tailor flood warning messages to the local impacts on the Cootamundra flood-affected areas including the flooding hotspots. (**OFI-13**)	18	No improvement to flood warning lead time and accuracy. Easy to implement, low cost. Should help community understanding of possible impacts on their properties and appropriate safe actions.
Message Communication	Liaise with at-risk residents and vulnerable land-uses to develop a local flood warning messaging approach for Cootamundra. (**OFI-14**)	18	No improvement to flood warning lead time and accuracy. Easy to implement, low cost. Should help residents receive warnings in ways suitable to them.
Response	Liaise with existing social networks (e.g. places of worship, clubs) in Cootamundra particularly to assist emergency services with response and recovery as required. (**OFI-16**)	18	No improvement to flood warning lead time and accuracy. Easy to implement, low cost. Provides community support to emergency services and Council.
Understanding Flood Risk	Regularly engage with residents, particularly in the hot spot areas, to discuss the potential flood levels and impacts to them for all flood events up to the PMF. (**OFI-1**)	17	No improvement to flood warning lead time and accuracy. Easy to implement, low cost. Should help community understanding of possible flood risks to their properties.

TFWS Component	Opportunity For Improvement (OFI)	Overall MCA Score	Assessment Rationale
Community Flood Education	Prepare a simple fact sheet about local flood warning and safe response for the Cootamundra community. (**OFI-8**)	15	No improvement to flood warning lead time and accuracy. Easy to implement, low cost. Should help community understanding of possible flood risks, impacts on their properties and appropriate safe actions.
Community Flood Education	Construct a historical flood marker in a suitable location to educate residents and visitors about flood risks and possible levels related to local landmarks. (**OFI-9**)	15	No improvement to flood warning lead time and accuracy. Should help community and visitor understanding of possible flood risks, impacts on their properties and appropriate safe actions. Medium cost and little maintenance required.
Data Collection	Design and install an extra telemetered stream gauge on Muttama Creek. (**OFI-10**)	15	Slightly increase flood warning lead time and accuracy. May improve emergency agency intelligence and community situational awareness. High cost – construction & maintenance.
Review	Conduct an annual review of the flood warning system for Cootamundra. (**OFI-18**)	15	No improvement to flood warning lead time and accuracy. Easy to implement, low cost. Ensures flood warning system is part of review by emergency services.
TFWS Integration	Regularly monitor the integration of all components of the flood warning system for Cootamundra. (**OFI-20**)	15	No improvement to flood warning lead time and accuracy. Easy to implement, low cost. Ensures all aspects of the TFWS are working and linked to each other.

TFWS Component	Opportunity For Improvement (OFI)	Overall MCA Score	Assessment Rationale
Emergency Management Planning	Conduct regular emergency exercises with the flood-prone community in Cootamundra including safe response to flood warnings. (**OFI-7**)	14	No improvement to flood warning lead time and accuracy. Relatively easy to implement, low cost. Encourages community participation in emergency planning and is a useful practical reminder of safe flood actions particularly during dry times e.g. drought.
Emergency Management Planning	Encourage all businesses in the floodplain to have an emergency plan (including related to flood) as part of their business continuity planning. (**OFI-6**)	14	No improvement to flood warning lead time and accuracy. Relatively easy to implement, low cost. Will help ensure businesses are prepared for flood and now what to do if a flood is imminent.
Understanding Flood Risk	Provide online flood risk maps and a non-technical explanation of how to read them on Council's website. (**OFI-2**)	12	No improvement to flood warning lead time and accuracy. Relatively easy to implement, low cost. Should help community understanding of possible flood risks to their properties.
Response	Continue psychological and readiness interventions in the town in addition to flood preparedness education. (**OFI-15**)	12	No improvement to flood warning lead time and accuracy. Relatively easy to implement, medium cost. Should help community prepare for next flood and understand safe actions related to flood warnings.
Response	Review the safety and management of road crossings regularly based on improvements such as those recommended in the mitigation actions in the Cootamundra FRMS&P. (**OFI-17**)	12	No improvement to flood warning lead time and accuracy. Relatively easy to implement, low cost. Should help manage creek crossings including timely closures based on flood intelligence and warnings.

TFWS Component	Opportunity For Improvement (OFI)	Overall MCA Score	Assessment Rationale
Community Participation	Hold regular events (e.g. Open Days, field days) for the Cootamundra community to interact with emergency services and learn more about their roles and responsibilities particularly related to flood warning. (**OFI-19**)	12	No improvement to flood warning lead time and accuracy. Relatively easy to implement, low cost. Encourages community participation in emergency planning and is a useful practical reminder of safe flood actions particularly during dry times e.g. drought.

6 RECOMMENDED IMPROVEMENT ACTIONS

6.1 TFWS improvement configuration

The MCA scores (Table 5-1) provide an indication of the prioritisation of the opportunities for improvement identified in this report. These 20 opportunities for improvement can be further grouped and rationalised to form a preferred TFWS improvement configuration.

The scoring in the MCA (Table 5-1) shows that all opportunities for improvement appear to be viable noting that the lowest score was a reasonable 12 out of a possible maximum score of 25. Thus, all opportunities for improvement, regardless of MCA scoring, are considered in this TFWS configuration.

The rationalisation of the opportunities for improvement is based on the following groupings:

- Flood warning works (improvements that require physical construction and ongoing maintenance)
- Community education and engagement (improvements that involve education and engagement with stakeholders including residents, businesses and visitors)
- Emergency management planning (improvements to aspects of emergency agencies, Council, businesses and landuses housing potentially vulnerable people)
- Response (ways to help people to recover from previous floods and prepare for the next flood)
- TFWS review (reviewing components of the TFWS regularly and after floods).

The opportunities for improvement (from now called 'management actions') are categorised into these groupings in Table 6-1.

Table 6-1 Rationalisation of TFWS management actions for Cootamundra

Grouping	Management Action
Flood warning works	Design and install a bespoke flash flood alerting system for Cootamundra based on FLARE guidance.
	Install 3 visual reference gauges at flood hotspot locations in Cootamundra.
	Construct a historical flood marker in a suitable location to educate residents and visitors about flood risks and possible levels related to local landmarks
	Design and install an extra telemetered stream gauge on Muttama Creek.
Community education and engagement	Regularly engage with residents, particularly in the hot spot areas, to discuss the potential flood levels and impacts to them for all flood events up to the PMF.
	Liaise with at-risk residents and vulnerable land-uses to develop a local flood warning messaging approach for Cootamundra.
	Prepare a simple fact sheet about local flood warning and safe response for the Cootamundra community.
	Conduct regular emergency exercises with the flood-prone community in Cootamundra including safe response to flood warnings.
	Provide online flood risk maps and a non-technical explanation of how to read them on Council's website.

Grouping	Management Action
	Hold regular events (e.g. Open Days, field days) for the Cootamundra community to interact with emergency services and learn more about their roles and responsibilities particularly related to flood warning.
Emergency management planning	Update the Flood Intelligence Cards for Cootamundra and have these included in an updated Part 2 of the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan.
	Regularly monitor and review emergency plans for Wattle Grove Community Lifestyle retirement village, Creekside Kids Early Childhood Centre and Cootamundra Caravan Park.
	Develop and maintain an internal register or map of the location of vulnerable people, particularly in the hot spot areas.
	Tailor flood warning messages to the local impacts on the Cootamundra flood-affected areas including the flooding hotspots.
	Liaise with existing social networks (e.g. places of worship, clubs) in Cootamundra particularly to assist emergency services with response and recovery as required.
	Encourage all businesses in the floodplain to have an emergency plan (including related to flood) as part of their business continuity planning.
Response	Continue psychological and readiness interventions in the town in addition to flood preparedness education.
TFWS review	Conduct an annual review of the flood warning system for Cootamundra.
	Regularly monitor the integration of all components of the flood warning system for Cootamundra.
	Review the safety and management of road crossings regularly based on improvements such as those recommended in the mitigation actions in the Cootamundra FRMS&P

6.2 FLARE flash flood warning guidance

The national Flash Flood Advisory Resource (FLARE) is an authoritative resource created to assist agencies with flash flood warning responsibilities, such as councils and emergency services, to design, implement and manage fit-for-purpose flash flood warning systems.

The BoM is currently reviewing its FLARE guidance for flash flood warning systems. However, the current guidance is highly pertinent to the flood risks at Cootamundra.

The FLARE guidance provides a sequence of steps that should be adhered to in the development of a flash flood warning system as shown in Figure 4-4.

For a high-risk scenario such as Cootamundra, the FLARE guidance recommends the following general actions (Table 6-2) which are very similar to the more specific actions recommended in this report (Table 6-1).

Table 6-2 BoM guidance for developing flash flood warning systems in high-risk locations (Bureau of Meteorology, 2016)

TFWS Component	Recommended Management Action
Monitoring and Prediction	Predictive capability based on rainfall/runoff modelling and/or other tools.
Interpretation	Utilise detailed flood studies and flood modelling/mapping to identify areas likely to be affected and understand potential flood depths and velocities and properties likely to be impacted.
Message Construction	Predefined flash flood warning messages based on Bureau warnings, observed rainfall triggers and observed river/drain level triggers respectively.
Communication	Direct and automatic dissemination of rainfall triggers to the affected community e.g. via SMS. Automatic dissemination to the affected community is recommended for Low, Medium and High Risk due to the short lead times available in flash flood situations.
Response	Very proactive community and Emergency Services response underpinned by regularly run public flood awareness and education programs. Excellent community awareness of flooding and personal actions required; many community members have personal flood plans prepared. Detailed and current Municipal Flood Emergency Plan (MFEP) or response plan exists.
Review	Review performance of the system (including each individual element) after each significant flash flood event. Regular and scheduled reviews of the readiness and maintenance of system components such as gauges, communications, public education and planning.

6.3 Flash flood alerting system

Based on the MCA scoring (Section 5-4) and consultation with the BoM and NSW SES (Section 5-3), the main recommended improvement to the flood warning system at Cootamundra is the design and installation of a flash flood alerting system based on rainfall and other data such as flood forecasting products, soil moisture and rain radars. It could involve the rainfall rates and a model for identifying possible consequences for runoff.

As discussed in Section 4.5, the flash flood alerting system could provide at least 2 hours of extra warning lead time which can be crucial for small capacity emergency services and residents some of which may be housed in the retirement village, caravan park and early childhood facility.

The flash flood alerting system can provide rainfall triggers that can give an early heads-up for NSW SES related to possible inundation at fixed points.

With the lack of warning time, it is very clear that the only option for improved warning products must be based on forecast and observed rainfall. An early heads-up warning based on forecasted rainfall could be used 24 hours ahead of the storm, and in combination with near real time alerts of rainfall (gauged and RADAR) exceeding certain rainfall depth/intensity limits. The forecast rainfall could be used to correlate with flood maps to allow a consequence-based alerting (there are several approaches to do this), but the emphasis must be on speed of delivery of the alert given the lack of warning time.

The flash flood alerting system would mean that the BoM flood warning for Cootamundra (Section 4.5) would no longer be needed. NSW SES should investigate how its flood intelligence requirements can be obtained from the rainfall consequence-based alerting that the flash flood alerting platform could provide (rather than relying on stream gauge data).

6.3.1 Examples

An example of a flash flood alerting system installed in the Tamworth district is provided in Section 4.5.2. However, there are many examples of flash flood alerting systems installed throughout Australia and the world.

The BoM promotes the rainfall-based flood alerting system developed for Wallsend, a suburb of Newcastle (NSW). This system (Figure 6-3) uses several rainfall-based triggers for warning the local council, emergency agencies and the community.

Some automated flood warning systems cover both riverine and flash flood scenarios in a LGA such as Byron Shire. JBPacific undertook new hydrology and flood modelling, risk assessments, trigger level assessments, and software development to create a new flood forecasting and warning system for the Byron region, NSW. This Flood Early Warning System included configuration to live gauges, multiple forecast rainfall, tide and soil moisture datasets, a simulation library of flood hazards, and configuration within the Guardian Incident Management System (IMS). More details at https://jbpacific.com.au/projects/service/service-early-warning-systems/byron-bay-flood-warning-system/

There are a range of other providers of automated flash flood alerting systems including:

- Haskoning https://www.haskoning.com/en/services/flash-flood-forecast-and-warning
- Everbridge https://www.everbridge.com/products/public-warning/
- Indicium Dynamics (Figure 6-1) https://www.indicium.cloud/indicium-projects/flood-monitoring

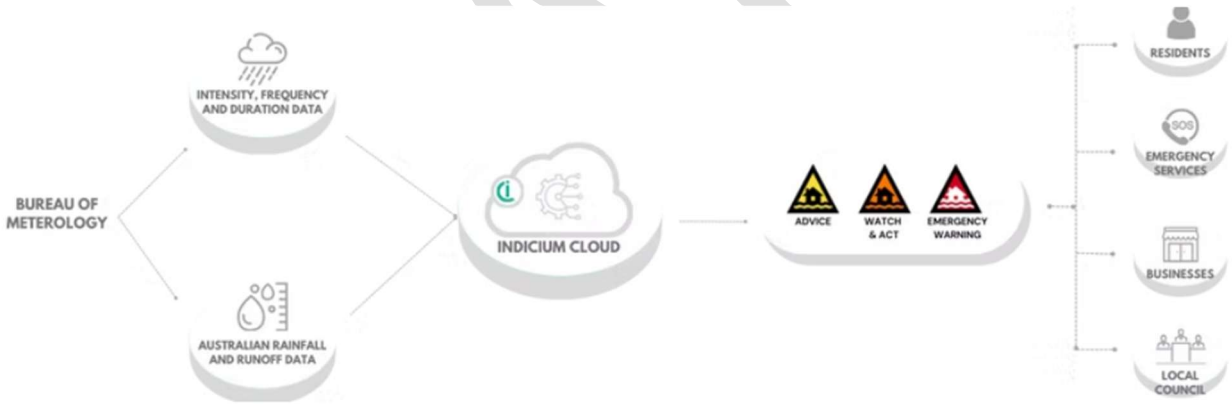


Figure 6-1 Flash Flood Alert System developed for St Marys (Tasmania)

6.3.2 Limitations

During the 2022 floods in Cootamundra, the mobile network went down and this could impact on the proposed flash flood alerting system. For Water Technology's WISER system (Section 4.5.2), if available, the system would be set up to also use radar rainfall data and that would still work. The system would still be able to make flood forecast using that data and send those alerts out. The end user would have to have some form of internet access to see the dashboards and receive published alerts, but they could login to their dashboard from anywhere in the world, so say one of their offices has internet access then they would still get dashboard access.

However, if the in-situ field loggers like river levels and rain gauges send their telemetry via 4G for example, which many do, then that data would not get sent out from the logger and Water Technology would also not see it in its system.

Also, the flood alerting system would sacrifice some accuracy of information for flood warning lead time as forecasting models and radar data is used. As rain falls the accuracy of predicting of predicting flood impacts becomes greater and can be aligned with impacts on particular locations in Cootamundra.

The BoM stresses that redundancy with regards to data transfer from the gauges is very important. 5G/Satellite type communications often fail when you need them the most. The most reliable methods tend to be hardwired or radio (although radio often requires repeaters to be installed which is not cheap).

As radar is an important component of the flash flood alerting service, it is recommended to discuss improvements of the radar fidelity with the Bom to try to improve this service (see Section 4.5.2).

6.3.3 Costs

Indicative costs associated with designing and installing a bespoke flood alerting system such as WISER (Section 4.5.2) are in the order of magnitude of $200K, with annual maintenance costs of up to $20K. However, the costs differ dependent on the needs of the end users (e.g. NSW SES, BOM, local community including flood-affected businesses and residents.

In Section 4.5.2, NSW SES suggests the extension of flash flood warning service to other flash flood prone locations. This should include some of the outlying villages also impacted by flash flooding.

This could be included in a wider regional Disaster Adaptation plan to cover Harden, Young, Cootamundra and parts of Junee Shire as there would be better financial support for systems that improve warnings and resilience in wider flash flood catchments. Wallenbeen and Stockinbingal are key points of concern within the general vicinity of Cootamundra.

6.3.4 Way forward

It is suggested that NSW SES and Council meet with the BoM and potential service providers (Section 6.3.1) to discuss needs, specifications and costs for the flash flood alerting system for Cootamundra (and neighbouring flash flood locations, if that is desired).

6.4 Integration and prioritisation of management actions

The proposed flash flood alerting system will be the linchpin of the improved flash flood warning system for Cootamundra. Using the grouping of recommended management actions in Table 6-1, a schematic describing this TFWS integration is provided as Figure 6-2.

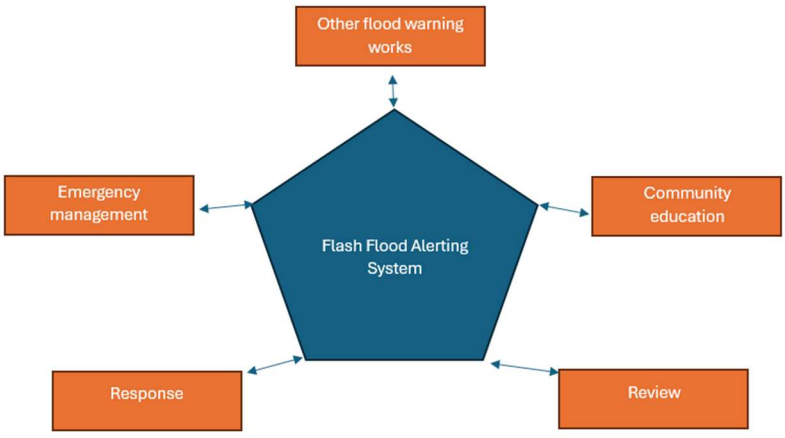


Figure 6-2 Integration of improved TFWS management actions for Cootamundra

Australian Government
Bureau of Meteorology

Trial Wallsend Flash Flood Alert Service

Location: Wallsend (Newcastle), NSW
Operator: Newcastle City Council
Date live: Monitoring August 2009, Warnings via EWN June 2015
Warning time: ≥ 1 hour
Capital cost: $120,000 (entire Newcastle network)
Ongoing cost: $15,000/year (entire Newcastle network)

1. Introduction

Ironbark Creek runs through the commercial area of Wallsend and floods around every 10 years, inundating commercial properties and the local shopping centre. Flooding can occur in as little as one hour and isolated areas above Wallsend may be affected sooner.

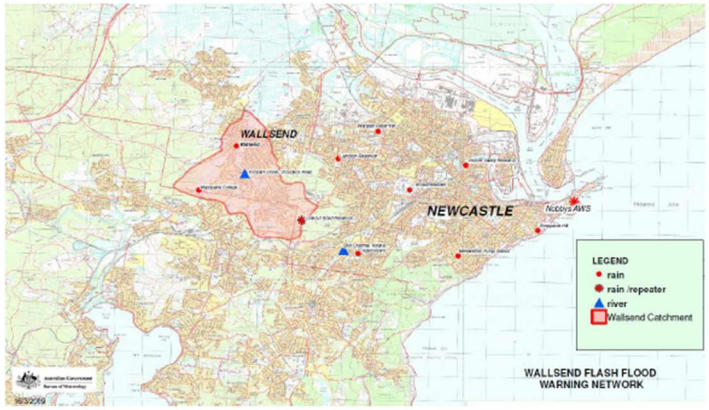
A significant storm event in 2007, which resulted in the grounding of the bulk carrier *MV Pasha Bulker*, also inundated shops in the Wallsend CBD with up to 1.6 metres of floodwater and required the evacuation of many properties, including the Wallsend shopping centre. Following the storm, Council determined to act. Following assessment by a Floodplain Risk Management Study, structural options to improve flow conveyance were deemed too expensive and a flash flood warning system was determined to be the preferred option.

Council undertook extensive community consultation to support the development of the flash flood warning system, including one-on-one interviews, letters to floodplain residents, visits with special interest groups, holding stalls at the Wallsend winter fair over two years, media releases, brochures and advice on its website.

The system was installed in August 2009 and monitored by the Bureau. Alerts using the Early Warning Network (EWN) commenced for a 12 month trial in June 2015. The system was used successfully during flash flooding in January 2016.

2. Monitoring and Prediction

The Bureau of Meteorology designed, costed and set up the system which consists of 10 rain gauges, two river gauges and one repeater. Seven existing Hunter Water rain gauges were incorporated into the system.



3. Interpretation

Three thresholds for all rain gauges in the network have been established for EWN alerts:

- **Alert Level 1**
  - 5 year ARI - 25mm/30 mins
  - 5 year ARI - 45mm/60 mins
- **Alert Level 2**
  - 10 year ARI - 80 mm/3 hrs

The Bureau (Hydrology and Regional Forecasting Centre) also receive alerts for the three trigger levels.

4. Message Construction

Enviromon directs standard predefined messages to EWN, which validates the alert with local river and rain gauges and issues predefined alerts to registered participants:

- **Alert Level 1**: Flood Alert. Heavy rainfall. Possible flash flooding in Wallsend area. Watch the situation and refer to your Flood Survival Plan - www.floodsafe.com.au
- **Alert Level 2**: Flood Alert. Very heavy rainfall. Imminent flash flooding in Wallsend area. Never drive or walk in floodwaters

The Bureau does not receive EWN alerts. Bureau products like Flood Watch or Severe Weather Warnings are also forwarded to residents but alerts do not link to Bureau products.

5. Communication

EWN sends messages to registered participants, who can choose between receiving SMS, email or a pre-recorded phone call.

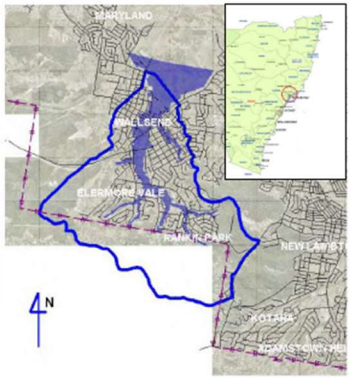
Council receives emails and SMS messages from EWN and contacts the Local Emergency Management Controller, SES Regional Controller, SES Local Emergency Management Officer and posts warnings to Council's Facebook page. However, Council does not receive messages or contact emergency services outside office hours. Alerts are sent directly to emergency services both during office hours and after hours.

The Wallsend warning system has no formal arrangements with media, which would only be alerted if they had registered with EWN. Council considers that media may over-embellish warnings, potentially communicating warnings to residents outside of the Ironbark Creek flood risk area and cause unnecessary alarm.

6. Protective Behaviour

No specific instructions are provided but recipients are advised to monitor the situation or to refer to the SES FloodSafe brochure. Council has sent letters to residents in the Ironbark Creek floodplain and has also engaged a media company to raise awareness of flooding.

The shopping centre has a flood management plan and downstream commercial managers share photos and messages, monitor EWN and physically monitor the creek level.



Source: WorleyParsons (2009)

7. Review

Following the January 2016 flash flood event, Council arranged a meeting with agency representatives to discuss positives and negatives of the messages provided by EWN. Community feedback after the January 2016 event was sought through a survey of all registered users.

As of May 2016 the flash flood warning system is still being trialled. Regular reviews will be scheduled should an ongoing service be established.

8. Conclusions

The alerts have proved more valuable than expected and residents have welcomed the opportunity to receive live information from their local area, whereas other warnings, media or social media sources may broadcast more generalised information about Newcastle City or the Hunter Region. Alerts allow people to prepare in advance for possible evacuation. Council has found that system operation was less onerous than was initially perceived.

For more information contact the FLARE Team:
FLARE.support@bom.gov.au

Figure 6-3 Wallsend Flash Flood Alert Service

In Table 6-3, the 20 management actions for flood warning improvement (Section 6.1) are prioritised as High, Medium and Low based on urgency and importance gleaned from the MCA scoring (Section 5.4) and TSC review (Section 5.3).

Table 6-3 Prioritisation of TFWS management actions for Cootamundra

Priority	Management Action
High (Essential)	Design and install a bespoke flash flood alerting system for Cootamundra based on FLARE guidance.
	Update the Flood Intelligence Cards for Cootamundra and have these included in an updated Part 2 of the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan.
	Liaise with at-risk residents and vulnerable land-uses to develop a local flood warning messaging approach for Cootamundra.
	Regularly monitor and review emergency plans for Wattle Grove Community Lifestyle retirement village, Creekside Kids Early Childhood Centre and Cootamundra Caravan Park.
	Tailor flood warning messages to the local impacts on the Cootamundra flood-affected areas including the flooding hotspots.
	Encourage all businesses in the floodplain to have an emergency plan (including related to flood) as part of their business continuity planning.
	Develop and maintain an internal register or map of the location of vulnerable people, particularly in the hot spot areas.
Medium	Regularly engage with residents, particularly in the hot spot areas, to discuss the potential flood levels and impacts to them for all flood events up to the PMF.
	Install 3 visual reference gauges at flood hotspot locations in Cootamundra.
	Continue psychological and readiness interventions in the town in addition to flood preparedness education.
	Construct a historical flood marker in a suitable location to educate residents and visitors about flood risks and possible levels related to local landmarks
	Prepare a simple fact sheet about local flood warning and safe response for the Cootamundra community.
	Conduct regular emergency exercises with the flood-prone community in Cootamundra including safe response to flood warnings.
	Provide online flood risk maps and a non-technical explanation of how to read them on Council's website.
Low	Hold regular events (e.g. Open Days, field days) for the Cootamundra community to interact with emergency services and learn more about their roles and responsibilities particularly related to flood warning.
	Design and install an extra telemetered stream gauge on Muttama Creek.
	Conduct an annual review of the flood warning system for Cootamundra.
	Regularly monitor the integration of all components of the flood warning system for Cootamundra.

Priority	Management Action
	Review the safety and management of road crossings regularly based on improvements such as those recommended in the mitigation actions in the Cootamundra FRMS&P
	Liaise with existing social networks (e.g. places of worship, clubs) in Cootamundra particularly to assist emergency services with response and recovery as required.

6.5 Implementation Action Plan

Using the prioritisation of the 20 management actions in Table 6-3, the following is provided in an Implementation Action Plan as Table 6-4:

- Recommendations of specific actions to implement a fit for purpose TFWS tailored to the Cootamundra community.
- Identification of roles and responsibilities for each recommended action.
- Identification of estimated costings for each recommended action.
- Clear prioritisation of each recommended action set out as a scalable TFWS.

Table 6-4 Recommended flood warning improvement/expansion actions

Priority	Management Action	Estimated cost	Responsibility	Timeframe
High (Essential)	Design and install a bespoke flash flood alerting system for Cootamundra based on FLARE guidance.	* Const=$200K Main= $20K/year	Council, NSW SES, BoM	2027-28
	Update the Flood Intelligence Cards for Cootamundra and have these included in an updated Part 2 of the Cootamundra-Gundagai Regional Flood Emergency Sub-Plan.	In-kind	NSW SES	2026
	Liaise with at-risk residents and vulnerable land-uses to develop a local flood warning messaging approach for Cootamundra.	In-kind	NSW SES	2026-27
	Regularly monitor and review emergency plans for Wattle Grove Community Lifestyle retirement village, Creekside Kids Early Childhood Centre and Cootamundra Caravan Park.	In-kind	NSW SES	Ongoing
	Tailor flood warning messages to the local impacts on the Cootamundra flood-affected areas including the flooding hotspots.	In-kind	NSW SES	2026-27
	Encourage all businesses in the floodplain to have an emergency plan (including related to flood) as part of their business continuity planning.	In-kind	NSW SES	Ongoing
	Develop and maintain an internal register or map of the location of vulnerable people, particularly in the hot spot areas.	In-kind	NSW SES	Ongoing
Medium	Regularly engage with residents, particularly in the hot spot areas, to discuss the potential flood levels and impacts to them for all flood events up to the PMF.	In-kind	NSW SES	Ongoing
	Install 3 visual reference gauges at flood hotspot locations in Cootamundra.	* Const=30K	Council	2027
	Continue psychological and readiness interventions in the town in addition to flood preparedness education.	In-kind	NSW Health	2026-27
	Construct a historical flood marker in a suitable location to educate residents and visitors about flood risks and possible levels related to local landmarks	*Const=$50K	Council, NSW SES	2028

Priority	Management Action	Estimated cost	Responsibility	Timeframe
	Prepare a simple fact sheet about local flood warning and safe response for the Cootamundra community.	In-kind	NSW SES	2027
	Conduct regular emergency exercises with the flood-prone community in Cootamundra including safe response to flood warnings.	In-kind	NSW SES	Ongoing
	Provide online flood risk maps and a non-technical explanation of how to read them on Council's website.	In-kind	Council, NSW SES	2026
Low	Hold regular events (e.g. Open Days, field days) for the Cootamundra community to interact with emergency services and learn more about their roles and responsibilities particularly related to flood warning.	In-kind	NSW SES	Ongoing
	Design and install an extra telemetered stream gauge on Muttama Creek.	* Const=$50K Main= $10K/year	Council, NSW SES, BoM	2027-28
	Conduct an annual review of the flood warning system for Cootamundra.	In-kind	NSW SES, Council	Ongoing
	Regularly monitor the integration of all components of the flood warning system for Cootamundra.	In-kind	NSW SES, Council	Ongoing
	Review the safety and management of road crossings regularly based on improvements such as those recommended in the mitigation actions in the Cootamundra FRMS&P	In-kind	Council, NSW SES	Ongoing
	Liaise with existing social networks (e.g. places of worship, clubs) in Cootamundra particularly to assist emergency services with response and recovery as required.	In-kind	NSW SES	Ongoing

*denotes estimate only and further detailed costing required based on specifications

7 GLOSSARY OF TERMS

Term	Description
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. Eg, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is a one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to sea level.
Average Annual Damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that could occur in a nominated development situation from flooding over a very long period of time.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
Flood prone land	Land susceptible to flooding by the probably maximum flood. Flood prone land is synonymous with flood liable land.
Flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this report, the hazard is flooding which has the potential to cause damage to the community.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probably maximum precipitation, and where applicable, snow melt, couple with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probability	A statistical measure of the expected chance of flooding (see AEP).

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