

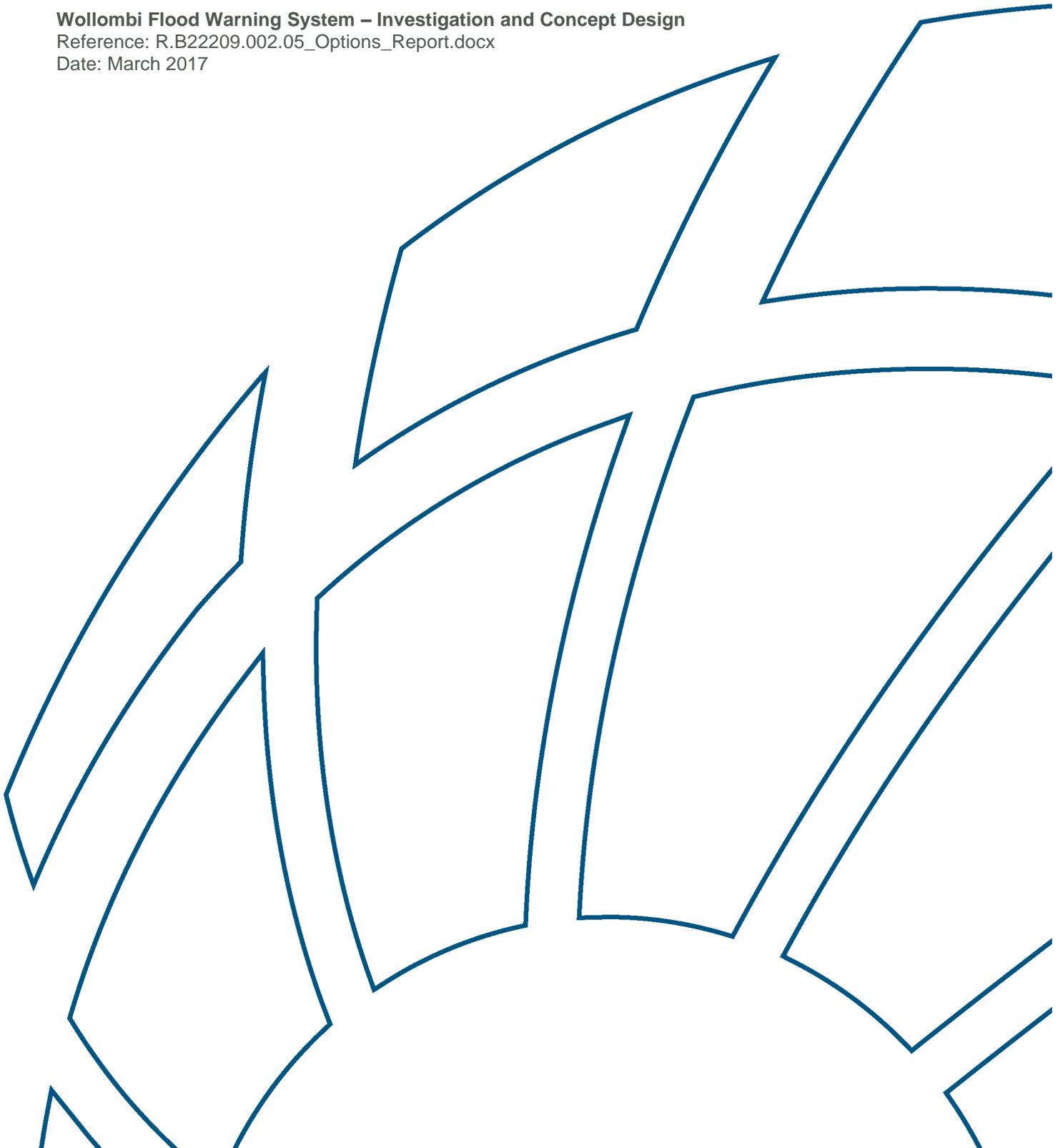


Wollombi Valley Total Flood Warning System Options Report

Wollombi Flood Warning System – Investigation and Concept Design

Reference: R.B22209.002.05_Options_Report.docx

Date: March 2017



Wollombi Valley Total Flood Warning System Options Report

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<p>Synopsis: This document contains the options for the total flood warning system (TFWS) for Wollombi</p>		

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by	Issued by
0	31/10/2016	Ben Caddis	Ben Caddis
1	1/11/2016	Ben Caddis	Ben Caddis
2	30/11/2016	Ben Caddis	Ben Caddis
3	17/01/2017	Ben Caddis	Ben Caddis
4	17/02/2017	Darren Lyons	Joshua Eggleton
5	10/03/2017	Darren Lyons	Ben Caddis

DISTRIBUTION

Destination	Revision										
	0	1	2	3	4	5	6	7	8	9	10
Cessnock City Council	PDF	PDF	PDF	PDF	PDF	PDF					
BMT WBM File	PDF	PDF	PDF	PDF	PDF	PDF					
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Executive Summary

Executive Summary

The Wollombi Valley has experienced numerous floods in the past, notably the most significant events including June 1949 and June 2007. The community experiences borne out of these events, particularly in June 2007, identified significant limitations in the flood warning and emergency response in the Valley. These limitations were reinforced in the broader investigation of flooding in the Wollombi Floodplain Risk Management Study and Plan (BMT WBM, 2012), and led to the recommendation for the investigation of a formal flood warning system for the Wollombi Village and surrounds. Cessnock City Council with financial assistance from the NSW Office of Environment and Heritage (OEH) engaged the current study to investigate potential options for a comprehensive Total Flood Warning System (TFWS) that effectively forewarns emergency responders and the community of a potential flood threat, and provides information to the community on what to do in the event of a flood.

The nature of flooding in the Wollombi Valley and limitation of existing flood warning systems present some significant challenges for effective flood warning and emergency response. These challenges include:

- Limited existing flood warning service for Wollombi Village – warning services for the Wollombi Brook catchment are currently provided by the Bureau of Meteorology (Bureau) in the form of flood watches and flood warnings for the Wollombi Brook at Bulga, some 50km downstream of the Wollombi Village. The Bureau also provides more general warning services including Severe Weather Warnings and Severe Thunderstorm Warnings. These services have a broad regional coverage but do not provide any quantitative assessment of potential flooding at Wollombi Village and surrounds.
- No reference gauges in the upper catchment or Wollombi Village – in addition to the water level gauge at Bulga, there is an existing water level gauge at Brickmans Bridge 17km downstream of Wollombi Village. There are no further water level gauges upstream of Brickmans Bridge and accordingly no real time monitoring of flood water levels at Wollombi or in the tributary channel upstream for floodwaters approaching the village.
- Extensive road inundation, even for relatively small flood events – the main regional access routes of the Great North Road, Paynes Crossing Road and Wollombi Road are all subject to closure at multiple points by floodwaters. These roads can be cut even for relatively minor flood events. In addition to these major routes, similar flood affectation will occur for access roads into the tributary valleys surrounding Wollombi, and access to properties.
- Dispersed population throughout the Valley and a transient population – whilst there is concentration of property around the Wollombi Village, a significant proportion of the community at risk are dispersed throughout the Valley along the numerous tributary alignments and upper reaches of the catchments. Coupled with the access issues, as identified above, and limitations in communications, there is significant risk of isolation during flood events for the broader community. The Valley is also popular as a tourist route, such that additional people with limited flood awareness may be exposed to flood risk.
- Constraints on emergency response agencies – the NSW State Emergency Service (SES) and Rural Fire Service (RFS) are the two principle agencies that may provide support to the Wollombi community during flood events. However, recognising the severe limitation of access with road flooding, on the ground support may be limited. Accordingly this places emphasis on the community to be prepared and take responsibility for appropriate planning and action during flood events.

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- Communication system inadequacies and failure – general communications throughout the Valley may not necessarily be relied upon prior, during, and after a flood event with the likelihood of system outages and limited service / coverage in some areas. This may limit the opportunity for flood warnings to be received and disseminated, and restrict contact to isolated residents.
- Community flood awareness – In recognition of the potential for limited on ground support via external flood response agencies due to the access constraints, there is a responsibility on the community to be prepared for self-help.

A Total Flood Warning System is defined as the process involved from first knowledge of potential or actual weather conditions that could lead to flooding, to the preparatory and responsive behaviour of the community and emergency responders. The TFWS is more than a network of rain and river gauges (as defined by a conventional flood warning system), and requires involvement of the whole community for successful implementation. To date, the response of the Wollombi Valley community has been very effective, despite the lack of available information during an event, and the challenges faced by isolation, power outages and inadequate communications. The key focus of this project has been to:

- provide better information to the community – through improved infrastructure (including rain and river gauges), formalised flood forecasting services, and communication of the consequences of observations and forecasts;
- identify where the capacity of the emergency response agencies can be improved; and
- build upon and formalise the current awareness, preparedness and response of the community.

The overarching challenges for flood warning in the Wollombi Valley are communications, and isolation due to the inundation of major access roads. The current status of the mobile and landline phone services means there is no single communications method that will operate seamlessly during an event. Therefore, the conceptual design for the TFWS must take into consideration a range of communication measures to provide redundancy to the mobile and landline phone service, and also consider community based action plans that anticipate limited external support, at least in the early stages of a major flood event.

In developing the options for a TFWS, consideration has been given to various levels of investment. This is in recognition of the uncertainty of funding for implementation of the options through Council budgets and external funding programs. A range of measures have been considered that could be implemented in the Wollombi Valley to develop an effective TFWS. These measures have been formulated into a series of three options for consideration, with escalating system enhancements, related benefits and costs of implementation. A summary of these options are presented below.

Option	Justification	Limitations
Option 1	<p>This option focusses on leveraging existing warning services and information, without any changes to the current infrastructure. Most of the measures presented in Option 1 are able to be implemented immediately with limited budget.</p> <p>Implementation of Option 1 will result in:</p> <ul style="list-style-type: none"> • Formalised response arrangements between the SES and RFS. • Formalised communications protocols (including mobile, landline, radio and satellite communications) 	<p>Despite improvements to community and agency response, and improved communications, there remains limited data available to the community and response agencies. The absence of rain and river gauges, and flood forecasting service, will result in a mostly reactive response to flooding triggered by verbal communication amongst the community.</p>

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Option	Justification	Limitations
	<p>to ensure there is always a method for communication between:</p> <ul style="list-style-type: none"> • SES, RFS and Council; and • Primary community meeting locations (Wollombi Village, Laguna Hotel and Millfield) • Promoting the ongoing use of social media amongst the community. • Establishment of a vulnerability register. • Every property having a flood information pack outlining the specific risks to the property, and identifying the property level measures that are required for best response (such as battery operated radios and evacuation plans). Information packs to be produced for clusters of properties having a comparable flood risk and/or access constraints. • Every property covered by a community flood action plan tailored to each part of the catchment. This will identify actions that the community should take to ensure their own safety and to communicate (where possible) their welfare status to the SES and others in the community. • Flood information website for communication of flood risks to the community. 	
Option 2	<p>Option 2 addresses the shortcomings of Option 1, by introducing additional rain and river gauges, and working with the Bureau to seek to have Wollombi Village included as an official flood warning location.</p> <p>Three ALERT river gauges are proposed; one at Wollombi Village and one each at Laguna and Millfield. The levels from river gauges can be used to help develop flood warnings and predictions for the Wollombi Valley. SMS and email alerts are able to be triggered by the software receiving the data from these gauges.</p> <p>Five additional ALERT rain gauges are proposed using VHF communications:</p> <ul style="list-style-type: none"> • The Quorrolong gauge is necessary to capture rainfall patterns in the low lying floodplain at Ellalong. • The Millfield gauge will be sited at the Millfield river gauge, thus providing an economical approach to improve the spatial coverage. • The remaining three gauges are repeaters, which are required to relay the signals for the rain and river gauges to the respective receiving base stations. <p>A flood information system (FIS) is proposed to display the consequences associated with observed and forecasted flood levels. The FIS will provide a dynamic link between the real-time data and outputs from the flood model. The FIS will provide an indication of potential road closures and property inundation.</p>	<p>The inclusion of new gauges in this option will result in a greater cost of implementation. Funding from external sources will be required for implementation, which may take a number of years to secure.</p> <p>Despite the additional gauges, there will remain an uncertainty around accessibility. The intelligence provided by the FIS will only be an estimate of possible conditions.</p>
Option 3	<p>For implementation of a TFWS addressing all of the key issues facing the Wollombi community, additional monitoring is required:</p>	<p>There are two limitations associated with Option 3:</p> <ul style="list-style-type: none"> • Further funding beyond that required

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Option	Justification	Limitations
	<ul style="list-style-type: none"> One further rain gauge is proposed to cover the Cedar Creek catchment. Water level sensors are proposed at all of the critical road crossings / low points. This network of sensors will provide the community and emergency responders with notification of access status. <p>An LED community information board is also included in Option 3 The LED board would display:</p> <ul style="list-style-type: none"> rainfall and river level observations water level trends (rising, falling or steady) water level classification (minor, moderate, major) rainfall magnitude forecast flood levels and timing road closures 	<p>for Option 2; and</p> <ul style="list-style-type: none"> Road inundation information will only be available when there is mobile or land line communications. When mobile and land line communications are out of service, then road inundation can only be communicated verbally using the satellite phones.

Capital and operational cost estimates for each option are provided in the tables below.

Capital Cost Summary

		Option 1	Option 2	Option 3
1	Monitoring and prediction	-	\$129k	\$177k
2	Interpretation	-	\$20k	\$20k
3	Message Construction	-	-	-
4	Communication	\$20k	\$51k	\$69k
5	Protective behaviour	\$40k	\$40k	\$40k
6	Review	-	-	-
	Total cost for implementation	\$60k	\$240k	\$306k

Operational Cost Summary

		Option 1	Option 2	Option 3
1	Monitoring and prediction	-	\$21k	\$27k
2	Interpretation	-	\$5k	\$5k
3	Message Construction	-	-	-
4	Communication	\$5k	\$17k	\$19k
5	Protective behaviour	\$10k	\$10k	\$10k
6	Review	-	-	-
	Total cost for implementation	\$15k	\$53k	\$61k

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It is recommended that implementation of Option 1 is commenced immediately as this presents the lowest cost option, with many of the measures requiring little or no funding. At the same time, funding should be sought from the State Government for contribution towards implementation of Option 2, and discussion should continue with the Bureau to work towards the development of flood warning services provided to Wollombi Village. The measures identified in Option 3 are not essential, but will add significant value. Once Option 2 has been implemented in its entirety, then the measure proposed under Option 3 should be re-considered.

By the implementation of recommendations to develop a TFWS for the Wollombi Valley, it is expected that flood management agencies and the Wollombi community will be better equipped to respond to floods when they occur in the future.

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Introduction

1 Introduction

Flooding is one of the most serious natural hazards in Australia, incurring the highest economic cost to the community and resulting in a small number of deaths most years. However, flooding is also a highly manageable hazard. An understanding of likely flood behaviour, derived from historical information and flood models, can be used to develop a plan to manage future floods.

A comprehensive flood warning system is essential to the effective management of floods. Flood warning assists flood management agencies and the community to understand the potential size and extent of developing floods, and what to do to lessen the impacts of the flood. The Flood Warning Manual¹ identifies six steps to the flood warning process:

- (1) Monitoring of rainfall and river flows that may lead to flooding, and prediction of flood severity and the time of onset of particular levels of flooding;
- (2) Interpretation of the prediction to determine the likely flood impacts on the community;
- (3) Construction of warning messages describing what is happening and will happen, the expected impact, and what actions should be taken;
- (4) Communication of warning messages;
- (5) Protective behaviour by the agencies involved and community members to respond to flooding; and
- (6) Review of the warning system after flood events.

This document forms the first part of a study to design a total flood warning system (TFWS) for the Wollombi Valley (including Wollombi Village and communities upstream of Wollombi Village).

¹ Emergency Management Australia 2009

2 Background

2.1 Location

The Wollombi Brook catchment is located within the Hunter Valley of New South Wales draining a catchment area of 2,150km² as shown in Figure 2-1. The village of Wollombi is located approximately 30km south west of Cessnock at the junction of Congewai Creek and Wollombi Brook. Other significant settlements within the catchment include Paxton, Millfield, Laguna, Broke and Bulga.

As shown in Figure 2-1, the upper reaches of the Wollombi Brook catchment is drained by two main tributaries:

- Wollombi Brook South Arm (known simply as Wollombi Brook): This tributary drains the southern and western sections of the catchment; and
- Congewai Creek (also known as the northern arm of Wollombi Brook): This tributary drains areas of the catchment to the east of Wollombi Village.

The confluence of these two tributaries occurs at the Wollombi Village. Downstream of the confluence, Wollombi Brook, also known as Cockfighter's Creek, flows northwards for some 45km to its confluence with the Hunter River at Warkworth around 16km to the west of Singleton.

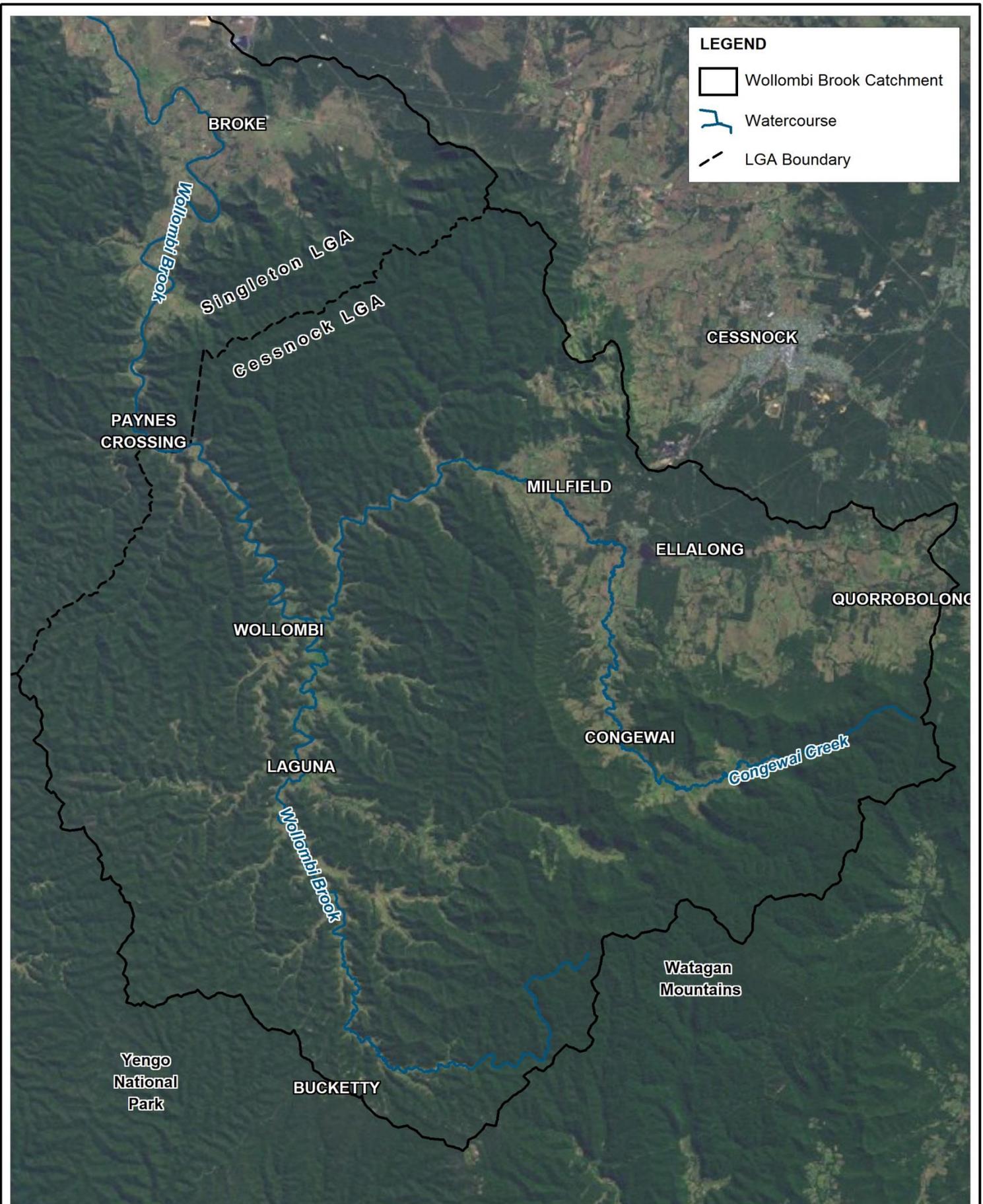
Wollombi Brook has experienced numerous floods in the past, including severe flooding in the 1860's, 1949, 2007 and 2015.

2.2 Previous Studies

A number of floodplain management studies have previously been completed in the Wollombi Brook catchment. The Wollombi Flood Study Review and Model Upgrade (BMT WBM, 2010) and Wollombi Floodplain Risk Management Study and Plan (BMT WBM, 2012) represents the most recent comprehensive floodplain management studies for the upper catchment located within the Cessnock LGA.

2.2.1 Wollombi Valley Flood Study (PBP, 2005)

In 2005 Patterson Britton & Partners (PBP) were engaged by Council to undertake the Wollombi Valley Flood Study. The study originated from the requirement to determine appropriate flood planning levels in the assessment of development applications. The study area was defined as the Wollombi Brook catchment area upstream of Paynes Crossing, which coincides with the local government boundary between Cessnock City and Singleton Councils.

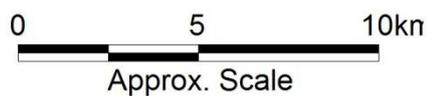


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Wollombi Brook Catchment

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2-1

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.



Background

The main components of the 2005 study included:

- Flood Study – historical background, rainfall and streamflow data, cross section survey, model build and calibration, compilation of historical flood levels
- Review of historical flooding in the catchment and community perspectives and experiences in previous events;
- Collation of historical flood level data, through identification and survey of flood levels, particularly for the 1949 flood;
- Summary of rainfall and streamflow gauges within the catchment and review of data for historical flood calibration;
- Development of a database of surveyed cross sections to define the topography of Wollombi Brook and Congewai Creek for developing hydraulic models;
- Development and preliminary calibration of hydrologic (XP-RAFTS) and hydraulic (HEC-RAS) models using available data; and
- Presentation of design flood information in the form of peak flood levels and inundation extents within the study area.

The results of the models developed for the 2005 Wollombi Valley Flood Study provided preliminary flood planning advice to Council. Based on the study findings Council adopted the 1% AEP design flood as the basis for planning levels at Wollombi Village rather than the higher 1949 historical flood levels.

2.2.2 Wollombi Flood Study Review and Model Upgrade (BMT WBM, 2010)

Given limitations in available historical flow data for model calibration purposes, and the limited initial scope of the location for flood level prediction, the Wollombi Valley Flood Study (PBP, 2005) concluded that the analysis could be improved by incorporating additional cross sections and additional hydrological analysis and calibration.

Accordingly, as part of the preparation of a Floodplain Risk Management Plan, Council decided to review the Wollombi Valley Flood Study (PBP, 2005) and develop a more refined (2D) hydraulic model for the Wollombi Village area to better model the complex flood behaviour due to the confluence of flows in this area.

Council engaged BMT WBM to undertake the Wollombi Village Floodplain Risk Management Study and Plan as a two stage commission:

- Flood Study Review and Model Upgrade: A comprehensive review of the Wollombi Valley Flood Study results, and update of data and computer modelling techniques to establish the existing models as necessary. This included development of a two-dimensional (2D) hydraulic model for the Wollombi Village area. The study aimed to produce information on flood flows, velocities, levels and extents for a full range of flood magnitudes under existing catchment and floodplain conditions.

Background

- Floodplain Risk Management Study and Plan (see Section 2.2.3): The outcomes of the Flood Study Review and Model Upgrade then formed the basis for the Floodplain Management Study and Plan. This study aimed to derive an appropriate mix of management measures and strategies to effectively manage flood risk in accordance with the Floodplain Development Manual. The findings of the study were then incorporated into a Plan of recommended works and measures and program for implementation.

The study area for the Flood Study Review was defined as the Wollombi Brook floodplain within a 5km radius of Wollombi Village. The review incorporated the following activities:

- Collation of database of historical flood information for the June 2007 flood in the Wollombi Brook;
- Acquisition of topographical data for the catchment including photogrammetric analysis and cross section survey;
- Consultation with the community to acquire historical flood information and liaison in regard to flooding concerns/perceptions and future floodplain management activities;
- Development of a hydrological model (using XP-RAFTS software) and hydraulic model (using TUFLOW software) to simulate flood behaviour in the catchment;
- Calibration of the developed models using the June 2007 flood event and model validation using the June 1949 flood event;
- Prediction of design flood conditions in the catchment, particularly at Wollombi Village, using the calibrated models, and
- Production of design flood maps.

The flood levels determined in the Wollombi Flood Study Review and Model Upgrade (BMT WBM, 2010) have been used for flood planning purposes since the adoption of the study by Cessnock City Council.

2.2.3 Wollombi Floodplain Risk Management Study and Plan (BMT WBM, 2012)

The outcomes of the Wollombi Flood Study Review and Model Upgrade (BMT WBM, 2010) formed the basis of the Wollombi Floodplain Risk Management Study and Plan (Wollombi FRMS&P) (BMT WBM, 2012).

The objectives of the Wollombi FRMS&P were to:

- Identify and assess measures for the mitigation of existing flood risk;
- Identify and assess planning and development controls to reduce future flood risks; and
- Present a recommended floodplain management plan that outlines the best possible measures to reduce flood damages in the Wollombi locality.

The study area of the Wollombi FRMS&P comprised the village of Wollombi and the surrounding floodplain within a five kilometre radius of the village.

Background

The nature of flooding in the Wollombi Valley, characterised by high flood volumes, flow depths and velocities, limit the opportunities for implementation of effective flood modification measures (e.g. flood mitigation dams, detention basins, levees and channel improvements). Rather the recommended measures focused on property modification (e.g. development controls) and response modification (e.g. local flood plans, emergency response and community awareness) measures.

The recommended measures included in the Wollombi FRMS&P include:

- Changes to planning and development controls including adoption of a 100-year flood level plus 0.5m freeboard as the flood planning level; and inclusion of a number of floodplain risk management controls into Council's Development Control Plan (2010);
- Improved public awareness;
- Flood warning enhancements;
- Improved emergency management operations including additional detail for the Wollombi Village in the Cessnock Local Flood Plan; and
- Investigation of improved emergency egress and voluntary house raising.

2.2.4 Extended Flood Mapping for the Wollombi Brook Catchment (BMT WBM, 2014)

In 2014, BMT WBM was requested by Council to undertake extended flood mapping using recently acquired LiDAR data for the Wollombi Brook catchment. This work was an extension to flood mapping previously completed by BMT WBM in 2010 as part of the Wollombi Flood Study Review and Model Upgrade.

Specifically, BMT WBM was requested to convert the previously modelled one-dimensional (1D) reaches of Wollombi Brook into two-dimensional (2D) reaches and undertake the following updates to the flood mapping:

- Downstream of Wollombi (existing 2D model limit on Wollombi Brook) to Paynes Crossing;
- Cedar Creek to Wollombi (existing 2D model limit on Congewai Creek arm) (note this reach joins the previous mapping undertaken for Council on Cedar Creek); and
- Ellalong Lagoon to Cedar Creek.

The extended flood mapping was undertaken for a range of design flood events.

2.2.5 Wollombi Brook Flood Study (BMT WBM, 2016)

The Wollombi Brook Flood Study has recently been completed for Singleton Council to define the existing mainstream flood behaviour in the Wollombi Brook catchment downstream of Paynes Crossing and establish the basis for subsequent floodplain management activities in the Singleton LGA.

Specifically, the study incorporated:

- Compilation and review of existing information pertinent to the study and acquisition of additional data including survey as required;

Background

- Undertaking of a community consultation and participation program to identify local flooding concerns, collect information on historical flood behaviour and engage the community in the on-going floodplain management process;
- Development and calibration of appropriate hydrological and hydraulic models;
- Determination of design flood conditions for a range of design events including the Extreme Flood (3 x 1% AEP), 0.5%, 1%, 2%, 5%, 10% and 20% AEP events; and
- Assessment of potential impact of climate change using the latest guidelines.

One key outcome from the Wollombi Brook Flood Study was the detailed analysis of the three active streamflow stations on Wollombi Brook. The analysis highlighted significant changes to the gauging site rating curves as a result of significant recovery of riparian vegetation in the catchment over the last 20 years or so.

2.3 Existing Flood Risk

2.3.1 Overview

The catchments of the two tributaries upstream of Wollombi Village (i.e. Wollombi Brook South Arm and Congewai Creek) are typically steep sided and forested, with a cleared, relatively narrow floodplain on the valley floors. From the headwaters in the Watagan Ranges, at some 640m AHD at the highest points, the catchment rapidly descends to Wollombi Village at approximately 100m AHD. The combination of these features results in a 'flashy' catchment that converts rainfall rapidly into relatively large flow rates and elevated flood levels in the upper catchment reaches. These floodwaters then progress down through the catchment before combining downstream of the Wollombi Village. The natural rainfall response of the Congewai Creek and Wollombi Brook catchments is such that the timing of the flood peaks tends to coincide, thereby exacerbating flooding at Wollombi Village.

In contrast to the Wollombi Brook South Arm, the upper floodplains of Congewai Creek and Quorrobolong Creek are relatively wide in the vicinity of Paxton and Millfield, flowing through broad lowland (at approximately 120m AHD) which includes the Ellalong Lagoon. However, from the Cedar Creek confluence, the Congewai Creek returns to a highly incised channel characterised by steep and narrow valley profile.

In the locality of Wollombi Village, the Wollombi Brook, Congewai Creek and Yango Creek converge. The total contributing catchment area to the confluence is some 815km². The relative contributions to this total catchment area are 470km², 285km² and 60km² for the Wollombi Brook, Congewai Creek and Yango Creek catchments respectively. As previously noted, the coincident flooding of the Congewai Creek and Wollombi Brook catchments has a major influence on flood levels in the village area.

Downstream of Wollombi Village, Wollombi Brook remains a highly incised channel with a narrow floodplain until Broke. From downstream of Broke, the floodplain widens progressively for the remaining 42km to the confluence with the Hunter River at Warkworth.

Background

It should be noted that there is a significant spatial variation in design rainfall intensity over the catchment, with higher rainfall in the upper catchment on the slopes of the Watagan Ranges and progressively lower rainfall moving down through the catchment to Paynes Crossing. This is generally consistent with the major flood events experienced in the catchment, in particular the 1949 and 2007 flood events.

A range of design event durations were simulated as part of the Wollombi Flood Study Review and Model Upgrade (BMT WBM, 2010) to determine the critical duration for flooding in the Wollombi Village locality. It is highly likely that the critical duration of flooding for some of the tributaries and upper catchment reaches will be different (i.e. potentially significantly shorter), however, given the focus of the study was mainstream Wollombi Brook flooding in the vicinity of the Wollombi Village, design event simulations were focused on critical flood conditions at this location. The model simulations indicated the peak discharge in Wollombi corresponded to the 36 hour duration. This conforms to the general rainfall pattern occurring during the two highest floods on record, being the 1949 and 2007 events.

The Wollombi Valley Flood Study Review and Model Upgrade (BMT WBM, 2010) defined design flood levels at Wollombi for a range of design event magnitudes, utilising detailed hydrologic and hydraulic models (XP-RAFTS / TUFLOW) calibrated to June 1949 and June 2007 historical event data. Table 2-1 presents a summary of design peak flood levels at Wollombi Village, along with peak historical event levels for comparison. Hydraulic hazard mapping for the 1% AEP and PMF events are shown in Figure 2-2 and Figure 2-3 respectively.

Table 2-1 Comparison of Historical and Design Peak Flood Levels at Wollombi Village

Flood Event	Peak Flood Level (m AHD)
5% AEP	98.0m AHD
2% AEP	98.9m AHD
June 2007	99.0m AHD
April 1927	~99.0m AHD
August 1857	~99.0m AHD
1% AEP	99.7m AHD
0.5% AEP	100.4m AHD
June 1867	~100.5m AHD
June 1949	101.6m AHD
3 x 1% AEP	105.8m AHD

Legend

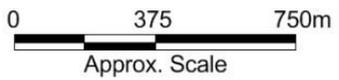
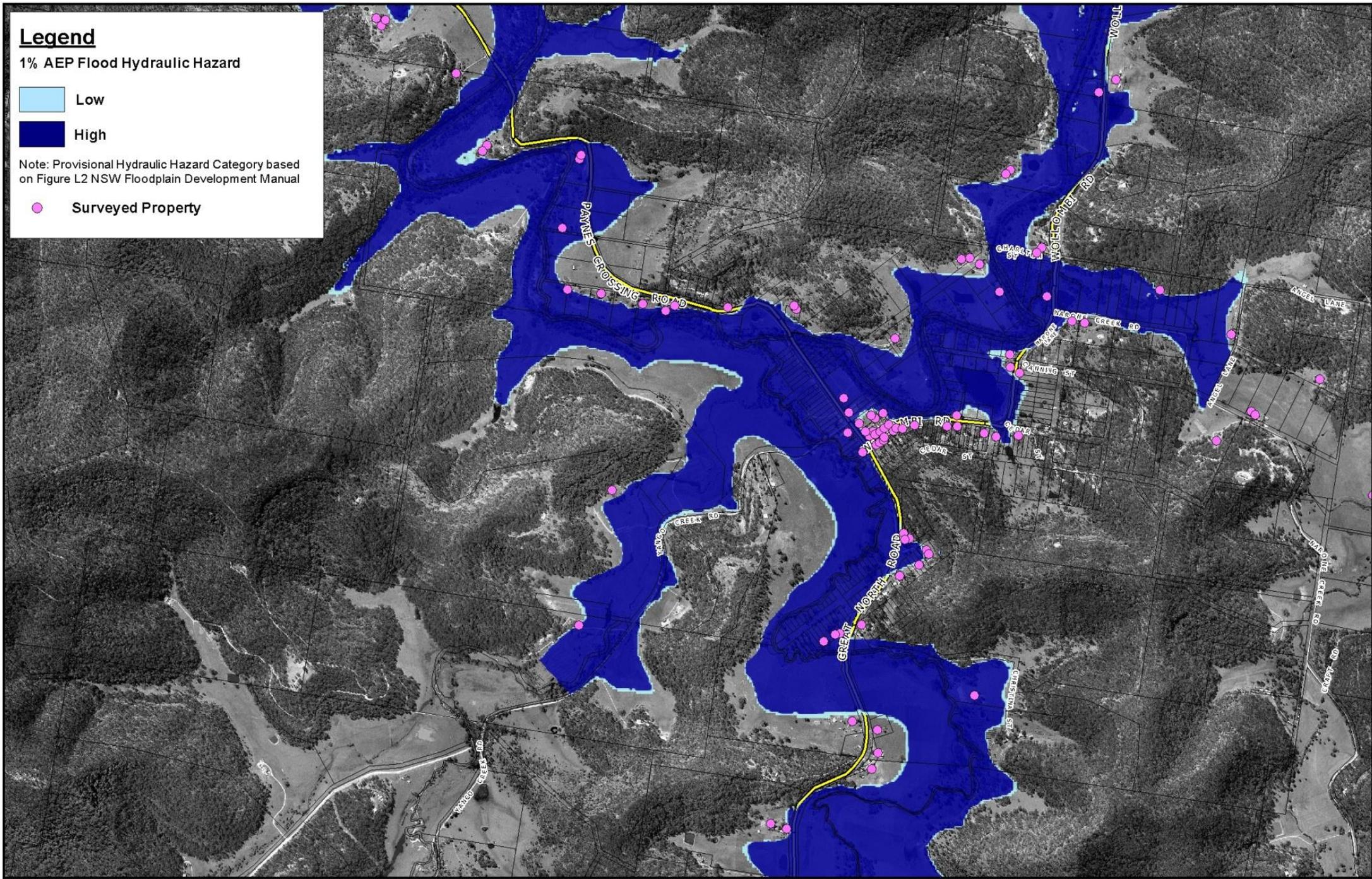
1% AEP Flood Hydraulic Hazard

Low

High

Note: Provisional Hydraulic Hazard Category based on Figure L2 NSW Floodplain Development Manual

Surveyed Property



Wollombi Flood Study Review and Model Upgrade
Design Event : 1% AEP
Provisional Hydraulic Hazard Category - Village Area

Figure Wollombi_1%AEP_z_R1

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Legend

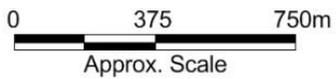
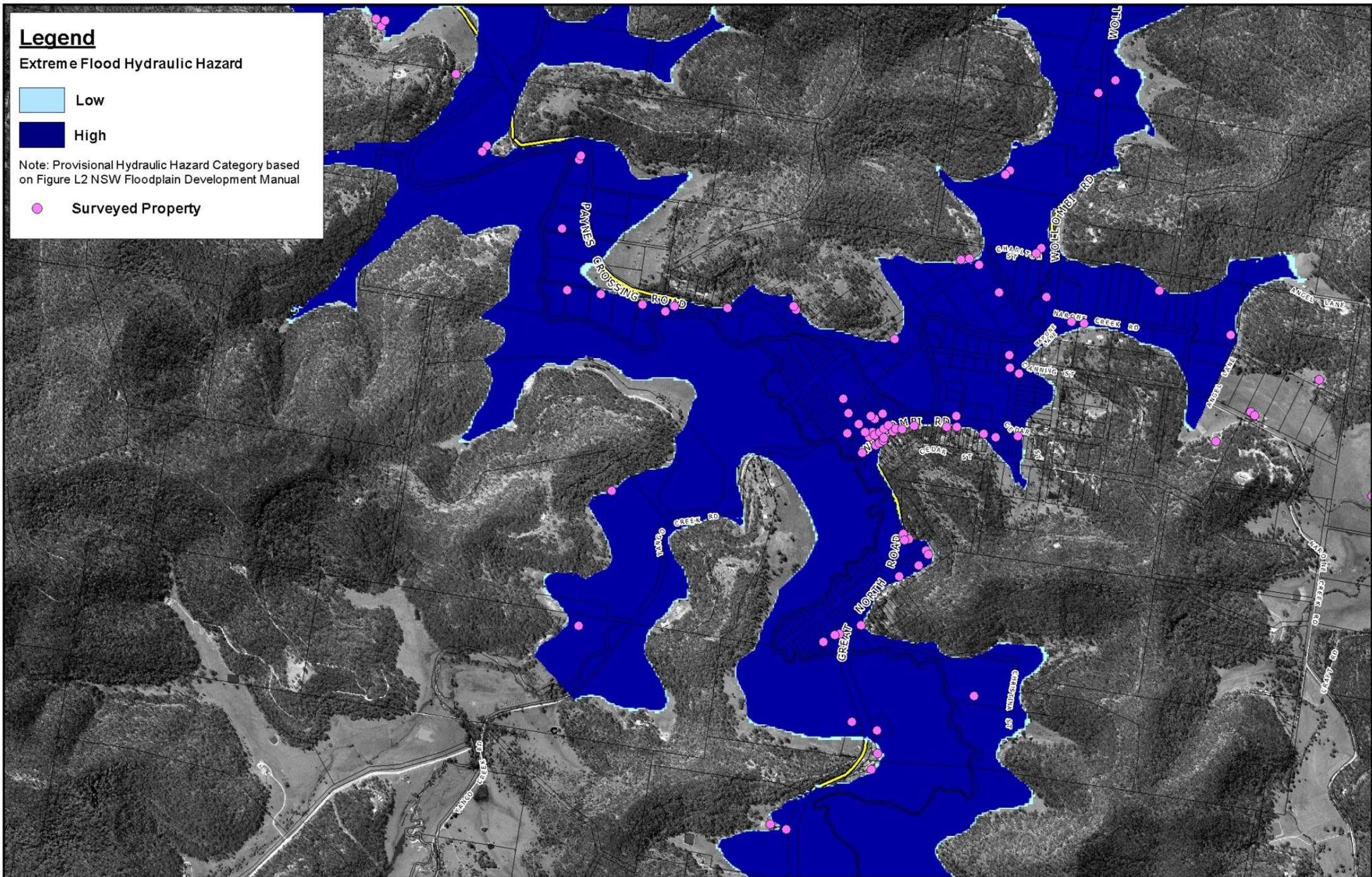
Extreme Flood Hydraulic Hazard

Low

High

Note: Provisional Hydraulic Hazard Category based on Figure L2 NSW Floodplain Development Manual

Surveyed Property



Wollombi Flood Study Review and Model Upgrade
Design Event : Extreme Flood (3 times 1% AEP)
Provisional Hydraulic Hazard Category - Village Area

Figure Wollombi_3times_1%AEP_z_R1

K:\M1310\W\Works\pases\FloodMaps_1% AEP_z_01.WOR



Background

The comparison of historical and design flood levels at Wollombi highlight the significance of the historical events previously experienced in the catchment. Moreover, the significant increases in flood depth with flood magnitude highlight the nature of flooding in the deeply incised valley. The nature of flooding in the incised valley is further demonstrated by the extent of the high hazard (primarily driven by peak flood depth) floodplain area shown in Figure 2-2.

It should be noted that only mainstream flooding of the Wollombi Brook and major tributaries (e.g. Narone Creek and Yango Creek) were investigated as part of the previous studies completed in the catchment. Flooding on the minor tributaries, and within small sub-catchment valleys has not previously been simulated.

2.3.2 Property Inundation and Flood Damages

The Wollombi Floodplain Risk Management Study and Plan (BMT WBM, 2012) identified properties within the study area potentially affected by flooding for a range of flood magnitudes, as shown in Table 2-2. The counts in the table represent numbers of properties with potential for flooding *above floor level* for each flood magnitude. The property type has been distinguished, represented by:

- Residential – assumed permanent residences;
- Weekender – typically smaller/lower value property (not permanent residence); and
- Commercial – a place of business/commercial operation.

Table 2-2 Number of Properties affected by Flooding above Floor Level

Design Return Period	Residential	Weekender	Commercial
5-year ARI	0	3	0
10-year ARI	2	4	0
20-year ARI	4	4	2
50-year ARI	4	6	2
100-year ARI	8	6	4
200-year ARI	9	6	5
Extreme Flood	50	17	13

It is evident that a total of 18 properties (all type) within the study area have floor levels lower than the 100-year ARI flood level. It should be noted that these properties are located within the mainstream flood extents of the Wollombi Brook (within the modelled study area) and only count properties that experience above floor flooding. It is likely that there are a number of properties within the modelled area that do not experience above floor flooding but are cut-off and isolated as a result of floodwaters. It is also likely that there a number of properties located outside of the study

Background

area, along the minor tributaries, and within small sub-catchment valleys, that are at risk of inundation, or are cut-off and isolated as a result of floodwaters. The exact number of affected properties is unknown at this stage as the flood extents along these catchment areas has not yet been assessed in detail. It should also be noted that due to the number of weekender properties that are flood affected, there may be a transient community that may not be aware of how floods affect the Wollombi Valley.

A flood damages assessment was completed as part of the Wollombi Floodplain Risk Management Study & Plan (BMT WBM, 2012) and found that the total estimated flood damage to occur in a 100-year ARI flood event is \$1.7M, increasing to an estimated \$11M worth of damage for the Extreme Flood.

2.3.3 Road Inundation

Extensive inundation of major access roads to Wollombi is expected in major flood events. This extensive road closure adds to the isolation of flood affected property and serious implications for emergency response.

The extent road inundation on the major routes to Wollombi, including Wollombi Road, The Great North Road and Paynes Crossing Road, at the peak of the 20% AEP and 1% AEP events is shown in Figure 2-4 and Figure 2-5 respectively. There are also numerous minor valley roads and property access roads that are not shown on Figure 2-4. Many of these access roads have low level crossing points with flood level immunity significantly less than even a 5-year event. This reinforces the fact that many properties would be isolated during the flood, with limited opportunity for access.

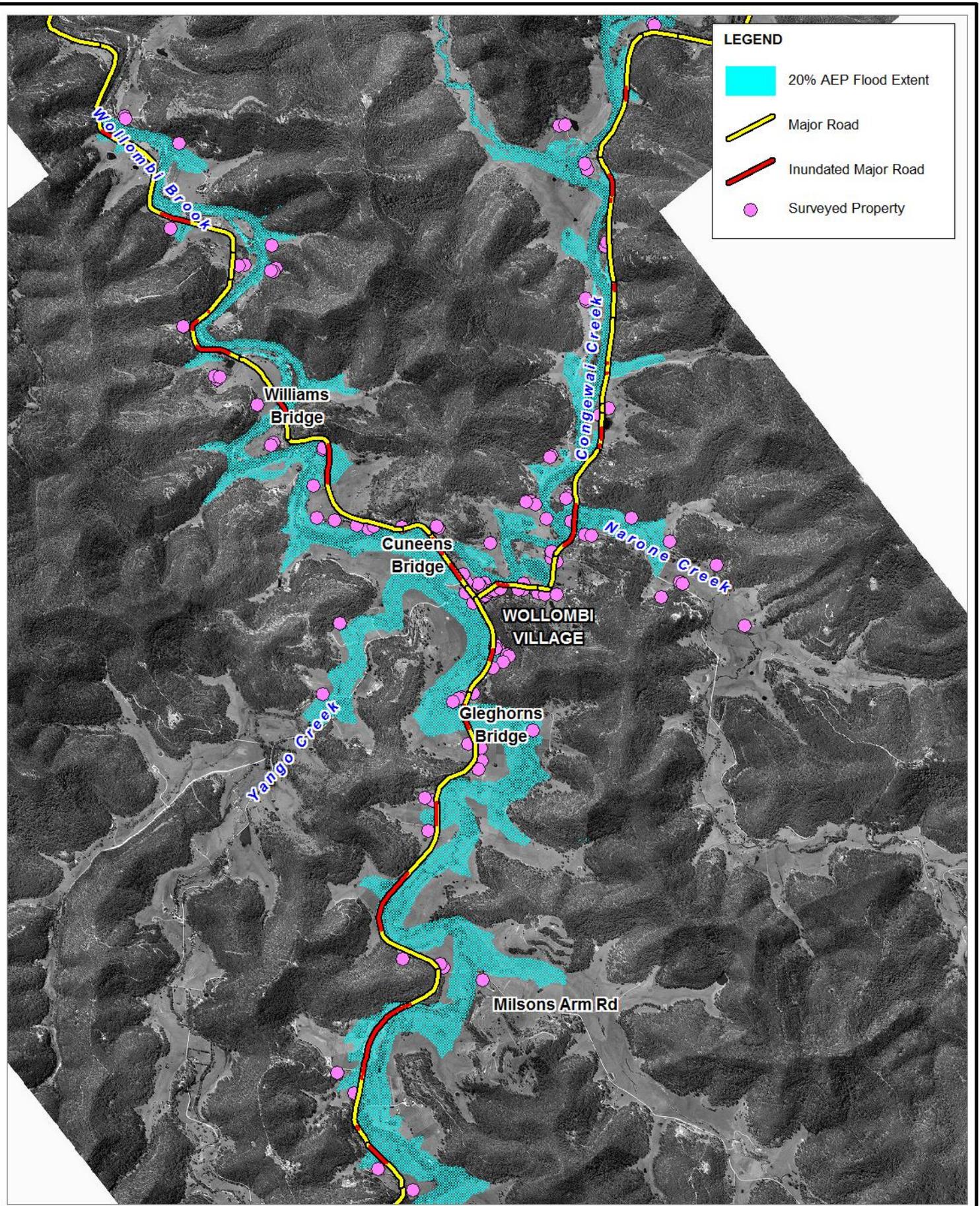
2.3.4 Key Travel Times

A critical piece of flood behaviour required for an effective flood warning system is the understanding of the rate of rise of floodwaters at specific locations, and the travel time of floodwaters between key locations in the catchment.

The simulated water level timeseries at Cuneens Bridge, immediately downstream of the Wollombi Village, for the June 2007 flood event is presented in Figure 2-6. The following observations can be made:

- The time difference between the initial response and peak of the event is some 24 hours;
- The initial response results in a relatively rapid rise in floodwaters of ~0.9m per hour;
- The water level remained elevated above the 20% AEP peak flood level for a period of some 32 hours.

The above observations highlight the rapid nature of the flood response in the narrow valley and the period of time that affected community members could potentially remain isolated due to road inundation.



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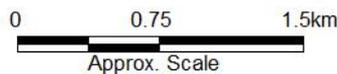
- 20% AEP Flood Extent
- Major Road
- Inundated Major Road
- Surveyed Property

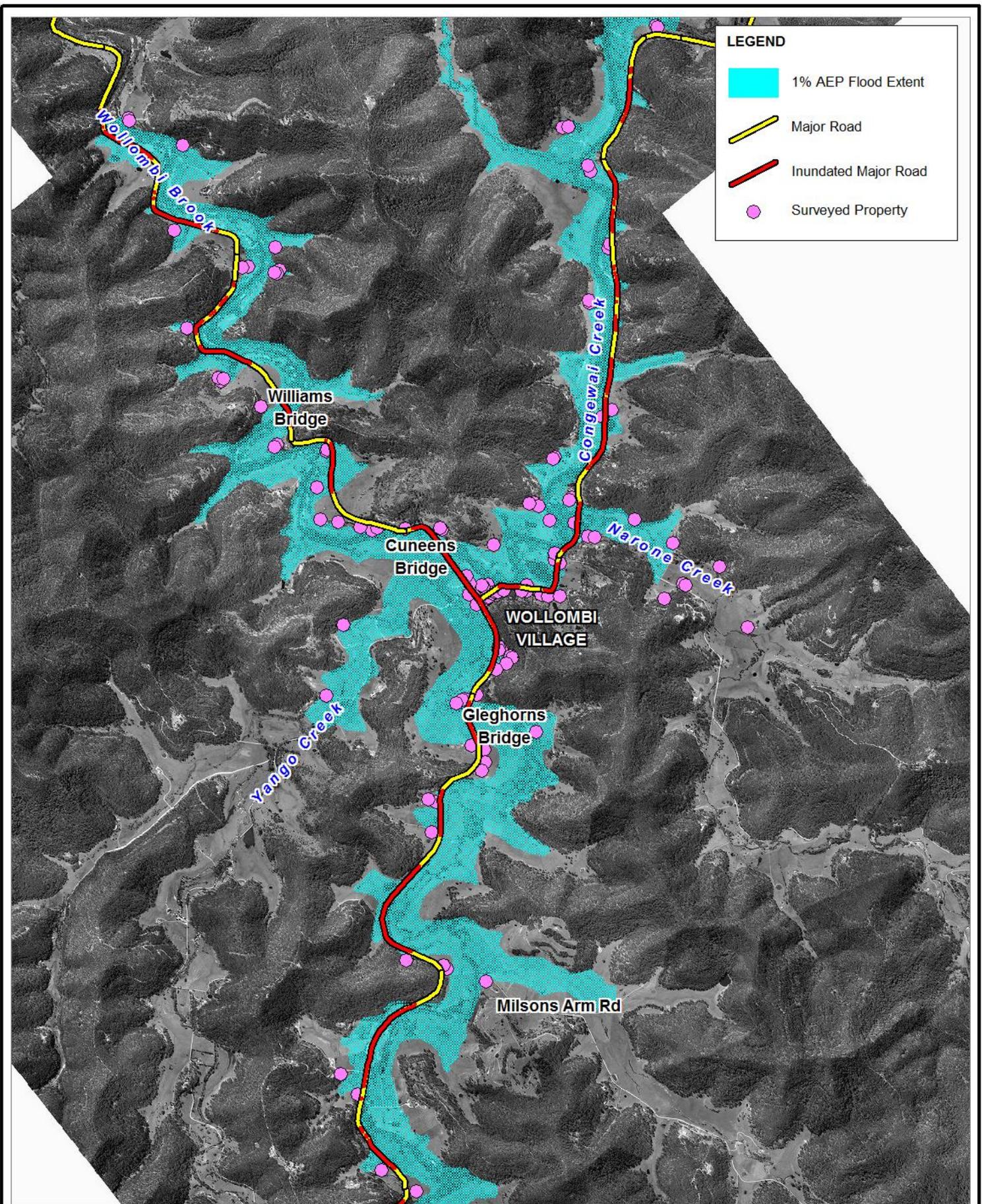
Title:
Road Inundation at 20% AEP Flood Level

Figure:
2 - 4

Rev:
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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.





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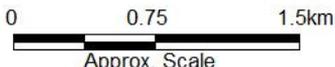
- 1% AEP Flood Extent
- Major Road
- Inundated Major Road
- Surveyed Property

Title:
Road Inundation at 1% AEP Flood Level

Figure:
2 - 5

Rev:
A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.



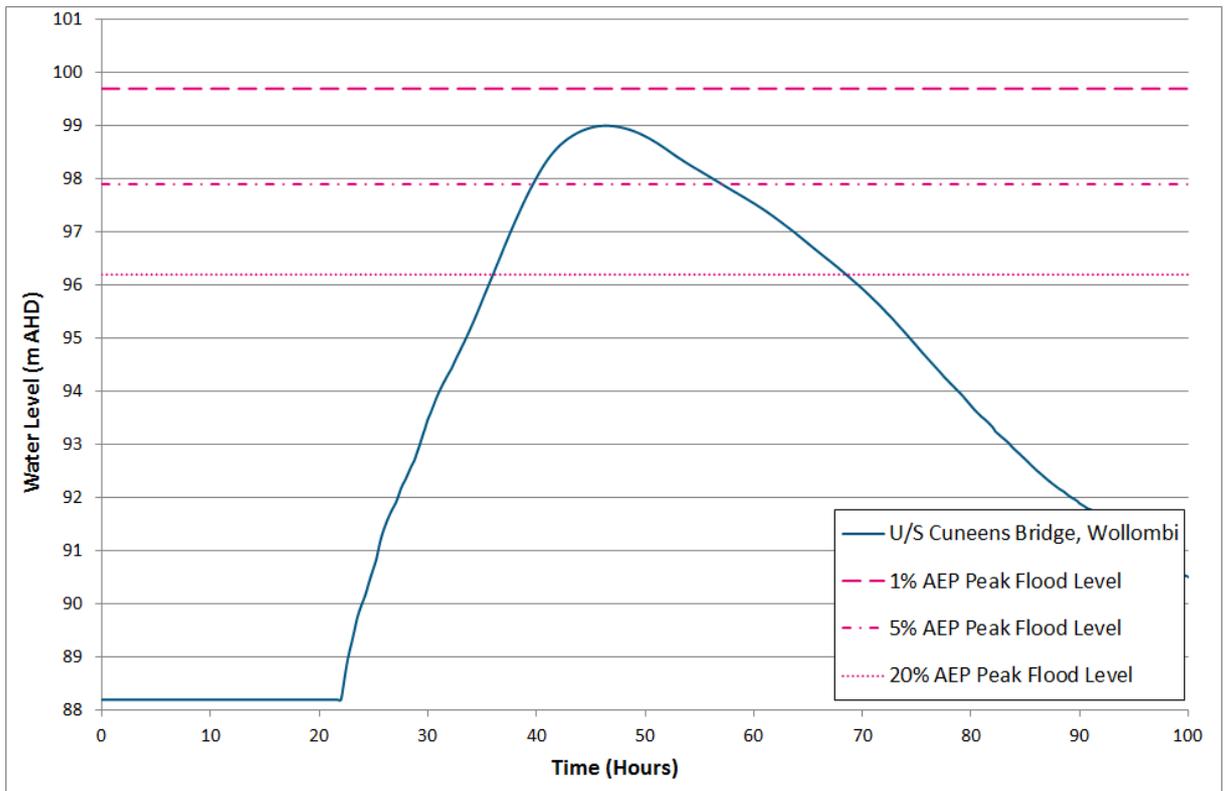


Figure 2-6 June 2007 Simulated Water Level Time Series – U/S Cuneens Bridge, Wollombi

The timing and response of flood behaviour within the Wollombi Village is dependent on the flood conditions emanating from the contributing catchments of the south and north arms of Wollombi Brook. This behaviour would typically vary from event to event dependent on the spatial and temporal distribution of rainfall across the catchment. A comparison of the simulated water level timeseries is presented in Figure 2-7 for the following locations:

- Watagan Creek Road Bridge, Laguna
- Millfield Bridge, Millfield; and
- Cuneens Bridge, Wollombi

The Laguna and Millfield locations provide the response on the south arm and north arm respectively, with Cuneens Bridge located downstream of the confluence at Wollombi. The simulated water levels shown in Figure 2-7 are for the June 2007 showing the relative response of the tributaries for the observed rainfall.

The rising water levels at the Millfield and Laguna sites typically provide for a response around 6-8 hours in advance of corresponding rise at Wollombi. This is significant in considering the flood warning opportunity for Wollombi Village based on the travel times of flood response through the upper catchment.

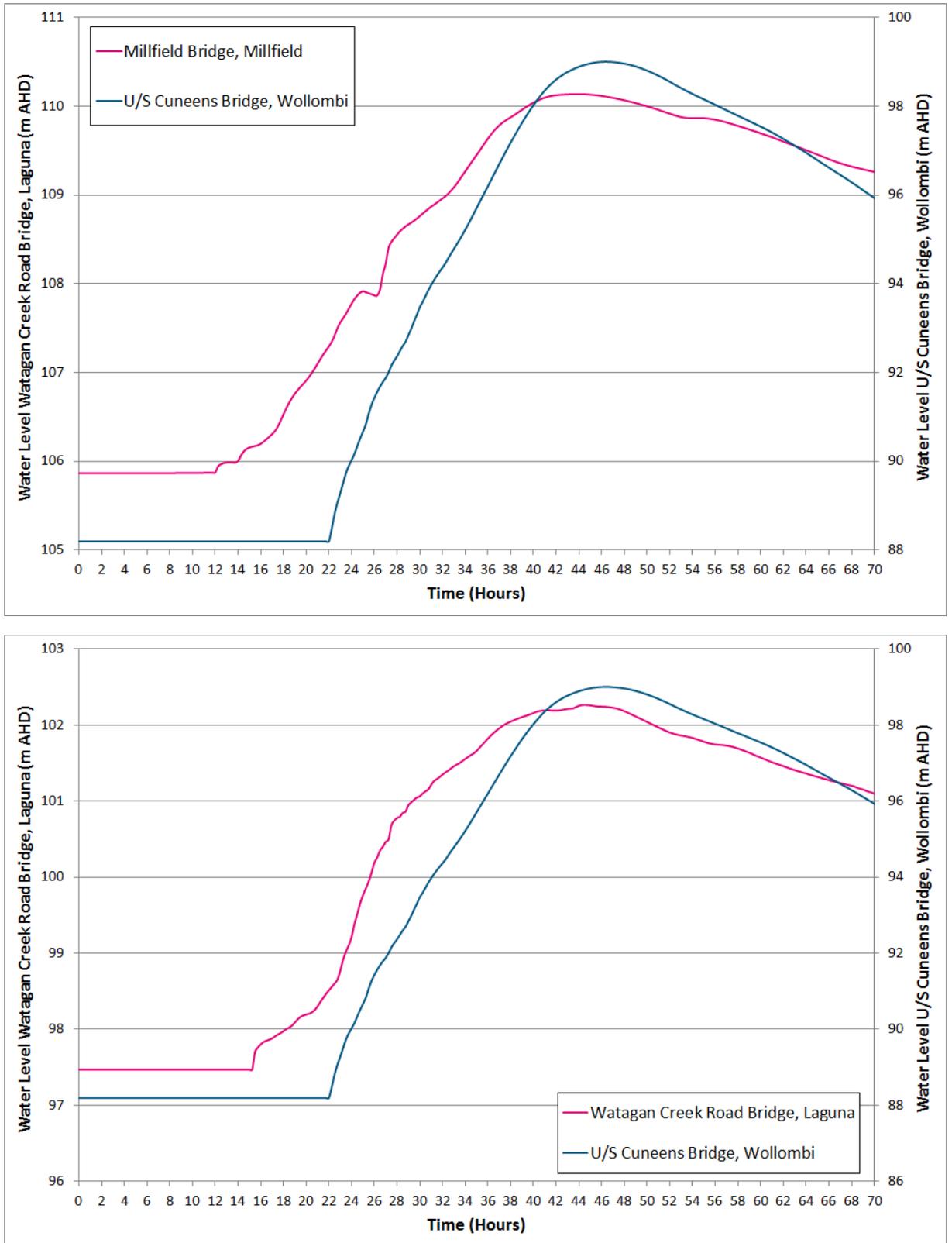


Figure 2-7 June 2007 Water Level Time Series

Background

2.4 Existing Flood Warning System

The formal flood warning service for the Wollombi Brook provided by the Bureau largely benefits the residents in the lower part of the Valley. In the upper part of the Valley, including Wollombi Village, there is no site specific flood warning system, however there are a number of general warning services provided by the Bureau including:

- **Flood Watches** – typically provide 24-48 hour notice. These are issued by the NSW Flood Warning Centre providing initial warnings of potential flooding based upon current catchment conditions and future rainfall predictions.
- **Severe Thunderstorm Warnings** – typically provide 0.5 to 2 hours notice. These short range forecasts are issued by the Bureau's severe weather team and are based upon radar, data from field stations, reports from storm spotters as well as synoptic forecasts.
- **Severe Weather Warnings** – for synoptic scale events that cause a range of hazards, including flooding. Examples of synoptic scale events are the deep low pressure systems off the NSW coast, such as that which produced the 2007 flood in the Wollombi Brook catchment.

The existing flood warning system is not highly effective for Wollombi Village and surrounds. Whilst flood watches and regional severe weather warnings should activate personal flood action plans, the level of existing flood awareness in the community meant that little effective action was taken in June 2007, and is perhaps typical of what would happen in any major flood event at present.

2.5 June 2007 Historical Event Overview

2.5.1 Event Summary

The flood of the 8th and 9th June in the Wollombi Valley was associated with an East Coast Low (ECL) pressure system that developed off the coast over this period. Consistent light rainfall fell across the Wollombi catchment throughout the day or so leading up to the main storm event. This provided for a "wetting-up" period for the catchment which ultimately would lead to higher run-off during the main storm burst that occurred during the evening and early morning of the 8th and 9th.

Many residents had commented that they went to bed with a "trickle" in the Wollombi Brook on Friday evening to awake to a "torrent" in the early hours of Saturday 9th. The Wollombi Brook at Wollombi Village peaked around mid-morning on Saturday 9th, the swollen watercourses taking many days to subsequently recede. Peak flood conditions occurred earlier in the upper catchment tributaries.

The June 2007 flood in the Wollombi Valley was the largest event experienced since 1949 and subsequently for many residents the largest flood of personal experience. The peak water level in Wollombi Village for the event was 99.0m AHD, compared to a peak level of 101.6m AHD for June 1949. The rapid rise of floodwaters within the valley, which predominantly occurred during the night, cut the majority of access roads and resulted in the isolation of many residents. The severe weather and extensive flood inundation led to significant disruption to services and some damage to infrastructure. Numerous residential and commercial properties were inundated.

Background

2.5.2 Flood Warning

The Bureau prepares and disseminates flood warnings and information to the public in close cooperation with state, territory and local government agencies and other stakeholders. Users of flood warning services include emergency management agencies and members of the public, particularly those in flood-prone areas. More detailed local interpretation of the Bureau flood warning products and information is provided directly to the public by flood response agencies. The Bureau warning products include early alerts to the possibility of flooding through a flood watch product, with site-specific forecasts of river height and the expected impact in terms of minor, moderate or major flooding in specific river basins.

Where dedicated flood forecasting systems have not been installed, more generalised products are issued on a regional basis. The free exchange of data in real time among stakeholder agencies and the timely availability of warnings, data reports and flood information to the public are cornerstones of the flood warning service (Bureau of Meteorology, 2007).

2.5.2.1 Bureau Flood Watch

A general flood watch for the Hunter Valley was issued around 5:30pm on the 7th June 2007. This was on the basis of predicted heavy rainfall across the region. At this stage in the Wollombi Valley, less than 40mm of rainfall had fell in the previous 24 hours.

2.5.2.2 Bureau Flood Warning

In an escalation from the Flood Watch, a series of Flood Warnings were issued for the Hunter River as heavy rainfall occurred across the region. Summarised hereunder is the initial five Flood Warnings issued for the Hunter. The italic text represents information directly included in the warnings with additional comments added in bold providing some context to the flooding at Wollombi.

Flood Warning 1

Issued:

Issued at 9:09pm on Friday the 8th of June 2007

The timing of issue corresponds to the start of the most intense rainfall period in the upper Wollombi Valley.

River Height Predictions

No current warning was in place at this stage for Wollombi Brook.

Reference Gauges:

<i>Wollombi Brook at Brickmans Bridge</i>	<i>1.12m steady</i>	<i>at 1200am Wed 06/06/07</i>
<i>Wollombi Brook at Bulga</i>	<i>1.12m rising</i>	<i>at 901pm Fri 08/06/07</i>
<i>Wollombi Brook at Warkworth</i>	<i>1.44m rising</i>	<i>at 400pm Fri 08/06/07</i>

Background

Note that the Wollombi Brook at Brickmans Bridge gauge had failed and accordingly no up to date water level information was available at this site, and remained the case through the remainder of the flood warning series.

Flood Warning 2

Issued:

Issued at 1:29am on Saturday the 9th of June 2007

River Height Predictions

No current warning was in place at this stage for Wollombi Brook. This warning is at the height of the rainfall event in the upper valley, but no response yet recorded at the lower valley water level gauges.

Reference Gauges:

Wollombi Brook at Brickmans Bridge	1.12m steady	at 1200am Wed 06/06/07
Wollombi Brook at Bulga	1.77m steady	at 117am Sat 09/06/07
Wollombi Brook at Warkworth	1.21m falling	at 100am Sat 09/06/07

Flood Warning 3

Issued:

Issued at 5:10am on Saturday the 9th of June 2007

River Height Predictions

Bulga [Wollombi Brook] - reach 6 metres by noon 9/6/07 with major flooding.

Note that this is the first direct reference to Wollombi Brook, albeit with reference only to the Bulga gauge. Peak flood conditions in Wollombi are expected at least 12 hours before Bulga.

Reference Gauges:

Wollombi Brook at Brickmans Bridge	1.12m steady	at 1200am Wed 06/06/07
Wollombi Brook at Bulga	4.69m rising	at 427am Sat 09/06/07
Wollombi Brook at Warkworth	1.27m rising	at 400am Sat 09/06/07

Flood Warning 4

Issued:

Issued at 7:58am on Saturday the 9th of June 2007.

At this stage peak flood conditions were occurring on the two arms of the Brook upstream of Wollombi.

River Height Predictions

Bulga [Wollombi Brook] - reach 6 metres by noon 9/6/07 with major flooding.

Background

Reference Gauges:

Wollombi Brook at Brickmans Bridge	1.12m steady	at 1200am Wed 06/06/07
Wollombi Brook at Bulga	6.03m rising	at 748am Sat 09/06/07
Wollombi Brook at Warkworth	1.27m rising	at 400am Sat 09/06/07

Flood Warning 5

Issued:

Issued at 10:32am on Saturday the 9th of June 2007

River Height Predictions

The Wollombi River (sic) at Bulga is currently approaching a peak near 6.3 metres.

Bulga [Wollombi Brook] - reach 6.3 metres by noon 9/6/07 with major flooding.

A dual peak was recorded at Bulga. Water levels at Bulga held steady at a gauge height around 6.3m for a period, before the main flood wave from the upper Wollombi Valley came through with water levels eventually peaking at 7.6m gauge height around noon on the 10/06/07 – some 24 hours after the peak in Wollombi.

Reference Gauges:

Wollombi Brook at Brickmans Bridge	1.12m steady	at 1200am Wed 06/06/07
Wollombi Brook at Bulga	6.24m rising	at 1019am Sat 09/06/07
Wollombi Brook at Warkworth	1.17m falling	at 1000am Sat 09/06/07

Other warning updates continued to be issued for the Hunter Valley over the course of a few days.

The main point of interest from the flood warning series is that the warnings issued had little direct relevance to Wollombi Village and other parts of the upper Wollombi Valley. The timing of the warnings, which are based on water level predictions at the Bulga gauge, are for the most too late to provide effective warning time for residents in the upper valley. As previously stated, whilst flood watches and regional severe weather warnings should activate personal flood action plans, the level of existing flood awareness in the community meant that little effective action was taken in June 2007, and is perhaps typical of what would happen in any major flood event at present.

2.5.3 Emergency Response

Given the inaccessibility of the Valley due to extensive road flooding, SES services were unable to be deployed in the area during the event. In any case, given the regional nature of the event across the Hunter and Central Coast, SES resources were already stretched.

Significant effort was provided by the local volunteer RFS Brigade and other local residents to provide assistance where possible to flood affected residents.

Background

In the most part, flood affected residents were largely left to deal with the flooding themselves given the inaccessibility to property as a result of access road flooding. Given the nature of flooding in the catchment, this is likely scenario whenever major flooding in the Wollombi Valley occurs. Accordingly, the emergency response effort and co-ordination must recognise the requirement for “self-help”.

The combination of the severe flood inundation and isolation amplified the risks to residents of the Valley. The Westpac Rescue Helicopter service answered 4 callouts to the Wollombi Valley as summarised in Table 2-3. The brief commentaries on the nature of the callouts reinforce the potential critical endangerment of residents during major flooding in the Valley.

Table 2-3 Westpac Rescue Helicopter Missions to Wollombi June 2007 Flood

Mission Date	Mission Description
09 June 2007	Tasked by Police to rescue a family of seven trapped in their home at Cedar Creek by rising flood waters. They were winched on board and taken to safety.
09 June 2007	Called to Wollombi to rescue two females trapped in the loft of a house by rising flood waters. They were winched on board and taken to safety.
09 June 2007	Called to Wollombi to rescue a female from the roof of her house after she was trapped by floodwaters. She was flown to John Hunter Hospital suffering leg injuries and shock.
10 June 2007	Called to Wollombi to rescue an 88-year old female who was trapped by floodwaters. She was taken on board the aircraft and flown to Wollombi and taken by road ambulance.

(Source: Mission Log extract from Westpac Rescue Helicopter Service website www.rescuehelicopter.com.au)

The last two rescues in the above table highlight the problems associated with extended isolation as a result of floodwaters. Significant risk is posed to highly vulnerable members of the community, such as the elderly, and others requiring medical attention.

2.5.4 Community Feedback Following the June 2007 Flood

Through post-event questionnaires, and subsequent community information sessions undertaken as part of the Wollombi Flood Study Review and Model Upgrade (BMT WBM, 2010), residents were asked to provide comment on personal experiences or opinion in regard to the June 2007 flood or general flooding and floodplain management within the Wollombi Valley. The common themes from the responses given are summarised below.

- No flood warnings – many respondents indicated that almost no warning of the rising floodwater was available. This was exacerbated in the upper reaches of the catchment where peak flooding occurred during the night. With no flood warning system in place, many residents awoke to the flooding problem and limited lead time (if any) to undertake appropriate action. Given the rapid rise of floodwaters within the Wollombi Valley, this posed a considerable risk.
- Lack of coverage on local media – whilst local media provided general coverage of the widespread flooding throughout the Hunter Valley, in particular major centres of Singleton,

Background

Maitland and Newcastle, very little publicity was given to the situation in Wollombi. Wollombi residents indicated very little Wollombi specific information.

- Limited flood support – acknowledgment was made of the contribution of the rescue helicopter service, Rural Fire Service and local community members. However there was a concern about the lack of coordinated response and support, and the feeling that the community was effectively left to fend for itself.
- Phone and electricity downtime – the severity of storm coupling intense rainfall, high winds and flooding led to a loss of services. Aside from the obvious inconvenience, the loss of these services severely impacted on communication and limited any effective and coordinated flood response amongst residents in the Wollombi Valley. Alternative power supplies and communication means were considered essential for future flood response.
- Access problems – the extent of flooding in the Wollombi Valley saw many access roads cut and resulted in a significant number of residents to be isolated and unable to leave their property. In addition to the safety issues posed with respect to the flood risk, the restricted access in conjunction with lost services/communication led to considerable anxiety. With access cut for a number of days, some residents indicated problems with limited food supplies. Concern over the lack of safe crossing points and adequacy of flood depth markers was also raised.
- Development planning controls - a number of references were made to Council's planning policy with respect to flood levels in Wollombi. The responses generally indicated concern over the lowering of the design flood standard, considering the magnitude of the 1949 and 2007 flood events and potential flood risks posed.
- State of the river - a number of respondents indicated concern over the extent of vegetation with the Wollombi Brook and its potential to increase flood levels. Also, the potential for contamination was raised given various drums/containers of oil, paint and other chemicals being transported down the river by floodwaters.

3 Stakeholder and Community Engagement

Stakeholder and community engagement is a critical component of the development of an effective TFWS. The stakeholder and community engagement strategy aimed to inform stakeholders and the community about the development of the TFWS, and provide an opportunity to collect information on their flood experience, and to collect feedback and ideas on potential measures to be included in the TFWS.

The key elements of the engagement process have been as follows:

- Distribution of an online survey to key stakeholders in the Wollombi Valley to collect information on their flood experience, and preliminary ideas on measures to be incorporated into the TFWS;
- Stakeholder workshop to discuss and develop preliminary options for each component of the TFWS; and
- Community workshop to present and discuss the preliminary options for the TFWS.

In addition to the above, ongoing communication was undertaken with Council, OEH and the Bureau.

3.1 Stakeholder Survey

An online stakeholder survey (presented in Appendix A) was distributed to key stakeholders in the Wollombi Valley. The purpose of the online survey was to collect information on previous flood experience, get an appraisal of the existing framework for flood emergency response in the Wollombi Valley, and seek preliminary ideas/advice on measures to be incorporated into the TFWS. A summary of the responses is provided below. A detailed overview of the responses is included in Appendix B.

A total of 22 responses were received, with survey respondents from a representative range of backgrounds. The respondents were responsible for various roles within the flood warning process, including formal roles, such as managing river and rain gauge data, communicating flood warning messages etc., as well as less formal roles such as maintaining contact with neighbours during flood events.

In summary, most respondents do not believe the current system is adequate. Particular issues include lack of formal system (many residents contact each other directly to share information), lack of warning time, poor communication facilities (e.g. mobile reception), and concern for out of town residents who are unfamiliar with the flood risk.

Most respondents believed there was a need for additional stream gauges both within the town area and upstream of the town, however comments indicate that respondents believe reliance on stream gauge data would not provide sufficient notice for evacuation.

A number of final comments were provided about the current and future flood warning systems, a summary of these are provided below:

- Wollombi Valley is a flood prone community, but while flooding affects a few homes most of the flood risk relates to ingress and egress. Tourists especially have taken unreasonable risks trying to get in/out of the area.
- Needs to be simple and easy to use/maintain. Not dependent of technology which is likely to fail during an event.
- A major concern in the past was the influx of visitors to weekend complexes who were caught in flood conditions, then expect the same support as in the cities. This doesn't happen in remote rural communities. The past Wollombi community was made up with farming properties where the locals just sat it out with enough food and supplies to carry over and did not require help.

3.2 Stakeholder Workshop

A stakeholder workshop was held at 10.30am on Wednesday 8th February at the Cessnock Performing Arts Centre. Attendees at the stakeholder workshop included representatives from the following organisations:

- Cessnock City Council;
- NSW Office of Environment and Heritage (OEH);
- Bureau of Meteorology (Bureau);
- NSW State Emergency Service (SES);
- NSW Rural Fire Service (RFS); and
- BMT WBM.

The purpose of the stakeholder workshop was to discuss the preliminary options for each component of the TFWS. The overarching topic of discussion at the stakeholder workshop was the issue of poor communication within the Wollombi Valley, and the need to develop a community information and awareness program to aid in the community's response to a flood event.

Emanating from the stakeholder workshop there was a general consensus on the measures required to develop a TFWS for Wollombi and the general approach to forming these into three scalable options. In principal verbal support was provided by each stakeholder group subject to subsequent approvals and funding arrangements.

3.3 Community Workshop

A community workshop will be held from 5:00pm to 6:30pm on the 22 March 2007 at the Wollombi Community Hall to discuss the Wollombi Valley Total Flood Warning System Options Report and seek community input into the options developed (refer Section 6).

4 Existing Framework for Flood Emergency Response

An initial review of the existing framework for flood emergency response has been undertaken to help inform stakeholder and community consultation, and design of a TFWS for Wollombi.

4.1 National Standards

4.1.1 Flood Warning Manual

The design and operation of flood warning systems in Australia is guided by the *Flood Warning Manual* (Emergency Management Australia 2009). The manual defines a total flood warning system (TFWS) as a system to assist flood management agencies and flood prone communities in understanding the nature of an impending flood and prompt actions to mitigate adverse effects. Six components make up a successful TFWS, operating in a cyclic manner. These are:

- Monitoring and Prediction
- Interpretation
- Message Construction
- Communication
- Protective Behaviour
- Review.

Without **all** of these components working in an integrated manner, the total flood warning system's effectiveness is compromised. These components, as they relate to Wollombi's current flood warning system, are reviewed in the subsequent sections.

4.1.2 Bureau of Meteorology Guidelines

The Bureau have adapted the World Meteorological Organization (WMO)'s guide to *Siting and exposure of meteorological instruments* (1993) to local conditions, published in *Observation Specification No 2013, Guidelines for the Siting and Exposure of Meteorological Instruments and Observing Facilities* (1997).

The Bureau's guidelines provide assistance for the selection of sites for rainfall and stream gauges to meet Bureau standards in relation to exposure, effectiveness and logistical / practical factors.

4.2 Monitoring and Prediction

Beyond water resource management, there are two distinct purposes for developing a comprehensive network of stream and rainfall gauges: flood warning and improving the understanding of local flood behaviour (through rainfall analysis and flood investigations).

Flood warning is normally the key driver for enhancing gauge networks. The main criterion used to assess the effectiveness of a flood warning gauge network is its ability to improve community safety and reduce damage to property. A robust flood warning system includes sufficient gauges to get a good understanding of rainfall patterns and water levels throughout the catchment. It is also

Existing Framework for Flood Emergency Response

important to ensure that gauges are sufficiently close to the area of interest to be hydraulically relevant, while being sufficiently far upstream that timely flood warnings can be issued.

The gauge network developed for flood warning can also be used to calibrate and verify models of historical flood events. A well calibrated model provides more reliable information about likely flood behaviour which can be used to inform flood management plans. It is important that the gauge network has sufficient coverage to accurately record rainfall patterns and stream levels throughout the catchment.

4.2.1 Monitoring

4.2.1.1 Rain Gauges

A review of rain gauges has been undertaken to identify active gauges within and surrounding the catchment. At present, there are ten operational rainfall gauges in the Wollombi Brook catchment (five of these are located within the Singleton LGA and five in the Cessnock LGA). Details of these gauges are provided in Table 4-1, with locations shown on Figure 4-1. Key points to note are:

- There are two operational ALERT² rain gauges in the Wollombi Brook catchment upstream of Wollombi Village. Both of these are located on the south arm of the Wollombi Brook with no active ALERT gauges on Congewai Creek (north arm of the Wollombi Brook);
- There are three operational daily rain gauges in the Wollombi Brook catchment upstream of Wollombi Village; and
- There are a number of closed gauges located within the Wollombi Brook catchment upstream of Wollombi Village.

Table 4-1 Summary of Bureau Rainfall Gauges in the Wollombi Brook Catchment

Station No.	Name	Type	Operator
61191	Bulga (South Wambo)	Daily	Bureau
61143	Bulga (Down Town)	Daily	Bureau
61309	Millbrodale (Hillsdale)	Daily	Bureau
61422	Millbrodale School	Continuous	Bureau
61100	Broke (Harrowby)	Continuous	Bureau
61226	Wollombi (St Johns Church)	Continuous	Bureau
61201	Watagan Central	Continuous	Bureau
61205	Yallambie (Mount Auburn)	Daily	Bureau
61152	Congewai (Greenock)	Daily	Bureau
61164	Laguna (Murrays Run)	Daily	Bureau

² ALERT is an acronym for Automated Local Evaluation in Real Time. This refers to the method of communication from the gauge. The gauge sends data to a central base station every time an 'event' occurs. In the context of rain gauges, an event is associated with the tip of a tipping bucket rain gauge (0.2mm, 0.5mm or 1mm depending on the size of rain gauge). In the context of river gauges, an 'event' is a change in water level of more than a certain amount (typically 50mm). ALERT gauges usually transmit data via VHF radio.

Existing Framework for Flood Emergency Response

There are seven further operational rainfall gauges surrounding the Wollombi Brook catchment. Details of these gauges are provided in Table 4-3, with locations shown on Figure 4-1. Key points to note are:

- The Pokolbin and Cessnock AP gauges are close to the catchment divide with Congewai Creek, therefore have value for estimation of rainfall in the Congewai Creek catchment;
- The Kulnura, Wyong (Olney Forest) and Martinsville gauges are just beyond the southern catchment divide of Wollombi Brook. Whilst it is recognised that rainfall on the eastern side of the range is typically higher than on the Wollombi Valley side, these gauges can be assumed to be an approximate representation of rainfall near the catchment boundary.
- The Howes Road and Singleton STP gauges surround the downstream parts of the Wollombi Brook catchment within the Singleton LGA. These gauges have no value for flood warning for Wollombi Village or other towns within the Cessnock City LGA.

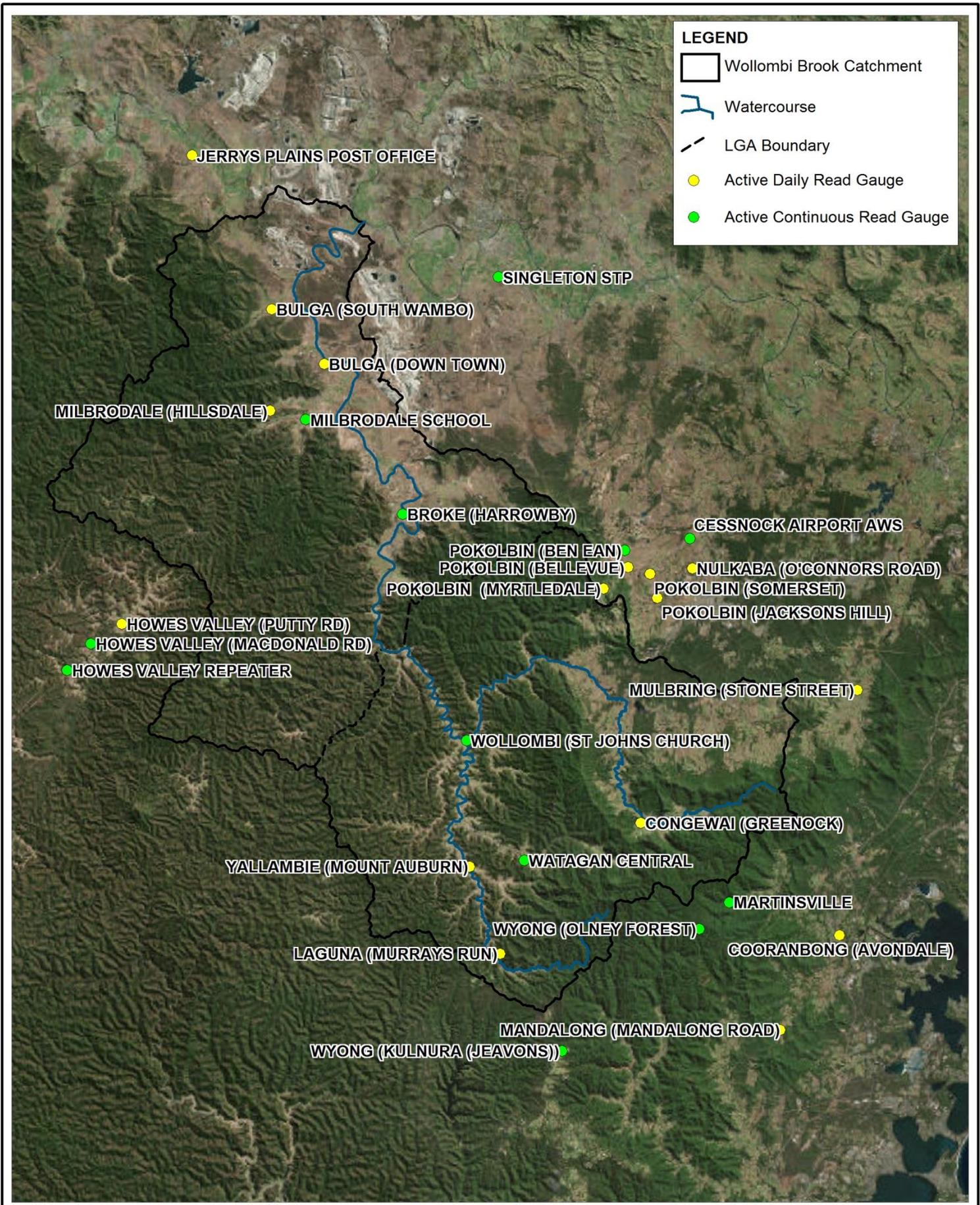
Table 4-2 Summary of Bureau Rainfall Gauges surrounding the Wollombi Brook Catchment

Station No.	Name	Type	Operator
61056	Pokolbin	Continuous	Bureau
61260	Cessnock AP	Continuous	Bureau
61382	Kulnura (Jeavons)	Continuous	Bureau
61385	Wyong (Olney Forest)	Continuous	Bureau
61397	Singleton STP	Continuous	Bureau
561036	Howes Valley (MacDonald Road)	Continuous	Bureau
561083	Martinsville	Continuous	Bureau

In addition to the Bureau rainfall gauges listed in Table 4-1, the Cessnock City SES Local Headquarters and local community members also monitor a number of manual read rainfall gauges as listed in Annex C of the *Cessnock City Local Flood Plan* (SES, 2009) and presented in Table 4-3. The exact location and monitoring arrangement for the gauges is to be confirmed with the SES and the local community.

Table 4-3 Summary of Manual Read Rainfall Gauges in the Wollombi Brook Catchment

Name	Reading Arrangement
Congewai	Local Readers
Laguna	Laguna Rural Fire Service
Wollombi (2 gauges)	Wollombi Police and Wollombi Rural Fire Service
Bucketty	Bucketty Rural Fire Service



Title:
**Locations of Rainfall Gauges in the
 Wollombi Brook Catchment**

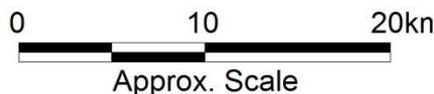
Figure:

4-1

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4.2.1.2 Stream Gauges

A review of stream gauges has been undertaken to identify active gauges within the Wollombi Valley. The Office of Water currently operates three automatic stream gauges in the catchment. Details of the three stream gauges are presented in Table 4-4, with locations shown in Figure 4-2. It is important to note that there are no automatically operated stream gauges within the Wollombi Brook catchment upstream of Wollombi Village.

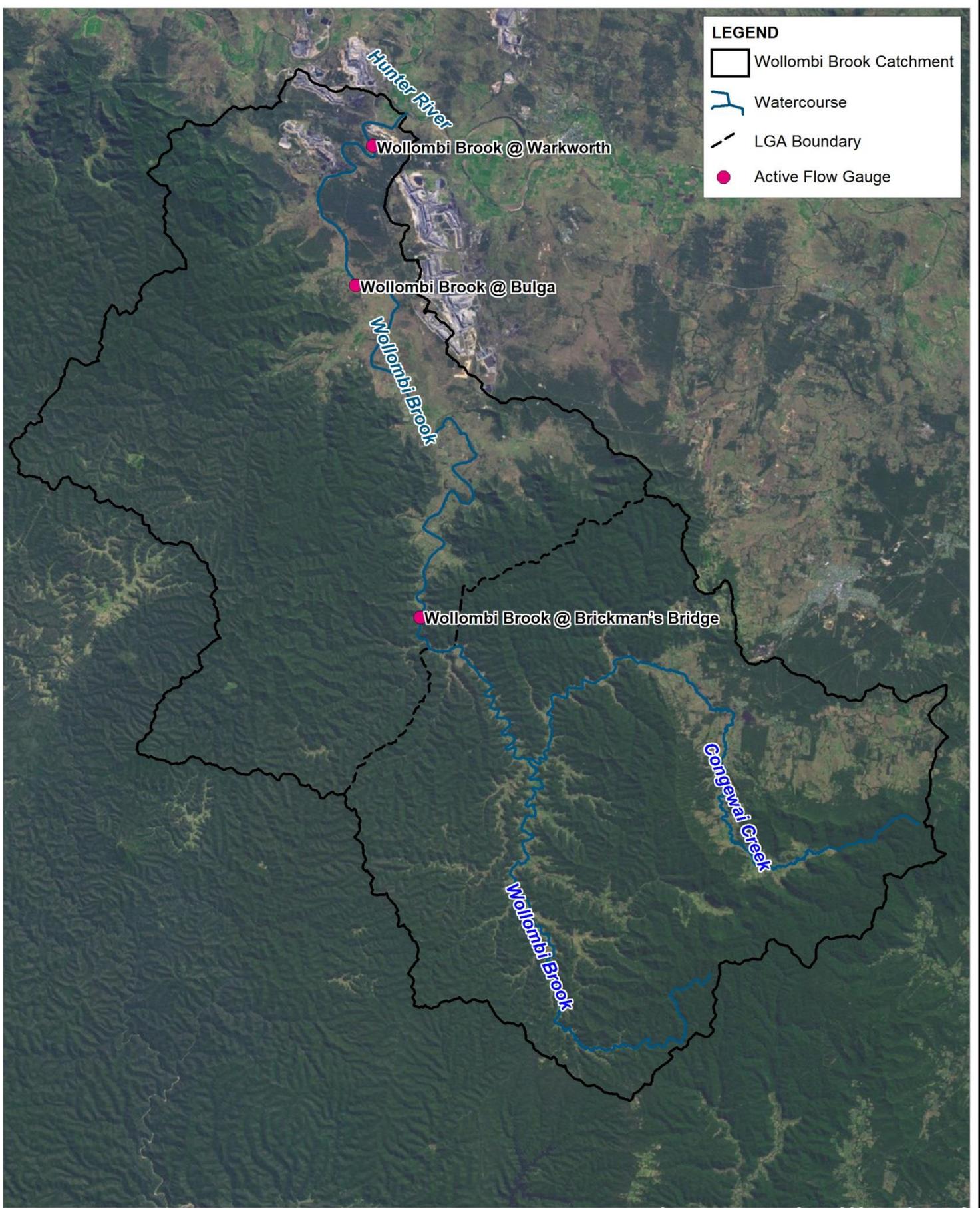
Table 4-4 Stream Gauges in the Wollombi Brook Catchment

Station No.	Station Name	Period of Record
210135	Wollombi Brook @ Brickman's Bridge	1908 - Present
210028	Wollombi Brook @ Bulga	1949 - Present
210004	Wollombi Brook @ Warkworth	1995 - Present

In addition to the Office of Water automatic stream gauges listed in Table 4-4, the Cessnock City SES Local Headquarters and local community members also monitor a number of manually read water level gauges distributed throughout the Wollombi Brook catchment as listed in Annex C of the *Cessnock City Local Flood Plan* (SES, 2009). These gauges are listed in Table 4-5 with locations presented in Figure 4-3. The location for three of the gauges and the monitoring arrangement for each manually read water level gauge is to be confirmed with the SES and local community.

Table 4-5 Summary of Manual Read Water Level Gauges in the Wollombi Brook Catchment

Name	Type	Waterway	Reading Arrangement
Congewai	Road (Ellalong Swamp)	Congewai Creek	Cessnock VRA
Millfield Bridge (Wollombi Road)	River	Congewai Creek	Local Reader or Millfield Rural Fire Service members
Wollombi	Road	Wollombi Brook	Wollombi Police, Wollombi Rural Fire Service, Cessnock City Council
Wollombi (Williams Bridge on Wollombi-Broke Road)	Road	Wollombi Brook	Wollombi Police, Wollombi Rural Fire Service, Cessnock City Council
Wollombi (Cuneen Bridge on Wollombi-Broke Road)	Road	Wollombi Brook	Wollombi Police, Wollombi Rural Fire Service, Cessnock City Council
Wollombi (Cleghorn Bridge on Wollombi-Laguna Road)	Road	Wollombi Brook	Wollombi Police, Wollombi Rural Fire Service, Cessnock City Council
Wollombi (Wollombi Bridge)	River	Wollombi Brook	Local Reader
Laguna (Watagan Creek)	River	Wollombi Brook	Laguna Rural Fire Service
Murrays Run	River	Wollombi Brook	Local Reader

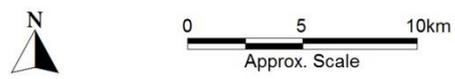


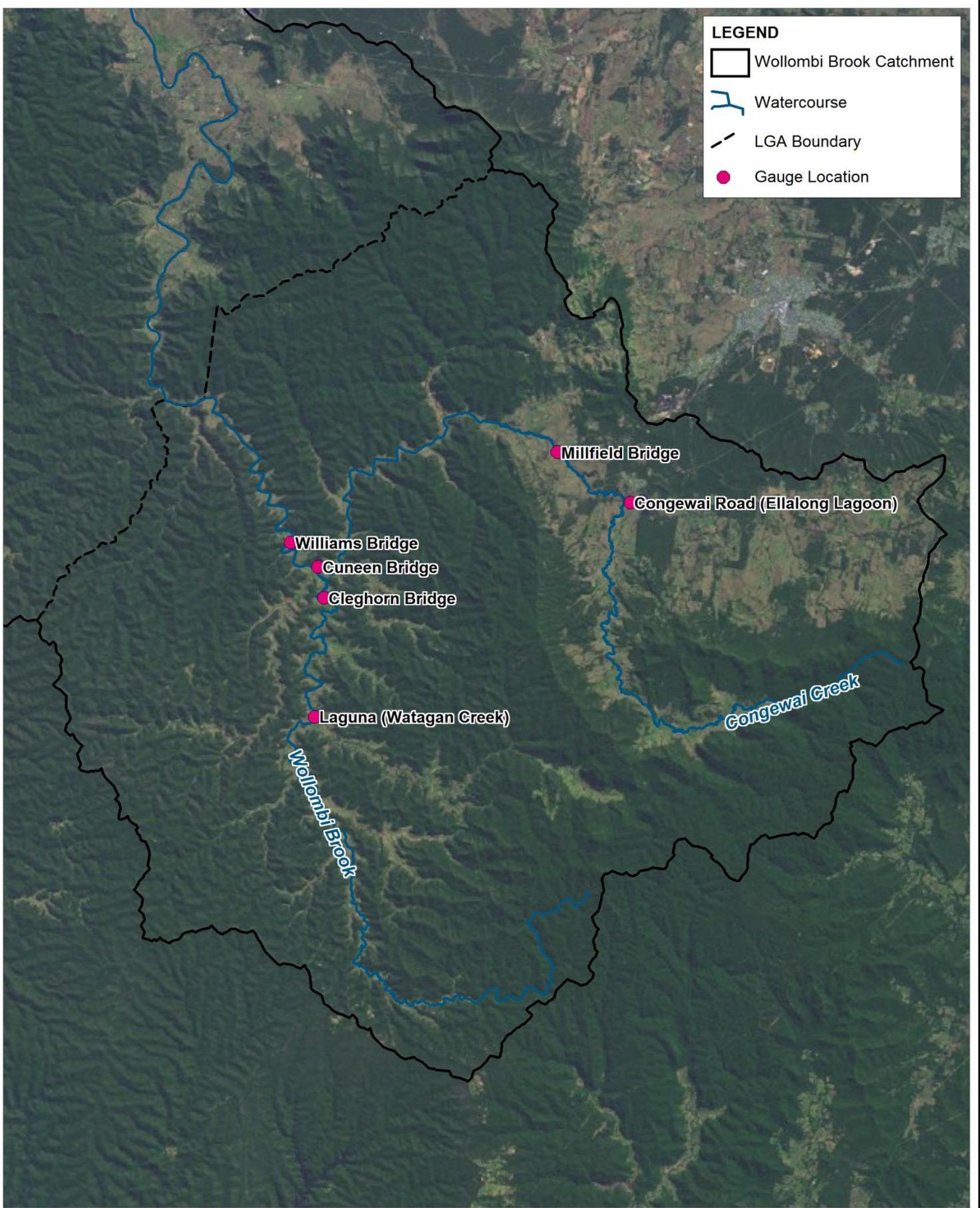
Title:
Locations of Flow Gauges in the Wollombi Brook Catchment

Figure:
4-2

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<p>Title:</p> <p>Locations of Manual Read Water Level Gauges (Some Locations To Be Confirmed)</p>	<p>Figure:</p> <p>4-3</p>	<p>Rev:</p> <p>A</p>
<p>BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.</p>	<p>N</p> <p>0 5 10km</p> <p>Approx. Scale</p>	 <p>BMT WBM</p> <p>www.bmtwbm.com.au</p>
<p>Filepath : K:\B22209_Wollombi_Flood_Warning_System\MapInfo\Workspaces\DWG_004_LevelGauges.WOR</p>		

4.2.2 Review of Monitoring

Review of Wollombi's monitoring network indicates that rainfall and stream gauge infrastructure is limited, and insufficient to inform a TFWS. The primary issues are:

- There are no automatic stream gauges in the catchment upstream of Wollombi.
- There are two continuous recording rainfall gauges in the catchment upstream of Wollombi, however they are both located on the south-arm of the Wollombi Brook and as such may not necessarily be representative of rainfall across the catchment. Furthermore, there is a spatial variation in rainfall intensity over the whole catchment that shows higher rainfall in the upper catchment on the slopes of the Watagan Ranges meaning that the gauges may not record the most intense rainfall. Gauges surrounding the catchment assist with understanding spatial distribution, however, rainfall patterns can differ significantly from one site of a catchment divide to another.
- Daily rainfall gauges and manually read rainfall gauges are insufficient to inform a TFWS due to the potential for fast onset flooding in Wollombi from the Wollombi Brook and/or Congewai Creek.
- Manually read stream gauges can support a TFWS, however are not in themselves sufficient, due to challenges with reading the gauges at regular intervals throughout an event (time of event, inclement weather, access to gauge etc.).

The *Wollombi Floodplain Risk Management Study and Plan* (BMT WBM, 2012) discussed a potential combination of continuous water level gauges that could provide adequate warning to Wollombi. This potential/example combination of gauges was as follows:

- South Arm: Watagan Creek Road (Laguna) - Located 10km upstream of Wollombi Village and incorporating approximately 90% of the South Arm catchment to Wollombi.
- North Arm: Cedar Creek Road – Located 12km upstream of Wollombi Village and incorporating approximately 90% of the North Arm catchment to Wollombi. Millfield Bridge is an alternative location, 6km further upstream and therefore potentially providing more warning time, however would not have the contribution from the Cedar Creek catchment.
- Confluence: Downstream of Cuneens Bridge – representative of Wollombi Village flood levels with total combined north and south arm flows.

These gauges would be required to transmit real-time data to allow maximum time for responsive action as required. It should be noted that the upstream gauges would not in themselves provide adequate forewarning of flooding to allow residents to respond. They will, however, provide verification of discharge estimated to occur due to rainfall recorded at the rain gauges. Rain gauges will provide the greatest lead time for flood warning. Recommendations for improvement to the monitoring network are discussed in Section 5.1.1.

4.2.3 Prediction

The Bureau can provide flood warning services for locations that have a greater response time than 6 hours. Shorter response time catchments are considered to be flash flood catchments and

Existing Framework for Flood Emergency Response

may not receive sufficient (if any) warning of an impending flood. Some Councils, with the assistance of the Bureau and the NSW SES, have developed smaller scale flood warning services for local catchments. Due to the significant distance between Wollombi and Bulga, and the nature of flooding in the upper Wollombi catchment (i.e. rapid rise of floodwaters in relatively narrow valleys), Wollombi receives little benefit from the Bureau flood forecasting for the Wollombi Brook, as warnings are generated based on predictions at Bulga in the lower catchment reaches of the Wollombi Brook. Wollombi would therefore benefit from a smaller scale flood warning services design specifically for the upper catchment reaches of the Wollombi Brook catchment. This system would then have follow-on benefits for townships downstream of Wollombi with advanced flood warning afforded by the upper catchment flood warning service. Recommendations for improvement to flood forecasting for the Wollombi Valley are discussed in Section 5.1.2.

4.3 Interpretation

Interpretation puts into perspective data collected from monitoring and predictions, and requires the compilation of flood risk information. The analysis of this flood risk information, through media such as flood studies and inundation mapping, results in a more tangible understanding of the resultant flooding from monitoring and predictions.

The Wollombi Flood Study Review and Model Upgrade, and Floodplain Management Study, provide some information to inform interpretation (e.g. flood mapping, critical duration of catchment etc.), however, at present, interpretation of flood data is limited due to poor monitoring and prediction data. Installation of additional stream and / or rainfall gauges will improve the ability to understand the current and potential flood risk during an event.

Should additional gauges be installed in the future, it will be necessary to develop relationships and triggers between recordings at the gauge location and flood outcomes in Wollombi. This would primarily be developed through hydraulic modelling, and may be supplemented in the future as recorded data becomes available (i.e. following a flood event). The SES and Council will also require a suitable medium to store and display information required for interpretation. Recommended interpretation measures are discussed in Section 5.2.

4.4 Message Construction

Once the magnitude of a flood event has been determined, this information is required to be provided in a manner understood by the target audience. This message should include the consequence of the predicted event to the chosen audience and advice on recommended actions which should be undertaken.

The current message template provided in the *Cessnock City Local Flood Plan* (SES, 2009) is standard text and does not relate to Wollombi-specific flood risk. As a result, the template may be challenging to populate during a flood event (particularly as the Bureau does not provide any predictive information for the Upper Wollombi Brook catchment including the Wollombi Village).

The development of relationships between recorded data and flood outcomes in the Wollombi Brook) will make the message construction process easier for the SES during future events.

4.5 Communication

The *Cessnock City Local Flood Plan* (SES, 2009) identifies three main mechanisms for communicating flood warning information to the public:

- NSW SES flood bulletins are issued to the media (TV, radio and newspaper outlets as listed in Annex D of the *Cessnock City Local Flood Plan*)
- NSW SES evacuation warnings and evacuation orders are issued to the media (template evacuation order provided in Annex E of the *Cessnock City Local Flood Plan*). Further details of additional methods of disseminating evacuation warnings are provided below; and
- The standard emergency warning signal (SEWS) may be played over radio and television.

In the event that evacuation warnings are required, the SES will disseminate the warnings via the following mechanisms (where available and appropriate):

- Radio and TV;
- Door knocks by emergency services personnel;
- Public address systems from emergency vehicles;
- Telephone;
- Two-way radio; and
- SES Flood Bulletins.

In addition, information on the status of roads will be included in SES flood bulletins as well as being available from Council, Police and the NSW Roads and Maritime Services (mechanism of communication not specified other than RMS website).

Although the above communication methods are recommended in the *Cessnock City Local Flood Plan* (SES, 2009), it is acknowledged that communication is a major challenge in the Wollombi Valley. Mobile communications are very limited in coverage and prone to failure during extreme weather. Land line phones are also prone to outages as they rely on power supply which can also be affected during extreme weather. Furthermore, the Telstra lines servicing the Wollombi Valley area are often aerial and are subject to damage from falling trees during severe weather events.

Other alternate communication methods described above are relatively limited and may not be effective during a flood event in the Wollombi Valley. In particular, it is noted that Wollombi (and other smaller townships across the upper Wollombi Brook catchment) is subject to rapid rises in floodwaters, indicating that the community needs to receive flood warning information as quickly as possible. Traditional communication methods (television, radio) may not be able to achieve this goal, and may need to be supplemented with additional communication channels. Due to significant distance between some properties, and isolation due to inundation of main access roads, door knocks and public address systems also have limited scope for use in the Wollombi Valley. Potential communication measures are discussed in Section 5.4.

4.6 Protective Behaviour

During the event, the need for appropriate and timely actions by responsible agencies and the wider community is necessary, as described in the *Manual 21 - Flood Warning* (Emergency Management Australia 1999).

The NSW State Emergency Service (SES) is the primary organisation responsible for management of flood warning and operations during a flooding event. The Cessnock City SES Local Controller is responsible for coordinating flood management responsibilities as outlined by the *Cessnock City Local Flood Plan* (SES, 2009).

However, the reality of the situation in the Wollombi Valley is that due to breakdowns in communication, and isolation due to inundation of main access roads, the SES may not be aware that Wollombi is experiencing a flood event until it is too late to take effective pre-emptive action, or provide assistance during the flood event. The June 2007 flood event highlighted the limited opportunity for the SES to provide support both during and post event, due in part to the isolation of the community through road closures, and the stretched resourcing of the SES in dealing with a region-wide event.

In addition to the SES, there are a number of other organisations, including Cessnock City Council and the NSW Rural Fire Service, that are responsible for numerous activities supporting response activities and recovery. Similar to the SES, Council's ability to provide assistance with flood response activities is generally limited due to the isolation of the community through road closures.

In the absence of the SES and Council, the majority of the response operations during a flood event in the Wollombi Valley is left to the NSW RFS. As previously stated, significant effort was provided by the local volunteer Fire Brigade and other local residents to provide assistance where possible to flood affected residents during the June 2007 flood event.

However, in the most part, flood affected residents are largely left to deal with the flooding themselves given the inaccessibility to property as a result of access road flooding. Given the nature of flooding in the catchment, this is a likely scenario whenever major flooding in the Valley occurs. Accordingly, the emergency response effort and co-ordination must recognise the requirement for "self-help". Consideration therefore needs to be given to developing community based action plans that anticipate limited external support, at least in the early stages of a major flood event. Recommended protective behaviour measures are discussed in Section 5.5.

4.7 Review

System review is the final component in the total flood warning system as identified in the *Manual 21 - Flood Warning* (Emergency Management Australia 1999). This iterative process should be undertaken with the aim to improve performance of the system as a whole. The *Cessnock City Local Flood Plan* (SES, 2009) details arrangements for debrief/after action reviews following a flood event but no specific details/requirements for reviewing the performance of any total flood warning system is included, however the possibility exists that a critical analysis of the total flood warning system would be undertaken. If this is not the case, provision needs to be made for an iterative review after each flooding event, with the aim of improving performance of the TFWS.

5 Possible Measures

The overarching challenge for flood warning in the Wollombi Valley is communications. Mobile phone coverage is limited within the steeper parts of the catchment, including most of Wollombi Brook South Arm, and the North Arm (Congewai Creek) downstream from Millfield. During the 2015 event, mobile phone coverage was lost. Although most properties have land lines, these rely on power supply at the telephone exchanges. Limited battery supply is available, allowing for short term loss of mains power supply.

Despite recent works by Telstra to improve the robustness of the telephone network, the availability of these services for most of the valley remains limited. Therefore, the conceptual design for the flood warning system must provide alternative means for critical data and voice communications.

For optimal outcomes from the total flood warning system, the communications equipment must be backed up by communications protocols and procedures, and stakeholder education relating to interpretation of information and associated actions required.

This chapter presents a range of measures that could be implemented in the Wollombi Valley to improve the flood warning arrangements. These measures have been formulated into a series of options for consideration. The options are presented in Chapter 6.

5.1 Monitoring and Prediction

5.1.1 Monitoring

5.1.1.1 ALERT Rain and River Gauges

Currently the community has no access to rainfall and river level data in the upper Wollombi Valley. The majority of respondents from the stakeholder survey indicated the need for additional rain and river gauges throughout the catchment, including river gauges upstream of Wollombi as well as in the town itself.

The enhanced monitoring network presented here leverages and builds upon the existing network within and surrounding the Wollombi Brook catchment. Furthermore, the infrastructure presented here will benefit flood monitoring and warning services for surrounding catchments, as well as the downstream reaches of Wollombi Brook in the Singleton LGA.

Across many of the populous areas of Australia, the Bureau operates a network of rain and river gauges using the ALERT³ communications protocol. Also referred to as Event Reporting Radio Telemetry Systems (ERRTS), data from each gauge are transmitted every time an 'event' occurs. In the case of a rain gauge, an event refers to the tip of the tipping bucket inside the rain gauge which relates to 0.2, 0.5 or 1.0mm of rainfall at the rain gauge. In the case of a river level gauge, an event refers to a change in water level (rising or falling) of a certain amount, typically adopted as 50mm.

ALERT networks operate via VHF radio on frequencies licensed to the Bureau. Line of sight is typically required between gauges, which presents a challenge when designing networks,

³ ALERT is an acronym for Automated Local Evaluation in Real Time

especially within hilly and forested catchments such as Wollombi Brook. Gauges can be installed as ‘repeaters’ enabling a strategically placed rain gauges at high elevations to relay data from one gauge onwards towards the receiving base station.

One of the many advantages of using ALERT technology is that data can be received and used at many locations. Therefore, rainfall and river level data from the enhanced Wollombi ALERT network could be received by:

- The Bureau for display on their website;
- Cessnock City Council in Cessnock for emergency response; and
- Wollombi Rural Fire Service for emergency response and local community use.

The enhanced network of rain and river gauges is shown on Figure 5-1. Indicative communication paths, guided by line of sight, are shown as green dashed lines.

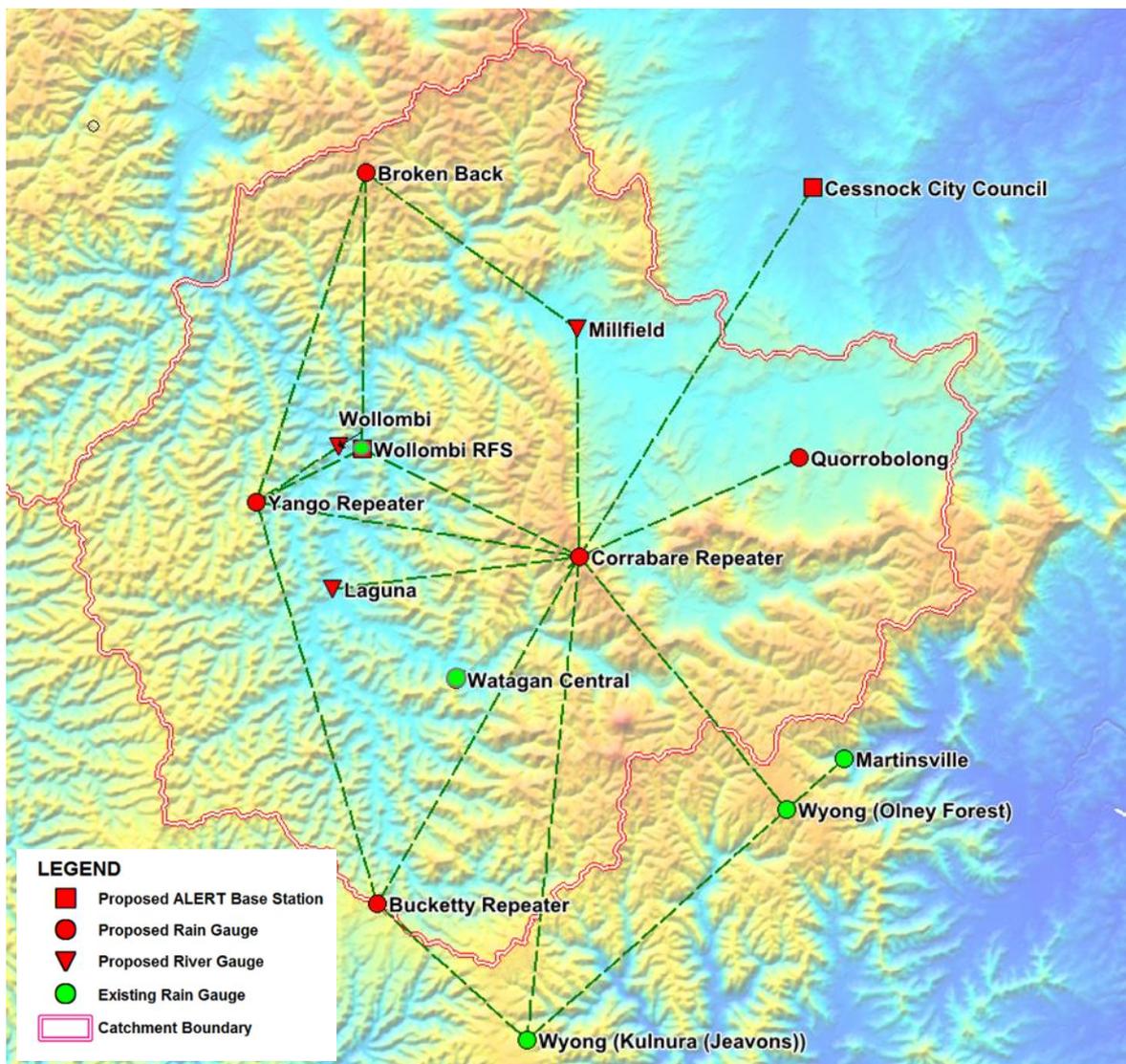


Figure 5-1 Proposed ALERT rain and river gauge network

Possible Measures

The following points have guided the network layout:

- River gauges at Laguna on Wollombi Brook South Arm, Millfield on Congewai Creek and on Wollombi Brook in the Wollombi Village (downstream of the confluence of Congewai Creek and Wollombi Brook). . A river gauge in Wollombi will enable:
 - Monitoring of river levels in Wollombi, particularly for observers not in Wollombi;
 - Post event analysis and verification of rainfall triggers; and
 - Advanced warning for communities along Wollombi Brook within the Singleton LGA.

As discussed in Section 2.3.4, gauges at Laguna and Millfield will provide advanced warning of up to 8 hours at Wollombi, although less for communities upstream from Wollombi. These river gauges will also provide an important verification of rainfall to runoff estimates. It is expected that the Bureau will provide further guidance relating to location of proposed gauges should they commence a formal flood forecasting service for the Wollombi Valley. Gauges will need to be sited to complement the flood forecast modelling.

- Existing ALERT rain gauges along the south eastern catchment boundary will be used to represent rainfall along the Watagan Ranges. The existing Bureau rain gauges at Wollombi and Watagan Central should remain using respective 3G and satellite communications.
- A network of rain gauges is presented, with locations selected to:
 - Provide an even distribution of gauges across the catchment
 - Ensure communications connectivity across the network, including:
 - Communications with the Wollombi RFS, Cessnock City Council and the Bureau
 - Ensure river gauges are linked into the network
 - Position within clearings in vegetation
 - Provide access for installation and maintenance, noting that some gauges are proposed on private land, therefore requiring land owner consultation and permission.
- A rain gauge is proposed to be mounted at the Millfield River gauge.
- Rainfall gauge repeaters are suggested for three locations to provide network connectivity, particularly with receiving systems (such as Council and the Bureau).
- ALERT base stations are suggested for Cessnock City Council and the Wollombi Rural Fire Service.

The spatial coverage of rain gauges is shown in Figure 5-2. This proposed network represents the minimum number of gauges that are required for implementation of an ALERT network. The three repeaters are required to relay data from the river and rain gauges to the base stations.

The repeater network will need to be carefully designed to ensure the correct ALERT pass ranges are configured to prevent the network from jamming up with signals continually being forwarded. As administrators of the ALERT network, and licensees of the radio frequency, this would be expected to be undertaken by the Bureau.

It should be noted that there is a formal approval process that needs to be followed prior to the Bureau agreeing to provide flood warning services to a new forecast location. Discussions are currently being held with the Bureau to initialise the formal approval process.

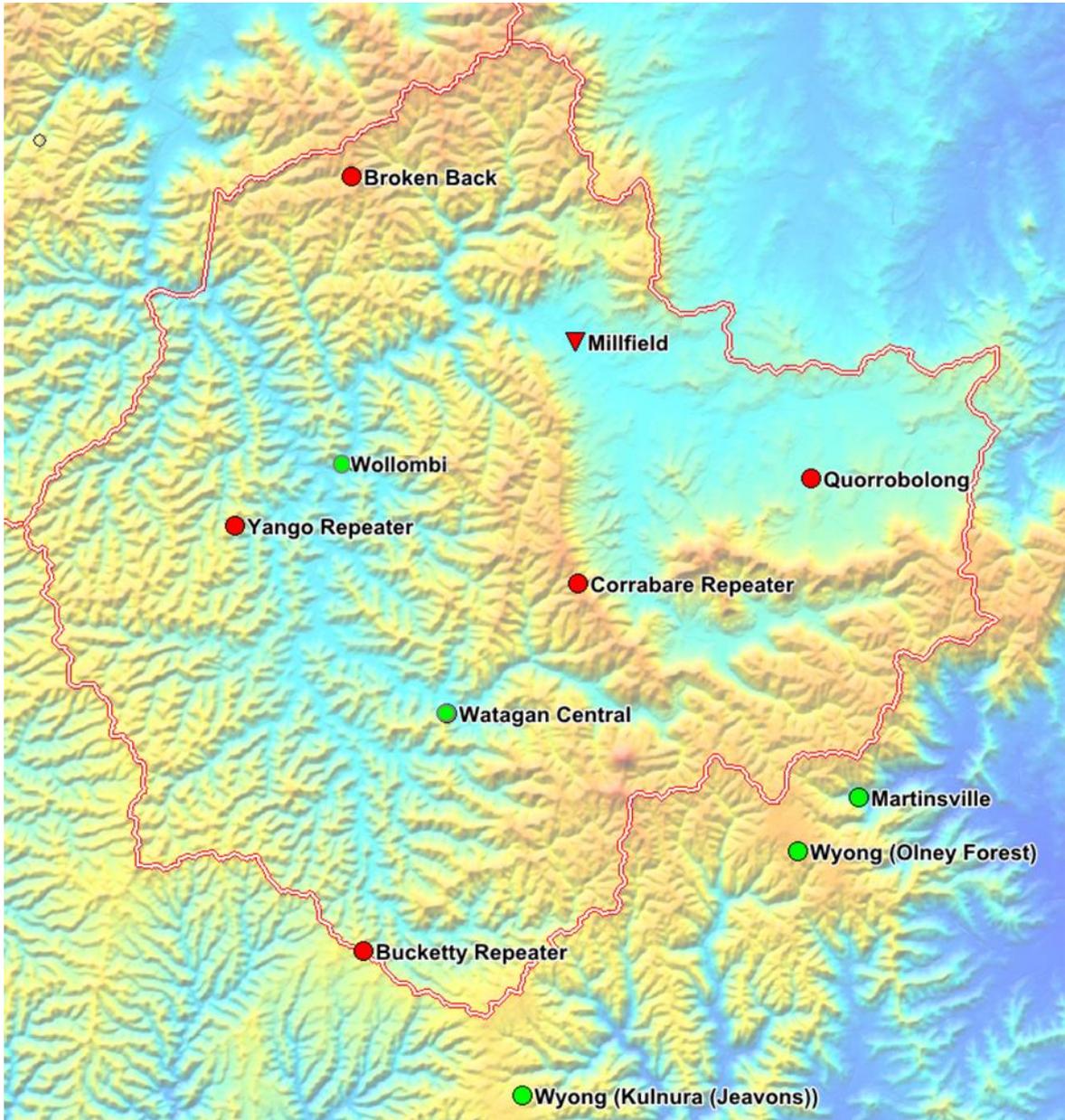


Figure 5-2 Spatial distribution of proposed rain gauge network

Indicative locations for the rain, river and base stations are listed in Table 5-1. Aerial photos of the rain and river gauge locations are shown below.

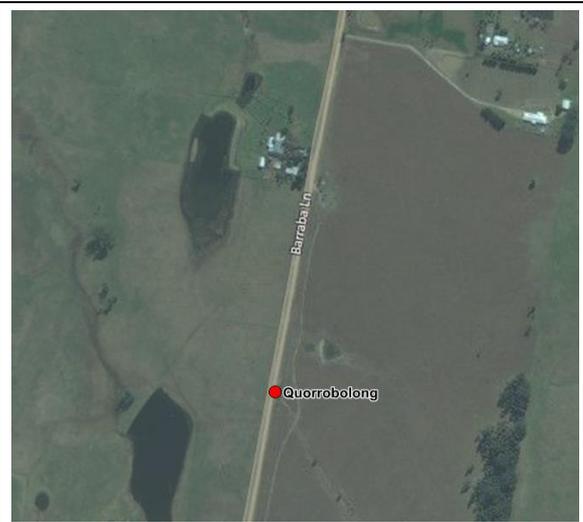
Table 5-1 Locations for rain, river and base stations

Name	Type	Longitude	Latitude
Bucketty Repeater	Rain	151.140	-33.111
Yengo Repeater	Rain	151.098	-32.955
Corrabare Repeater	Rain	151.246	-32.979
Quorrobolong	Rain	151.349	-32.941
Broken Back	Rain	151.151	-32.827
Watagan Central	Rain	151.188	-33.026
Laguna	River	151.132	-32.990
Millfield	Rain / River	151.247	-32.889
Wollombi	River	151.136	-32.934
Wollombi RFS	Base	151.147	-32.935
Cessnock City Council	Base	151.357	-32.835





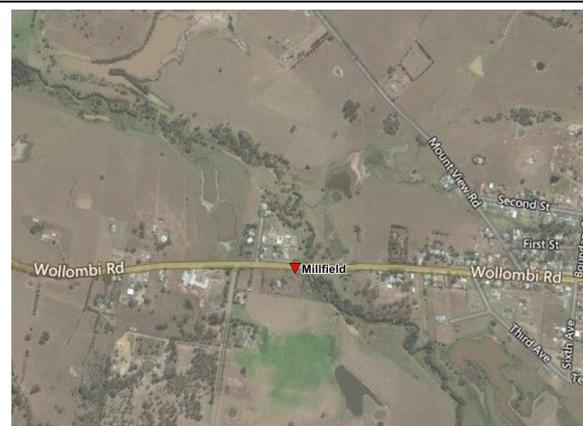
Corrabare Repeater – Rain (adjacent to existing repeater mast)



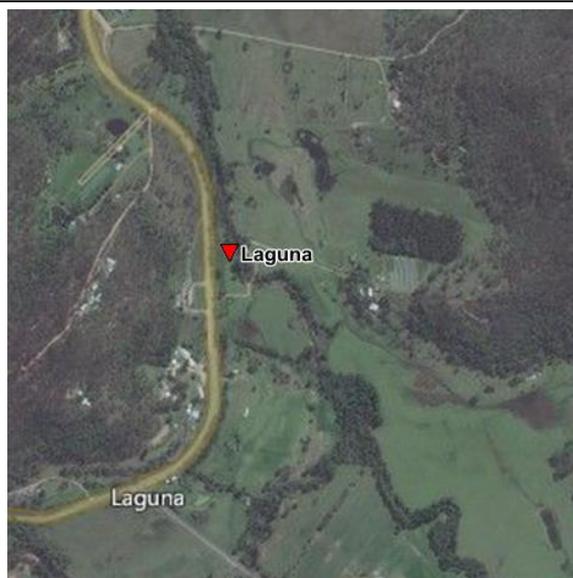
Quorrobolong - Rain



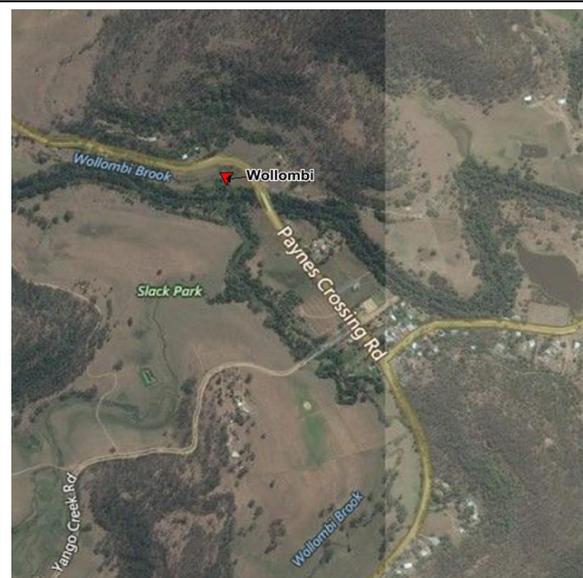
Broken Back - Rain



Millfield – Rain / River



Laguna – River (downstream from Watagan Creek confluence)



Wollombi – River (downstream from Congewai Creek confluence)

Possible Measures

5.1.1.2 Road Crossing Sensors

The road network in the Wollombi Valley is prone to inundation from relatively minor flood events. Both main roads and local access roads and tracks can be cut for days, isolating parts of the community. Whilst road inundation is not economically preventable, there is opportunity to automatically monitor road inundation so that the community know when they are able to evacuate prior to a flood, or when they can mobilise once flood waters recede. Road crossing sensors can be low cost using float switches and local radio communications.

It is recommended that low cost road crossing sensors are considered for the critical road crossings, and low points along the major roads. Indicative locations are:

- Wollombi Brook South Arm
 - Great North Road (between Wollombi and Milsons Arm Road)
 - Milsons Arm Road
 - Great North Road (between Milsons Arm Road and Watagan Creek Road)
 - Watagan Creek Road
 - Great North Road (between Watagan Creek Road and Dairy Arm Road)
 - Dairy Arm Road
 - Great North Road (between Dairy Arm Road and Murrays Run Road)
 - Murrays Run Road
- Congewai Creek
 - Narone Creek Road
 - Wollombi Road (between Wollombi and Cedar Creek Road)
 - Cedar Creek Road
 - Wollombi Road (between Cedar Creek Road and Millfield)
 - Congewai Road
 - Sandy Creek Road

Should this option be considered further, a more detailed analysis of the first point of inundation of the various road segments will be required. Only one monitoring point will be required per segment.

Information from the road crossing sensors can be distributed automatically to the community via SMS, email and social media (e.g. Facebook and Twitter). Communication to residents will require a telephone connection, unless residents are able to communicate via CB radio and manually relay information from areas where data is accessible.

Possible Measures

5.1.2 Prediction

5.1.2.1 Flood forecasting service

The Bureau can provide a flood warning service in catchments with a critical response time of six hours or greater. Catchments having a response time of less than six hours are considered flash flood catchments, for which the responsibility for flood prediction and warning rests with the local Council. As previously stated, the *Wollombi Flood Study Review and Model Upgrade* (BMT WBM, 2010) identifies Wollombi Town as having a 36 hour critical duration. Therefore, discussions are currently being held with the Bureau regarding their ability to provide this service for Wollombi. The questionnaire response from the Bureau indicated a need to identify the response time of the catchment and whether the Bureau were able to provide this service. Flood intelligence may be provided at the following locations to benefit residents of the Wollombi Valley:

- Wollombi;
- Laguna; and
- Millfield.

Notwithstanding the potential role the Bureau may provide in predicting floods at Wollombi, the communities upstream of Wollombi, along Wollombi Brook and Congewai Creek, will have flash flood risks. It is, therefore, imperative that the proposed Total Flood Warning System provides the upstream communities with information that can assist them to make decisions about how to react when heavy rainfall is expected, and observed.

5.1.2.2 Pre-determined rainfall triggers

It is recommended that Monte Carlo type hydrologic modelling is undertaken, using ranges of rainfall depths and durations across Wollombi Brook South Arm and Congewai Creek (varying distributions) to identify a range of rainfall 'triggers' that can provide early indication of flood conditions. The rainfall triggers can be applied to the observed rainfall using a Flood Information System to initiate alerts via SMS, email and social media. Email and SMS alerts can also be triggered by the Bureau's Enviromon software where ALERT data are first received at the base stations.

Depending on the software adopted for warning, rainfall triggers could also potentially be applied to forecast rainfall giving advanced warning. It is critical that alerts produced from rainfall triggers are issued with a likelihood of occurrence. It is also critical that alerts derived from rainfall triggers are not communicated as flood forecasts, to ensure a differentiation between such alerts and formal flood forecasts issued by the Bureau.

5.2 Interpretation

Rainfall and river level observations should be made available through the Bureau's website. Flood forecasts for Wollombi will also be available should the Bureau commence forecasting in the Wollombi Valley. Whilst information relating to the current and forecast gauge levels is valuable to the community, there is a wealth of other information available from the Flood Studies and Floodplain Risk Management Studies that can add value to the gauge level information.

A Flood Information Website can be made available to the community which relates current and forecast flood levels to on-ground consequences, such as inundated roads, properties and services (refer to Figure 5-4 for example). It is imperative that the uncertainty associated with flood mapping is well communicated to ensure warnings and mapping is used within context. The Flood Information Website does not need to have real-time data feeds, but can provide the community with an environment to explore and better understand their flood risk either during or before an event.

A Flood Information System using real-time data feeds can provide a mechanism for issuing alerts through a range of media such as SMS, email and social media. The Flood Information System can provide real-time data feeds for display on the Website.

Road inundation detected by the low cost road crossing sensors can also be displayed on the Flood Information Website.

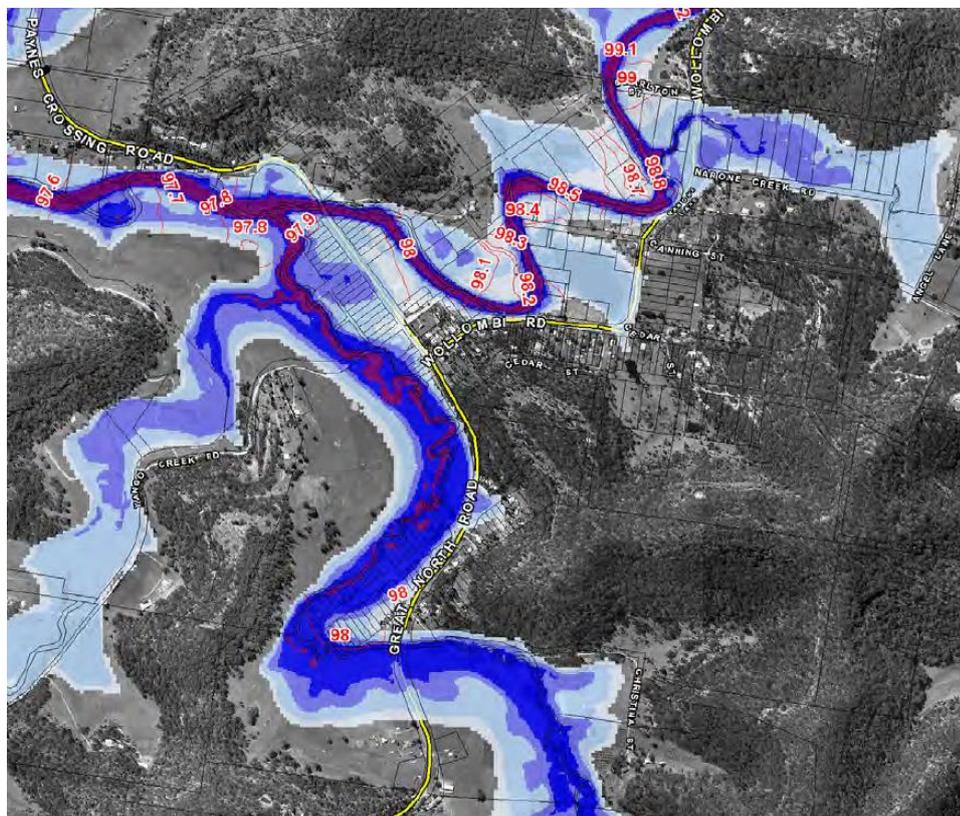


Figure 5-3 5% annual exceedance probability flood map for Wollombi

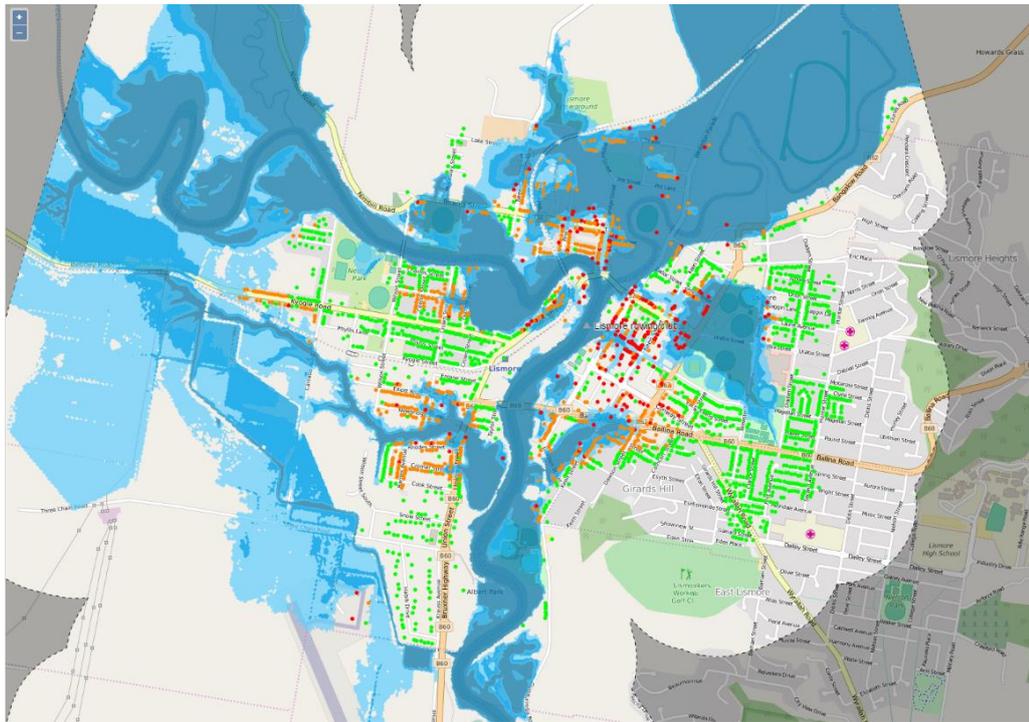


Figure 5-4 Example flood information website showing flood map and affected properties

5.3 Message Construction

Currently the only formal flood warning messages available for Wollombi are the Hunter River Flood Watches issued by the Bureau. Should the Bureau provide a flood warning service for Wollombi, they will use standard Bureau template flood warnings for display on the Bureau website and for issue to other stakeholder agencies via a range of methods.

Template messages, such as those currently being prepared by the Hunter SES, should be incorporated in to the Flood Information System so that messages contain relevant information to the recipient group, as well as specific actions required.

5.4 Communication

As previously identified, communication is a major challenge in the Wollombi Valley. Mobile communications are very limited in coverage and prone to failure during extreme weather. Land line phones are also prone to outages as they rely on power supply which can also be affected during extreme weather. Anecdotal evidence⁴ forwarded to BMT WBM by OEH suggests that:

- the Blaxland Arm exchange has very limited battery life and is flood affected.
- the Telstra Wollombi exchange has now been fitted with a fuel cell which gives longer service during a power outage of 3-5 days.
- negotiations are ongoing with Telstra to permit locals to top up the specialist fuel (methanol) in the event the fuel cell runs out.

⁴ Note that the information contained here has not been verified with the service providers

- the Optus tower gives max 1 day battery life.

An effective Total Flood Warning System will use multiple communication media for dissemination of information and warnings. The following communications are recommended for Wollombi:

- Websites:
 - Bureau website for rainfall, and river observations, and flood warnings.
 - Flood Information Website for interpretation of currently observed water levels and forecasted water levels.
- Flood Information System:
 - Access to the Flood Information System from within the Wollombi Rural Fire Service and Cessnock City Council even if landline and mobile communications are unavailable. This will rely on ALERT data feeds at each base station.
 - An LED community information board should be considered for installation in Wollombi. The LED board should display:
 - rainfall and river level observations
 - water level trends (rising, falling or steady)
 - water level classification (minor, moderate, major)
 - rainfall magnitude
 - forecast flood levels and timing
 - road closures
- Social Media:
 - The Wollombi community currently have a Facebook page for sharing information (Wollombi Valley Fire and Flood). Facebook has proven to be a valuable asset to the community during flood events, although is only accessible when mobile or landline communications are available. Information shared on the Facebook page includes manually read water level observations, road closure information and welfare checks for people unable to contact friends or relatives.
 - Should a Flood Information System be implemented, it should be configured to automatically publish rainfall and river level information to Facebook and Twitter. Official flood warnings issued by the Bureau can also be published to social media sites by the Flood Information System.
- SMS and email
 - All warnings issued by the Bureau and the Flood Information System should be able to be disseminated by SMS and email. It is recognised that phone and internet access is limited in the Wollombi Valley, however, people receiving warnings (in areas of service or whilst travelling) can relay messages to friends, relatives and neighbours.
- Dial-out telephone

Possible Measures

- An automated dial-out telephone message service could be established for subscribed users. These messages can provide a recorded message to all properties within a particular region. It is recommended that Council use a provider to manage user subscriptions and issue dial-out telephone messages. The message to be issued is for the current situation, thus needs recording as part of the flood response. The message should be updated as the situation changes.
- CB Radio
 - The SES and RFS have already agreed to implement a dedicated GRN radio channel for use when all other communication channels are out of action.
 - It is recommended to dedicate a UHF radio channel for the community to use during an emergency. CB radio will not be accessible across the whole catchment, however, search and rescue crews can use this channel and periodic information can be broadcast by the SES or RFS. The community should be encouraged to invest in UHF radios.
- Staff gauges
 - At each river gauge location, a series of staff gauges should be provided, including markers for historic flood event levels, design flood levels and flood level classifications. This will help the community to recognise that larger floods than those they have experienced are possible.
 - This will also help residents relate forecasted levels to consequences.
- Satellite phones
 - Satellite phones provide a reliable method of communication should all other methods have failed. It is recommended that the SES and RFS crews within Wollombi have access to a satellite phone. Additional satellite phones are proposed to be placed at community meeting places (i.e. Wollombi, Laguna Hotel and Millfield).
- Community measures
 - There is a range of actions that the community can take to improve their flood resilience. Such measures include satellite phones and Emergency Position Indicating Radio Beacons (EPIRBs). Measures such as these will be promoted in the flood information packs.

The use of sirens was raised with the stakeholders in the survey. Their use was generally not supported. Due to the dispersive nature of the community throughout the Wollombi Valley, sirens are not recommended.

5.5 Protective Behaviour

The following approaches for protective behaviour are recommended:

- Inter-agency arrangements
 - Define clear roles of responsibility during flood
 - Warning issue and dissemination

Possible Measures

- Potential increased use of Rural Fire Service resources (additional training/equipment requirements)
- Community education
 - Information packs should be prepared and distributed to the community to communicate flood risks and protocols. Property or location specific information packs should be provided for those having specific risks. Information packs to be produced for clusters of properties having a comparable flood risk and/or access constraints.
 - Whilst the community generally has a sound appreciation of the issues faced during a flood event, there is a transient community that may not be aware of how floods affect the Wollombi Valley. Installation of new rain and river gauges, as well as other interpretive tools, presents a good opportunity to update the community. The community should be consulted on new or updated procedures.
 - Encourage development of Personal Flood Action Plans – in recognition of the potential for limited external support and requirement for self help.
- Vulnerability checks
 - Building upon the informal Facebook method for community vulnerability checks, a register should be established for periodic checks of residents. This should be administered by the SES or Council.
- Evacuation / rescue
 - The SES has recently expressed interest to pre-emptively deploy an SES crew to Wollombi prior to the onset of extreme weather. The RFS have offered space in the 'shed bunkroom' to accommodate temporary SES crew members. This measure is supported and should be discussed further amongst the RFS and SES.
 - Cessnock City Council to investigate feasibility of periodic fly overs over the catchment by emergency services or other available helicopters. The intention of the fly overs is to identify people requiring rescue. Indicative times for fly overs are sunrise, midday and sunset, although will depend upon the availability of helicopters.
 - Residents should be advised to lay a white sheet out in a cleared area should they require assistance. This measure is reliant upon the periodic fly overs discussed above. As part of an information pack to be issued to all residents, a white sheet with large red cross could be distributed to the community. This would assist with educating the community about the protocol.

5.6 Review

The flood warning rainfall triggers to be developed are intended as a starting point which will be refined as floods are experienced and triggers verified. Conservative values shall be selected initially for the following reasons:

- The triggers will be based on limited historical data and will therefore contain a high level of uncertainty; and

Possible Measures

- The consequences of false alarms (i.e. unnecessary warning/evacuation) are far less serious than the consequences of delayed or non-existent alerts.

The numerous assumptions inherent in the development of the hydrologic triggers will ultimately affect the reliability of the warning system. Since the catchment is currently ungauged and there are inadequate rainfall records for a comprehensive analysis, each future rainfall event (whether detected or undetected) should be recorded and used for continual improvement of the system. Reviews shall include:

- Review of alerts that have detected flooding:
 - Was the alert sent early enough, hence, should the lead time be increased?
 - Were the correct people alerted?
 - Was the correct information provided and was it relevant?
- Review of 'false alarms' where alerts have not preceded flooding:
 - Why was the alert triggered?
 - Could the trigger values be refined?
- Review of flooding that was undetected:
 - Why was the alert not triggered?
 - Could the trigger values be refined? This may include further hydrologic and hydraulic modelling.

Reviews should be conducted following an alert and/or occurrence of flooding and should include all aspects of the flood response and how the Total Flood Warning System operated as a whole.

6 Options

The suggested flood warning measures presented in the previous Chapter are here formulated into implementation options as follows:

- Option 1 – comprising essential measures for implementation that constitute the best value for money. Many of the individual measures proposed in Option 1 should be considered for immediate implementation where budget permits.
- Option 2 – this option introduces hardware for installation, hence requires a larger investment than Option 1 and requires working with the Bureau to seek to have Wollombi Village included as an official flood warning location. . Implementation of Option 2 is expected to require external funding assistance through the state government grants programs.
- Option 3 – this option presents a high end option based on no financial constraints. This option will provide the Wollombi Valley community with the best possible outcome for the flood warning system.

The measures proposed for each option are listed below in Table 6-1.

Table 6-1 Implementation Options

		Option 1	Option 2	Option 3
1.	Monitoring and prediction			
1.1	Rain gauges			
1.1.1	Bucketty Repeater	x	✓	✓
1.1.2	Yengo Repeater	x	✓	✓
1.1.3	Corrabare Repeater	x	✓	✓
1.1.4	Quorrobolong	x	✓	✓
1.1.5	Broken Back	x	x	✓
1.2	River gauges			
1.2.1	Laguna	x	✓	✓
1.2.2	Millfield	x	✓	✓
1.2.3	Wollombi	x	✓	✓
1.3	Base stations			
1.3.1	Wollombi RFS	x	✓	✓
1.3.2	Cessnock City Council	x	x	✓
1.4	Road crossing sensors	x	x	✓
1.5	Prediction			
1.5.1	Bureau flood forecasting service	x	✓	✓
1.5.2	Pre-determined rainfall triggers	x	✓	✓
2.	Interpretation			

		Option 1	Option 2	Option 3
2.1	Flood Information System	x	✓	✓
3.	Message Construction			
3.1	Template flood warning messages ⁵	x	✓	✓
4.	Communication			
4.1	Observations shown on Bureau website	x	✓	✓
4.2	Flood Information Website	✓	✓	✓
4.3	LED community information board	x	x	✓
4.4	Promotion of social media sites	✓	✓	✓
4.5	Integration of social media with Flood Information System	x	✓	✓
4.6	Dial-out telephone service	✓	✓	✓
4.7	Dedicated radio channel for SES / RFS	✓	✓	✓
4.8	Promote single radio channel for community use	✓	✓	✓
4.9	Staff gauges at proposed river gauge sites	x	✓	✓
5.	Protective behaviour			
5.1	Community flood information packs	✓	✓	✓
5.2	Periodic community consultation	✓	✓	✓
5.3	Event based welfare checks	✓	✓	✓
5.4	SES deployment of crew to Wollombi	✓	✓	✓
5.5	Helicopter fly overs	✓	✓	✓
5.6	Promotion of 'white sheet' assistance request	✓	✓	✓
6.	Review			
6.1	Post-event review	✓	✓	✓

Justification and limitations of each option are listed in Table 6-2.

Table 6-2 Justification for Options

Option	Justification	Limitations
Option 1	<p>This option focusses on leveraging existing warning services and information, without any changes to the current infrastructure. Most of the measures presented in Option 1 are able to be implemented immediately with limited budget.</p> <p>Implementation of Option 1 will result in:</p> <ul style="list-style-type: none"> Formalised response arrangements between the SES and RFS. Formalised communications protocols 	<p>Despite improvements to community and agency response, and improved communications, there remains limited data available to the community and response agencies. The absence of rain and river gauges, and flood forecasting service, will result in a mostly reactive response to flooding triggered by verbal communication amongst the community.</p>

⁵ Template messages will be an integral part of the Bureau flood forecasting service and/or implementation of a Flood Information System

Option	Justification	Limitations
	<p>(including mobile, landline, radio and satellite communications) to ensure there is always a method for communication between:</p> <ul style="list-style-type: none"> • SES, RFS and Council; and • Primary community meeting locations (Wollombi Village, Laguna Hotel and Millfield) • Promoting the ongoing use of social media amongst the community. • Establishment of a vulnerability register. • Every property having a flood information pack outlining the specific risks to the property, and identifying the property level measures that are required for best response (such as battery operated radios and evacuation plans). Information packs to be produced for clusters of properties having a comparable flood risk and/or access constraints. • Every property covered by a community flood action plan tailored to each part of the catchment. This will identify actions that the community should take to ensure their own safety and to communicate (where possible) their welfare status to the SES and others in the community. • Flood information website for communication of flood risks to the community. 	
Option 2	<p>Option 2 addresses the shortcomings of Option 1, by introducing additional rain and river gauges, and working with the Bureau to seek to have Wollombi Village included as an official flood warning location.</p> <p>Three ALERT river gauges are proposed; one at Wollombi Village and one each at Laguna and Millfield. The levels from river gauges can be used to help develop flood warnings and predictions for the Wollombi Valley. SMS and email alerts are able to be triggered by the software receiving the data from these gauges.</p> <p>Five additional ALERT rain gauges are proposed using VHF communications:</p> <ul style="list-style-type: none"> • The Quorrobolong gauge is necessary to capture rainfall patterns in the low lying floodplain at Ellalong. • The Millfield gauge will be sited at the Millfield river gauge, thus providing an economical approach to improve the spatial coverage. • The remaining three gauges are repeaters, which are required to relay the signals for the rain and river gauges to the respective receiving base stations. <p>A flood information system (FIS) is proposed to</p>	<p>The inclusion of new gauges in this option will result in a greater cost of implementation. Funding from external sources will be required for implementation, which may take a number of years to secure.</p> <p>Despite the additional gauges, there will remain an uncertainty around accessibility. The intelligence provided by the FIS will only be an estimate of possible conditions.</p>

Option	Justification	Limitations
	<p>display the consequences associated with observed and forecasted flood levels. The FIS will provide a dynamic link between the real-time data and outputs from the flood model. The FIS will provide an indication of potential road closures and property inundation.</p>	
Option 3	<p>For implementation of a TFWS addressing all of the key issues facing the Wollombi community, additional monitoring is required:</p> <ul style="list-style-type: none"> • One further rain gauge is proposed to cover the Cedar Creek catchment. • Water level sensors are proposed at all of the critical road crossings / low points. This network of sensors will provide the community and emergency responders with notification of access status. <p>An LED community information board is also included in Option 3 The LED board would display:</p> <ul style="list-style-type: none"> • rainfall and river level observations • water level trends (rising, falling or steady) • water level classification (minor, moderate, major) • rainfall magnitude • forecast flood levels and timing • road closures 	<p>There are two limitations associated with Option 3:</p> <ul style="list-style-type: none"> • Further funding beyond that required for Option 2; and • Road inundation information will only be available when there is mobile or land line communications. When mobile and land line communications are out of service, then road inundation can only be communicated verbally using the satellite phones.

7 Cost estimates

7.1 Responsibility

Similar systems throughout NSW are funded by the Council, both for installation and maintenance. The Bureau and NSW Office of Water are able to undertake the installation and maintenance, although on a cost recovery basis. The availability of the Bureau and NSW Office of Water to undertake the works will be confirmed when funding has been secured.

7.2 Cost Estimates

7.2.1 Capital Costs

The cost estimates for each measure are listed in Table 7-2 and are summarised in Table 7-1. The estimates have been derived based on current industry rates and discussions with the SES and BoM.

Table 7-1 Capital Cost Summary

		Option 1	Option 2	Option 3
1	Monitoring and prediction	-	\$129k	\$177k
2	Interpretation	-	\$20k	\$20k
3	Message Construction	-	-	-
4	Communication	\$20k	\$51k	\$69k
5	Protective behaviour	\$40k	\$40k	\$40k
6	Review	-	-	-
	Total cost for implementation	\$60k	\$240k	\$306k

Table 7-2 Capital Cost Breakdown

		Option 1	Option 2	Option 3
1.	Monitoring and prediction			
1.1	Rain gauges			
1.1.1	Bucketty Repeater	x	\$10k	\$10k
1.1.2	Yengo Repeater	x	\$10k	\$10k
1.1.3	Corrabare Repeater	x	\$10k	\$10k
1.1.4	Quorrobolong	x	\$8k	\$8k
1.1.5	Broken Back	x	x	\$8k
1.2	River gauges			
1.2.1	Laguna	x	\$25k	\$25k
1.2.2	Millfield	x	\$23k	\$23k
1.2.3	Wollombi	x	\$23k	\$23k

Cost estimates

		Option 1	Option 2	Option 3
1.3	Base stations			
1.3.1	Wollombi RFS	x	\$10k	\$10k
1.3.2	Cessnock City Council	x	x	\$10k
1.4	Road crossing sensors	x	x	\$30k
1.5	Prediction			
1.5.1	Bureau flood forecasting service*	✓	✓	✓
1.5.2	Pre-determined rainfall triggers	x	\$10k	\$10k
2.	Interpretation			
2.1	Flood Information System	x	\$20k	\$20k
3.	Message Construction			
3.1	Template flood warning messages	x	✓	✓
4.	Communication			
4.1	Observations shown on Bureau website	x	✓	✓
4.2	Flood Information Website	\$20k	\$20k	\$20k
4.3	LED community information board	x	x	\$15k
4.4	Promotion of social media sites	✓	✓	✓
4.5	Integration of social media with Flood Information System	x	\$5k	\$5k
4.6	Dial-out telephone service	x	\$20k	\$20k
4.7	Dedicated radio channel for SES / RFS	✓	✓	✓
4.8	Promote single radio channel for community use	✓	✓	✓
4.9	Staff gauges at river gauge sites	x	\$6k	\$9k
5.	Protective behaviour			
5.1	Community flood information packs	\$20k	\$20k	\$20k
5.2	Periodic community consultation	\$20k	\$20k	\$20k
5.3	Event based welfare checks [#]	✓	✓	✓
5.4	SES deployment of crew to Wollombi [#]	✓	✓	✓
5.5	Helicopter fly overs [#]	✓	✓	✓
5.6	Promotion of 'white sheet' assistance request [#]	✓	✓	✓
6.	Review			
6.1	Post-event review [#]	✓	✓	✓

* cost to be determined following Bureau agreement to providing forecasting service

costing not provided for operational measures

7.2.2 Operational costs

The operational, or maintenance, costs estimates for each measure are listed in Table 7-4 and summarised in Table 7-3.

Table 7-3 Operational Cost Summary

		Option 1	Option 2	Option 3
1	Monitoring and prediction	-	\$21k	\$27k
2	Interpretation	-	\$5k	\$5k
3	Message Construction	-	-	-
4	Communication	\$5k	\$17k	\$19k
5	Protective behaviour	\$10k	\$10k	\$10k
6	Review	-	-	-
	Total cost for implementation	\$15k	\$53k	\$61k

Table 7-4 Operational Cost Breakdown

		Option 1	Option 2	Option 3
1.	Monitoring and prediction			
1.1	Rain gauge network (6 monthly)	×	\$10k	\$10k
1.2	River gauge network (3 monthly)	×	\$10k	\$10k
1.2.2	Base stations	×	\$1k	\$2k
1.4	Road crossing sensors	×	×	\$5k
1.5	Prediction			
1.5.1	Bureau flood forecasting service	-	-	-
1.5.2	Pre-determined rainfall triggers	×	-	-
2.	Interpretation			
2.1	Flood Information System	×	\$5k	\$5k
3.	Message Construction			
3.1	Template flood warning messages	×	-	-
4.	Communication			
4.1	Observations shown on Bureau website	×	-	-
4.2	Flood Information Website	\$5k	\$5k	\$5k
4.3	LED community information board	×	×	\$2k
4.4	Promotion of social media sites	-	-	-
4.5	Integration of social media with Flood Information System	×	\$2k	\$2k
4.6	Dial-out telephone service	×	\$10k	\$10k
4.7	Dedicated radio channel for SES / RFS	-	-	-

		Option 1	Option 2	Option 3
4.8	Promote single radio channel for community use	-	-	-
4.9	Staff gauges at river gauge sites	x	-	-
5.	Protective behaviour			
5.1	Community flood information packs	\$5k	\$5k	\$5k
5.2	Periodic community consultation	\$5k	\$5k	\$5k
5.3	Event based welfare checks [#]	-	-	-
5.4	SES deployment of crew to Wollombi [#]	-	-	-
5.5	Helicopter fly overs [#]	-	-	-
5.6	Promotion of 'white sheet' assistance request [#]	-	-	-
6.	Review			
6.1	Post-event review [#]	-	-	-

[#] costing not provided for operational measures

8 Reference List

BMT WBM 2010, *Wollombi Flood Study Review and Model Upgrade*, report for Cessnock City Council.

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State Emergency Service 2009, *Cessnock City Local Flood Plan*

Appendix A Online Stakeholder Survey Questions

Wollombi Flood Warning System - Investigation and Concept Design

Survey Introduction

BMT WBM, on behalf of Cessnock City Council, are currently undertaking a study to undertake a concept design of a total flood warning system (TFWS) for the Wollombi Valley. As part of this study, we're seeking input from relevant stakeholders to ensure that the system makes best use of available infrastructure and processes, and meets the needs of users.

The formal flood warning service for the Wollombi Brook provided by the Bureau of Meteorology largely benefits the residents in the lower part of the Wollombi Valley. In the upper part of the Valley, including Wollombi Village, there is no site specific flood warning system currently in place, however there are a number of general warning services provided by the Bureau including Flood Watches, Severe Thunderstorm Warnings and Severe Weather Warnings.

Based on experiences of the June 2007 event, the existing flood warning system is not highly effective for Wollombi Village and surrounds. Whilst flood watches and regional flood warnings should activate personal flood action plans, the level of existing flood awareness in the community meant that little effective action was taken in June 2007, and is perhaps typical of what would happen in any major flood event at present.

Further details of the existing flood warning system is included in the Wollombi Floodplain Risk Management Study (Section 8.2). If you wish to access a copy of the study, please contact Martin Conner at Cessnock City Council (martin.conner@cessnock.nsw.gov.au).

Wollombi Flood Warning System - Investigation and Concept Design

Respondent Information

1. Which organisation do you work for?

2. What is your role there?

3. What is your role in the flood warning process? (select all that apply)

- Manage rain or river gauges
- Manage rain or river gauge data
- Interpret rain or river gauge data to estimate flood impacts
- Plan emergency response actions (e.g. whether to issue warnings, evacuation notices etc)
- Communicate flood warning messages
- Use information from flood warning system to respond to flooding
- Review flood warning information after a flood
- Design flood warning system or associated IT systems
- Other (please specify)

Wollombi Flood Warning System - Investigation and Concept Design

Flood Warning System

As previously stated, the formal flood warning service for the Wollombi Brook provided by the Bureau of Meteorology largely benefits the residents in the lower part of the Wollombi Valley. In the upper part of the Valley , including Wollombi Village, there is limited flood warning system infrastructure currently in place.

There are two ALERT* rainfall gauges in the upper catchment area (namely Watagan Central and Wollombi (St Johns Church)) and no ALERT stream gauges. All other gauges in the catchment are either manual, or only collect data on a daily basis. Due to the rapid rate of rise of floodwaters in the Wollombi Brook, these gauges cannot provide sufficient information during a flood.

In addition, the Bureau provides general warning information such as Flood Watches and Severe Weather and Thunderstorm Warnings.

Consultation during the Wollombi Floodplain Risk Management Study and Plan found that there is strong support for a flood warning system consisting of direct phone communications and sirens.

For further information or to obtain a copy of the Wollombi Floodplain Risk Management Study and Plan, please contact Martin Conner at Cessnock City Council on 4993 4376 or martin.conner@cessnock.nsw.gov.au.

***[ALERT rain and stream gauges measure and transmit rainfall and stream measurements by radio**

telemetry in real time, as required. ALERT is an acronym for Automated Local Evaluation in Real Time, which is a method of using remote sensors in the field to transmit environmental data to a central computer in real time.]

4. Do you have any views on the adequacy of the current flood warning system for the upper Wollombi Brook valley?

- No
- Yes - here they are:

5. Do you think Wollombi requires additional ALERT rainfall gauges?

- No
- Yes - here are my suggestions for potential locations

6. Do you think the Wollombi township requires an ALERT stream gauge in the town area?

- Yes
- No - here's why

7. Do you think Wollombi township **ALSO** requires ALERT stream gauge/s upstream of the town area?

- Yes
- No - here's why

8. Do you have any suggestions for locations of additional stream gauges?

9. Do you have any ideas for better using existing infrastructure? (e.g. combining a new ALERT gauge with an existing daily gauge)

- No
- Yes - here's my good idea

10. Who should be responsible for installing and maintaining new gauges?

- Bureau of Meteorology
- NSW Office of Water
- Cessnock City Council
- Other (please specify)

Wollombi Flood Warning System - Investigation and Concept Design

Interpretation of data

Assimilating and interpreting rainfall and stream data is one of the most critical steps of flood warning. Different combinations of rainfall intensity, stream height, stream rate of rise, and catchment saturation can result in distinctly different flood outcomes. Many of these combinations can be considered as part of flood planning, however a good understanding of local conditions will always be vital during a flood event.

11. Where do you believe information from stream and rain gauges should be collected and shared?
(Select all that apply)

- Bureau of Meteorology's website
- Council's website
- Purpose built flood information and intelligence website
- SMS and / or email alerts
- Other (please specify)

12. What information do you need from a flood warning system? (Select all that apply)

	Must have	Would like	Don't need	Don't know
Rainfall intensity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rainfall IFD (i.e. "20 year, 6 hour rain intensity" or chart of plotted intensity-frequency-duration curves)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Forecast rainfall intensity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Current stream level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Forecast stream level	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rate of rise in stream	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flood mapping related to stream gauge heights	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flood intelligence card associated with stream gauge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Real-time consequences of flooding (what's happening now)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Predicted consequences of flooding (what's likely to happen in the future)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Wollombi Flood Warning System - Investigation and Concept Design

Message construction

Warning messages are the critical link in communicating information on expected flooding. They provide the signal for those at risk to take action before the flood arrives or reaches particular levels.

13. What information does the community need to receive in a warning message? (Select all that apply)

- When flood waters will arrive / peak / reach a certain height
- How long the flood will last
- Where the flooding will occur
- Expected depth / velocity / hazard of the flooding
- If they need to evacuate
- When they need to evacuate
- How to prepare for evacuation
- Where to evacuate
- Evacuation routes / road closures
- Where to get more information / how to seek help
- Other (please specify)

14. Do you think there is a need for a suite of pre-populated warning messages (i.e. relating to rainfall intensities or stream levels)?

- Yes
- No - here's why

Wollombi Flood Warning System - Investigation and Concept Design

Communicating flood warnings

The communication of flood warnings may occur between stakeholder agencies (e.g. BoM and SES), or between the SES and the community. These messages may be of a general nature (broadcast to the whole community), or more specific to particular locations or parts of the community.

15. To the best of your knowledge, how are flood warnings currently shared **between stakeholder agencies**? (Select all that apply)

- Email
- Website
- Phone call
- Text message
- In person
- Other (please specify)

16. Do you believe the current modes of sharing flood warning messages **between stakeholder agencies** are effective?

- Yes
- No - here's why

17. Do you have any ideas for improving the current modes of sharing flood warning messages **between stakeholder agencies**?

- No
- Yes - here's my great idea

18. To the best of your knowledge, how are flood warnings currently issued to the **community**? (Select all that apply)

- Radio announcements
- Television announcements
- Door knocking
- Council's website
- Social media (e.g. Facebook, Twitter)
- Other (please specify)

19. Do you believe the current modes of communicating flood warning messages to the **community** are effective?

- Yes
- No - here's why

20. Do you have any ideas for improving the current modes of sharing flood warning messages to the **community**?

- No
- Yes - here's my great idea

21. Do you support the use of flood sirens and lights in the Wollombi flood warning system?

- Yes, they'd be valuable
- Maybe, I'd need to know more
- No, I don't support the use of flood sirens and lights
- Please add any further comments below

Wollombi Flood Warning System - Investigation and Concept Design

System review and improvement

System review involves critical examination of some or all aspects of the flood warning system with the aim of improving performance. The Cessnock City Local Flood Plan has provision for 'after action reviews' following a flood, to be coordinated by the NSW SES Cessnock City Local Controller.

22. To the best of your knowledge, would an 'after action review' include review of the flood warning system, with aim of improving performance?

Yes

No

23. Do you think the Cessnock City Local Flood Plan should be updated to explicitly require a review of the flood warning system (including details of how to undertake the review)?

Yes

No - here's why

Wollombi Flood Warning System - Investigation and Concept Design

Summary

Thanks for taking the time to complete this survey. Responses from the survey will be used to inform the design and operation of the Wollombi flood warning system.

24. Do you have any further comments about the current or future Wollombi flood warning system?

25. Do you wish to be contacted about this issue further

No thanks

Yes, please. I've provided my email address below.

Appendix B Online Stakeholder Survey Responses

A total of 22 responses were received, with survey respondents from a representative range of backgrounds, including:

- Bureau of Meteorology
- Office of Environment and Heritage
- WaterNSW
- Cessnock City Council
- Singleton Council
- NSW State Emergency Service
- NSW Rural Fire Service
- Cessnock Volunteer Rescue Squad
- Wollombi Valley Progress Association
- Family and Community Services
- Bucketty Tidy Bush
- Residents, private land holders, businesses

The respondents were responsible for various roles within the flood warning process, including formal roles, such as managing river and rain gauge data, communicating flood warning messages etc., as well as less formal roles such as maintaining contact with neighbours during flood events.

Most respondents had input regarding the adequacy of the current flood warning system in the upper Wollombi Brook valley. The feedback provided is listed below:

- More upstream ALERT rainfall sites required.
- No formal flood warning service in place, but the Bureau provides a flood watch for the Hunter River Valley.
- Currently there is no flood warning system. The village is at the high end of the catchment so has little forward warning.
- Not currently adequate. Communication difficulties will provide for significant constraints.
- They are not widely known and need to include the large number of part-time property owners who travel up from Sydney on the weekend
- Inadequate
- We are located above Wollombi and so are affected very early in any flood event, usually within hours of the flood event. We have been relying on our own observations and predictions to

Reference List

know if the causeway will become impassable. When it becomes impassable, about 20 residential properties become isolated.

- It currently heavily relies on residents communicating with each other (as long as phone / power remain)
- Strong support for a flood warning system consisting of direct phone communications and sirens. How long is it since we told the authorities that? Years! No action! And when a flood does come, we are completely cut off from communication – the mobile phone signal system in Wollombi Village covers only 4km from its location and the batteries only last a short time (though this has been recently improved by Telstra). We need some kind of reliable 21st century communication system above all else. And access to at least one emergency boat / dinghy of some kind.
- Totally inadequate
- Residents use their local knowledge and are aware when the Brook is about to flood
- They are inadequate, not communicated and no warnings are issued, either to the RFS or residents
- Manual river heights and rain gauges at points of concern
- Due to aging population of farmers and out-dated contact details, I believe an electronic monitoring system is needed.

In summary, most respondents do not believe the current system is adequate. Particular issues include lack of formal system (many residents contact each other directly to share information), lack of warning time, poor communication facilities (e.g. mobile reception), and concern for out of town residents who are unfamiliar with the flood risk.

In terms of new rainfall gauges, most respondents believe that additional gauges are required in the system. Suggestions for potential locations include:

- The main tributaries, such as Upper Wollombi Brook at Bucketty, Bournes Creek at Blair Athol, and Upper Yengo Creek at Yengo Fire Trail
- Upstream, within the Murrays Run area
- At the top of the brook, about Bucketty or near Will-o-win in Murrays Run
- Yango Creek Road, Williams Bridge, Narone Creek Road, corner of Wollombi Road and Paynes Crossing Road
- Watagan Creek (bridge) which feeds into the Wollombi Brook
- Paynws Crossing and Laguna
- At road intersections and road crossings of rivers

Similarly, most respondents believed there was a need for additional stream gauges both within the town area and upstream of the town, however comments indicate that respondents believe reliance

Reference List

on stream gauge data would not provide sufficient notice for evacuation. Suggestions for potential stream gauge locations (both in town and upstream) include:

- Congawai Creek and Wollombi Creek
- Laguna Bridge and / or further upstream where road can be compromised early.
- Millfield Bridge or downstream from junction of Congewai Creek and Cedar Creek
- Murrays Run vicinity
- Dairy Arm Laguna
- Milsons Arm
- Watagan Creek
- Paynes Crossing

Some opportunities were also identified to make better use of existing infrastructure, primarily:

- Use the existing Bureau IP-ERTS loggers at Wollombi Church and Watagan Central
- Use the RFS for monitoring flood conditions and informing residents

There were slightly mixed responses regarding which agency(s) should be responsible for installation and maintenance of new gauges; likely complicated by the potential separation in roles between funding and physical installation / maintenance. Responses provided by the Bureau of Meteorology note that Cessnock City Council should fund the installation and maintenance, with NSW Office of Water responsible for the physical installation and maintenance of stream gauges, and Bureau of Meteorology responsible for the physical installation and maintenance of rain gauges. Opportunities to cost share with downstream users, such as Broke (Singleton LGA), were also raised by respondents.

Most respondents believe that information should be collected and shared via the Bureau of Meteorology's website (77%), although again the responses may be complicated by potential separation in collection and sharing roles. There was also strong support for collation and sharing of information via Council's website (47%), SMS and / or email alerts (59%), a purpose built flood information and flood intelligence system (35%), and a range of other channels including:

- Portal through Wollombi tourism website
- Local RFS brigades
- Local fire / flood information on social media pages
- SES regional headquarters
- Local SES unit

Respondents are seeking a range of information from the flood warning system, with all provided information types listed as 'must have' by at least 3 and up to 14 respondents (out of 19). The information types which were highest rated as 'must have' were:

- Real-time consequences of flooding (what's currently happening)
- Current stream level
- Rate of rise in stream

Similarly, respondents believe the community needs to receive a wide range of information in flood warning messages, with all provided information types noted as required by at least 50% of respondents. The information types which are most strongly viewed as needing to be included in warning messages to the community are:

- When flood waters will arrive / peak / reach a certain location
- Where the flooding will occur
- Evacuation routes / road closures

Respondents also noted that warning messages could include:

- Information about the dangers of driving through flood water
- How to communicate and by which method
- Contact numbers

A majority of respondents believe there is a need for a suite of pre-populated warning messages, although it is noted that these should only be used if communication difficulties are taken into account, and as long as users don't overly rely on these messages for fear the public may become desensitised and ignore them.

Respondents noted that stakeholder agencies share flood warnings via a range of channels, with no dominant channel identified. In addition to those channels noted in the survey, comments indicate that agencies might communicate via public media, social media (in particular the Wollombi RFS fire and flood page), and fax. These modes of sharing information are generally not believed to be effective, with respondents commenting that communication either doesn't happen or doesn't work. However, numerous suggestions were provided for improving communication between stakeholders, including:

- Better integrated warning products between stakeholder agencies
- SES and RFS need preferential access to real-time gauge readings and updated flood cards stating what the readings mean
- A locally-based emergency contact email and telephone contact database at the local RFS brigade
- By ensuring that we have a good communication system. Previous floods have seen ALL coms not operative
- Immediate action plan

Reference List

- Using electronic data transfer would eliminate human error and be faster

[Note that responses which referred to issuing warnings to the community, not communication between stakeholder agencies, has not been included here.]

Regarding the distribution of flood warnings to the community, many respondents understand that this happens primarily via social media, though a range of other nominated channels are used. In addition to the provided options, respondents noted the following methods are also used to distribute warnings to the community:

- Bureau of Meteorology current warning website
- Word of mouth
- Wollombi Facebook page
- Bush telegraph at local general store and pubs / cafes. The local school also has emergency contact plans for parents.
- Email alerts
- Phone calls and SMS

It was also noted that flood warnings can be issued by the community to the community, with no external body providing up to date information for the Wollombi / Laguna area.

Approximately 60% of respondents believe that current modes of communicating flood warnings to the community are not working, with the following reasons identified:

- Very widespread, sparse population.
- Poor internet access and phone communication system loses power early in flood. Not everyone has the internet and connectivity is not the best.
- Lots of tourists present in community with no understanding of risk, and many part-time residents and visitors are overlooked.
- Warnings are too late / after the event.
- Too reliant on local residents who are active on social media being around with power / phone.

Suggestions for improving communication of flood warnings to the community include:

- Use of printed media used in tandem with improved communication and power
- Guesthouses and local businesses need information
- Weekenders need to be contacted via a phone tree or email etc.
- Flashing flood warning signs could be strategically positioned on each road entrance to the Wollombi Valley
- Communication technology must be improved. Satellite phones at strategic locations (more than currently available).

Reference List

- RFS could do annual flood preparation workshops and training, especially for new residents and weekenders.
- Ensure we have backup systems for mobile phones / have a two-way radio system in conjunction with the RFS
- Suggest all land holders have GPS information of their properties and evacuation plans

There was a mixed response concerning the potential use of flood sirens and lights in the Wollombi flood warning systems. Some respondents were interested in obtaining more information on the topic, and numerous points were noted regarding the use of lights and sirens:

- Need to be maintained and tested routinely like a fire alarm
- There may be community resistance to the installation of lights and sirens
- Due to the local geography, homes may be too spread out to benefit (particularly from sirens)
- Lights are likely to be of benefit, but not sirens
- Lights may be useful at the entrance to the valley

Most respondents (95%) believe that an 'after action review' should include a review of the flood warning system, with the aim of improving system performance, and that this review should be included in the Cessnock City Local Flood Plan (agreed by 89%).

A number of final comments were provided about the current and future flood warning systems, provided below:

- Need to confirm the response time for the catchment, noting that flood warnings for catchments with a response time > 6 hours could be provided by the Bureau.
- Wollombi Valley is a flood prone community, but while flooding affects a few homes most of the flood risk relates to ingress and egress. Tourists especially have taken ridiculous risks trying to get in/out of the area.
- Needs to be simple and easy to use/maintain. Not dependent of technology which is likely to fail during an event.
- I understand the reason Wollombi floods is due to a narrowing of the valley between Wollombi and Broke. Why don't you simply widen this section?
- I wasn't aware we have a Wollombi flood warning system in place (do we?)!? I am a local living here permanently. And have been flooded in 6 times in the last 5 years. Each time we were able to predict ourselves when we would be stuck, and get supplies etc. beforehand. All the information we receive / give in a flood is done person to person by phone or Facebook by locals. I have seen no external input (other than incorrect and/or late information regarding road closure details on the Council's web site).
- Get a move on and fix the issues ASAP. As I complete this survey it is pouring with rain - the creeks are filling up very quickly

- Sirens would not help in a flood or imminent flood.
- I hope it happens. Many surveys do not produce results.

A major concern in the past was the influx of visitors to weekend complexes who were caught in flood conditions, then expect the same support as in the cities. This doesn't happen in remote rural communities. The past Wollombi community was made up with farming properties where the locals just sat it out with enough food and supplies to carry over and did not require help.



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