2007 Flooding Between Urbenville and Woodenbong
Photo Source: NSW SES

# URBENVILLE AND WOODENBONG FLOOD STUDY

TENTERFIELD SHIRE COUNCIL
KYOGLE COUNCIL

ISSUE / Public Exhibition Report
CLIENT / Tenterfield Shire Council & Kyogle Council
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Document *Control*

| Revision | Date | Description | Prepared | Reviewed | Approved |
|---|---|---|---|---|---|
| A | 20/09/2021 | Draft | S Mortimer | L Baxter | L Baxter |
| B | 01/11/2021 | Public Exhibition Report | S Mortimer | L Baxter | L Baxter |
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# GLOSSARY AND ABBREVIATIONS

| | |
|---|---|
| **1d** | **1-dimensional – in flood modelling this typically refers to models where flow moves perpendicular to given cross sections. In these study 1d elements have been embedded in the 2d model to represent drainage.** |
| **2d** | 2-dimensional – in flood modelling this typically refers to the modelling of a gridded elevation surface (DEM) over which runoff can move in all direction on a 2-dimenasional plane eg left, right, backward, forwards. |
| **AEP** | Annual Exceedance Probability – the chance of a flood of a given size or larger occurring in any one year, usually expressed as a percentage. |
| **AHD** | Australian Height Datum |
| **AIDR** | Australian Institute for Disaster Resilience |
| **ARI** | Average Recurrence Interval – the long term average number of years between the occurrence of a flood as larger as or larger than the selected event. |
| **ARR2019** | Australian Rainfall and Runoff 2019 (Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019). A national guideline used for flood estimation across Australia. |
| **ARR87** | Australian Rainfall and Runoff 1987 (Institution of Engineers Australia, 1987). A national guideline to flood estimation now updated with ARR2019. |
| **BoM** | Bureau of Meteorology |
| **Catchment** | Land area draining to a given point |
| **Cumec** | Cubic metre per section also expressed as $m^3/s$. |
| **DCP** | Development Control Plan |
| **DEM** | Digital Elevation Model |
| **DFE** | The Defined Flood Event (DFE) is selected by council for floodplain risk management purposes for an area/catchment, generally through the FRM process outlined in the Floodplain Development Manual. DFEs form the basis for determining the level of exposure to flooding and associated risks to life and property damage. The manual identifies the 1% AEP flood event, or an equivalent historic flood, as an appropriate starting point for determining the DFE for development controls |
| **Discharge** | The rate of flow of water typically measures in volume per unit of time, for example $m^3/s$ |
| **DPIE** | Department of Planning, Industry and Environment |
| **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. |

| | |
|---|---|
| **EY** | Exceedances per Year |
| **FDM** | Floodplain Development Manual 2005 |
| **FFA** | Flood Frequency Analysis – a statistical means of establish the Annual Exceedance Probability of flood based on gauged data records. |
| **Flash flooding** | Flooding which is often sudden and can be unexpected. Usually caused by localised intense rainfall. Often defined as flooding which peaks within six hours of the causative rain (Floodplain Development Manual: the management of flood liable land, April 2005). |
| **Flood fringe** | The remaining area of flood prone land after floodway and flood storage areas have been defined. |
| **Flood prone land** | Land subject to flooding up to and including the Probable Maximum Flood (PMF) extent. |
| **Flood storage area** | Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. |
| **Floodway** | Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels. |
| **FPA** | Flood Planning Area is land at or below the Flood Planning Level (FPL) |
| **FPL** | Flood Planning Level is a combination of the flood level from the defined flood event (DFE) and freeboard selected for flood risk management purposes. |
| **Freeboard** | Provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the Flood Planning Level (FPL) is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the Flood Planning Level. |
| **FRM** | Flood Risk Management |
| **FRMC** | Floodplain Risk Management Committee |
| **FSL** | Full Supply Level – refers to the top design water level in a dam. |
| **ha** | hectares |
| **Habitable Room** | In a residential situation: a living or working area such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom<br>In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood. |
| **Hazard** | A source of potential harm or a situation with a potential to cause loss. |
| **Hydrograph** | A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood. |

| | |
|---|---|
| **Hydrology** | Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods. |
| **ICM** | InfoworksICM – a hydrology and hydraulic modelling software. For this study ICM has been used as the rainfall routing model. |
| **LEP** | Local Environmental Plan |
| **Local overland flooding** | Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam. In this study, local overland flooding refers to flooding caused by the local catchments and rainfall within the township areas. |
| **Mainstream flooding** | Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam. In this study mainstream flooding refers to flooding from Tooloom Creek. |
| **ML** | megalitre |
| **NSW** | New South Wales |
| **PMF** | Probable Maximum Flood - the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. |
| **PMP** | Probable Maximum Precipitation - the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation. |
| **Rainfall routing model** | A hydrology models which converts rainfall depths over time to a flow hydrograph. |
| **RFFE** | Regional Flood Frequency Estimation |
| **Risk** | Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood e.g. AEP |
| **Runoff** | Rainfall which actually ends up as streamflow. |
| **SES** | State Emergency Services |
| **TUFLOW** | Hydraulic modelling software for flood, urban drainage, estuarine and coastal assessments. |

# TERMINOLOGY

Australian Rainfall and Runoff 2019, referred to as ARR2019, describes terminology for describing the frequency of flooding which has been adopted in this Flood Study report.

| Frequency Descriptor | EY | AEP (%) | AEP (1 in x) | ARI |
|---|---|---|---|---|
| Very Frequent | 12 | | | |
| | 6 | 99.75 | 1.002 | 0.17 |
| | 4 | 98.17 | 1.02 | 0.25 |
| | 3 | 95.02 | 1.05 | 0.33 |
| | 2 | 86.47 | 1.16 | 0.5 |
| | 1 | 63.21 | 1.58 | 1 |
| Frequent | 0.69 | 50 | 2 | 1.44 |
| | 0.5 | 39.35 | 2.54 | 2 |
| | 0.22 | 20 | 5 | 4.48 |
| | 0.2 | 18.13 | 5.52 | 5 |
| | 0.11 | 10 | 10 | 9.49 |
| Rare | 0.05 | 5 | 20 | 19.5 |
| | 0.02 | 2 | 50 | 49.5 |
| | 0.01 | 1 | 100 | 99.5 |
| Very Rare | 0.005 | 0.5 | 200 | 199.5 |
| | 0.002 | 0.2 | 500 | 499.5 |
| | 0.001 | 0.1 | 1000 | 999.5 |
| | 0.0005 | 0.05 | 2000 | 1999.5 |
| Extreme | 0.0002 | 0.02 | 5000 | 4999.5 |
| | | | ↓ | |
| | | | PMP/<br>PMP Flood | |

*Preferred terminology indicated in blue. Source ARR2019*

**Figure T-1-1: ARR2019 Terminology (Preferred terminology indicated in blue)**

# EXECUTIVE SUMMARY

## Report Status

This working draft report comprises the findings at the design flood modelling stage. This report has been provided for Tenterfield Shire Council, Kyogle Council and DPIE review and will be updated prior to Public Exhibition.

## Purpose of the Urbenville and Woodenbong Flood Study

The Urbenville and Woodenbong Flood Study has been prepared under the Floodplain Risk Management Process to develop a detailed understanding of the flood behaviour at both Urbenville and Woodenbong from both Tooloom Creek (mainstream flooding) and from the local catchment and overland flows through the townships. In addition, Boomi Creek has also been considered.

Detailed hydrologic analysis and hydraulic modelling has been undertaken to map the predicted flood extents, levels, depths, velocities and hazards associated with a range of design flood events; 20% AEP, 5% AEP, 1% AEP, 0.2% AEP and PMF events. Predicted effects of climate change on flood behaviour are also presented.

The information in this Flood Study will be used to inform the subsequent Floodplain Risk Management Study and Plan which will set out flood risk management measures to minimise the risk and consequences of future flooding.

## Flooding in the Study Area

Flooding at Woodenbong and Urbenville are subject to two types of flooding; overland flows from local catchments and mainstream from Tooloom Creek and its tributaries.

At Woodenbong, flooding is affected by local overland flows due to the terrain and Woodenbong sitting on a high point in comparison to Tooloom Creek. Overland flows join Black Gully which overtops Roseberry Street and affects properties to the south in severe events. This tributary then drains into Tooloom Creek. The local catchment of Woodenbong is 8.4 $km^2$ and the catchment area of Tooloom Creek upstream of Woodenbong is 112 $km^2$.

At Urbenville, flooding is dominated by Tooloom Creek especially in the larger events. There is overland flow flooding throughout the town in smaller events and in the north east of the town in larger events between Beaury Street and Stephen Street. The catchment of Tooloom Creek upstream of Urbenville is 170.9 $km^2$, the local catchment of Urbenville is 2.6 $km^2$, and the catchment of Boomi Creek which intersects with Tooloom Creek downstream of the Urbenville is 114.8 $km^2$.

## Community Consultation and Public Exhibition

In preparing the Flood Study information was sought from the community with regard to their experiences of flooding. This was used in validating the findings of the flood modelling against actual event-based data.

Prior to adopting the Urbenville and Woodenbong Flood Study, a period of Public Exhibition will be held during which the community and key stakeholders will be invited to provide further comment on the study findings. This report will be updated following Council and DPIE review prior to the Public Exhibition.

# 1 INTRODUCTION

## 1.1 The Floodplain Risk Management Framework

The NSW Floodplain Development Manual (Department of Infrastructure, Planning and Natural Resources, April 2005) and Australian Institute for Disaster Resilience's Handbook 7 (Managing the Floodplain; A Guide to Best Practice in Flood Risk Management in Australia, 2017), sets out the floodplain risk management process and provides guidance to local councils for the development of flood studies to lead to the development and implementation of floodplain risk management plans.

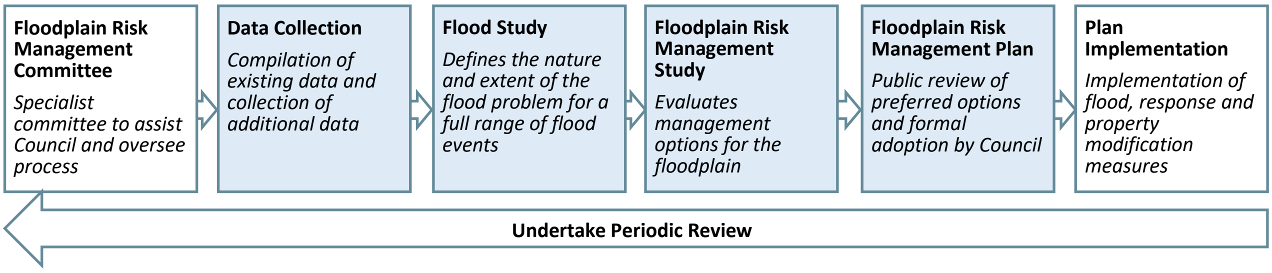



**Figure 1-1: Floodplain Risk Management Framework**

This is typically overseen by a Floodplain Risk Management Committee (FRMC) comprising representatives from Council and other interested parties including NSW State Emergency Services (NSW SES), Department of Planning, Industry and Environment (DPIE) any other key stakeholders.

For the Urbenville and Woodenbong areas, no detailed studies have been undertaken in the past and planning has been based on previous known flood events. The Urbenville and Woodenbong Flood Study provides opportunity for Council and other interested stakeholders to understand in detail, the flood behaviour in the area and allows, though the later Floodplain Risk Management Study and Plan, to improve safety of the community through flood related development controls and evacuation and warning, provisions of cost-effective flood mitigation measures and improve community awareness.

## 1.2 Purpose of the Urbenville and Woodenbong Flood Study

The Urbenville and Woodenbong Flood Study has been prepared to provide a detailed understanding of the precited flood behaviour at each town from Tooloom Creek (mainstream flooding) and also from the local catchments comprising both local tributaries to Tooloom creek and local overland flows. The findings of the Flood Study will inform a later Floodplain Risk Management Study and Plan for each town which will investigate options for flood mitigation to minimise future losses due to flooding including flood planning development controls and options such as drainage upgrades, flood protection levees etc. At present, flood planning for both areas is based on anecdotal flood evidence of the highest flooding through the towns. The Flood Study is also important to inform emergency planning and has been prepared to address the Floodplain Risk Management Guideline SES Requirements from the FRM Process (Department of Environment and Climate Change, 2007).

# 2 BACKGROUND

## 2.1 The Study Area

The project study area (refer Figure 2-1) includes the townships of Urbenville and Woodenbong as well as Tooloom Creek and Boomi Creeks between the two townships.  The study focusses on mainstream flooding from the two creeks and its effect on travel between the two locations as well as local overland flows affecting the each of the towns.

Urbenville, is mostly within the Tenterfield Shire local government area and is situated 13 km south of Woodenbong which is located in the Kyogle local government area. The local government boundary largely follows the line of Tooloom Creek. Although in different local government areas, Urbenville and Woodenbong have close ties, connected by Clarence Way with the local Muli Muli Aboriginal Community located between the two townships. The communities share resources and community facilities such as the high school located in Woodenbong and the hospital located in Urbenville.

## 2.2 The Catchment Area

To the Toolom Falls the combined catchment area is 312.6 km$^2$. To their confluence near Urbenville, Tooloom Creek and Boomi Creek have catchment areas of about 170.9 km$^2$ and about 114.8 km$^2$ respectively. Smaller sub-catchments drain through the towns (refer Figure 2-2). At Urbenville, an unnamed tributary to Tooloom Creek flows south west of the town draining a catchment area of about 2.3 km$^2$.

At Woodenbong, a tributary to Tooloom Creek known as Black Gully flows east to west along the north side of the town. A smaller tributary of Black Gully flows through the town east of properties on Richmond Street. A levee was constructed in Richmond Street to provide some protect from flooding during minor flood events. Overland flows also occur within the town from stormwater runoff. To Tooloom Creek the total catchment area is about 8.4 km$^2$. The catchment of Tooloom Creek upstream of Woodenbong is 112 km$^2$.

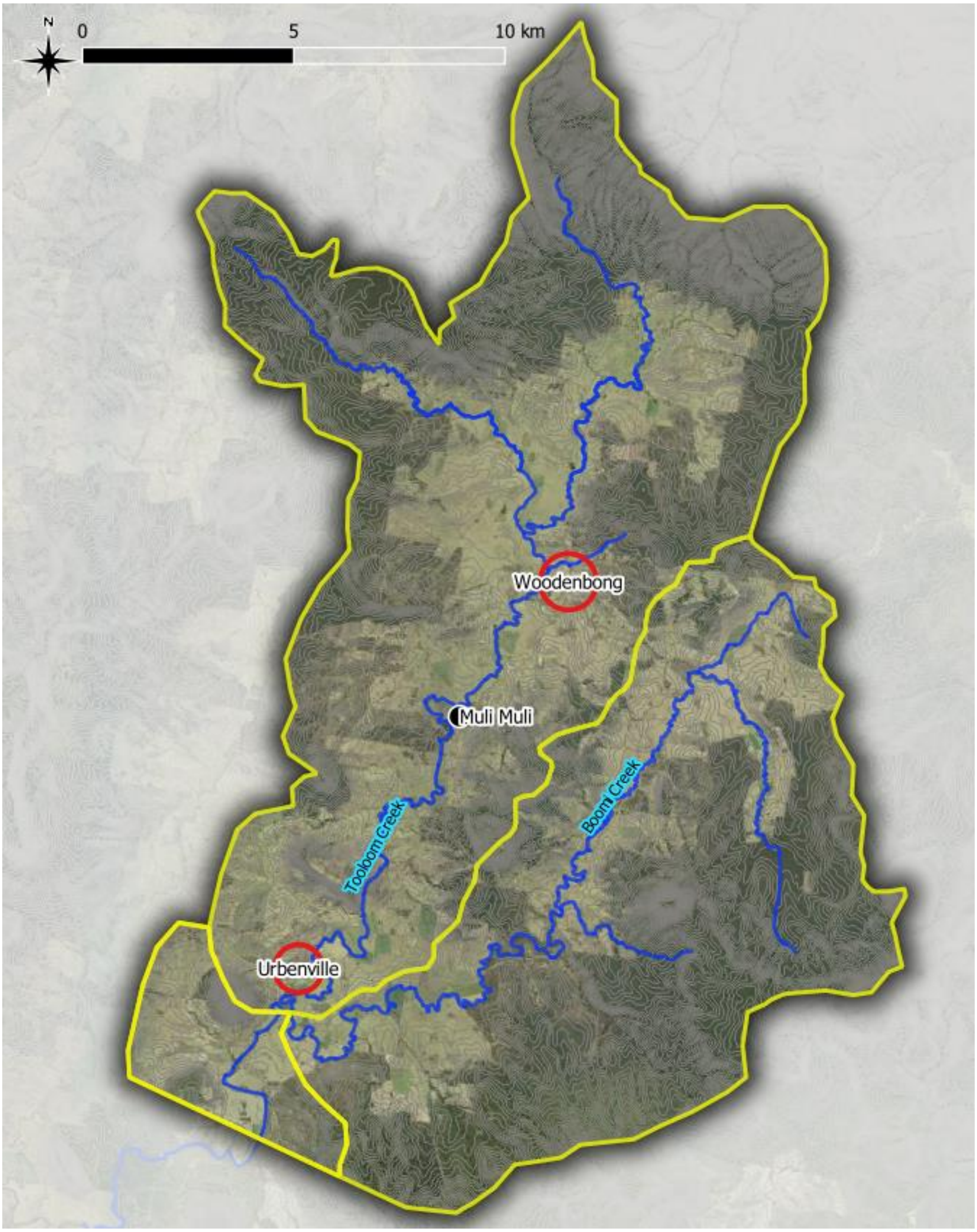



**Figure 2-1: The study area and Tooloom and Boomi Creek catchment area**

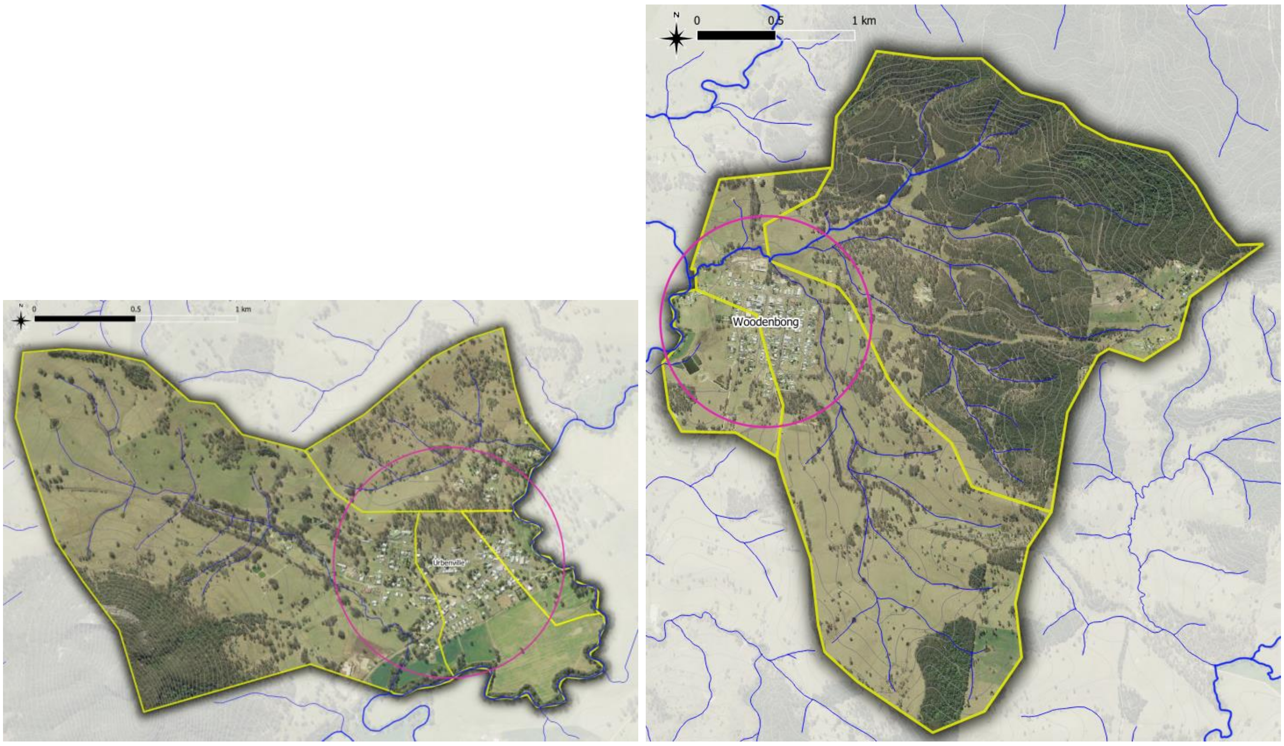



**Figure 2-2: Local catchments at Urbenville (left) and Woodenbong (right)**

## 2.3 Historic Flooding

The Tooloom Creek and Boomi Creek valleys that connect Urbenville and Woodenbong are subject to flooding causing inundation of the roads and isolating the community. Flooding also can occur in the towns from the local creeks and overland flows.

In events such as December 2010, January 2011, January 2013, March 2016, March 2017 rising flood waters from Tooloom Creek cut of the road between Urbenville and Woodenbong resulting in isolation of residents.

Damage to the road during flood events prolongs the period of closure. For example following the January 2011 the road about 9 km south of Urbenville was severely damaged meaning the road had to be closed to traffic until it could be repaired.

Recent flooding occurred in 2010, 2011 2013, 2016 and 2017. Although roads were cut and the villages isolated, no floor levels were reported as being inundated. However, elevated homes in the low-lying areas of Urbenville were surrounded by flood waters. These flood events were smaller and more frequent than a 20% AEP event on the Tooloom Creek catchment and larger flood events could occur.

While a number of small floods have occurred in recent years, it has been some time since the Tooloom Creek catchment has suffered from a major flood. Flooding in 1950 and 1954 is thought to be some of the highest on record although there is limited available observed data. From rainfall gauges these events were estimated to be in the order of a 45% to 5% AEP rainfall event.

Looking down from Tooloom Street (Source: Urbenville SES)

**Figure 2-3: Photographs of Flooding in the Study Area – December 2010**

Tooloom Road (Source: Urbenville SES)

Urbenville Showgrounds (Source: Urbenville SES)

**Figure 2-4: Photographs of Flooding in the Study Area – January 2011**


Tooloom Road north east of Tooloom Creek Bridge (flooding from overland flows) (Source: Urbenville SES)


Flooding on Urben Street from local catchment (Source: Urbenville SES)

Elevated house Tooloom Street surrounded by waters (Source: Urbenville SES)

**Figure 2-5: Photographs of Flooding in the Study Area – January 2013**

Urbenville Showgrounds (Source: Urbenville SES)

Clarence Way heading towards Bonalbo (Source: Urbenville SES)

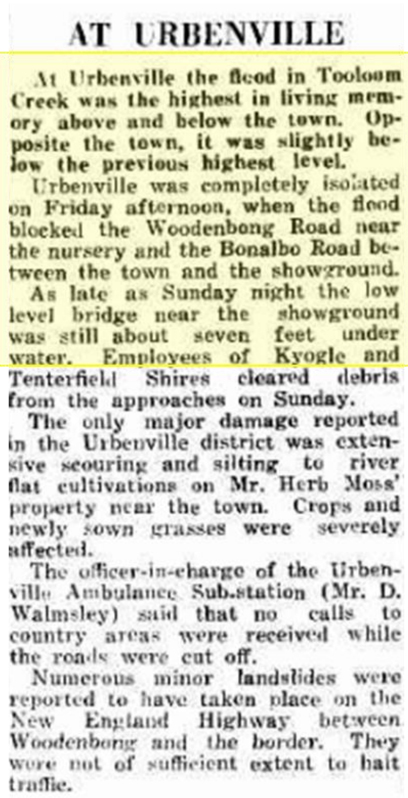
**Figure 2-6: Photographs of Flooding in the Study Area – March 2016**

On the road between Urbenville and Woodenbong (Source: Urbenville SES)

On the road between Urbenville and Woodenbong (Source: Urbenville SES)

Flooding around elevated homes on Toloom Street (Source: Urbenville SES)

**Figure 2-7: Photographs of Flooding in the Study Area – March 2017**



AT URBENVILLE

At Urbenville the flood in Tooloom Creek was the highest in living memory above and below the town. Opposite the town, it was slightly below the previous highest level.

Urbenville was completely isolated on Friday afternoon, when the flood blocked the Woodenbong Road near the nursery and the Bonalbo Road between the town and the showground.

As late as Sunday night the low level bridge near the showground was still about seven feet under water. Employees of Kyogle and Tenterfield Shires cleared debris from the approaches on Sunday.

The only major damage reported in the Urbenville district was extensive scouring and silting to river flat cultivations on Mr. Herb Moss' property near the town. Crops and newly sown grasses were severely affected.

The officer-in-charge of the Urbenville Ambulance Sub-station (Mr. D. Walmsley) said that no calls to country areas were received while the roads were cut off.

Numerous minor landslides were reported to have taken place on the New England Highway between Woodenbong and the border. They were not of sufficient extent to halt traffic.

*Kyogle Examiner, 27th June 1950*

WOODENBONG

Flood Damage

Woodenbong was left high and dry by the recent flood, but was completely isolated from the outside world for a couple of days.

All telephonic communications were cut off also.

Urbenville Road was the first trafficable on the Monday following the flood's climax.

It was not until last Wednesday that traffic was able to get beyond Urbenville.

Traffic, including Watson's truck with clothing for Kyogle from Woodenbong, got through to Kyogle on the next day.

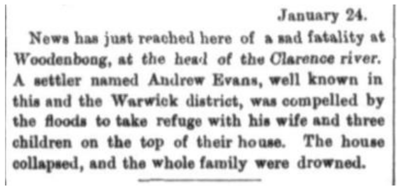
Clothing was also sent on the following Thursday and Friday and Woodenbong schoolchildren sent 100 loaves of bread to Kyogle people.

Many travelers were stranded at the Hotel Woodenbong and a Casino family there were wondering if their home was still safe.

One guest at the hotel, a diabetic, ran out of insulin and was supplied by the Woodenbong Bush Nurse.

Mr. Ernie Martin, a local grazier, had to do a lot of swimming after his cattle and saved all except one cow which was calving.

*Kyogle Examiner, 5th March 1954*



January 24.

News has just reached here of a sad fatality at Woodenbong, at the head of the Clarence river. A settler named Andrew Evans, well known in this and the Warwick district, was compelled by the floods to take refuge with his wife and three children on the top of their house. The house collapsed, and the whole family were drowned.

*Warwick Argus, 25th Jan 1887*

**Figure 2-8: News articles detailed flooding at Urbenville and Woodenbong**

## 2.4 Flood Behaviour

### 2.4.1 Urbenville

At Urbenville, flooding from Tooloom Creek is the dominant source of flooding. This is due to the winding nature of the creek creating slowing down the conveyance of floodwaters within the natural creek bed. The intersection of the Boomi and Tooloom Creek occurs just downstream from Urbenville which also contributes to the higher creek levels.

Flooding caused by overland flows affects Welch and Urben Streets. The majority of local overland flooding travels down the natural channel south of Urbenville Road to Tooloom Creek. In the 20% AEP or more frequent events Tooloom Creek spills from the creek channel into the floodplain and affects properties on the south side of Tooloom Street. These floodwaters build up in the larger events to overtop Tooloom Street and affects properties on the northern side of the street in the 1% AEP event. In the PMF event the creek flood extent spreads further into the town and depths of up to 9 m occur on Tooloom Street.

### 2.4.2 Woodenbong

At Woodenbong floodwaters from Tooloom Creek are predicted to exceed capacity of the creek channel in the 20% AEP or more frequent events. These inundate the floodplain which includes the sporting fields and showground. Floodwaters from the creek do not encroach into the town until the PMF where it affects the northern most lots of Roseberry Lane.

Local catchment flows at Woodenbong affect properties along Richmond Street as flows from the township and the natural channel in this area encroach into backyards of properties in as frequent as the 20% AEP event. Mount Lindsay Road also becomes inundated to the east of Richmond Street intersection. Within the town there is minimal flooding within properties as local flows are typically contained within the drainage channels alongside the roads.

### 2.4.3 Toloom Creek

Throughout the Tooloom Creek catchment, the Tooloom Creek expands into the floodplain in the 20% AEP or more frequent event. There are a number of areas where Clarence Way is overtopped in particular near to Muli Muli. Refer to section 9.2 for more details.

### 2.4.4 Boomi Creek

Boomi Creek runs alongside Boomi Creek Road until it joins Tooloom Creek downstream of Urbenville. In events more frequent that the 20% AEP event, floodwaters spread out of creek channel and into the floodplain. Boomi Creek overtops Boomi Creek Road where the road is in a close vicinity to the creek and where Boomi Creek road crosses the creek. Local tributaries also overtop the road however, these depths typically are less significant than the creek flooding. See section 9.2 for more details.

### 2.4.5 Muli Muli

Muli Muli is located near to Tooloom Creek on an area of high ground. The town is not affected from flood waters in the 0.5% AEP event but in events greater than this up to the PMF event, Muli Muli Crescent, the street closest to Tooloom Creek, is inundated. Clarence Way to the north and the south is predicted to be flooded events more frequent than the 20% AEP flood event. This road is the only road access way to Muli Muli.

## 2.5 Relevant Policies, Legislation and Guidance

Flood planning at Urbenville and Woodenbong is governed by local government legislation and policies as well as several NSW and Australia wide Guidance Documents. Development in Urbenville is subject to the flood controls of the Tenterfield Shire Council Local Government Area. Development in Woodenbong is subject to the flood controls of the Kyogle Council Local Government Area.

### 2.5.1 Local Environmental Plans

The LEP is the principal planning document for the LGA. Flood Planning Areas for Urbenville and Woodenbong are not currently well defined. This Flood Study will provide opportunity to develop suitable Flood Planning Areas for both towns.

With regard to flooding, the LEP applies clauses to areas identified in the Flood Planning Area (FPA). Within areas affected by the FPA, the LEP seeks to ensure that new development is compatible with the flood function and behaviour on the land and does adversely affect flood behaviour in a way that results in detrimental increases in flood affectation and adverse effects on the safe occupation and evacuation of people or environment.

The NSW Flood Prone Land Package replaced previous LEP flood clauses with a new standard clause effective of 14 July 2021. The new clause removes the definition of the Flood Planning Level as the 1% AEP flood level plus 0.5 m freeboard and instead allows Councils to define an appropriate Flood Planning Level through studies such as this one.

### 2.5.2 Tenterfield Shire Development Control Plan 2014 (amended 2018)

The Tenterfield Shire DCP requires that where there are no available Flood Studies (as currently as is the case for Urbenville) developers may be required to undertake studies including survey and evidence of historic flood levels to show that development will be above designated flood levels.

The DCP defines the Flood Planning Level as the 1% AEP flood level plus 0.5 m freeboard. At present Council use the highest observed flood level plus a freeboard to determine flood levels. At Urbenville this is based on historical flooding at a property on Tooloom Street plus a freeboard. Depths of between 1.0 - 1.2 m were experienced at properties.

### 2.5.3 Kyogle Development Control Plan 2014

The Kyogle DCP provides controls to manage development within the LGA and is prepared to be consistent with the objectives and provisions of the LEP. With regard to flooding the DCP sets out a number of controls (performance criteria) and acceptable solutions which vary slightly depending on the development type.

Typically development controls require that:

- Buildings, structures and persons on a development site are not exposed to unacceptable risk from flooding including overland flow.
- Rural subdivisions maintain stock access to flood free land and lot layouts maintain access for flood refuge areas.
- Buildings are not located in flood prone land where possible and where a building envelope is proposed on land mapped or known to be flood prone, floor levels of at a least the 1% AEP plus 0.5 m freeboard is achieved.
- Stormwater to be managed so that it does not contribute to flooding or nuisance flooding on adjoining properties.

### 2.5.4 Guidance Documents

The following key guidance documents are considered in this Flood Study:

- NSW Floodplain Development Manual (2005)
- Australian Rainfall and Runoff 2019 (ARR2019)
- AIDR Handbook Series
- Floodplain Risk Management Guidelines series published by DECC and OEH (now DPIE)

# 3 REVIEW AND ANALYSIS OF AVAILABLE DATA

## 3.1 Previous Studies

### 3.1.1 Kyogle Flood Study (WBM Oceanics Australia, February 2004) and Floodplain Risk Management Plan (BMT WBM, April 2009)

The Kyogle Flood Study and Floodplain Risk Management Plan were adopted in 2009. While the study area does not cover the Urbenville and Woodenbong area, the study and plan provide useful information on the historic rainfall events including the 2008 event.

The study used Australian Rainfall and Runoff 1987 (ARR87) methods and Flood Frequency Analysis (FFA) to determine design event flood behaviour and calibrated the modelling to historic events. The report refers to major flooding around 20 February 1954 as well as smaller flooding in 1974, 1976, 1978, 1980, 1987, 1989,1996, 2001 and 2008. The study found that that the January 2008 event to affect Kyogle was approximately a 2% AEP event.

### 3.1.2 Tabulam Flood Study (Jacobs, March 2019) and Floodplain Risk Management Study and Plan (Jacobs, December 2019)

Although the study area of the Tabulam Flood Study and Floodplain Risk Management Study and Plan does not cover Urbenville and Woodenbong, the studies provide some insights into historic flooding in the Kyogle LGA noting significant flood events in 1967 and 2011. The study notes that the 1967 event was considerably larger than the 2011 event.

The Tabulam Flood Study undertook FFA (using ARR2016 procedures) to determine design event flood behaviour. The January 2011 event was approximated as a between a 2% AEP and 5% AEP event.

## 3.2 Historic Data

Historic data was obtained through the community consultation (refer Section 4), data supplied by Tenterfield Shire Council, SES and a search of old media reports. This was used to supplement rainfall gauge data to develop an understanding flood behaviour and also for calibrating and validating the hydrology and hydraulic flood models (refer Section 7).

### 3.2.1 River Gauges

There are no river gauges within the study area on Tooloom Creek or Boomi Creek.

### 3.2.2 Rain Gauges

Rainfall data was obtained from Bureau of Metrology (BoM). Within the catchment to the study area there is one rainfall gauge within each town, Urbenville (57020) and Woodenbong (Unumgar Street) (57024). These gauges are daily-read gauges with records back to 1933. Other daily read gauges are sparsely located outside of the catchment area (refer Appendix A). The nearest pluviometry gauges approximately 15 km from the study area. Availability of additional daily-read and sub-daily (pluviograph) gauges are summarised in Table 3-1. Further analysis of the flood events used for calibration is provided in Section 7.

**Table 3-1: Rain gauge data availability**

| Name | BOM Gauge | Year Opened | Year Closed | Gauge Type | Distance to Urbenville (km) | Distance to Woodenbong (km) | Calibration Events Captured |
|---|---|---|---|---|---|---|---|
| Woodenbong (Unumgar St) | 57024 | 1933 | Open | Daily Rainfall | 11.2 | - | 2008, February 2010, December 2010 |
| Urbenville | 57020 | 1935 | Open | Daily Rainfall | - | 11.2 | 2008, February 2010, December 2010 |
| Urbenville State Forest | 57021 | 1938 | Closed – 1955 | Daily Rainfall | 0.8 | 10.4 | - |
| Castille | 58010 | 1933 | Closed – 1989 | Daily Rainfall | 5.9 | 6.9 | - |
| Killarney Post Office | 41056 | 1972 | Closed - 2017 | Pluviograph | 29.0 | 31.3 | 2008, February 2010, December 2010 |
| Rathdowney Post Office | 40178 | 1965 | Closed - 2016 | Pluviograph | 42.7 | 31.9 | 2008, February 2010, December 2010 |
| Moogerah Dam | 40135 | 1964 | Closed - 2017 | Pluviograph | 49.1 | 40.0 | 2008, February 2010, December 2010 |
| Legume (New Koreelah) | 56022 | 1973 | Closed - 2016 | Pluviograph | 19.2 | 26.6 | 2008 |
| Unumgar (Summerland Way) | 58016 | 2000 | Open | Pluviograph | 21.2 | 14.9 | 2008 |
| Maroon Dam | 40677 | 1977 | Closed - 2017 | Pluviograph | 34.7 | 24.0 | 2008, February 2010 |

### 3.2.3 Anecdotal Flood Information

Anecdotal evidence included responses from the community questionnaire and information provided by Tenterfield Shire Council and Urbenville SES. Community consultation responses are summarised in Appendix D and typically relate to the overland flow flooding within the town asides from properties along Tooloom Street in Urbenville.

### 3.2.4 Summary of Flood History at Woodenbong and Urbenville

Some of the key flood events affecting the study are summarised in Table 3-2. The AEP has either been estimated from the rainfall data obtained for this study. Residents reported some flooding on other occasions but did not include dates (refer Appendix D).

**Table 3-2: Historic Flood Events**

| Date | Description | AEP estimate (if known) |
|---|---|---|
| January 2008 | • Approximated as 2% AEP event (Kyogle Council based on Kyogle Flood Study), through data at Urbenville and Woodenbong, this was estimated as an approximate 7% and 25% AEP at each town.<br>• Tooloom Street near the Old Saw Mill flooded at Urbenville<br>• Clarence Way flooded at the bridge in Urbenville heading to Bonalbo<br>• 17752 Clarence Way, flooding breaks banks of creek and 6 inches deep at the back paddock of the property. | 7% AEP (Urbenville and Woodenbong daily-read gauge) |
| February 2010 | • Approximated as either a 20 to a 50% AEP event through the daily gauge at Woodenbong<br>• Water lapping at 6 Urben Street, came in through the driveway<br>• Depths of 130 mm in front yard of 6 Urben Street | 20% to a 50% AEP event. |
| December 2010 | • Specific AEP is not known, expected to be a short sharp event which would not be captured in the daily readings at Urbenville gauge.<br>• Showground flooded, and water over recreation road and inundated the lower paddock<br>• Flood waters affecting the properties along Richmond Street.<br>• Backyard flooding along in Woodenbong along Richmond Street<br>• SES photos of Beaury Creek Road<br>• Richmond Street 25-33 backyards are flooded, floodwaters have reached back steps of and house footings.<br>• 77 Recreation road water came over the banks of creeks and inundated the lower paddock. | Unknown, ranging from 10% to 47% AEPs in surrounding catchments |
| January 2011 | • SES photos of flooding at Beaury Creek Road, along Tooloom Street Urbenville and the showground | 30% AEP at Urbenville |
| March 2017 | • SES photos of flooding along Tooloom Street Urbenville | 20% AEP at Urbenville |
| March 2019 | • SES photos of flooding along Tooloom Street Urbenville and on roads heading towards Bonalbo | <63.2 % AEP at Urbenville |

## 3.3 Topographic and Aerial Survey and Imagery

### 3.3.1 Topographic Data

Aerial imagery was used from Bing Aerial Imagery, SixMaps WMS link, and Google Maps Hybrid. Multiple sources were used as the detail of each was varying in quality.

### 3.3.2 LiDAR

A 2m resolution LiDAR DEM data is available for the Tooloom Creek and Boomi Creek catchments from elevation.fsdf.org.au (ELVIS, 2020). Data was flow in 2017 and the DEM has a 2m grid resolution. The LiDAR DEM is not hydrologically enforced. The data used to create this DEM has an accuracy of 0.3m (95% Confidence Interval) vertical and 0.8m (95% Confidence Interval) horizontal. This is typical of Classification 3 LiDAR obtained in this way and is considered suitable for flood modelling in rural areas (DFSI Spatial, May 2015).

### 3.3.3 Survey Data – Watercourses

No survey of the watercourse was available and therefore LiDAR data has been adopted. LiDAR does not typically pick up channel dimensions as the LiDAR beam does not typically penetrate water and therefore the cross sections of the channel itself may not be well represented in the flood modelling.

Although this is a limitation of the flood modelling, the effect of this is that peak flood levels may be conservative, particular in the smaller magnitude flood events.

### 3.3.4 Survey Data – Hydraulic Structures

No survey data was available for the Tooloom Creek or Boomi Creek watercourse crossings. Bridge and culvert length details were provided from Council records. Photos were provided of Mount Lindsay Road Bridge over Tooloom Creek and Woodenbong. A database of the storm water network was provided from each Council however no invert levels were included. The location hydraulic structures such as the levee behind Richmond Street in Woodenbong was provided in this database from Kyogle Council. Other details of these structures was not available.

## 3.4 GIS data

Tenterfield Shire Council and Kyogle Council provided GIS data including cadastre, land use zoning, and details of the drainage network in the towns and culvert crossing for Clarence Way road and Boomi Creek road. The data did not include invert levels for all culverts and therefore assumptions were made where necessary (refer Table 6-1).

## 3.5 Data Gap Analysis

A data Gap Analysis reviewed data suitability for use in the study and noted limitations of any assumptions. For some hydraulic structures, such as the Mount Lindsay Road Bridge crossing of Tooloom Creek drawings were available from November 2007, no other survey or work-as-executed drawings or similar was available as assumptions had to be made in the flood modelling.

The data used is considered to be sufficient for the purposes of the Flood Study. Recommendations for additional data to be obtained for the future Floodplain Risk Management Study and Plan are detailed in Table 3-3.

**Table 3-3: Data Gap Analysis and Recommendations for Further Data at Later Stages**

| Issue | Comment | Recommendations to be completed at Floodplain Risk Management Study Stage |
|---|---|---|
| **Watercourse cross sections** | Watercourse has been based on LiDAR as previously surveys sections and models were not available. | Undertake watercourse survey in areas identified for assessment of potential flood mitigation options – to be confirmed at FRMS&P. |
| **Features in the floodplain** | Based on LIDAR data. | Obtain survey if in critical flood areas before completing FRMS&P. The levee behind Richmond Street, Woodenbong, and the channel running behind the properties is one such area. |
| **Drainage network** | The urban stormwater GIS data was missing invert information for Woodenbong, within Urbenville grate RLs were provided for some areas. Where no invert information was available cross drainage culverts were assumed to have invert levels from the LiDAR. Suitable cover was adopted in areas where LiDAR levels were not appropriate. | For areas where drainage is critical in terms of flood behaviour, or areas where floodplain risk mitigation options are to be considered detailed survey should be obtained. |
| **River Gauge Data** | No river gauge is available within the catchment for either town. | The FRMS&P should recommend that a river gauge is installed on Tooloom Creek. |
| **Floor levels** | The Flood Study identified properties flooded based on LiDAR DEM ground levels. Over floor flooding will require survey and will be assessed in the next stage; the Floodplain Risk Management Study and Plan. | Obtain floor level survey. |
| **Bridge Crossing of Tooloom Creek near Towns** | Road Bridge crossings of Tooloom Creek occur nearby to both Woodenbong and Urbenville on Mount Lindsay Road and Clarence Way. These bridges vicinity to the town have the potential to dictate flood behaviour at the towns. Bridge details were not available for the bridge crossing at Urbenville at Clarence Way, bridge details and photos of the bridge at Woodenbong on Mount Lindsay Road were provided. | Bridge survey. |

# 4 COMMUNITY CONSULTATION

## 4.1 Community Consultation Program

A community consultation program included newsletters, a questionnaire, and a project website. Community information sessions will be held during the Public Exhibition period.

## 4.2 Project Website

Project websites are available at:

- www.bgeeng.com/FloodStudies/Urbenville and
- www.bgeeng.com/FloodStudies/Woodenbong.

The websites are being maintained for the duration of the project and provides updates to the community and contact details. The project website is being updated at key milestones throughout the project and includes:

- Summary of study objectives
- Map of the study area
- Link to online questionnaire
- Contact details for residents to obtain further information or provide flood information for use in the study

During the Public Exhibition period the website will be updated to include:

- Information about community information session dates and times
- Copies of draft report for download during Public Exhibition
- Mapping of predicted flood behaviour and flood planning areas
- Feedback form for Public Exhibition submissions and general enquires

## 4.3 Community Questionnaire and Newsletter

A community newsletter and questionnaire were mailed to 215 Urbenville addresses and 309 Woodenbong addresses in September 2020 and was also made available online. The findings of the questionnaire are useful to understand the community's experiences of past flooding, the level of flood awareness, highlight areas for flood mitigation and allow residents to provide flood information for use in calibration of the flood models. A project email address was also created to allow people to email photographs and addition information.

A detailed analysis of the findings is provided in Appendix D.

### 4.3.1 Urbenville

Two responses were received online and 20 responses by mail which equates to a 10% response rate. Additional contact was made with two residents who requested it.

The majority of respondents were from residential properties. Half of respondents understood that their property is flood affected, and of these, about half has also experienced flooding at their property. Two had been evacuated. More people had observed flooding from the local creeks and catchments than they had from Tooloom Creek.

Notably the town of Urbenville has a rather transient population with 23% of people who responded to the questionnaire having moved into the area within the last five years. This means that a significant portion of the population are unlikely to have experienced any major flooding.

Residents were asked to identify areas where they had observed flooding and areas where they thought flood mitigation was required. The responses are mapped in Appendix D and include:

- Tooloom Street – frequent inundation of area
- Area at lower end of Urben and Welch Street and Stephen Street – local catchment flooding
- Forest Park and Urbenville Showground area – one of the first areas to be affected in every flood
- Beaury Street – 2 people mentioned flooding from Tooloom Creek into backyards and paddocks
- General street drainage issues on Urben Street – 3 people mentioned concerns in this area.

Details on historic flooding were requested for use in flood model validation (refer Section 7). Most residents recalled flooding in January 2008 and 2013 including at the locations above.

#### 4.3.2 Woodenbong

Three responses were received online and 23 responses by mail which equates to an 8% response rate. One resident was contracted for further information at their request.

The majority of respondents were from residential properties. More than half respondents do not believe that their property is flood affected.

Like Urbenville, the town of Woodenbong has a reasonable number of new arrivals in the last five years comprising 15% of the population. However nearly 40% of residents have lived in the area for over 40 years.

Residents were asked to identify areas where they had observed flooding and areas where they thought flood mitigation was required. Very few residents had experienced flooding at Tooloom Creek and were not typically concerned with creek flooding however nearly 60% of residents reported having experienced flooding from local creeks.

The responses are mapped in Appendix D and include:

- Paddock areas and Bonalbo Lane/Richmond Street/Dalmorton Street – 4 residents reported inundation of roads leading to isolation
- Lindsay Creek Road creek crossing (Black Gully) and Mount Lindsay Road (east of town) creek crossings (tributary Black Gully) is frequent and a nuisance. One resident suggested flood depth markers.
- Woodenbong Showground and Caravan Park – 6 people highlighted this area

Details on historic flooding were requested for use in flood model validation. Few residents were able to provide information but two provided information in the 2010 event.

### 4.4 Community Information Sessions

Community information session will be held during the Public Exhibition period.

# 5 HYDROLOGIC ANALYSIS

## 5.1 Hydrologic Assessment Approach

The hydrologic assessment considers the Tooloom Creek and Boomi Creek catchments and the local catchments of Urbenville and Woodenbong. Due to no catchments being gauged within the study area, additional methods were required to define flows to input into the hydraulic model.

An approach was adopted which used a rainfall routing model for the entire catchment. Integrated Catchment Modelling (ICM) was adopted for this purpose. ICM is the successor software to XP-RAFTS which has typically been used for similar studies in the past (Kyogle Flood Study) but essentially provides the same functions and calculations.

The purpose of the rainfall routing modelling is to determine the input flows into the hydraulic (TUFLOW) model by converting rainfall depths to hydrographs. Design rainfall data in input from Intensity-Frequency-Duration (IFD) data which has been developed by BoM for the whole of Australia. Parameters such as catchment area, slope, vegetation cover (roughness), initial and continuing losses, lag times and routing parameters are input into the hydrologic model.

## 5.2 (IFD) Data Review

There is some variation in the IFD across the catchment as shown in refer Figure 5-1. Higher intensity rainfalls are likely in the upper catchment areas where the steeper hillslopes are likely to have orographic effects on rainfall patterns. Rainfall at Urbenville and Woodenbong is likely to be less intense than across other areas of the catchment where the terrain is higher.

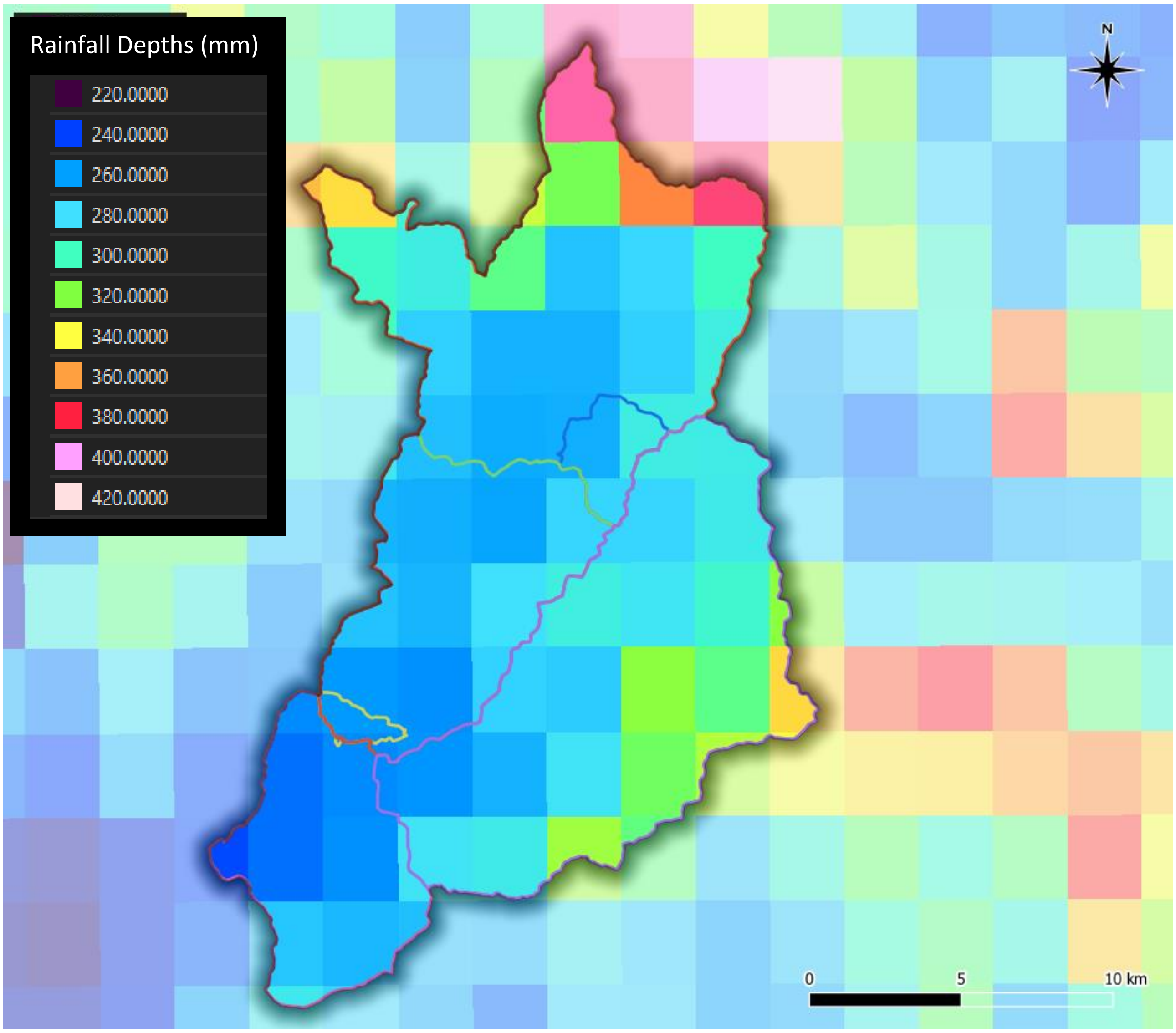



**Figure 5-1: Gridded IFD data – Depths – 1% AEP event 24 hours (source: BOM)**

A comparison of the IFD data and at-site gauge data is typically desirable for flood studies as a check on the BoM IFD data. However for the Urbenville and Woodenbong Flood Study catchment, there are no sub-daily gauges within the catchment area and only one daily read gauge within each town (refer Section 3.2.2).

At site IFD data was generated based on the daily read gauges at Urbenville (57020) and Woodenbong (57024). The gauges have a record of 88 years at Woodenbong and 86 years at Urbenville, both will therefore give a reasonable IFD estimate of a range of AEP rainfall events. However, this analysis can only be undertaken for durations of 24 hours and longer as the gauge is daily read. Furthermore, it is possible that the daily gauges could underestimate the 24 hour total rainfall as the observed 24 hour rainfall totals are limited to rainfall recorded in the 24 hour period to 0900 hours each day. Should the rainfall event occur either side of this, it would be recorded over a 48 hour period and thus under estimate the 24 hour total.

A comparison of the point IFD data and gauge derived IFD is presented in Figure 5-2 and Figure 5-3, these show the differences between the calculated at site IFD and the BOM IFD for Urbenville  and Woodenbong with the points representing observed data and the line representing the BOM IFD.

The BOM IFDs for the shorter durations are consistently higher than the at site IFD, in the frequent events. This would be due, in part, to the reporting durations of the daily gauges being between 9 am each day which may mean that the storm which occurs either side of 9am is recorded as two smaller 24 hour totals. In the intermediate events, the at site IFD and BOM IFD are close to each other. In the rare events there is a significant difference between the at site, and BOM IFDs. This is due to the gauge at Urbenville not experiencing 1% AEP across all durations, weighting the results down.

The longer duration measurements from the gauge are the most at risk of having reporting errors with multiple days of rainfall being attributed to one day. The cumulation of this could result in overstated longer duration IFDs. This behaviour is also repeated in Figure 5-3 at Woodenbong with the at site IFD and BOM IFD close until the rare events, where the gauge has not experienced storm events of this severity across all durations.

The comparison of the daily gauge data and BOM IFDs show that the BOM IFD is appropriate for use with minimal differences in the less frequent events. In the rare events the comparison is limited by the amount of at site data of this magnitude available.

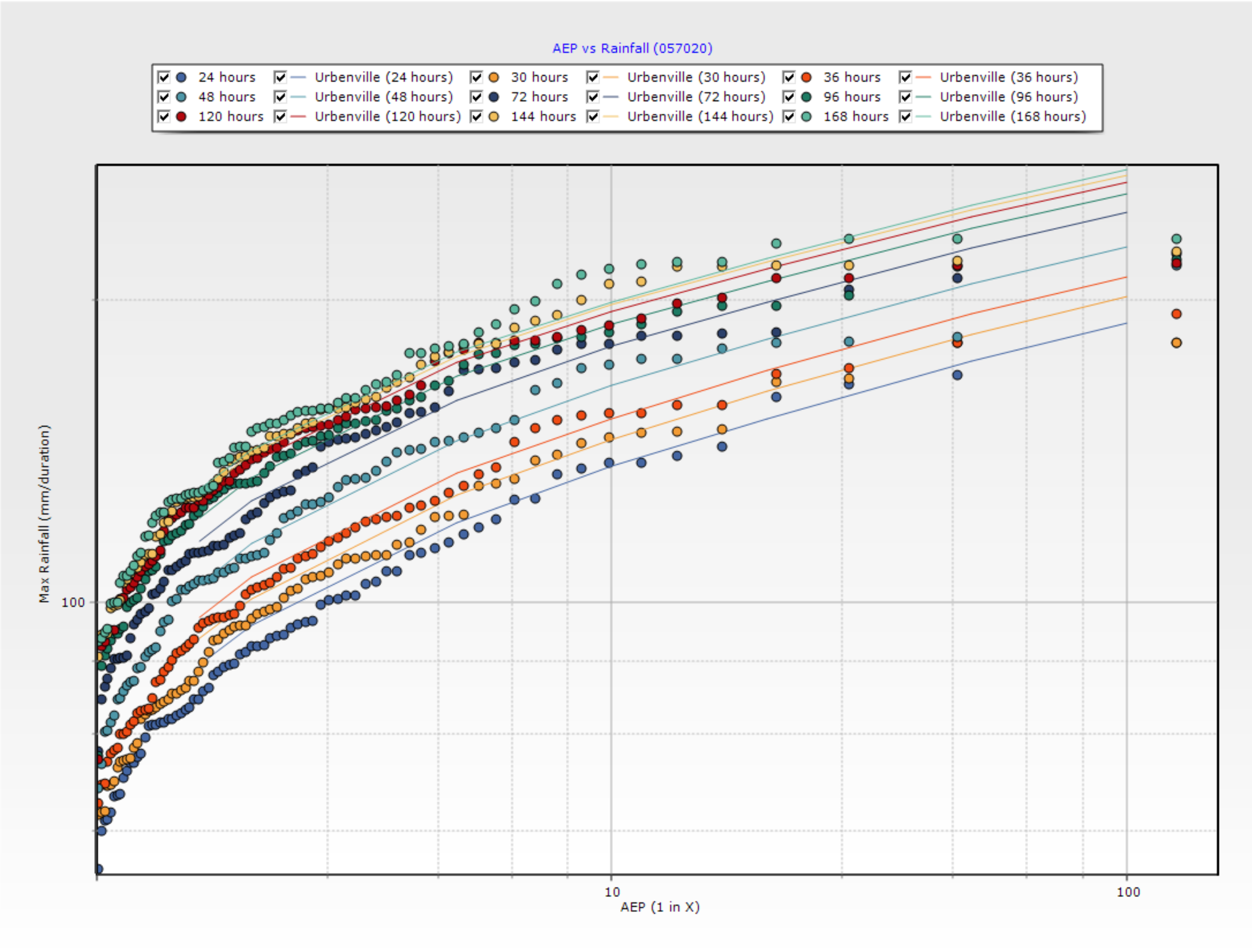



**Figure 5-2: Urbenville (57020) and ARR2019 point IFD Comparison**

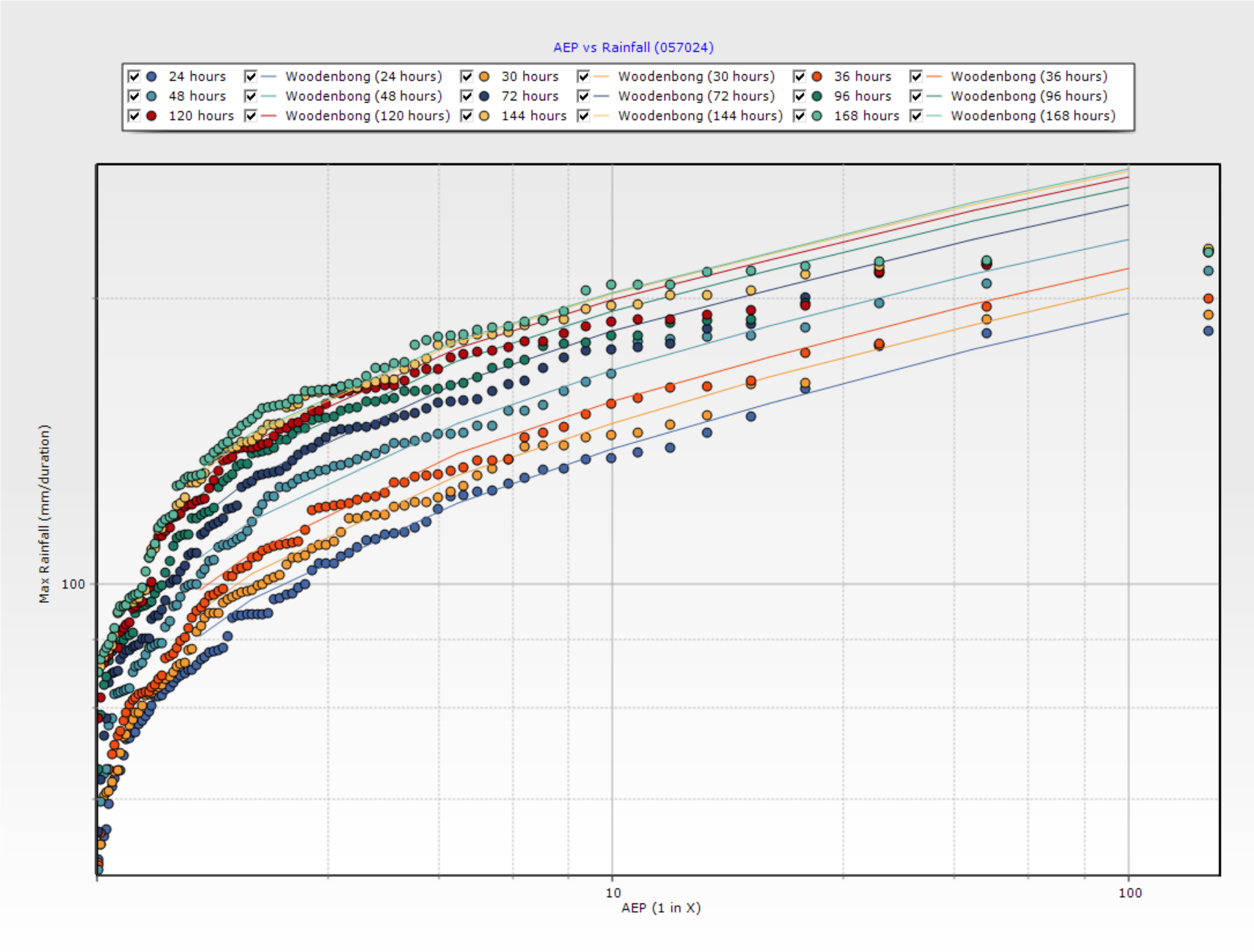



**Figure 5-3: Woodenbong (57024) and ARR2019 point IFD Comparison**

## 5.3 Rainfall routing model (ICM)

A rainfall routing model was developed for the catchment to the study area using ICM software.

The rainfall routing model comprised 542 sub-catchments (refer Figure A 4) each with catchment specific parameters applied. Catchment parameters such as percentage impervious and slope were determined using GIS methods, aerial and topographic data and are summarised in Table 5-1.

Hydrological inputs were varied when calculating the flows from flooding from the Tooloom Creek and flows from the local catchments of each town.

### 5.3.1 Model Parameter Selection

Rainfall routing model parameters are summarised in Table 5-1.

**Table 5-1: ICM Model Setup and Adopted Parameters**

| Parameter | Comment |
|---|---|
| Catchment delineation | Catchments were delineated in GIS using the 2017 2m LiDAR DEM. |
| Slope | Catchment equal area slopes were calculated using the 2017 2m LiDAR. |
| % impervious | Impervious areas of the catchments were estimated using aerial imagery. |

| Parameter | Comment |
|---|---|
| Roughness | Manning's n was applied to the catchments based off the impervious, pervious nature of the catchment. A Manning's n of 0.04 was adopted for pervious areas and 0.025 for impervious areas. |
| Lag time | Lag times were varied depending on the slope and distance of the watercourse between catchments and a typical flow velocity for similar watercourse systems. The velocity within the watercourses were estimated between 1 and 2 m/s dependent on the slope. |
| Losses | NSW-FFA reconciled losses were adopted from a nearby catchment Peacock Creek. These losses were adopted for the entire study area due to the vicinity of the sub-catchments and similarity of terrain to the rest of the catchment. The losses provided from the NSW-FFA were IL: 49.7 mm and CL 3.26 mm/hr. These losses had been calibrated against the Peacock Creek stream gauge and were given a good quality rating.<br>The ARR19 data hub losses for Urbenville and Woodenbong were IL: 49 mm and CL: 4.6 mm/hr and IL: 51 mm, CL: 4.7 mm/hr. The adoption of NSW-FFA losses provided a more conservative approach with more flow being generated in the hydrology model.<br>Impervious losses were adopted as IL: 1 mm and CL: 0 mm.<br>The initial loss burst adopted was the Probability Neutral Burst Loss from the ARR data hub. This provides the end result of Storm Loss less Pre-burst rainfall for each AEP event and duration. |

### 5.3.2 Spatial Distribution of Rainfall Across Tooloom and Boomi Creeks

The BOM provides gridded IFD data at a resolution of about 6 $km^2$. The catchment size for the study area is 112.2 $km^2$ and 170.9 $km^2$ for Woodenbong and Urbenville town and therefore, spatially variability of the inputs needed to be considered. For the Tooloom Creek catchment to the townships, the average design rainfall depth was calculated for each design event as per ARR2019. This involves calculating the IFD depth at each individual catchment and applying a weighted average as per the sub-catchment area to calculate a spatially distributed catchment average. This was applied for each duration and AEP event within the hydrology model.

A comparison of the total catchment weighted average IFD and the IFD at each town indicated a difference in estimated rainfall depths varying between 1-6%. Using the catchment weighted average method, the rainfall depths were overstated at each township. This is due to the distribution of the IFD across the Tooloom Creek catchment where higher rainfall depths occur due to the natural geography of the upper catchment (refer Figure 5-1). This effect was more dominant in larger magnitude events.

The difference between applying a weighted average IFD for Tooloom Creek upstream of Woodenbong in comparison to the entire catchment including Woodenbong was approximately 1-2%. Therefore just one weighted average IFD for the whole creek was applied.

The townships of Urbenville and Woodenbong have local catchment areas of 2.3 $km^2$ and 8.4 $km^2$ respectively. Therefore, instead of using the catchment average rainfalls, a point IFD was applied for each duration and event within the hydrology model when calculating the flows from the local catchments of each town.

### 5.3.3 Temporal Patterns

Due to the area of the catchment Tooloom Creek catchment to Urbenville and Woodenbong, areal temporal patterns were applied for the full catchment. Areal temporal patterns are applicable for catchments of 75 $km^2$.

For the Urbenville and Woodenbong towns where the combined local catchments are smaller than 75 $km^2$, point temporal patterns were applied for the hydrology models . The joint probability of Tooloom Creek and the local town catchments is addressed in Section 6.2.1.

### 5.3.4 Hydrology Model Calibration

There are no stream gauges within the study are for flow calibration. The rainfall runoff model outputs were checked against RFFE flows (refer section 5.3.6).

### 5.3.5 ARRR2019 Ensemble Approach for Design Event Flows

The rainfall runoff routing model was run for the 20% AEP, 5% AEP, 1% AEP, 0.2% AEP events using the ARR2019 ensemble approach. A total of six durations were assessed for the Tooloom Creek and 18 durations were assessed at the townships.

The temporal pattern producing the upper median for each storm duration was identified (rank 5 of 10). For each storm duration assessed, the representative storm for input into the hydraulic TUFLOW model was selected on the following criteria:

- The pattern that provides the upper median flow downstream of the Mount Lindsay Road Bridge at Tooloom Creek at Woodenbong.
- The pattern that provides the upper median flow in Tooloom Creek near Urbenville town.
- The pattern that provides the upper median flows through the Urbenville and Woodenbong townships from local catchments.

Box plots showing the range, median and mean of peak flows for the ensemble are shown in Figure 5-4 and Figure 5-5 for the individual towns catchment flow, the critical durations vary for each design event at each town. For the 1% AEP event at both towns the critical duration is the 1 hour event as shown in the figures.

For Tooloom Creek where the catchment size is larger, the 12 hour event gave the critical duration at Urbenville and Woodenbong as the durations become longer. It is noted that this is the shortest duration assessed. Following ARR2019 guidance for catchments greater than 75 $km^2$, areal temporal were used for the Tooloom Creek catchment to the towns. The 12 hour storm is the smallest duration pattern available while using areal temporal patterns. Due to the size of the Tooloom Creek catchment and the ARR2019 approach is it assumed smaller durations would not provide the critical duration for this catchment. The box plots for the flows along Tooloom Creek at Urbenville and Woodenbong are shown in Figure 5-6 and Figure 5-7.

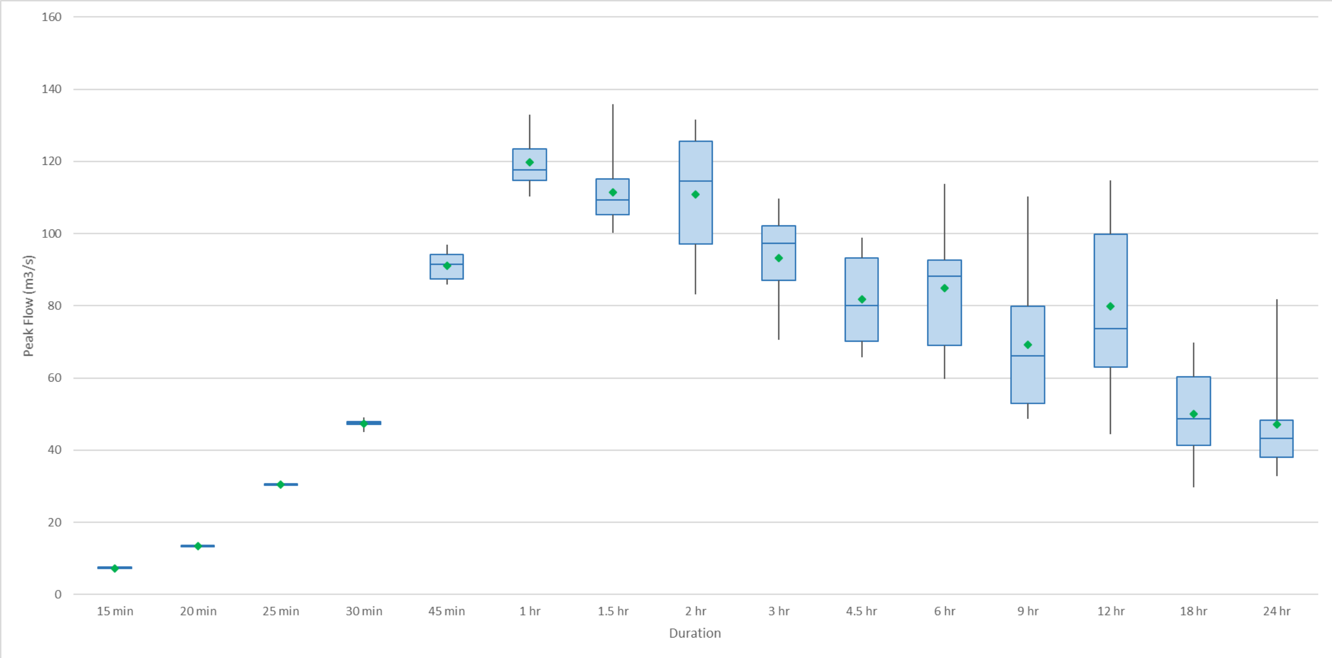



**Figure 5-4: Box Plot for 1% AEP at Woodenbong**

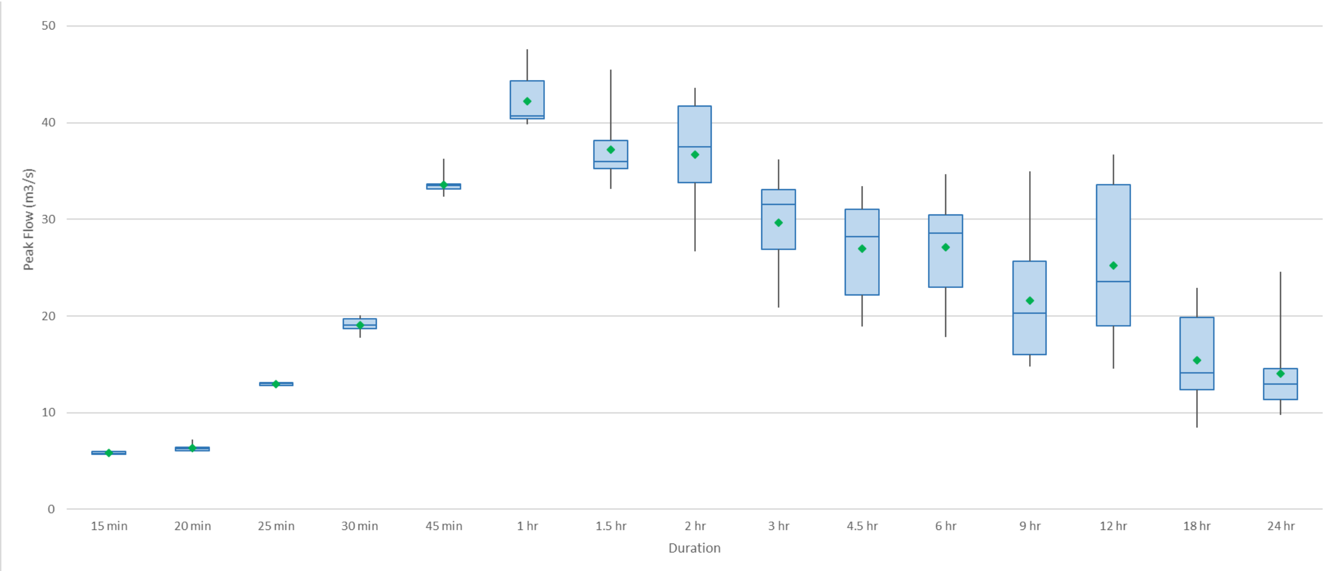



**Figure 5-5: Box Plot for 1% AEP at Urbenville**

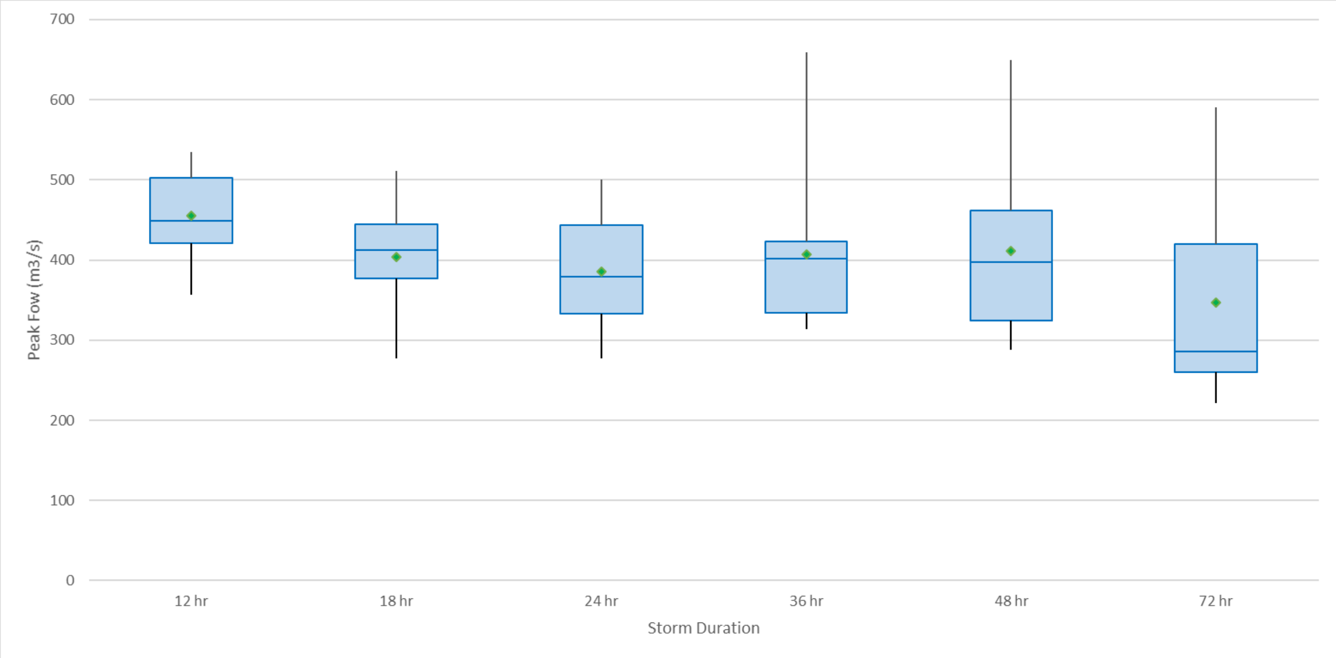



**Figure 5-6: Box Plot for the 1% AEP on Tooloom Creek at Woodenbong**

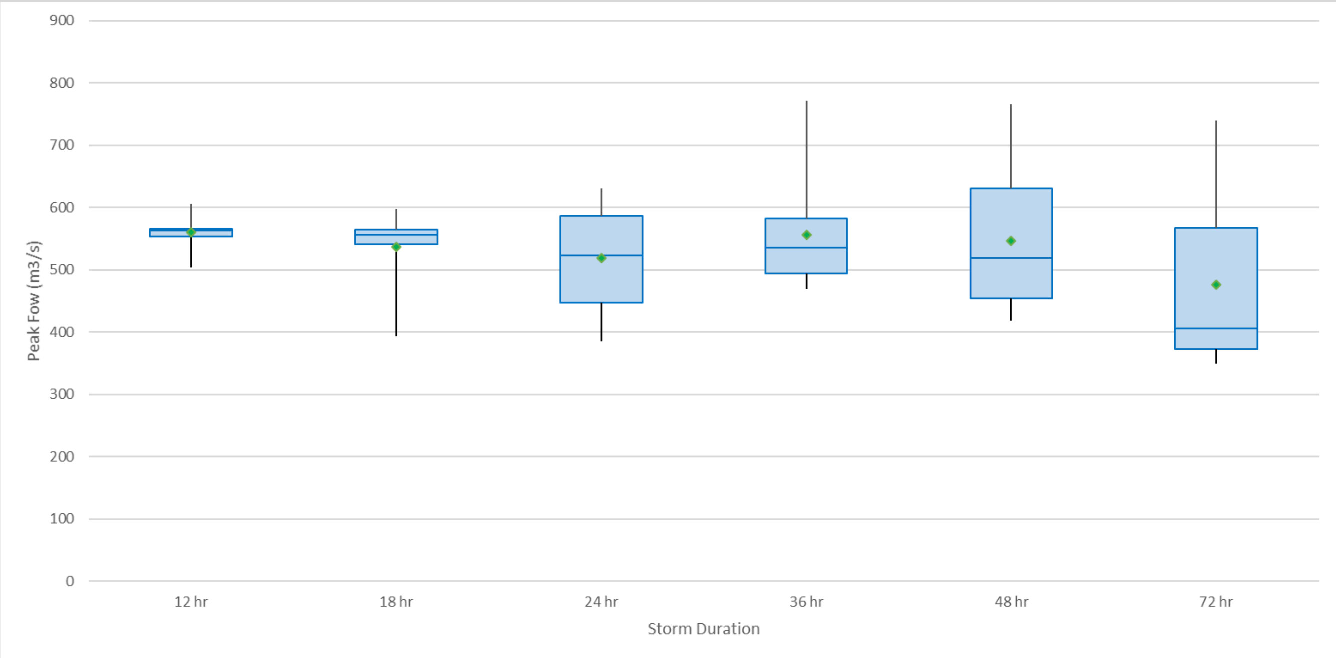



**Figure 5-7: Box Plot for the 1% AEP on Tooloom Creek at Urbenville**

### 5.3.6 Comparison of Rainfall Routing Model to Regional Flood Frequency Estimation (RFFE)

ARR2019 recommend that at least two hydrology methods are used to determine peak flows to assess uncertainties. The RFFE method allows for design flood estimates on ungauged catchments based on data from a number of nearby gauged catchments and/or gauged catchments with similar characteristics. RFFE is an estimation tool and is not appropriate for the detailed assessment of design events but can be used as a check that results from rainfall routing models are within reasonable expected bounds.

A comparison of the rainfall runoff model peak flows and RFFE peak flows is presented in Table 5-2. The results show that the rainfall runoff model outputs is within the confidence bounds of the RFFE.

The RFFE results give a greater flow at Woodenbong than at Urbenville despite a smaller catchment area to Woodenbong. The RFFE estimation for Woodenbong may be unreliable with a shape factor of 0.49. This is outside of the bounds of most catchment used to inform the RFFE model. Less than 10% of all selected gauged catchments used in the RFFE model have catchment shape factors less than 0.51. As an atypical catchment ARR19 guidelines recommend further hydrologic and hydraulic analysis to refine the RFFE model results.

**Table 5-2: RFFE Results at Urbenville**

| AEP (%) | RFFE Discharge ($m^3/s$) | RFFE Lower Confidence Limit (5%) ($m^3/s$) | RFFE Upper Confidence Limit (95%) ($m^3/s$) | ICM Median Temporal Pattern Flow ($m^3/s$) |
|---|---|---|---|---|
| 20 | 133 | 55.7 | 323 | 168 |
| 5 | 323 | 112 | 933 | 309 |
| 1 | 703 | 183 | 2650 | 504 |

**Table 5-3: RFFE Results at Woodenbong**

| AEP (%) | RFFE Discharge ($m^3/s$) | RFFE Lower Confidence Limit (5%) ($m^3/s$) | RFFE Upper Confidence Limit (95%) ($m^3/s$) | ICM Median Temporal Pattern Flow ($m^3/s$) |
|---|---|---|---|---|
| 20 | 160 | 67.1 | 386 | 134 |
| 5 | 391 | 137 | 1110 | 235 |
| 1 | 854 | 229 | 3140 | 357 |

## 5.4 Probable Maximum Precipitation Flood

Probable Maximum Precipitation (PMP) was calculated for the Urbenville and Woodenbong townships catchment and the upstream catchment. The generalised short-duration method (GSDM) (Bureau of Meteorology, 2003) was applied for the local catchments of each township. Durations between 15 minutes to 6 hours were assessed and the township catchments were found to have a PMP critical storm duration of 1 hour at Urbenville and 1.5 hours at Woodenbong.

The PMP calculation for the catchment for Tooloom Creek to where it passes each town was undertaken using GSDM for critical durations 15 minutes to 6 hours. The found critical duration using the GSDM approach was the 6 hour storm for Urbenville and the 5 hour storm at Woodenbong.

The 5 hour duration was taken as the critical PMP storm duration for Woodenbong. Due to the 6 hour storm being the longest duration of the GSDM, the Generalised Tropical Storm Method (GTSM) (Bureau of Meteorology, 2003) approach was also adopted for Urbenville to assess longer durations. The 24 hours to 72 hour storms were assessed for Tooloom Creek catchment to Urbenville and a 12 hour storm was iterated from between the rainfall depths of the 24 GTSM and 6 hour GDSM. The application of the rainfall within the rainfall routing model found the critical duration was the 12 hour for Tooloom Creek at Urbenville.

## 5.5 Australian Rainfall and Runoff 1987

### 5.5.1 Intensity-Frequency-Depth data

A comparison of the ARR87 and 2019 IFD data was undertaken for the point IFD at Urbenville and Woodenbong and for the catchment average IFD. The results are summarised in Figure 5-8, Figure 5-9 and Figure 5-10.

At Woodenbong and Urbenville for shorter duration events (typically less than one hour) the ARR2019 IFD gives higher or similar rainfall depth compared to the ARR87 IFD except for the 20% AEP event. For longer duration events, at Woodenbong the rainfall depth of a given AEP is typically reduced when comparing the 2019 IFD to the ARR87 IFD. At Urbenville it is greater in the 2019 IFD for the 12 and 24 hour events. This indicates that, when compared to the ARR 87 IFD, the revised 2019 IFD may lead lower flood levels for longer duration events.

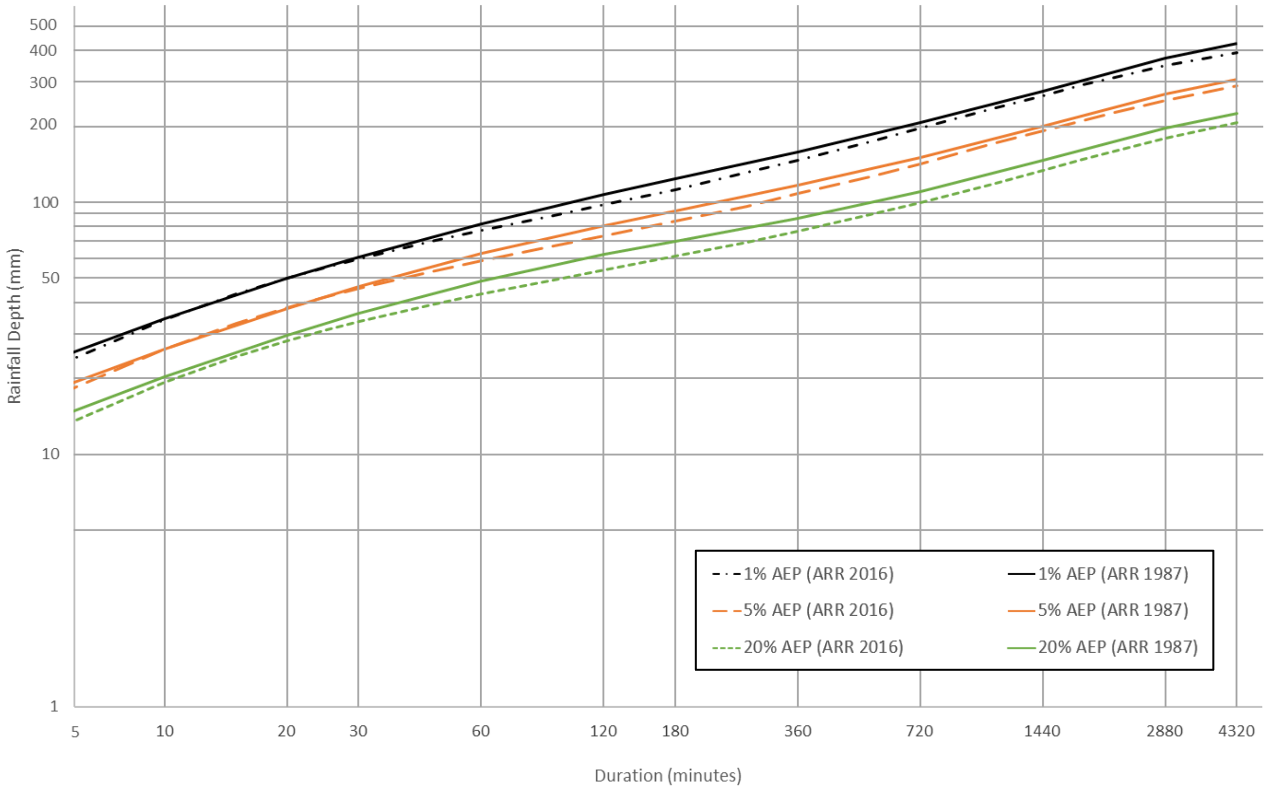



**Figure 5-8: ARR87 and ARR2019 Point IFD Comparison – Woodenbong town**

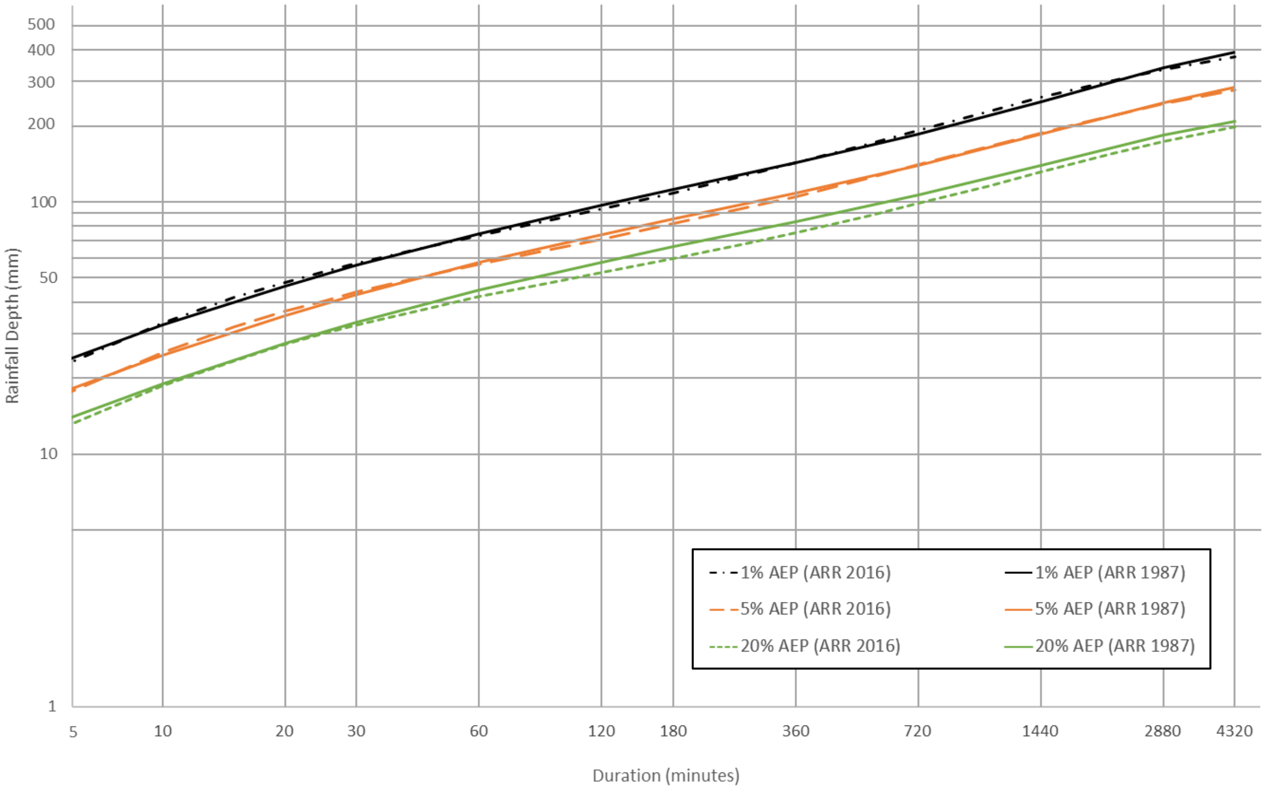



**Figure 5-9: ARR87 and ARR2019 Point IFD Comparison – Urbenville town**

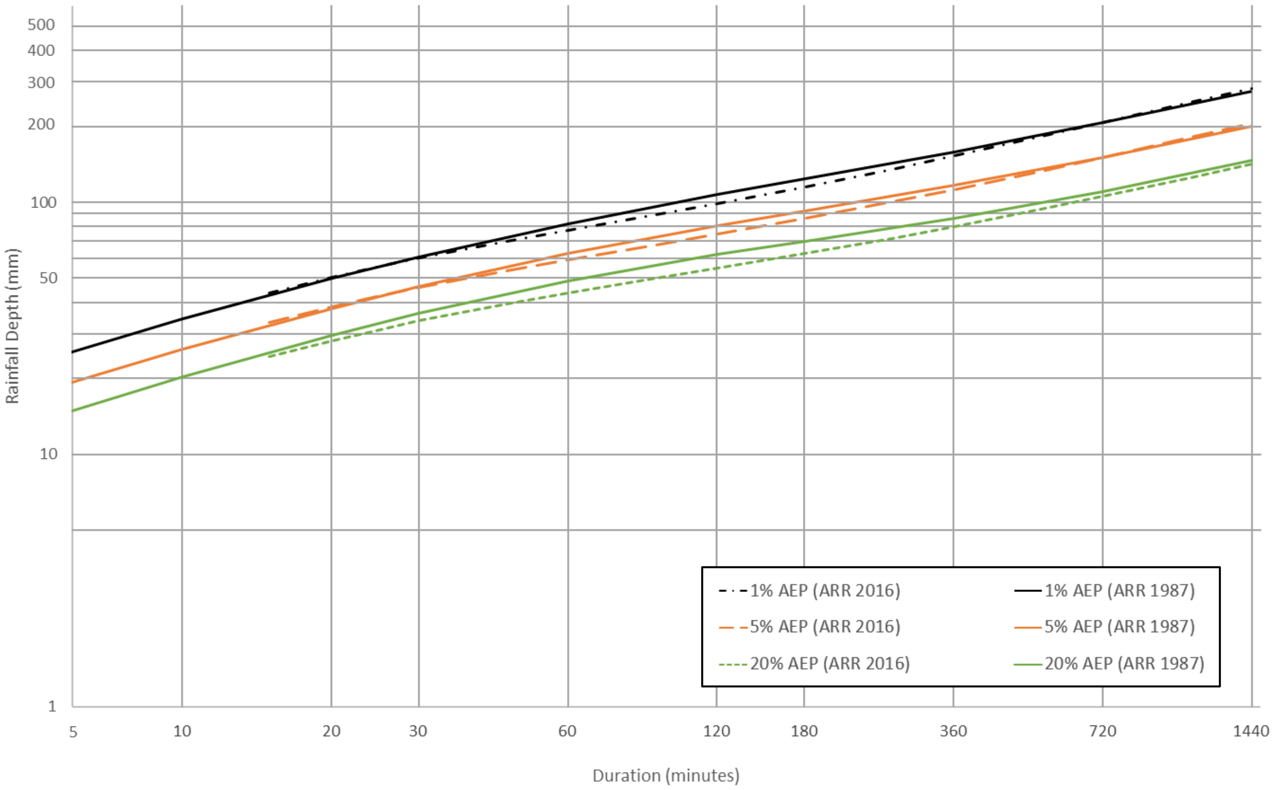



**Figure 5-10: ARR87 and ARR2019 Catchment Average Weighted IFD Comparison**

### 5.5.2 ARR87 and ARR2019 Losses

The conversion of rainfall depths to runoff is also affected by other factors such as the application of losses. Losses adopted for this study used the FFA reconciled losses for NSW (refer section 5.3). A comparison of ARR87 and ARR2019 losses is provided in Table 5-4.

On first inspection the ARR87 losses in comparison to the NSW-FFA reconciled losses are significantly different and the ARR2019 losses are much higher than the ARR87 losses. The ARR87 losses are rainfall burst losses however the ARR2019 loss from the ARR data hub is a total storm loss (pre-burst loss plus burst loss). With the application of pre-burst losses which are varied for each event and duration, the loss that is applied in the hydrology model to the rainfall burst is the rainfall burst loss (the initial loss less the pre-burst). An example of this can be seen in the 1% AEP 12 hour storm in Table 5-4.

**Table 5-4: Comparison of ARR87 and ARR2019 losses**

| | Initial loss (mm) | Continuing Loss (mm/hr) |
|---|---|---|
| ARR87 (Burst Loss) | 10 | 2.5 |
| ARR2019 (Strom Loss) | 49.7 | 3.26 |
| 1% AEP 12 hour Burst Loss | 3.6 | 3.26 |

### 5.5.3 Hydrology Assessment

The 5% AEP and 1% AEP events were run through the rainfall routing model using ARR87 procedures. A comparison of the hydrographs for the Tooloom Creek catchment at Woodenbong and Urbenville in Figure 5-11 and Figure 5-12.

For the 5% and 1% AEP events the revised ARR2019 method produces shorter duration critical storms, except for the 1% AEP storm at Woodenbong which is a 6 hour.

For Tooloom Creek, the ARR2019 procedures result in reduced peak flows at both Woodenbong and Urbenville compared to ARR87. The cause of the lower peak flows can also be attributed to a combination of the lower catchment average rainfall depths and greater continuing losses. In addition the varying temporal patterns also has an effect. While ARR87 adopts a single temporal pattern, the introduction of 10 varying temporal patterns in the ARR2019 ensemble approach gives more variation in rainfall distribution and hydrograph shape.

For the 1% AEP event the comparison of ARR87 and ARR2019 methods gives similar results to the 5% AEP event. For the Tooloom Creek catchment at Woodenbong and Urbenville the peak flow is reduced, and the critical duration reduced from 36 to 12 hours at Urbenville and increased from 6 to 12 at Woodenbong. The peak flow for the ARR87 storms occurs in the middle of the storm as opposed later in the ARR19 storms due to the difference in the selected temporal patterns. The 12-hour duration is the smallest duration available using ARR19 guidelines for catchments greater than 75 $km^2$.

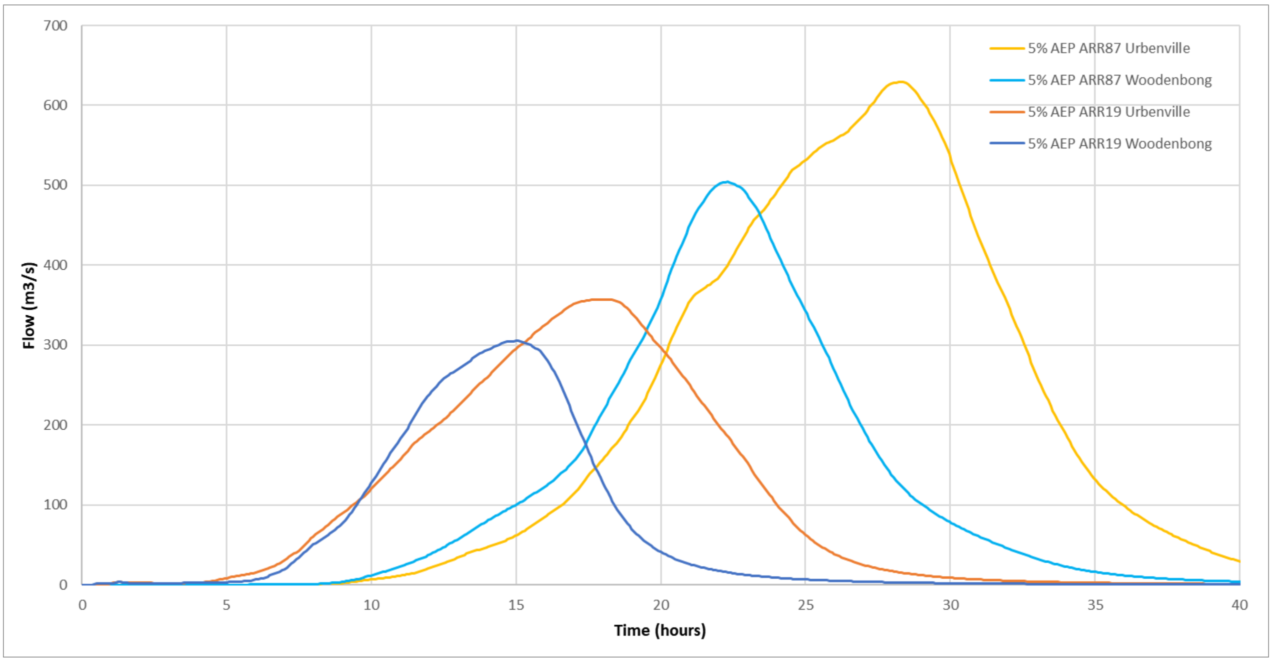



**Figure 5-11: 5% AEP ARR87 and ARR19 Flow Comparison – Tooloom Creek**

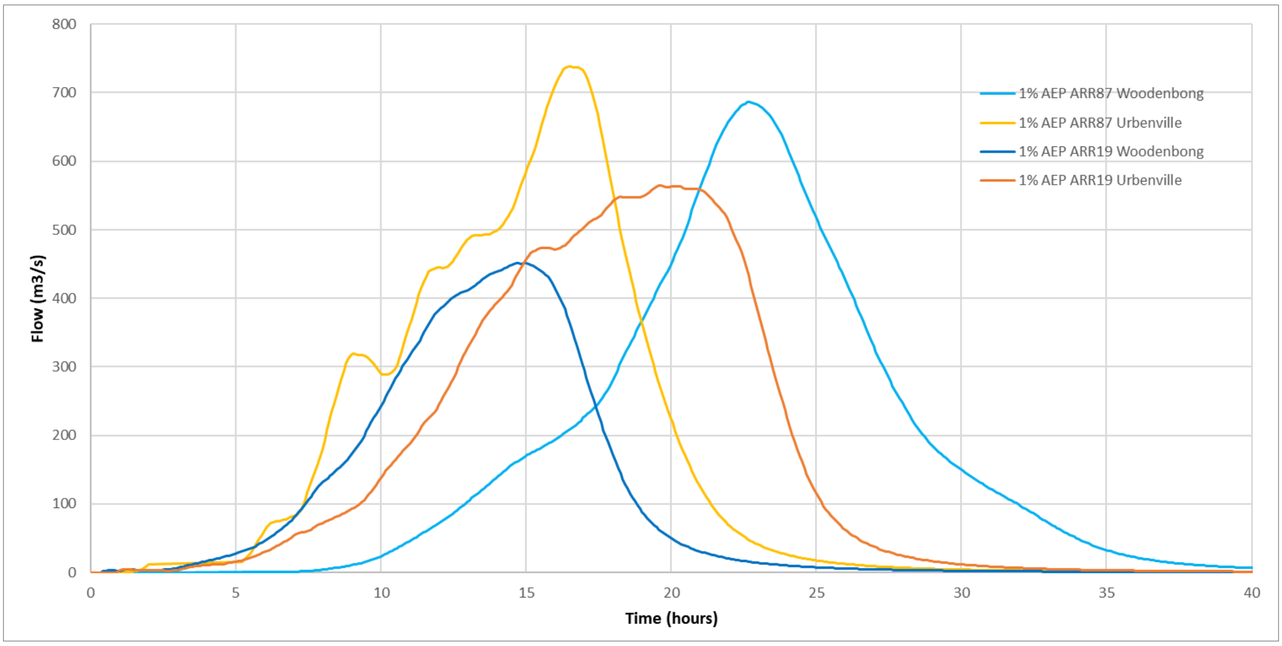



**Figure 5-12: 1% AEP ARR87 and ARR19 Flow Comparison – Tooloom Creek**

# 6 HYDRAULIC ANALYSIS

## 6.1 Hydraulic Modelling

Hydraulic modelling was undertaken using TUFLOW. This modelling package allows effective linking of both 1d and 2d modelling methods. The 2d modelling is grid based, but with the inclusion of 1d elements embedded into the 2d domain, allows for representation of finer details such as narrow waterways, the drainage network, and detailed hydraulic structures.

The model setup is summarised in Table 6-1 and also in Appendix A.

**Table 6-1: TUFLOW Model Setup and Adopted Parameters**

| Parameter | Comment |
|---|---|
| Model Version | 2020-01-AB |
| Adopted grid cell size | A 2m model grid size was adopted for smaller town models of Woodenbong and Urbenville.<br>For the larger model of Tooloom Creek a 10m grid size was adopted while using 2 m sub-grid-sampling. This gives the model more refined definition within the 10m grid. A larger model size was used for the Tooloom Creek due to the larger model and to reduce model run times. The selected grid size if sufficient for the level of detail required in a largely undeveloped area. A smaller cell size was used for the town models for more refined results. |
| Model Extent | The Urbenville town model extends approximately 2.5 km upstream and downstream of Tooloom Creek and contains the local catchment to the west.<br>The Woodenbong town model extends 1 km upstream and downstream of Mount Lindesay Road crossing of Tooloom Creek and captures the local catchment to the east.<br>The Tooloom Creek model upstream boundary was set approximately 5 km upstream of Woodenbong and 9 km downstream of Urbenville. It contains the Tooloom Creek between the two towns and captures Mulli Mulli. It also contains Boomi Creek up until Brumby Plains Road.<br>The model extents were set larger than the study area so that any boundary conditions effects have no effect of flood behaviour within the flood study area. Refer to Appendix A for more details. |
| Digital Elevation Model (DEM) | Developed from 2 m resolution 2017 LiDAR from NSW Spatial Services. LiDAR sourced from NSW Spatial services flown in 2017 has Horizontal Spatial Accuracy: +/-0.80 @95% Confidence Interval and Vertical Spatial Accuracy: +/-0.30 @95% Confidence Interval.<br>Areas in the model terrain which influence hydraulic behaviour such as areas of raised or lowered land, features have been digitised using break lines so that the hydraulic effect of crest levels and depressions is considered. |
| Manning's roughness values | Based on aerial photography using Manning's 'n' Ranges for Different Land Use Types outlined in ARR2016 ARR Project 15: Two Dimensional Simulations in Rural and Urban Floodplains. |
| Upstream inflow boundaries | Catchment boundary conditions for the hydraulic model used flow hydrographs established during the hydrologic analysis. The rainfall-runoff routing model (ICM) was used to determine inflows from external catchments. The representative hydrographs from the calibrated ICM rainfall runoff routing model was used to input hydrographs into the hydraulic model.<br>For the town models the inflows from Tooloom creek were input from the flows established from the Tooloom Creek hydraulic model. |

| Parameter | Comment |
|---|---|
| Internal flow boundaries | For local catchments and catchments internal to the TUFLOW model extent flows have been determined from the rainfall-runoff routing model and input as point inflows at suitable locations. |
| Downstream boundary | For the Tooloom Creek model an automatically generated HQ (level-flow) boundary based on terrain slope was used. Sensitivity has been undertaken to ensure no boundary effects on the modelled flood behaviour in the study area.<br><br>For the town models, water levels from the Tooloom Creek model were extracted from the larger Tooloom Creek catchment model and were used to set a HT (water level – time) boundary for each AEP event. |
| Hydraulic structures – Tooloom Creek and Boomi Creek | Bridge locations were provided from Council. This information did not include pier or deck information, it was assumed that the bridges had a deck thickness of 1m or 0.5m depending on the bridge length and a total blockage from pier obstructions of 5%. The deck levels were set from LiDAR. |
| Hydraulic Structure – Clarence Valley Way and Boomi Creek Road | Culverts along the roadways within the model such as Clarence Valley Way and Boomi Creek Road were supplied from council. This data included the culvert location and size. Invert levels were taken from LiDAR data. |
| Stormwater drainage network | Based on Council GIS data and incorporated as 1d elements. Invert levels were not provided for all 1d networks. Pipe inverts were set to ground level using the terrain. Pipes less than 375 mm in diameter were assumed to be blocked providing a conservative approach to overland flow assessment, except for pipes that provided transverse drainage under road crossings to keep connectiveness of flow paths. |
| Buildings | Buildings within the model extent were digitised from aerial imagery and blocked out of the model extent; it is assumed no flow would pass through buildings. Buildings were digitised to make sure that flow paths were maintained around buildings. |
| Blockage | All pipes smaller 375 mm were excluded from the model (unless where connecting larger upstream and downstream systems) and effectively assumed as 100% blocked. This provides a conservative of overland flows, particularly in the smaller magnitude events.<br><br>For other pipes, for the 20%, 5% and 1% AEP a 50% blockage factor was applied to all stormwater networks within the model. For more severe events (0.02% AEP and PMF) a 100% blockage factor was applied to the stormwater networks. This is due to the higher risk of potential blockage in more severe events as per ARR2019.<br><br>For bridges an extra 10% blockage was applied for the 0.02% AEP and PMF events. For all other events no extra blockage was applied. This is due to the size of the openings of the bridges in comparison to the size of potential debris, as per ARR 2019.<br><br>Blockage sensitivity was also undertaken (refer section 8.5). |
| Shallow drains / depressions | Drainage features, or natural depressions which convey flow, were incorporated as a gully (or minimum) line in the flood model. This ensure that flows continue from one cell to the next without artificial obstruction due to grid size. |
| Roads / Levee | Roads crossing Tooloom Creek and Boomi Creek or running parallel to them such as Clarence Way, Mount Lindsay Road, Tooloom Road and Boomi Creek Road were incorporated as a ridge (or maximum) line in the flood model. This ensured that the rises in topography from the road were captured in the model grid. |

| Parameter | Comment |
|---|---|
| | |
| Levee at Woodenbong | The levee behind Richmond Street in Woodenbong was input into the model as a ridge line based on LiDAR and with Council's supplied data. |

## 6.2 Modelling Design Events

The flood model was run for the 20% AEP, 5% AEP, 1% AEP, 0.2% AEP and PMF events. Results are presented in Appendix B and summarised in Section 8.

### 6.2.1 Joint Probability Approach

Given the relative catchment sizes between the Tooloom Creek upstream of Urbenville (170.9 km$^2$) and Woodenbong (112.2 km$^2$) and the local catchments at Urbenville (2.6 km$^2$ to Tooloom Creek) and Woodenbong (8.4 km$^2$ to Tooloom Creek), an event of a given magnitude may not occur on both catchments the same time. In addition, the temporal pattern and storm duration that produces the representative storm for the larger catchment is unlikely to be the same for the local catchments.

Therefore, a joint probability approach was adopted based on the Floodplain Risk Management Guide (OEH, November 2015), as per Table 6-2. For each of the AEP design events at each town the design flood was determined by enveloping two scenarios to extract the maximum values. The critical durations and temporal patterns adopted for the TUFLOW hydraulic model had been determined in the hydrologic modelling (refer section 5).

**Table 6-2: Combinations of Catchment Probability for Determining Design Event Flood Behaviour**

| Design AEP | Town | Scenario | Tooloom Creek catchment | Town catchments |
|---|---|---|---|---|
| 20% | Urbenville | 1 | 12 hour 20% AEP Temporal Pattern ID 17 | |
| | | 2 | Creek full | 2 hour 20% AEP<br>Temporal Pattern ID 4643 |
| | Woodenbong | 1 | 12 hour 20% AEP Temporal Pattern ID 17 | |
| | | 2 | Creek full | 2 hour 20% AEP<br>Temporal Pattern ID 4641 |
| 5% | Urbenville | 1 | 12 hour 5% AEP Temporal Pattern ID 15 | |
| | | 2 | Creek full | 1 hour 5% AEP<br>Temporal Pattern ID 4567 |
| | Woodenbong | 1 | 12 hour 5% AEP Temporal Pattern ID 17 | |
| | | 2 | Creek full | 1 hour 5% AEP<br>Temporal Pattern ID 4565 |
| 1% | Urbenville | 1 | 12 hour 1% AEP | 1 hour 5% AEP |

| Design AEP | Town | Scenario | Tooloom Creek catchment | Town catchments |
|---|---|---|---|---|
| | | | Temporal Pattern ID 20 | Temporal Pattern ID 4475 |
| | | 2 | 12 hour 5% AEP<br>Temporal Pattern ID 15 | 1 hour 1% AEP<br>Temporal Pattern ID 4405 |
| | Woodenbong | 1 | 12 hour 1% AEP<br>Temporal Pattern ID 17 | 1 hour 5% AEP<br>Temporal Pattern ID 4565 |
| | | 2 | 12 hour 5% AEP<br>Temporal Pattern ID 17 | 1 hour 1% AEP<br>Temporal Pattern ID 4360 |
| 0.2% | Urbenville | 1 | 12 hour 0.2% AEP<br>Temporal Pattern ID 17 | 1 hour 1% AEP<br>Temporal Pattern ID 4360 |
| | | 2 | 12 hour 1% AEP<br>Temporal Pattern ID 20 | 1 hour 0.2% AEP<br>Temporal Pattern ID 4555 |
| | Woodenbong | 1 | 12 hour 0.2% AEP<br>Temporal Pattern ID 17 | 1 hour 1% AEP<br>Temporal Pattern ID 4360 |
| | | 2 | 12 hour 1% AEP<br>Temporal Pattern ID 17 | 1 hour 0.2% AEP<br>Temporal Pattern ID 4463 |
| PMF | Urbenville | 1 | 12 hour PMF | |
| | | 2 | 1 hour PMF | |
| | Woodenbong | 1 | 5 hour PMF | |
| | | 2 | 1.5 hour PMF | |

# 7 MODEL CALIBRATION AND VALIDATION

## 7.1 Data for Model Calibration and Validation

Within the Urbenville and Woodenbong catchments there are only two active gauges available for model calibration and validation. The Urbenville gauge (Gauge ID: 57020) has daily rainfall readings from 1935 to present day and Woodenbong (Unumgar St) (Gauge ID: 57024) has daily rainfall readings from 1933 to present day. No sub-daily rainfall gauges exist with the Tooloom Creek catchment although in the surrounding catchments there are pluviometer gauges with varying years of record (refer section 3.2). There are no discharge / water level gauges on either Tooloom Creek or Boomi Creek. Figure 7-1 shows the gauge locations within and outside the catchment.

For model calibration, as well as historical rainfall, observed flood marks are useful so that the flood behaviour in the modelling can be calibrated to actual event-based data. Calibration data was collected through the community consultation and SES (refer Appendix D). Little data was available for the 2013 and 2015 events, which are the most recent significant events in both towns. Most residents commented on the flooding in February 2010 in Urbenville and December 2010 in Woodenbong, and 2008 in both. As they had the most available data for model calibration, the 2008 event and the 2010 events were used as the calibration events for the model. SES and council photographs of flooding were also used to visually validate the behaviour of the flood model.

## 7.2 Rainfall Analysis

### 7.2.1 Daily Rainfall Gauges

Analysis of the daily gauges within the catchment was undertaken to identify large rainfall events with potential for use in model calibration and validation. Figure 7-1 shows the daily recorded data at Urbenville, Figure 7-2 shows the daily recorded data at Woodenbong. The 1976 and 1954 events are two largest across both locations, the most recent significant events to occur in a single 24 hour period are the March 2017, January 2013 and January 2008 events. The December and February 2010 events are less severe in comparison to these.

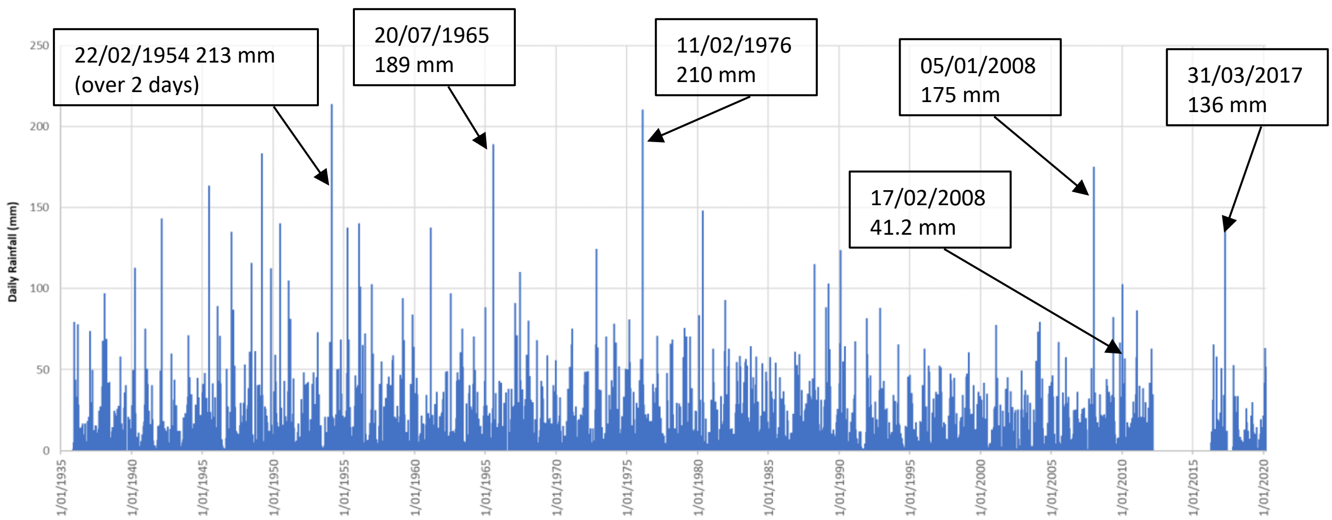



**Figure 7-1 Daily Rainfall Data Recorded at Urbenville Gauge (57020) since 1935**

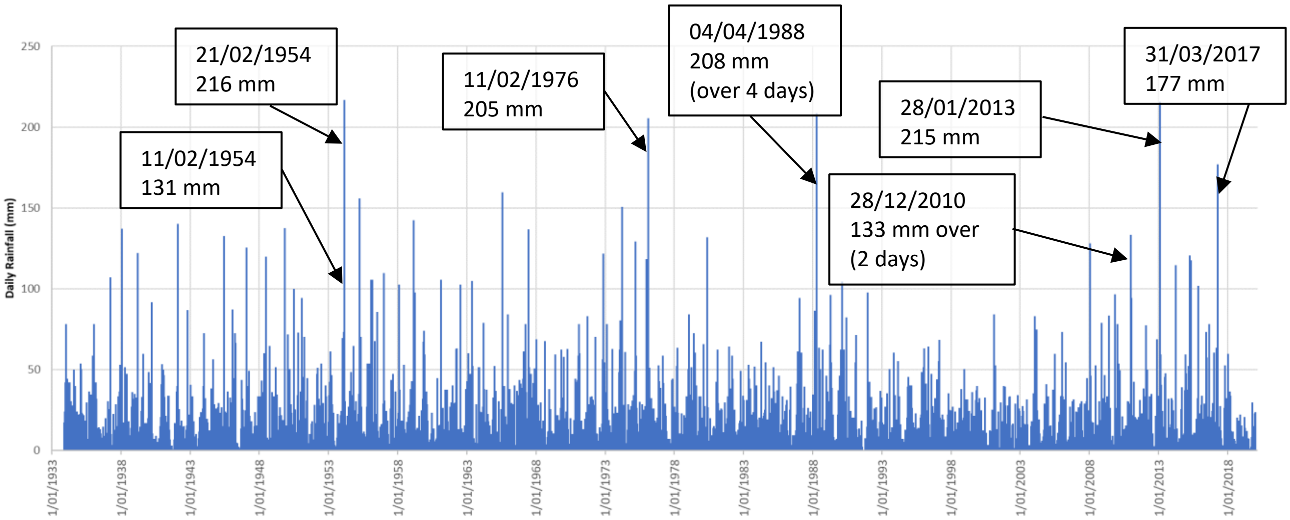



**Figure 7-2 Daily Rainfall Data Recorded at Woodenbong Gauge (57024) since 1933**

### 7.2.2 Sub-daily rainfall gauges

There are no sub-daily rainfall gauges (pluviometers) within the catchment and therefore a combination of gauges outside of the catchment was used to establish input rainfall for the calibration events.

For the 2008 event at this time of record there was data available at all pluviographs outside the catchment. For the February 2010 event there was pluviograph data available for Killarney PO, Maroon Dam, Rathdowney PO and Moogerah Dam. For the December 2010 event there was only sub-daily data available for Killarney PO, Rathdowney PO and Moogerah Dam.

## 7.3 January 2008 Event

The January 2008 event was run as a calibration event for both Urbenville and Woodenbong. An analysis of the available data seen below in Table 7-1, shows the January 2008 rainfall event was approximately a 7% and 25% AEP event at Urbenville and Woodenbong. These are both daily rainfall gauges which will record rainfall in a 24 hour period from 0900 to 0900 and could therefore underestimate the AEP of the storm where the rainfall fell within a different 24 hour period.

The surrounding pluviograph data from outside the catchment varies with the peak AEP and duration ranging from a 3% AEP 9 hour event at Killarney to a 40% AEP 4.5 hour event at Legume. The large differences shows the spatial variability of the storm event over the area. By comparison, the Kyogle Flood Study the 2008 event was found to be a 2% event through FFA of a stream gauge (WBM Oceanics Australia, February 2004).

**Table 7-1: Gauges available for the January 2008 Historical event**

| Gauge | Gauge ID | Gauge Type | AEP for a 24 hour event | Peak AEP and Duration |
|---|---|---|---|---|
| Urbenville | 57020 | Daily Rainfall | 7% | 7% 1 day |
| Woodenbong | 57024 | Daily Rainfall | 25% | 25% 1 day |
| Legume | 56022 | Pluviometer Rainfall | 56% | 39% 4.5 hour Event |
| Unumgar | 58016 | Pluviometer Rainfall | 19% | 9% 7 Day Event |
| Killarney PO | 41056 | Pluviometer Rainfall | 6% | 3% 9 hour |
| Maroon Dam | 40677 | Pluviometer Rainfall | 40% | 17% 15 min |
| Rathdowney PO | 40178 | Pluviometer Rainfall | 11% | 4% 12 hour |
| Moogerah Dam | 40135 | Pluviometer Rainfall | 37% | 19% 4 Day Event |

## 7.4 February 2010 Event

The February 2010 event was run as a calibration event specifically for the town of Urbenville. For the Februrary 2010 event four pluviometer gauges captured data for the storm. From the daily read gauge at Urbenville the AEP for the event is recorded as less than a 63.2% AEP, or less than a 1 in 1 year. The pluviometer gauges in surrounding catchments show the peak AEP ranging from about a 10% AEP in a 1 hour duration at Moogerah Dam and a 50% AEP in a 15 minute storm.

As the Urbenville gauge is a daily gauge read from 0900 to 0900 and the surrounding catchments have critical durations of typically less than 24 hours, it is expected that the storm AEP at Urbenville would be rarer than a 63.2% AEP for a short duration. Table 7-2 shows this in more detail.

**Table 7-2 Gauged Data Available for the February 2010 Event at Urbenville**

| Gauge | Gauge ID | Gauge Type | AEP for a 24 hour event | Peak AEP and Duration |
|---|---|---|---|---|
| Urbenville | 57020 | Daily Rainfall | >63.2% | >63.2% |
| Killarney PO | 41056 | Pluviometer Rainfall | >63.2% | 45% 30 hour |
| Maroon Dam | 40677 | Pluviometer Rainfall | >63.2% | 46% 15 min |
| Rathdowney PO | 40178 | Pluviometer Rainfall | >63.2% | 40% 1 hour |
| Moogerah Dam | 40135 | Pluviometer Rainfall | 17% | 10% 1 hour |

## 7.5 December 2010 Event

The December 2010 event was run as a calibration event specifically for the town of Woodenbong. At the Woodenbong daily rainfall gauge the rainfall measured was from a 2 day period. Therefore a range of AEPs were determined for this storm, about 21% AEP if all the rainfall occurred in one day and about 46% AEP if the rainfall occurred over both. Only three pluviometer gauges in surrounding catchments were online during this event. The range of peak AEPs and durations they experienced were quite similar ranging from a 18% to 30% all over 24 hours. This is seen in more detail in Table 7-3.

**Table 7-3 Gauged Data Available for the February 2010 Event at Woodenbong**

| Gauge | Gauge ID | Gauge Type | AEP for a 24 hour event | Peak AEP and Duration |
|---|---|---|---|---|
| Woodenbong | 57024 | Daily Rainfall | 21%-46% | 21%-46% 1 or 2 days |
| Killarney PO | 41056 | Pluviometer Rainfall | 30% | 30% 24 hour |
| Rathdowney PO | 40178 | Pluviometer Rainfall | 21% | 21% 24 hour |
| Moogerah Dam | 40135 | Pluviometer Rainfall | 18% | 18% 24 hour |

From the historical rainfall captured from pluviography data, the historical storms were recreated in ICM to generate flows and then were run in TUFLOW for flood levels and depths. This occurred for each calibration event.

## 7.6 Model Validation

No detailed flood level markers were available for flood model calibration and therefore a model validation approach has been undertaken against anecdotal evidence provided by the community, and photos provided from SES and council. Some of these photos can be seen in Section 2.3. As many of the comments provided did not include actual dates, times or recorded depths it is difficult to compare directly with the model outputs. A comparison of community comments against the results of the flood modelling has been undertaken to validate that the flood model is reasonably replicating actual flood behaviour.

As shown in Table 7-4 and Table 7-5, generally the model matches well to the anecdotal evidence with key areas replicating similar flood behaviour in the model to what has been reported e.g. inundation in particular areas.

**Table 7-4 Comparison of Flood Model Results and Anecdotal Flooding Evidence from the Community Consultation at Urbenville**

| Location | Date Observed | Observed Flood Behaviour | Model Result |
|---|---|---|---|
| South side of Tooloom Street | 2015 | Ponding | A reasonable match with observed data.<br>Depths of 700 mm seen ponding in the in 2008 storm event. |
| 6 Urben Street | February 2010 | Water in over driveway lapping at house | A reasonable match with observed data<br>150mm depths seen in the model up the side of the property over the driveway in the February 2010 event |
| 6 Urben street | February 2010 | 130 mm of water in front yard | A reasonable match with observed data.<br>Depths of 150 mm observed in the front yard of the property in the February 2010 event. Depths may differ from anecdotal advice as the point of observation is unknown. |
| Tooloom Road (at Old Saw Mill) | 2008 and 2013 | Water over road | A reasonable match with observed data.<br>The road is flooded at this location with varying depths between 300 mm to 1.5 m over road in the 2008 event. |

| | | | |
|---|---|---|---|
| Clarence Way (at bridge heading to Bonalbo | 2008 and 2013 | Water over road | A reasonable match with observed data.<br><br>Depths in the model reach up to 400 mm on road in the 2008 event. |
| 6 Welch Street | No Date | Frequent water ponding at corner of street | A reasonable match with observed data.<br><br>Depths up to 400 mm ponding in the Feb 2010 event which is the smallest calibration event run. |

**Table 7-5 Comparison of Flood Model Results and Anecdotal Flooding Evidence from the Community Consultation at Woodenbong**

| Location | Date Observed | Observed Flood Behaviour | Model Result |
|---|---|---|---|
| 31 Richmond Street | No Date | 500 mm of water in backyard | A reasonable match with observed data.<br><br>400 mm depths in calibration events. Depths may differ from anecdotal advice as data of operation is unknown. |
| Woodenbong Caravan Park / Camping Ground / Baths | No Date | Knee deep slow flowing water | A reasonable match with observed data.<br><br>Up to 300 mm depths in December 2010 and 600 mm in 2008 events across sporting field, these depths are ponded are have low velocities |
| Showground | December 2010 | Showground flooded | A reasonable match with observed data.<br><br>Depths of up to 1.2 m in showground in the December 2010 event. |
| Recreation Road | December 2010 | Water over the banks of creeks and inundated lower paddock | A reasonable match with observed data.<br><br>Depths of 1.2 m in the modelled December 2010 event. |
| 29 Richmond Street | December 2010 | Flood waters affecting properties | A reasonable match with observed data.<br><br>Depths of up to 500 mm on the property in the December 2010 event. |
| 25 and 27 Richmond Street that back onto Bonalbo Lane | December 2010 | Backyard flooding | A reasonable match with observed data.<br><br>Depths up to 200 mm in backyard in the December 2010 event. |
| Black Gully Culvert on Lindsay Creek Road | No Date | Depths of about 1m over road | A reasonable match with observed data.<br><br>Depths of 1.2 and 1.7 m over road in 2010 and 2008 event. Depths may differ from anecdotal advice as data of operation is unknown. |

# 8 MODEL RESULTS

## 8.1 Summary of Flood Behaviour

### 8.1.1 Urbenville

In Urbenville floodwaters exceed the creek capacity in the 5% AEP event causing inundation of roads into the town such as Clarence Way and Toloom Street. As the magnitude of events becomes larger, the flooding from Tooloom Creek becomes more and more significant. This is due to the natural winding topography of the creek near Urbenville and the junction of Boomi and Tooloom Creek occurring just downstream of Urbenville. These two occurrences slow the floodwaters within the creek and cause backwater up into the town from the Creek. There is also flooding from the local catchments as floodwaters travel between Welch and Urben Street downhill.

### 8.1.2 Woodenbong

Breakout flows from Tooloom Creek combine with local catchment flows through Black Gully to flood the showground and the sporting fields in events more frequent than the 20% AEP event.

At Woodenbong, properties at Richmond Street experience flooding in their backyards from the channel running behind the properties. There is also flooding in areas near Roseberry Street from Tooloom Creek and Black Gully. This only occurs in severe events. The remainder of the township is affected by minor flow paths along the roads which are typically shallow and contained in the kerb and gutters or drains.

### 8.1.3 Tooloom and Boomi Creeks

In the Tooloom and Boomi Creek catchment the roads between the two towns are subject to flooding from the creek, and from flow paths coming to the creek. As the events become larger and the flood extent of Tooloom and Boomi Creek grows the amount of flooding of roadways increases. The primary source of flooding on roads along Tooloom and Boomi Creek is from mainstream flooding where this is little elevation change between the road and creek.

### 8.1.4 Muli Muli

Muli Muli is located next to Tooloom Creek. Clarence Way Road, the only road connecting Muli Muli to the other townships is flooded in events as frequent as the 20% AEP event. Muli Muli is typically not inundated until events greater than the 0.2% AEP event when Muli Muli Crescent can become inundated.

### 8.1.5 Urbenville Flood Behaviour

#### 8.1.5.1 20% AEP event

At Urbenville floodwaters largely remain within Tooloom Creek in the 20% AEP, although there are breakout flows downstream of Clarence Way road bridge into the open areas behind Tooloom Street. Depths are between 200 to 300 mm and inundate some lots south of Tooloom Street.

Floodwaters also overtop Clarence Way near to the showground with depths of 200 mm over the road. There is no culvert crossing at this location, although drainage channels are evident either side of the road.

The flooding that occurs in the town is dominated by flow from the local catchments. The majority of flooding occurs in the natural flow path as water travels from the hill slopes west of the town. Minor flow paths from between the Welch and Urben Street as overland flows downhill. When the overland flows join the Tooloom

Creek they overtop Tooloom Street with depths up to 400 mm. Flood levels here are dominated by flows from Tooloom Creek.

#### 8.1.5.2 5% AEP Event

At Urbenville in the 5% AEP floodwaters have broken out of the Tooloom Creek, with up to 1 m depths on the floodplain south of Tooloom Street. There are flood water depths of up to 600 mm on the lots on the south side of Tooloom Street. Clarence Way road is overtopped with depths of 400 mm on the road. Tooloom Street is overtopped from tailwaters of Tooloom Creek with depths of 1 m over the road. The flooding in the town is caused from flows in local catchments with floodwaters travelling downhill between Welch and Urben Street.

#### 8.1.5.3 1% AEP Event

At Urbenville in the 1% AEP event, depths of up to 1.6 m is predicted to occur on lots on Tooloom Street. Floodwaters from Toloom Creek cross Tooloom Street to properties on the north side of the street. There are predicted depths of up to 0.8 m on Clarence Way and backwaters from the creek cause depths of 2.6 m on Tooloom Street near the Old Saw Mill, the flooding from Tooloom Creek reaches the south end of Boomi Street. The flooding within the town is from overland flows besides the floodwaters south of Boomi Street.

#### 8.1.5.4 0.2% AEP Event

At Urbenville In the 0.2% AEP even the flood behaviour is similar to the 1% AEP event in terms of areas affected by creek and overland flow flooding asides from the creek floodwaters have crept further into the town crossing further over Tooloom Street and approaching Stephen Street.

#### 8.1.5.5 PMF Event

At Urbenville in the PMF event all the floodwaters are predominantly from Tooloom Creek. Depths become very significant and reach up to 9 m on Tooloom Street. High hazard affects most of the study area.

### 8.1.6 Woodenbong Flood Behaviour

#### 8.1.6.1 20% AEP event

Breakout flows from Tooloom Creek combine with local catchment flows through Black Gully to flood the showground and the sporting fields in events more frequent than the 20% AEP event . The backwaters from the creek cause and tributary cause flooding on the sporting fields and showground, with the waters extending as far east as Black Gully.

The town flooding is predominantly within the kerb and gutter which is caused by overland flows, with only minor flooding along the streets. There is some inundation of properties and backyards on Richmond Street from the local catchment and the channel running behind these properties to the south. Mount Lindsay Road is flooded in a localised section from the local catchment with depths up to 500 mm.

#### 8.1.6.2 5% AEP Event

In Woodenbong the 5% AEP flooding is very similar except the flood extents caused by the creek backwaters have expanded. The showground and playing fields have larger depths and flood extents. The flooding within the town remains within the drains and gutters alongside the roads except for minor breakout flow. At Richmond Street floodwater from the local catchments travels in the natural channel behind Richmond Street and overtops the levee. The number of properties inundated from remains the same as the 5% AEP, however the flood extent on these properties has increased.

#### 8.1.6.3 1% AEP Event

In Woodenbong in the 1% AEP event, the floodwater behaviour is very similar to the 5% AEP event. There are greater flood depths on the showground, playing fields and Lindsay Creek Road from Tooloom Creek backwaters. The flooding within the town stays confined to minor flow paths alongside the roads with small depths travelling between properties. The majority of flows from the external catchment travel through the flowpath behind Richmond Street and overtopping the levee into the properties.

#### 8.1.6.4 0.2% AEP Event

In Woodenbong in the 0.2% AEP the floodwater behaviour is very similar to the 1% AEP. There are greater flood depths on the showground, playing fields and Lindsay Creek Road from Tooloom Creek backwaters. The industrial sheds along Roseberry Road are inundated from these floodwaters. There town still remains predominantly flood free with minor flow paths alongside the roads. The majority of flows from the external catchment travel through the flowpath behind Richmond Street and overtopping the levee into the properties, all properties north of Dalmorton Street are inundated in this event with depths up to 1.0 m.

Across the Tooloom and Boomi Creeks between the two towns in the 0.2% AEP event the connecting roads between towns are inundated in multiple areas; see Section 9.2 for more details.

#### 8.1.6.5 PMF Event

In the PMF event at Woodenbong there are greater flood depths on the showground, playing fields and Lindsay Creek Road from Tooloom Creek backwaters. Properties up to Roseberry Lane are inundated by floodwaters. The town still remains predominantly flood free with flow paths alongside the roads and crossing a small amount of properties. The majority of properties behind Richmond Street are now inundated from floodwater in the channel behind the properties.

### 8.1.7 Tooloom and Boomi Creek

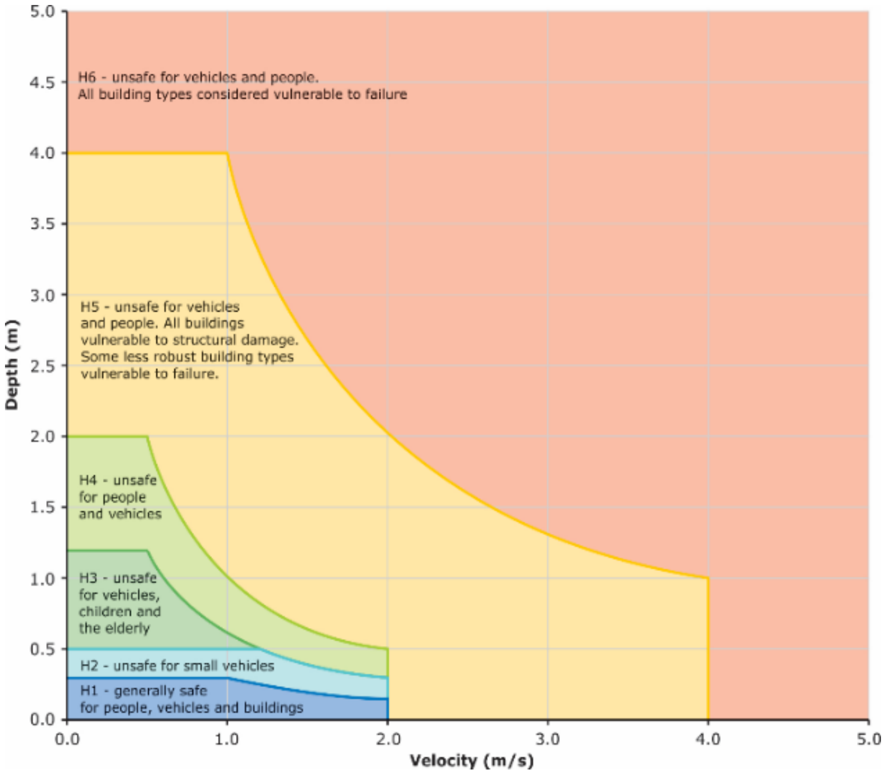
In the 5% AEP for the Tooloom Creek catchment between the towns, the creek remains mainly within its channel with minor locations of breakout flows such as at Woodenbong. There is a small number of locations where the road is  are flooded with the major flooding of the roadway occurring near Muli Muli. The town of Muli Muli is above the creek flood level in this flood event. The road is not passable with the path to the north and south with a hazard rating of unsafe for vehicles.

In larger events such as the 20% AEP event Tooloom Creek and Boomi Creek have expanded to fill the floodplain. In the 1% AEP event between the two towns the connecting roads are inundated at multiple locations near Mulli Mulli and Urbenville. Further inundation occurs from mainstream flooding of the creeks and connecting tributaries flooding the roads, more information on this can be seen in Section 9.2.

In Tooloom Creek and Boomi Creek in the PMF event there are greater flood depths than other events, with more floodwater crossing more areas of Clarence Way and Boomi Creek Road.

## 8.2 Flood Hazard

Mapping of flood hazard for is included in Appendix B. Flood hazard classifications described in ARR 2016 (Book 6, Chapter 7: Safety Design Criteria) have been adopted for the Urbenville and Woodenbong Flood Study as they it provide a greater range of hazard classifications than the provisional hazard categories described in the Floodplain Development Manual 2005. The ARR2019 hazard classifications are in line with AIDR Guideline 7-3 Flood Hazard (Australian Institute for Disaster Resilience (AIDR), 2017).




H1 – Generally safe for vehicles, people and buildings.

H2 – Unsafe for small vehicles.

H3 – Unsafe for vehicles, children and the elderly.

H4 – Unsafe for vehicles and people.

H5 – Unsafe for vehicles and people. All buildings vulnerable to
structural damage. Some less robust buildings subject to failure.

H6 – Unsafe for vehicles and people. All building types considered vulnerable to failure.

**Figure 8-1: ARR2019 / AIDR General Flood Hazard Curves**

### 8.2.1 Urbenville

At Urbenville in the 20% and 5% events the hazard is quite similar with few areas of high hazard within the town. Areas of high hazard are on the defined flow paths both the overland flow path from the west and Tooloom Creek. There is a high hazard rating at Tooloom Street near the Old Saw Mill, and Clarence Way Road. In the 5% event some properties south of Tooloom Street near the floodplain are classified as H4 due to the flood depths. The 1% and 0.02% AEP event areas of high hazard are present towards the town as the creek flood levels starts to dominate over local catchment flood levels. In the PMF event the whole town is in high hazard H6 due to the depths of floodwater and velocities.

### 8.2.2 Woodenbong

In Woodenbong in the 20% and 5% there are typically no areas of high hazard with the area being zoned H1 and H2 asides for the defined channels and creeks. As depths increase on the showground and sporting fields their hazard rating increases. In the 1% and 0.2% event the majority of the town is still H1, with flow paths now becoming H5 rating. Some properties on Richmond street are defined as H3 due to flood depths, as does the showground and sporting fields. Mount Lindsay Road is classified as H4 and H5 in certain areas where flooding overtops the road. In the PMF, the properties along Richmond Street and on the northern end of Roseberry Street are classified as H5.

### 8.2.3 Muli Muli

Muli Muli Crescent is flooded and is classified as H4 in a PMF event. In the 20% AEP event Clarence Way to the north and south of Muli Muli is classified as H4 which is considered unsafe for vehicles and people.

## 8.3 Flood Function

Hydraulic categories were determined in consideration of with the Floodplain Risk Management Guideline Floodway Definition and the Floodplain Development Manual definitions. Floodways are areas important for conveyance of water flows during floods. These areas are typically naturally defined channels. Flood storage is areas of large depths but slower velocities. These areas are typically overbank flow from the defined channels and creeks and if filled would cause adverse effects on flood behaviour elsewhere. Flood fringe considered as areas of shallow depths and slow velocities.

The following criteria was used to establish the provisional flood function based on Howells et al. (2004) and is mapped in Appendix B:

Floodway:

- Velocity x Depth must be greater than 0.25 $m^2/s$ AND velocity must be greater than 0.25 m/s; OR
- Velocity is greater than 1 m/s

All other areas were determined as Flood Storage except areas where flood depths were less than 200 mm which were classified as Flood Fringe.

At Urbenville in the 20% AEP event, the floodways occur in the main channels such as Tooloom Creek and the channel running south of Urbenville Road. In the 1% AEP event, areas of floodplain in the fields south of Tooloom Street are classified as floodway as the depths and velocities in this area increase. The channel running south of Urbenville Road has a larger area of floodway. In the PMF event the majority of the town is classified as floodway as depths from the creek are significant. The velocities from the overland flows are high reaching greater than 1 m/s classifying the area as floodway .

At Woodenbong, in Tooloom Creek in the 20% AEP event the flow through the creek is classified as floodway due to the high velocities and depths through the natural creek path. In the 20% AEP the floodways occur in the main drainage channels, Tooloom Creek, Black Gully and the channel running behind Richmond Street. There are areas of floodway within the town in the drainage channels along the streets, as the velocities in the drainage channels are high.

In the 1% AEP event the floodways extents increase in all areas of the town. In the PMF event the extent of floodway has expanded to affect a number of properties on Richmond Street and the industrial lots of Roseberry Street.

## 8.4 Climate Change

Assessment of the potential effects of climate change allows for Council to understand the implications of on flood planning into the future, for example, if the flood planning area need to be extended or flood planning levels increased.

ARR2019 recommends the application of percentage increases in rainfall based on climate scenarios assessed by CSIRO. Through the ARR data hub, Interim Climate Change Factors are provided with percentage increase in rainfall to be applied to a range of future years. ARR2019 recommends the use of RCP4.5 and RCP8.5 values. For Urbenville and Woodenbong this equates to an increase in rainfall of about 9.5% (RCP4.5) and 19.7% (RCP8.5) to 2090.

As per the project brief, a comparison of the 0.2% AEP event to the 1% and AEP event has been used as a proxy to assessment of climate change and also the recommendations of ARR2019. Figure 8-3 and Figure 8-2 shows the difference in peak water levels between the 1% AEP and 0.5% AEP events for Woodenbong and Urbenville. While a percentage increase in rainfall does not directly equate to the same percentage increase in peak flows, adopting 0.5% AEP as a proxy for climate change is considered a suitable estimate.

At Woodenbong there are increases of 15% of flows in Tooloom Creek and water level increases of up to 250 mm. This increase also occurs on Black Gully and the natural channel behind Richmond Street. Within the town of Woodenbong itself there are increases of approximately 3 mm across properties and up to 15 mm in some localised channels.

At Urbenville there is a 36% increase in catchment flows between the 1% and 0.2% AEP events and there are increases in predicted peak water level of up to 900 mm. In areas affected by local catchment flows, there are smaller increases of up to 50 mm on properties within the town, and up to 300 mm on the main flow path from the north west. The Was Dry Now Wet sections of the floodplain show the increase of flood extents between the two events.

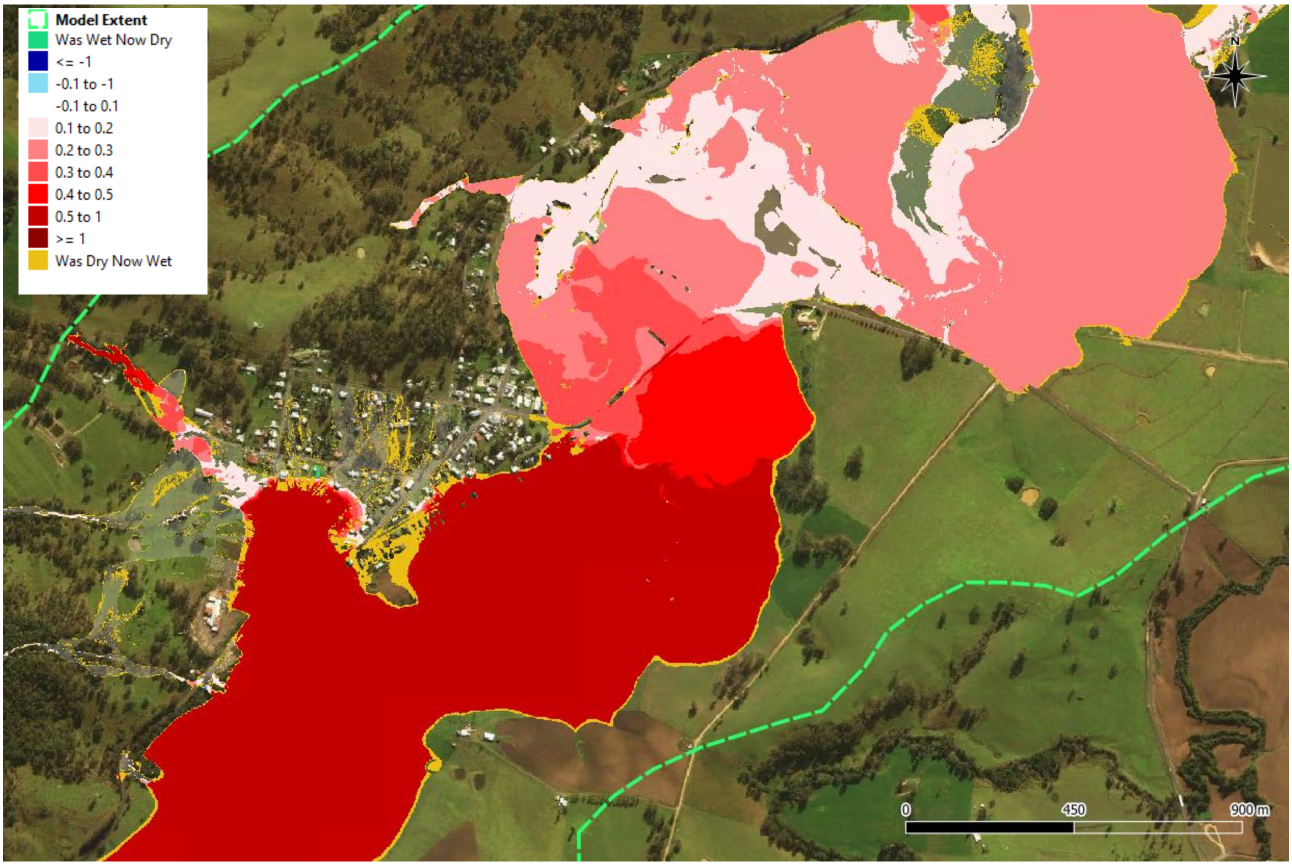



**Figure 8-2: Urbenville - Water Level Difference between 0.2% and 1% AEP**

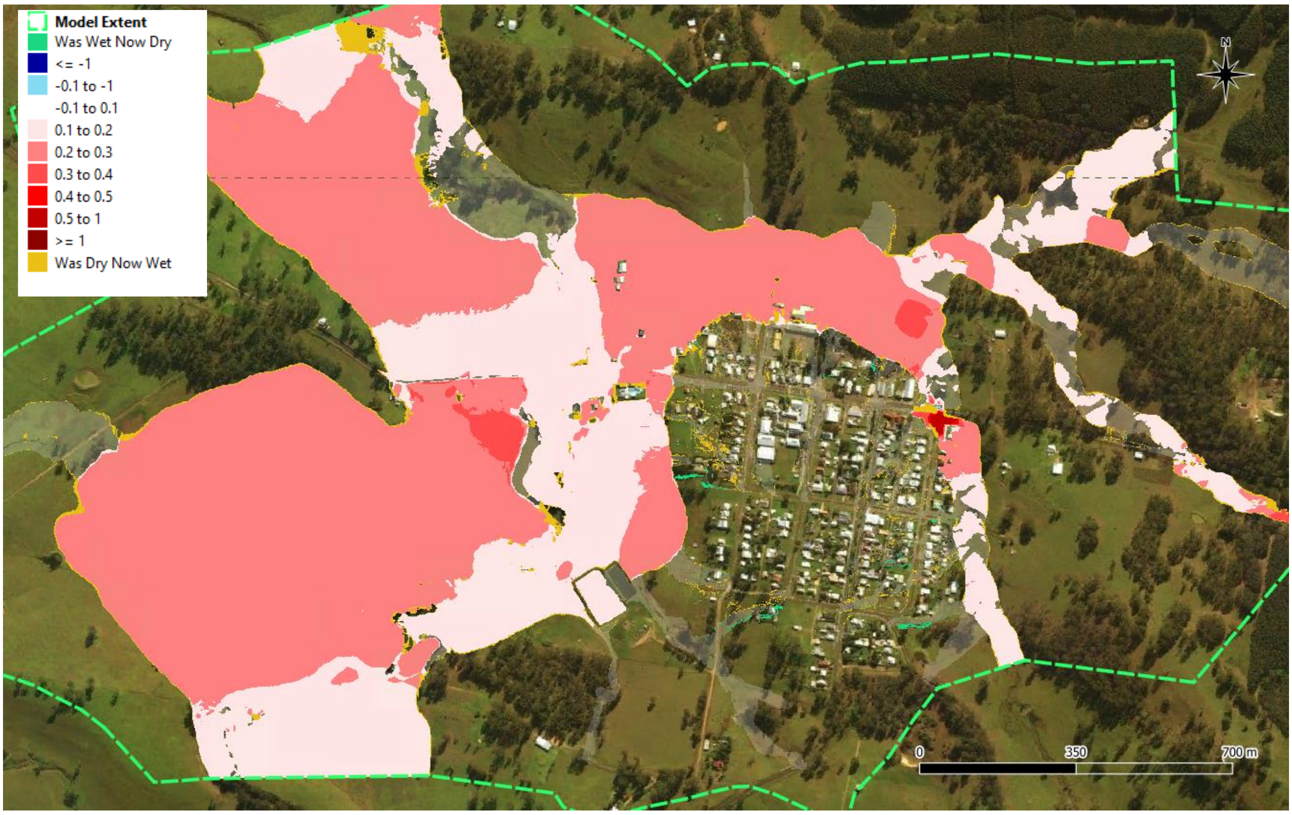



**Figure 8-3: Woodenbong - Water Level Difference between 0.2% and 1% AEP**

## 8.5 Blockage Analysis

Sensitivity testing of the model was undertaken with blockage analysis with the blockage increased from 50% to 100% in the stormwater network across all the models, this is increasing the risk factor of blockage from Medium to High in ARR2019. The results from the sensitivity test show no large differences with only localised changes occurring at culvert entry locations.

At Urbenville there are localised increases at the intersection of Beaury Street and Tooloom Street with increases of 200 mm in the 1% AEP due to the blockage of the two 450 mm culverts under Tooloom Street.

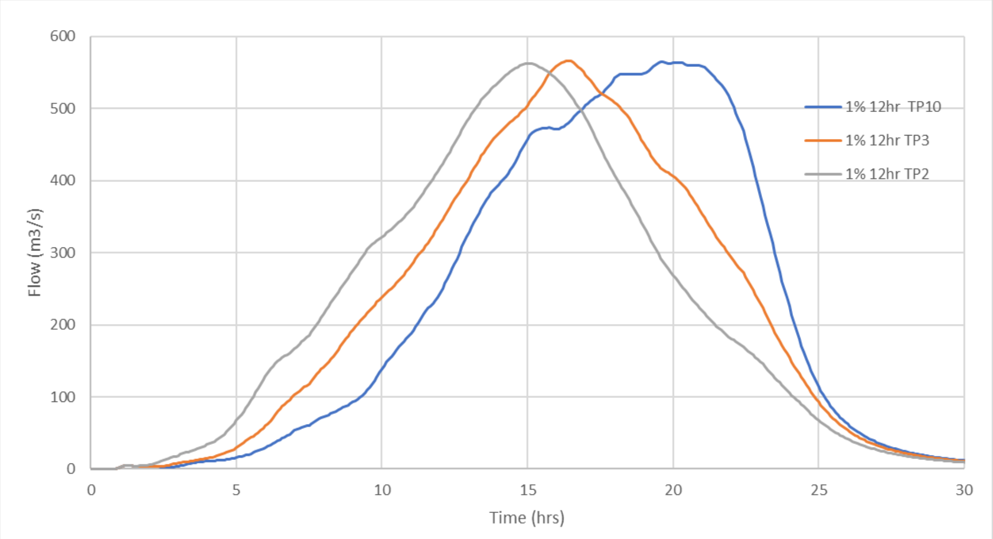
At Woodenbong significant increases in peak flood level occur at the natural overland channel behind Richmond Street crosses Mount Lindsay Road. There are increases in this area of up to 400 mm in the 1% AEP. This is due to the increased blockage at the culvert crossing under Mount Lindesay Road. Although no existing buildings are affected by this increase, this shows the importance of maintenance of the waterways and structures to minimise blockage risk.

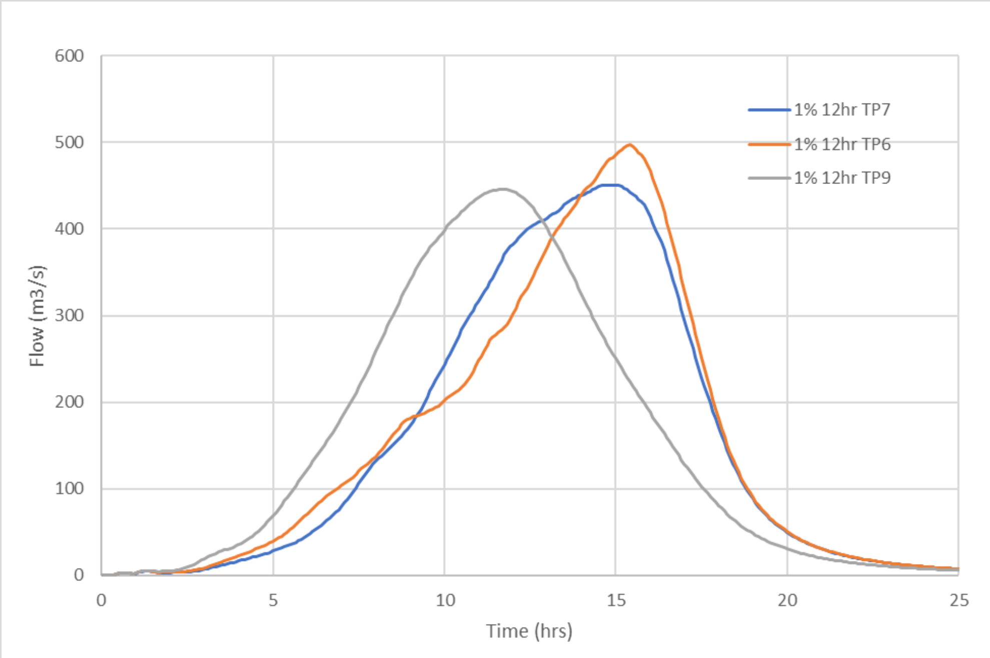
## 8.6 Sensitivity Analysis

Sensitivity analysis has been undertaken to observe the influence of model parameters on the predicted flood behaviour. Sensitivity was undertaken by adjusting relevant parameters in both the hydrologic rainfall routing model (ICM) and hydraulic (TUFLOW) models and assessed against the 5% AEP and 1% AEP design events.

**Table 8-1: Model Sensitivity Assessment**

| Parameter and Sensitivity Assessment | Outcomes |
|---|---|
| Initial and Continuing losses<br><br>a) Adopt ARR19 Losses: IL to 51 mm and CL to 4.7 mm/hr | NSW FFA-reconciled losses applied in the hydrology model are IL 49.7 mm and CL 3.26 mm/hr. As a sensitivity these have been increased to ARR data hub values for the region of IL 51 mm and CL 4.7 mm/hr.<br><br>At Woodenbong there is a decrease of flows due to the increase of initial and continuing losses. There is a 7% and 11% decrease in flows in the 1% and 5% AEP events respectively. These are decreases from 451 to 418 $m^3/s$ and 305 to 272 $m^3/s$ for each event. For Urbenville the results are very similar with decreases of 8% and 14% in flows in the 1% and 5% AEP events. These are decreases from 564 to 521 $m^3/s$ and 357 to 308 $m^3/s$.<br><br>The adopted NSW FFA-reconciled losses are therefore more conservative than the ARR data hub values. The NSW FFA-reconciled losses are considered more appropriate for the Tooloom catchment as they are based on observed data at a nearby similar catchment. |
| Hydraulic roughness<br><br>a) Increase of 20%<br><br>b) Decrease of 20% | Increasing the Mannings n roughness value slows down the floodwater velocities within the model extent and typically causes higher flood depths. By increasing the roughness by 20% within the model there is an increase of flood levels across the model. At properties within Urbenville there is maximum increases of 6 mm and within Tooloom Creek near Urbenville these increases vary between 70 to 100 mm. At Woodenbong there are increases of up to 5 mm within the town. Inside defined channels such as Black Gully and Tooloom Creek these increases are up to 100 mm.<br><br>Decreasing the roughness by 20% has the opposite effect, increasing flood velocities and lowering flood depths. At Urbenville within well-defined channels there are decreases up to 120 mm. In the township there are decreases up to 10 mm in local overland flows. At Woodenbong within the town flood levels decrease by 5 mm, and within defined channels such as Black Gully and Tooloom Creek levels decrease by up to 50 mm and 100 mm respectively.<br><br>While the model has some sensitivity to hydraulic roughness, the large differences are seen to occur in the defined waterways and have little impact on properties within either town. |
| Structure losses at bridges over Tooloom Creek<br><br>a) Increase by 10%<br><br>b) Decrease by 10% | Increasing the form losses in the bridges of each model has no significant result in Tooloom Creek in the 5% or 1% AEP events. At Urbenville there are increases of 1 mm upstream of the Clarence Way Bridge. And at Woodenbong there are decreases of 5 mm and decreases of 4 mm either side of Mount Lindsay Road Bridge over the Tooloom Creek.<br><br>Decreasing the form losses at Urbenville has no significant result in the creek in the 5% AEP event or the 1% AEP event. There are decreases upstream of Clarence Way Ridge of 1 to 3 mm in each event. At Woodenbong there are decreases of 5 mm upstream of Mount Lindsay Road Bridge, and increases of 1 mm downstream as floodwater move more efficiently through the structure.<br><br>The model has limited sensitivity to structural losses. |

| Parameter and Sensitivity Assessment | Outcomes |
|---|---|
| Downstream boundary conditions<br>a) Increase slope by 20%<br>b) Decrease slope by 20% | Downstream boundary sensitivity is undertaken to ensure that the model extends suitably downstream so that boundary affects do not influence the predicted flood behaviour in the study area.<br>By increasing the slope on the downstream boundary the flood levels are reduced by at up to 300 m upstream of the boundary of the creek model. This is still significantly far from Urbenville to have no impact on flood levels within the town.<br>Decreasing the slope by 20% increases flood levels by up to 300mm upstream of the boundary. This is still significantly far from Urbenville to have no impact on flood levels within the town.<br>This has no effect on the flood behaviour at the towns as the boundary is significantly far away from Urbenville. |
| Temporal Patterns | Sensitivity to temporal patterns assists in understanding flood response times to rainfall and available warning times for flood emergency response and will be considered further in the Floodplain Risk Management Study and Plan.<br>The upper median temporal pattern is the closest highest neighbor to the median has been chosen for each design event from the 10 potential temporal patterns as per ARR2019. For sensitivity testing the temporal pattern which produces the peak flow either side of this has been compared in the rainfall routing model.<br>In Tooloom Creek at Urbenville the upper median temporal pattern (TP10) has a peak flow of 564 $m^3/s$. The temporal pattern producing the peak above the selected temporal pattern has a peak flow of 566 $m^3/s$ (TP3) and the temporal pattern below has a peak flow of 562 $m^3/s$ (TP2). The peak flows are with 1 % of each other and will have negligible effect on flood levels within the town.<br>The hydrographs for these patterns are seen below. The selected temporal pattern (TP10) has a similar rate of rise than the others, with 5 hours difference between the two peaks.<br><br>**Figure 8-4: Urbenville Temporal Patterns**<br>At Woodenbong in Tooloom Creek there is a peak flow of 451 $m^3/s$ in the selected temporal pattern (TP7). The temporal pattern below (TP9) has a peak flow of 446 $m^3/s$ and the temporal pattern above (TP6) has a peak flow of 497 $m^3/s$. The difference in flows are insignificant to impacts on flood levels within the township. There is a slight difference in |

| Parameter and Sensitivity Assessment | Outcomes |
|---|---|
| | timings between the chosen and lower temporal pattern, with approximately 3 hours difference in peaks between the two.<br><br>**Figure 8-5: Woodenbong Temporal Patterns** |

# 9 CONSEQUENCES OF FLOODING ON THE COMMUNITY

## 9.1 Flood Emergency Reponses Classification of Communities

The Flood Emergency Response Classification of Communities (DECC, 2007) is defined to assist in managing flood evacuation and response. Areas are broadly classified based on the flood effect to the area and to the local evacuation routes before the flood peak.

The Flood Emergency Response Classification is mapped in Appendix C.

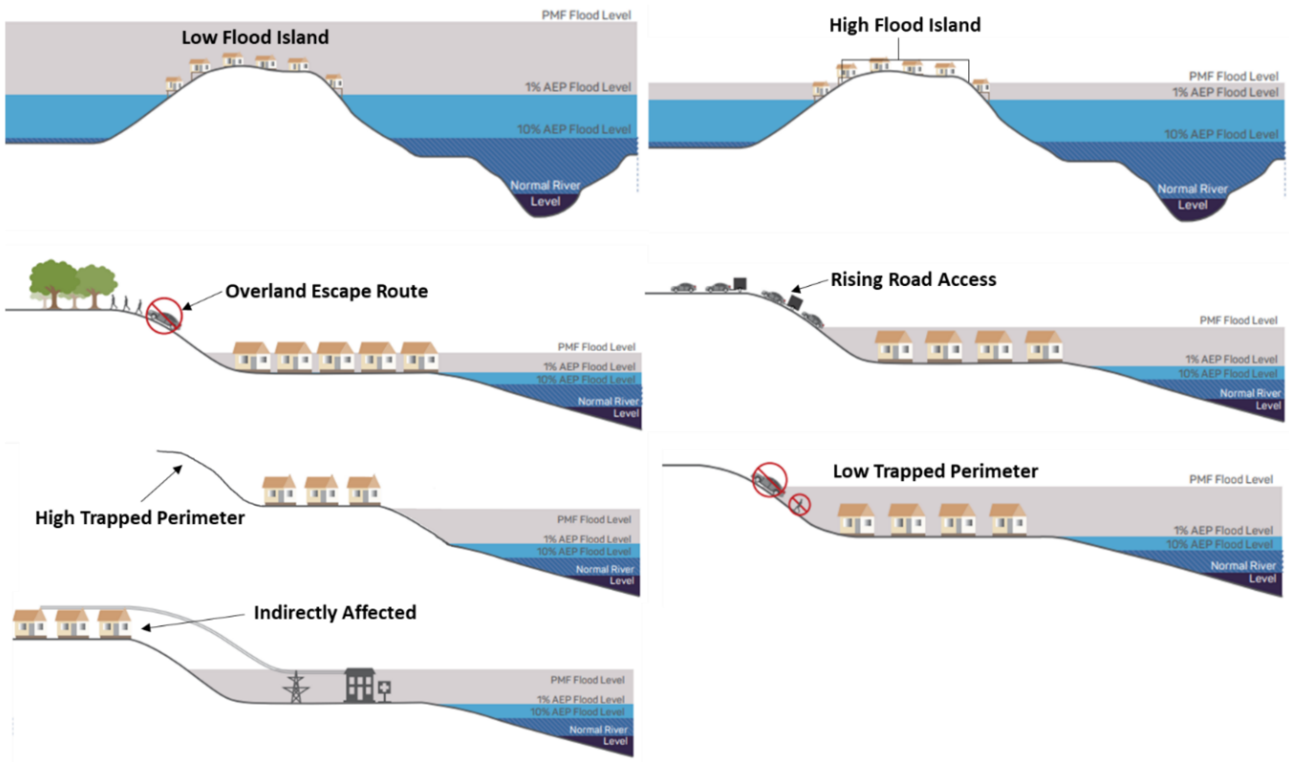



**Figure 9-1: Schematic of ERP Classifications (adapted from Guideline 7-2; Flood Emergency Response Classification of the Floodplain (Australian Institute for Disaster Resilience (AIDR), 2017))**

### 9.1.1 Urbenville

The north side of the town within the Tooloom Creek flood extent is classed as Rising Road Access where people can evacuate via vehicle before the peak of the flood (subject to sufficient warning). Outside of the flood extent is typically classed as High Trapped Perimeter. This area is above the PMF extent of the creek but has no route for evacuation. It is expected that Urbenville Road to the west would be cut by flooding from Beaury Creek based on photographs provided of flooding along this road (note the road is outside of the study area and therefore has not been included in the flood modelling).

The Old Saw Mill on Tooloom Road is classified as Area with Overland Escape Route, the roads are cut off from the local catchment overland paths. This area is within the PMF extent and could be subject to inundation. There are overland escape routes via foot, this would be to no habitable areas to evacuate to only the surrounding bushland which is classified as High Trapped Area. Within the floodplain there are areas of Low Flood Islands this includes the Urbenville Showground and Camping Ground.

**Table 9-1: Urbenville Township Number of Lots in FERP Category**

| Classification | Number of Lots |
|---|---|
| Rising Road Access Area | 141 |
| High Trapped Area | 129 |
| Area with Overland Escape Route | 3 |
| Low Flood Island | 7 |

### 9.1.2 Woodenbong

At Woodenbong, the majority of the town is classed as Indirectly Affected. There is an escape route from the town through Boomi Creek Road and Old Bruxner Creek Road. This is an unsealed road, which may not be passable to all vehicles in an extreme weather event. This road joins Mount Lindesay Road further east of the town outside of the flooding from Tooloom Creek. Areas within the flood extent are classed as Rising Road Access as they have road access to move to higher ground before being inundated. There are areas of Low Flood Islands within the floodplain near Woodenbong this includes the Woodenbong Campground and swimming pool.

**Table 9-2: Woodenbong Township Number of Lots in FERP Category**

| Classification | Number of Lots |
|---|---|
| Indirectly Affected | 184 |
| Rising Road Access | 58 |
| Low Flood Island | 3 |

### 9.1.3 Tooloom and Boomi Creek

Throughout the Tooloom Creek catchment areas in the floodplain are typically considered as High Trapped Perimeter Areas. Areas outside of the flood extents could be cut from vehicular or overland on foot access to areas of safety. Areas within the PMF flood extent are classified as Areas with Overland Escape Routes, these areas are able to leave before being flooded, however can only travel to the High Trapped Perimeter Areas.

### 9.1.4 Mulli Mulli

Muli Muli is a High Trapped Perimeter are due to inundation of the Clarence Way to the north and south in the 20% AEP event. The town itself is not flooded until events larger than the 0.05% AEP event however has no means of evacuation or self-resupply.

## 9.2 Road Inundation

Clarence Way runs between Urbenville and Woodenbong towns. The road is prone to flooding at various locations. Figure 9-4 shows a long section of Clarence Way between the towns.

There are sections of the road where flooding occurs more frequently such as the section south and north of Muli Muli which is more prone to flooding due to the natural topography. In the 20% AEP event the road could be inundated for about 8 hours and in the 1% AEP event for about 15 hours.

In the PMF the road is flooded along most of its length. This flooding is predominantly from Tooloom Creek overtopping the road. This can be seen in the Figure 9-4: Long Section of Clarence Way from Urbenville to .

Figure 9-5 shows a long section of Boomi Creek Road which runs alongside to Boomi Creek. Areas where the road is flooded frequently can be seen. For the majority of areas subject to frequent flooding, inundation occurs where the road crosses the creek or the where it is inundated from mainstream flooding from the rise in water levels in the creek. Road inundation occurs from tributaries of Boomi Creek but not as significant depths. The most significant area of flooding is the Boomi Creek Road crossing of Boomi Creek to the east of the Boomi Creek Road and Clarence Way Road intersection. At this location the road can be submerged for about 15 hours in the 20% AEP event and 20 hours in the 1% AEP event.

Mount Lindesay Road crosses Tooloom Creek at Woodenbong to the west of the town. Figure 9-2 shows the modelled design water levels over the bridge, the bridge is expected to be inundated above deck from the 5% AEP and greater events. Depths of 3 metres over the bridge are expected in the PMF event.

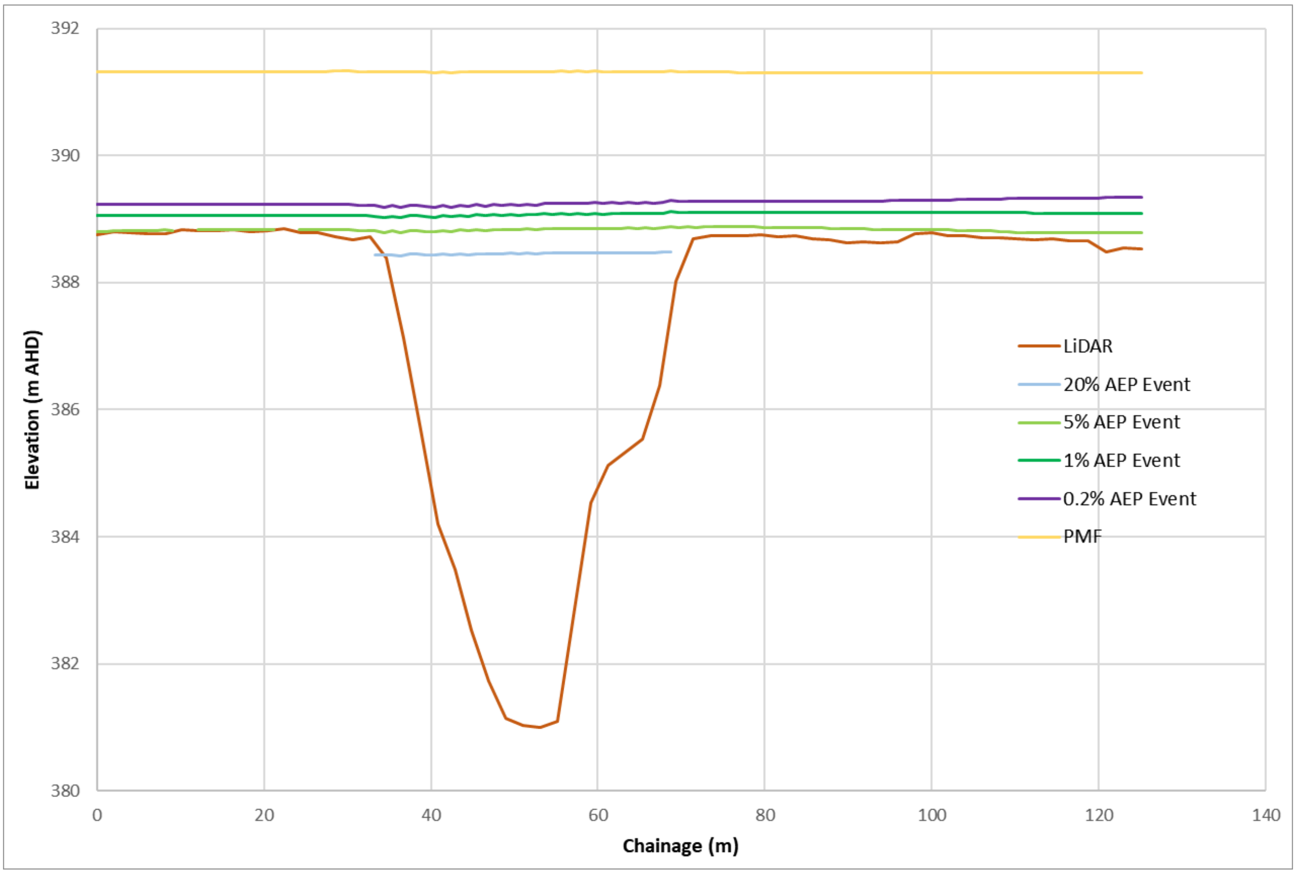



**Figure 9-2: Mount Lindesay Road Bridge over Tooloom Creek at Woodenbong**

At Urbenville the Clarence Way Road Bridge crosses Tooloom Creek to the north of the town. Figure 9-3 shows the design modelled water levels on the bridge crossing. The bridge is not anticipated to be overtopped above deck level until events greater than the 0.2% AEP event.

Further to the east, Clarence Way Road is flooded in all events as it passes the showground and camping ground. At this location there is no culvert however drainage channels are evident either side of the road. The hazard in the 20% AEP is H1 generally safe for people and vehicles meaning the road is still trafficable in this event however in the 5% AEP is H4 unsafe for vehicles and people. From this event onwards the road is not safe to use.

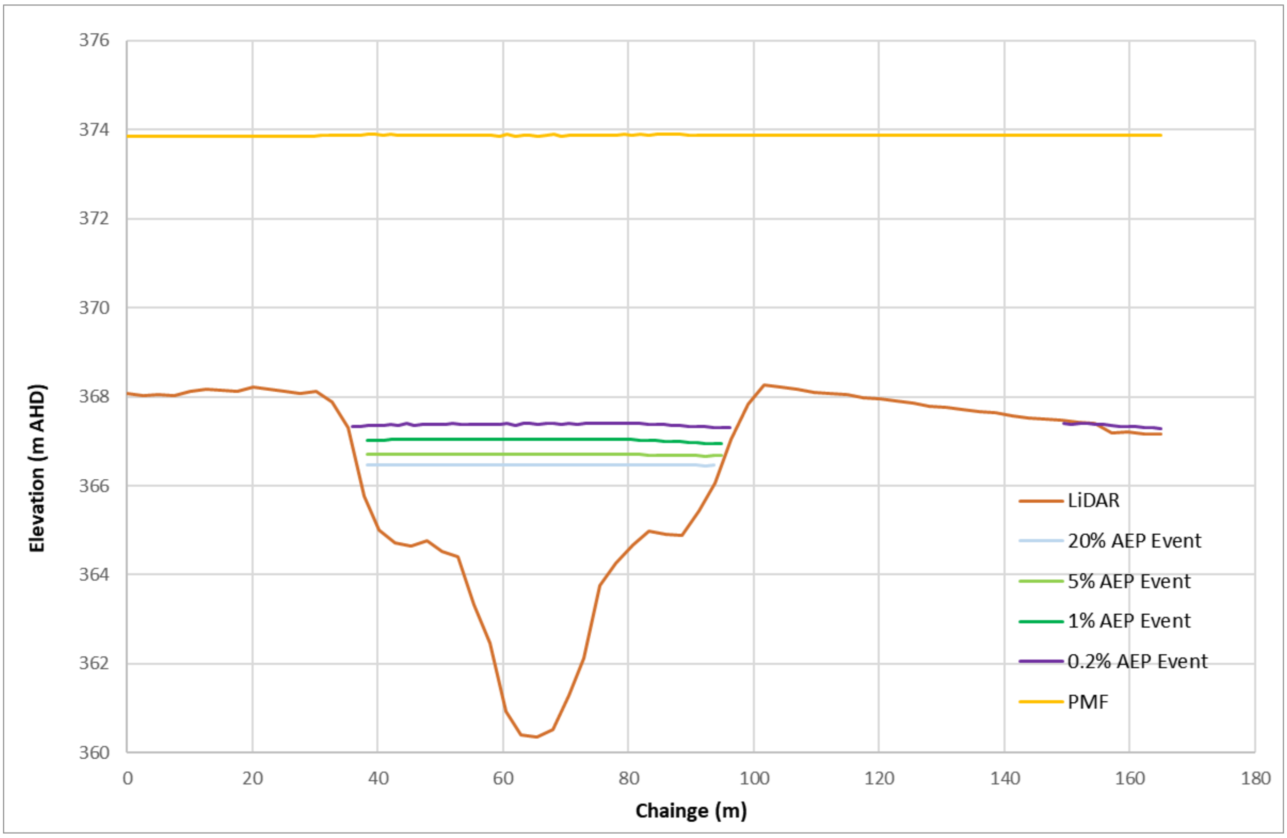



**Figure 9-3: Clarence Way Road Bridge over Tooloom Creek at Urbenville**

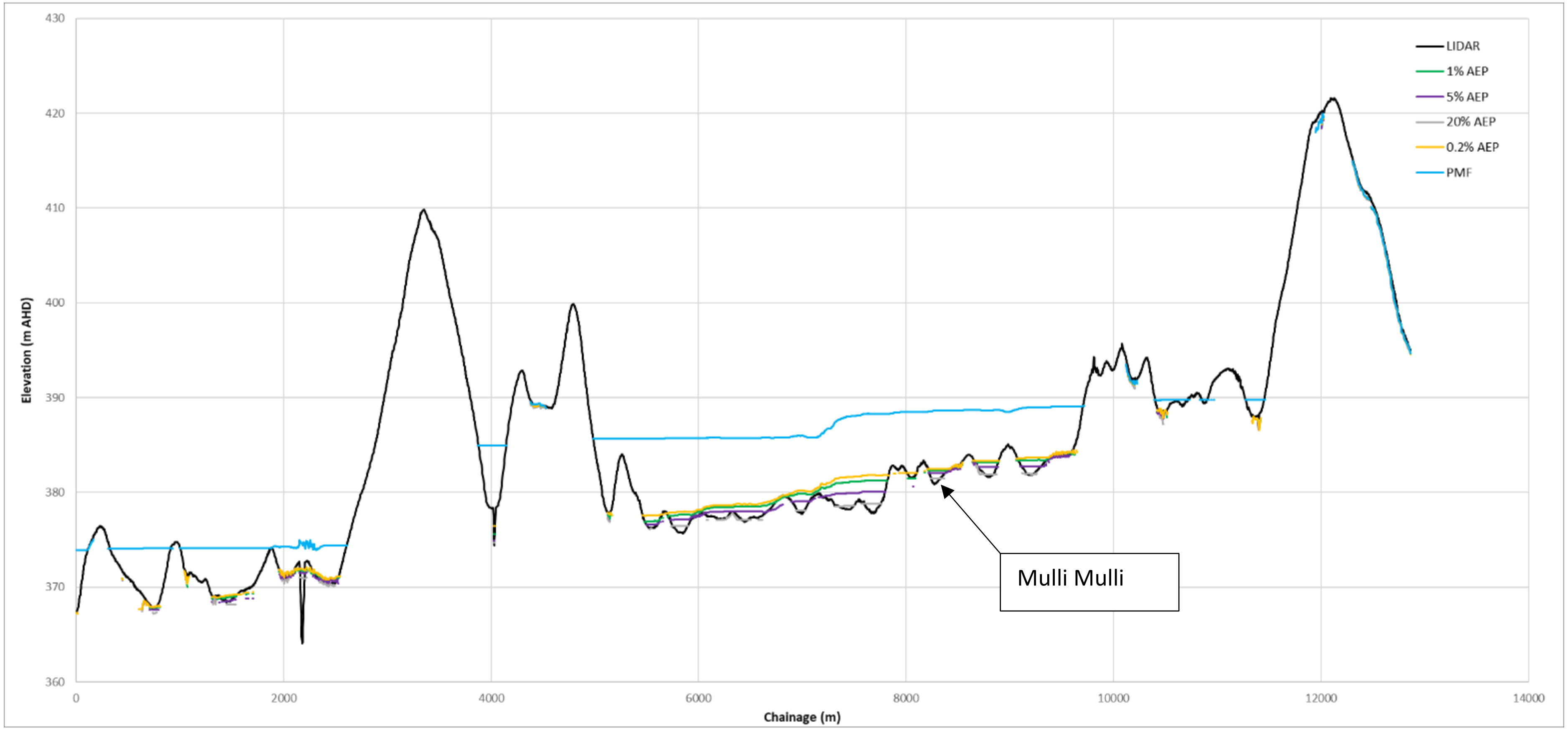



**Figure 9-4: Long Section of Clarence Way from Urbenville to Woodenbong**

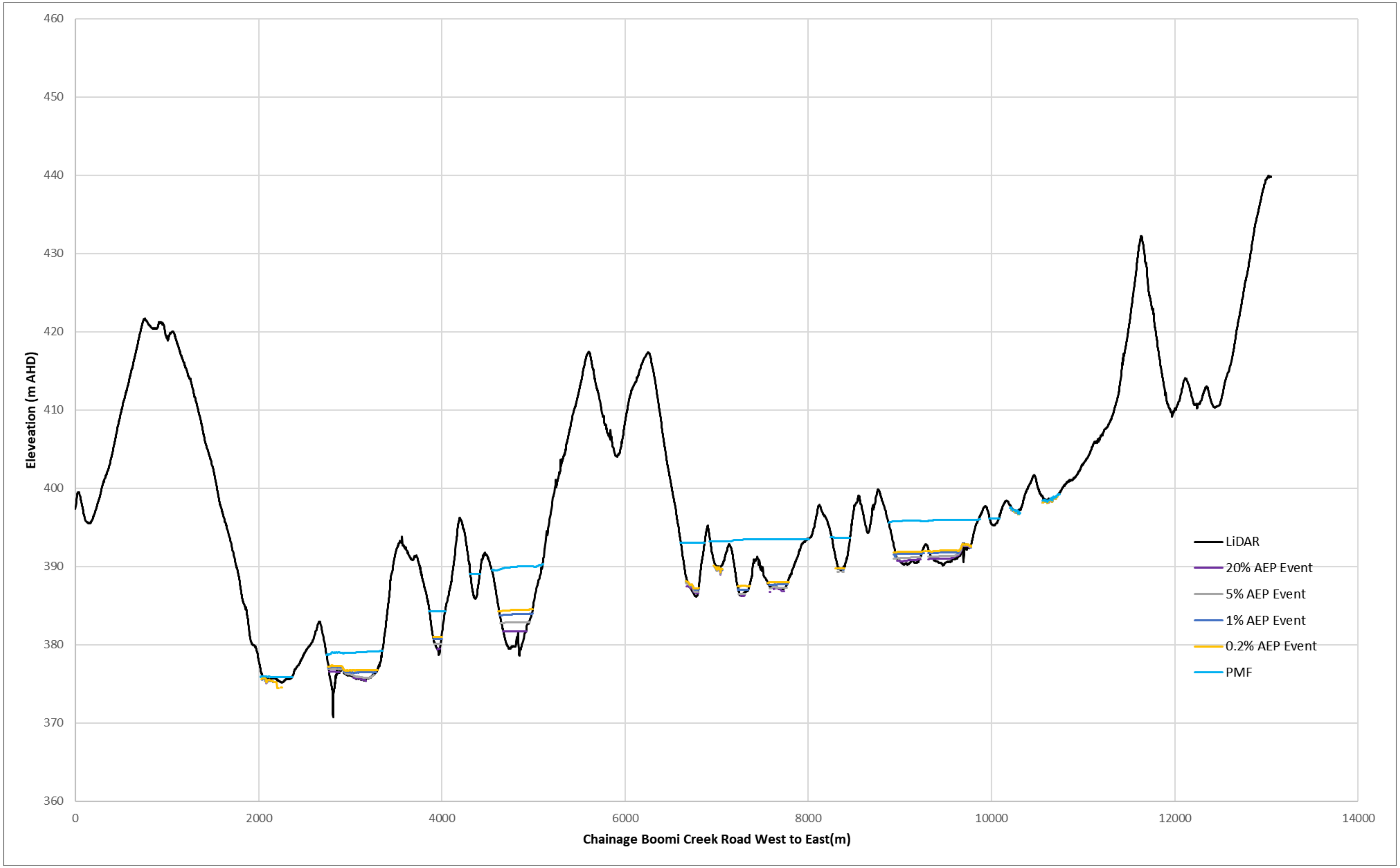



**Figure 9-5: Long Section of Boomi Creek Roa**

# 10 MANAGING ACTIVITIES IN THE FLOODPLAIN AND FLOOD RISK

## 10.1 Land Use Planning

### 10.1.1 Urbenville

The town of Urbenville is classified as RU5 Village with the surrounding area classified as RU1 Primary Production and areas of national park classified as E1 National Parks and Nature Reserves to the east of the town.

Where Tooloom Creek fills the floodplain in areas south of Tooloom Street it is recommended that the future Floodplain Risk Management Study and Plan consider appropriate land use zoning in this area to restrict further development in the floodway. The showground and campground is flooded frequently in the 5% and 20% event as H4 unsafe for vehicles and people. This area should not be rezoned in the future.

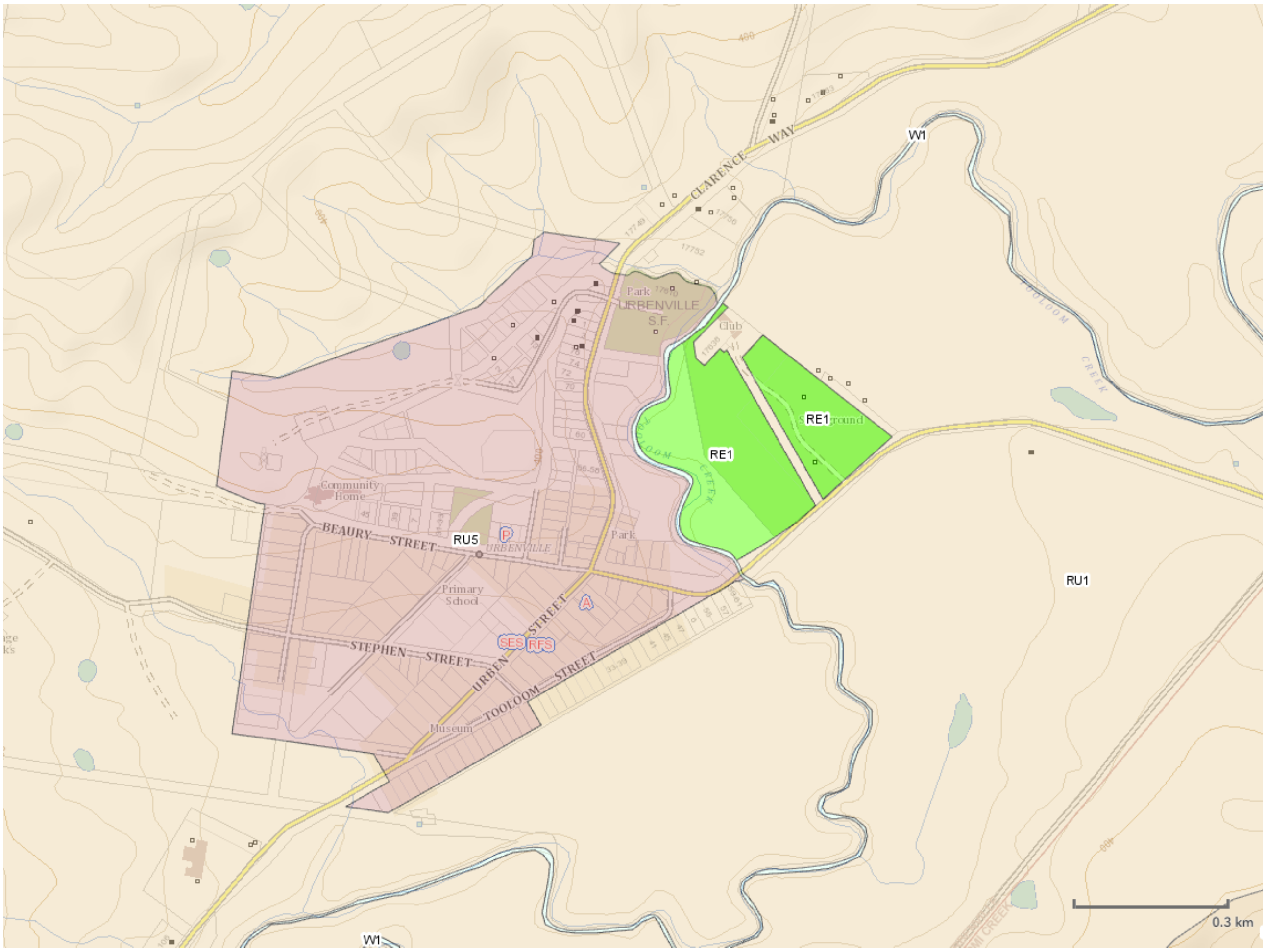



**Figure 10-1: Urbenville Land Use Zones**

### 10.1.2 Woodenbong

The town of Woodenbong is typically zoned RU5 Village while the surrounding area is RU1 Primary Production and RE1 Public Recreation. There are areas of R5 Large Lot Residential and RU4 Primary Production Small lots to the south-east of the town. An area of concern is Black Gully as a tributary of Tooloom Creek is more subject to flooding than the rest of the township. Future rezoning of the floodplain surrounding the tributary may be appropriate to prevent further development. The Sewerage System at Woodenbong is surrounded by floodwaters in all events as flows breakout of Tooloom Creek, and is inundated in the 1% AEP events and greater. The hazard of flooding at this area is H1 generally safe for vehicles people and buildings in the 1% and 0.2% AEP events, in the PMF it is H5 unsafe for vehicles and people, all building types vulnerable to structural damage.

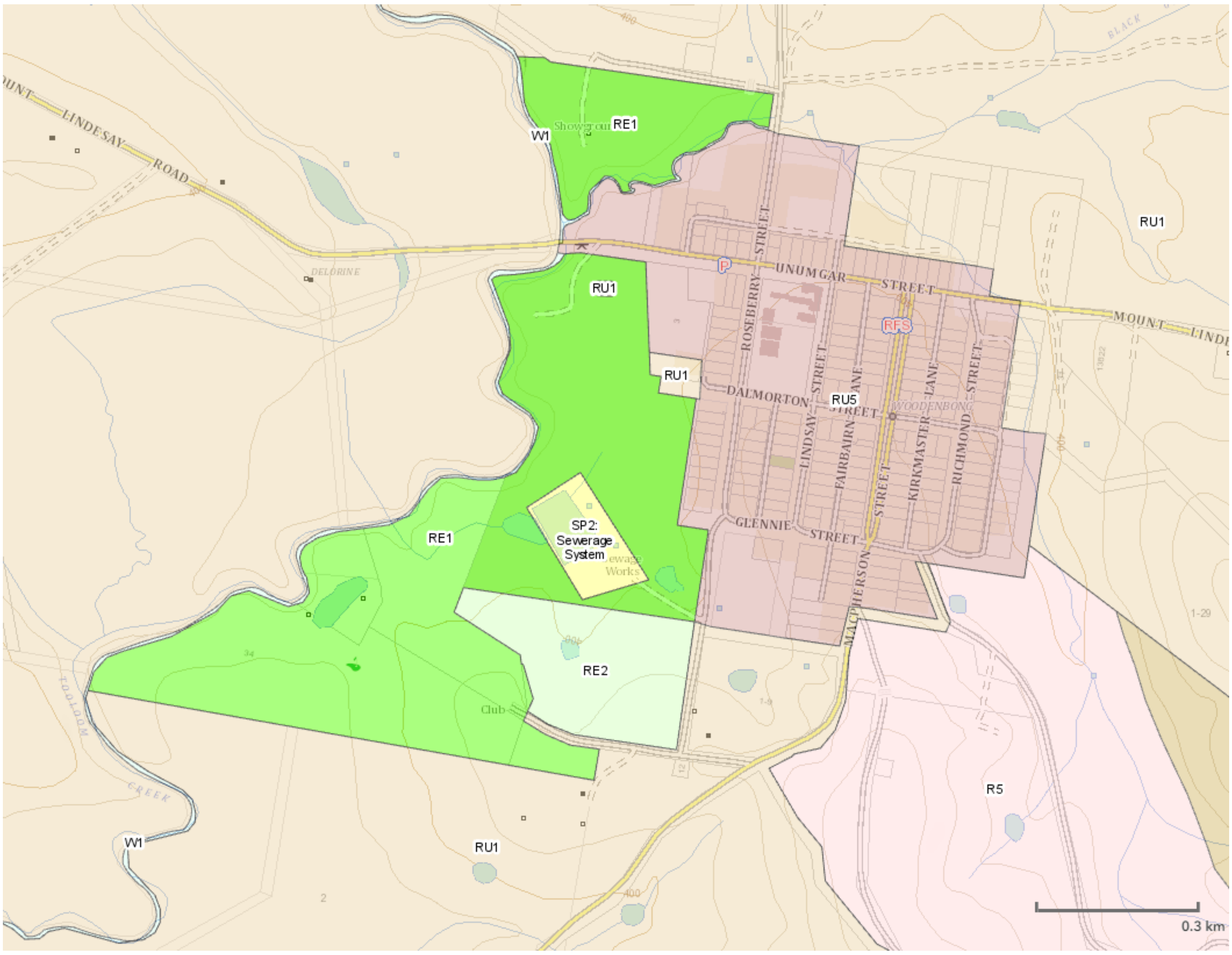



**Figure 10-2: Woodenbong Land Use Zones**

### 10.1.3 Muli Muli

The town of Muli Muli is classified as R5 Large Lot Residential. The land use zoning is generally compatible with the flood hazard of the land subject to appropriate development controls.

## 10.2 Flood Planning Levels (FPL) and Flood Planning Area (FPA)

As summarised in section 2.5 of the Kyogle Council, the DCP typically requires floor levels to be at least 500 mm above the 1% AEP flood level. The Tenterfield Shire Council DCP defines the FPL as the 1% AEP flood event plus 0.5 metres. Currently the 1% AEP flood level at Woodenbong and Urbenville is based on anecdotal evidence of historic events.

Current guidance makes several recommendations for setting a freeboard for flood planning purposes:

**Table 10-1: Guidance (and Legislation) on Determining of Freeboard, FPAs and FPLs**

| Source | Type | Freeboard / Comment |
|---|---|---|
| Tenterfield Council Development Control Plan | Legislation | • The FPL is typically determined as the 1% AEP flood level plus a 0.5 m freeboard. Where the 1% AEP is not known, such as Urbenville historical flood marks are used. |
| Kyogle Council DCP | Legislation | • The FPL is typically determined as the 1% AEP flood level plus a 0.5 m freeboard. |
| NSW Floodplain Development Manual (2005) | Legislation / Guidance | • Freeboard to FPL typically 0.5 m applied to the 1% AEP flood for residential property unless benefits of a higher FPL eg vulnerable uses such as aged care facilities, hospitals<br>• Consideration should also be given to using the PMF as the FPL when siting and developing emergency response facilities such as police stations, hospitals, SES headquarters, and critical infrastructure, such as major telephone exchanges, if possible.<br>• Potential for commercial and industrial properties to be based on event more frequent than the 1% AEP flood. |
| ARR2019 | Guidance | • No specific freeboard value stated |
| AIDR Handbook 7 (2017) | Guidance | • Freeboard range from 300 mm to 600 mm<br>• 300 mm for shallow floodwater<br>• > 600 mm where flood level estimates are uncertain |
| Queensland Development Code (Queensland Government, 2013) | Interstate | • Minimum floor level for habitable room of 300 mm for all residential building types |
| Queensland Urban Drainage Manual (IPWEAQ, 2017) | Interstate | • Minimum freeboard of 300 m above the defined flood event (typically the 1% AEP event) for minimum floor levels |

### 10.2.1 Urbenville

The traditional FPA approach of a 0.5 m freeboard to the 1% AEP flood level affects the full town of Urbenville including areas where 1% AEP flood depth are shallow.

In areas north of Beaury Street the PMF flood levels are lower than the 1% AEP plus 0.5 m level in areas where flooding occurs due to local catchment flooding and is not affected by Tooloom Creek in frequent events. In this case application of an FPL of the 1% AEP plus 500 mm level may be over conservative if the extent is larger than the PMF extent.

### 10.2.2 Woodenbong

For Woodenbong the traditional approach of setting an FPA of a 0.5 m freeboard to the 1% AEP flood level was also applied. The resulting FPA includes the majority of the town, except for southern portions. A lot of these areas are not subject to significant flooding depths within the town drainage along the roads.

The FPA extent for much of the town is caused by flow paths alongside the roads that are contained to the drainage channels. The depths in these channels are less than 100 mm, with some localised low points of 300 mm. Where breakout flow does occur of these channels and travel between buildings the floodwaters sheet flow and have shallow depths that are typically less than 50 mm. The flooding contributing to the FPA in these areas are from local catchments. The PMF level is lower than the FPL level using this application, using this approach may be overly conservative.

### 10.2.3 Tooloom and Boomi Creek areas

Generally for the Tooloom and Boomi Creek floodplain the PMF extent is larger than the FPA (based on 1% AEP event plus 0.5 m freeboard). A 0.5 m freeboard is likely to be suitable.

### 10.2.4 Recommended Approach

For the Tooloom Creek flooding the PMF level higher than the Flood Planning level, however within the Woodenbong township and areas of Urbenville the FPL assuming a 500 mm freeboard applied to 1% AEP flood depths is higher than the PMF level. For the township this may be overconservative.

Therefore, the recommended approach is to:

- Adopt a FPA based on all flood levels plus 0.5 m.
- Adopt variable FPLs based on the source and depth of inundation at properties.

This approach means that properties which only subject to shallow depths are not subject to onerous development controls and that new development is not limited by unrealistic development controls.

During the Floodplain Risk Management Study and Plan further analysis on appropriate freeboard should be considered to define the Flood Planning Area for Urbenville and Woodenbong. There are areas of Woodenbong where less strenuous flood controls need to be applied. In overland flow areas an approach where the greater of the PMF or 1% AEP plus a 0.3 m freeboard may be more appropriate.

# 11 CONCLUSIONS

## 11.1 Flood Study Summary

The Flood Study has developed robust flood modelling to establish the design flood behaviour for the 20% AEP, 5% AEP, 1% AEP, 0.2% AEP and PMF events. Where possible, the flood modelling has been validated against observed flood marks from the 2008, February 2010 and December 2010 and anecdotal evidence obtained for the community during the community consultation. SES and council photographs of flooding were also used to validate the behaviour of the flood model.

The study has identified the two main sources of flooding for each town; the local catchments that flow through the towns, and flooding from Tooloom Creek.

## 11.2 Urbenville

At Urbenville, the Tooloom Creek is the dominant source of flooding. In the 5% event the creek flows into floodplain and extends towards the town. In larger events, overland flows travel between Welch and Urben Streets.

The Flood Study has also considered provisional Flood Hazard and Flood Function. Typically, when under overland flow conditions the floodways are limited to the channels and drains with the exception of a few streets. In the larger events and under flooding from Tooloom Creek, areas of floodway affect more properties at Urbenville as the Tooloom Creek flood extent becomes larger in the 1% AEP and PMF events.

At Urbenville the extent of properties within the PMF are classified as Rising Road Access given available evacuation routes via foot to higher ground. These areas of higher ground outside the flood extent are classified as High Trapped Perimeter due to the surrounding roads being cut off.

In the northern area of the town where it is affected by overland and local catchment flows, flood depths are typically less than 0.5 m in the 1% AEP event and therefore adoption of a 0.5 m freeboard above the 1% AEP flood level may be over conservative for flood planning, especially where this causes the FPL to be above the PMF level. A reduced freeboard for these areas is recommended.

## 11.3 Woodenbong

At Woodenbong the local catchments are the dominant source of flooding as floodwater from Tooloom Creek does not inundate developed areas of the town until greater than a 0.02% AEP event. In the larger events the flows from the channel near Richmond Street and Black Gully exceed the channel capacity and cause areas of high hazard floodway in the 1% AEP and PMF events.

In the 20% AEP the floodways occur in the main drainage channels, Tooloom Creek, Black Gully and the channel running behind Richmond Street. As the magnitude of the flood increases, the floodway extents increase in all areas of the town. In the PMF event the extent of floodway has expanded to affect a number of properties on Richmond Street and the industrial lots of Roseberry Street.

Much of the town is classified as indirectly affected with evacuation routes from the town still accessible. This is subject to the road condition of Old Bruxner Road, an unsealed road connecting Boomi Creek Road Mount Lindesay Road. Areas within the flood extent are classified as Rising Road Access because they have evacuation routes available via foot and road to them before inundation. There are areas of low flood islands within the Tooloom Creek floodplain at Woodenbong.

Within the town, flood depths are typically less than 0.5 m and typically confined to the drainage channels in the roads which is from the local catchments. Due to this the adoption of a 0.5 m freeboard above the 1% AEP flood level may be over conservative for flood planning. A reduced freeboard for these areas is recommended.

## 11.4 Tooloom and Boomi Creeks

Clarence Way which runs parallel to Tooloom Creek, can remain inundated for about 15 hours in the 1% AEP event. Boomi Creek road which travels next to Boomi Creek remains flooded for about 20 hours in the 1% AEP event.

Around Tooloom Creek and Boomi Creek the majority of area is classed as High Trapped Perimeter where dry and Overland Escape Route where innundated, due to the terrain and scarcity of roads making evacuation via vehicles difficult.

## 11.5 Next Stage

The next phase of the Flood Study is for Public Exhibition of this document following Council and DPIE review. Following adoption, Council will move to the Floodplain Risk Management stage which will build upon the findings of this Flood Study to identify options for floodplain risk management.

# REFERENCES


Australian Institute for Disaster Resilience (AIDR). (2017). *Guideline 7-2 Flood Emergency Response Classification of the Floodplain.* Commonwealth of Australia.

Australian Institute for Disaster Resilience (AIDR). (2017). *Guideline 7-3 Flood Hazard.* Commonwealth of Australia.

Australian Institute for Disaster Resilience (AIDR). (2017). *Managing the Floodplain; A Guide to Best Practice in Flood Risk Management in Australia.* Commonwealth of Australia.

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors). (2019). *Australian Rainfall and Runoff: A Guide to Flood Estimation.* Commonwealth of Australia.

BMT WBM. (April 2009). *Kyogle Floodplain Risk Management Plan.* prepared for Kyogle Council.

Bradley, J. N. (March 1978). *Hydraulic Design Series No.1 Hydraulics of Bridge Waterways.* FHWA.

Bureau of Meteorology. (2003). *Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method.*

Bureau of Meteorology. (2003). *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method.*

DECC. (2007). *Flood Emergency Response Classification of Communities.*

Department of Commerce. (July 2015). *Bonalbo Long Term Water Supply and Srought Strategy.*

Department of Environment and Climate Change. (2007). *SES Requirements from the FRM Process.* NSW Government.

Department of Infrastructure, Planning and Natural Resources. (April 2005). *Floodplain Development Manual: the management of flood liable land.* NSW Government.

DFSI Spatial. (May 2015). *Elevation data products specification and description. Source Airbourne Light Detecting and Ranging (LiDAR).* NSW Spatial Services.

ELVIS. (2020, June 25). *Elevation and Depth - Foundation Spatial Data*. Retrieved from https://elevation.fsdf.org.au/

Howells et. al. (2004). *Defining the Floodway - Can One Size Fit All?*

Institution of Engineers Australia. (1987). *Australian Rainfall and Runoff: A Guide to Flood Estimation.* (Editor-in-chief D.H. Pilgrim, Ed.) Barton, ATC.

Jacobs. (December 2019). *Tabulam Floodplain Risk Management Study and Plan, Final FRMS&P.* prepared for Kyogle Council .

Jacobs. (March 2019). *Tabulam Floodplain Risk Management Study and Plan Final Flood Study Report.* prepared for Kyogle Council.

NSW Department of Public Works and Services. (November 2001). *Bonalbo Dam Probable Maximum Flood Study.* prepared for Kyogle Council.

NSW Department of Public Works. (August 2004). *Bonalbo Dam Dambreak Study.* prepared for Kyogle Council.

NSW Public Works. (April 2015). *Bonalbo Dam Addendum to Flood Study.* prepared for Kyogle Council.

OEH. (November 2015). *Floodplain Risk Management Guide Modelling the Interaction of Catchment Flooding and Oceanic Innundation in Coastal Waterways.* NSW Office of Environment and Heritage.

Public Works Advisory. (July 2017). *Bonalbo Dam 2017 Piping Risk Assessment report number DC17020.* prepared for Kyogle Council.

WBM Oceanics Australia. (February 2004). *Kyogle Flood Study.* prepared for Kyogle Council.