Jacobs

in association with hydrology and risk CONSULTING

Upper Avoca River Flood Investigation

Flood Warning Feasibility Assessment Report

IS297900-RPT-006-Warning-RevB

14 May 2021

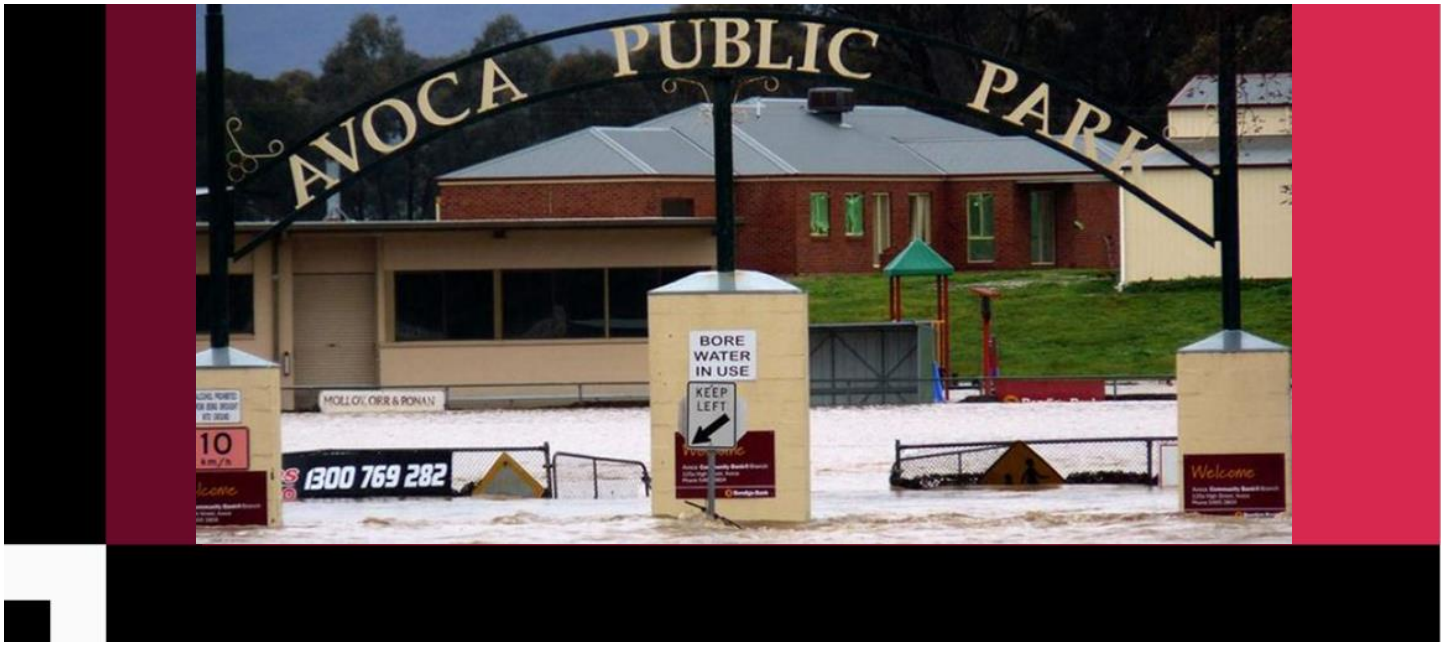
Pyrenees Shire Council

Australian Government

VICTORIA State Government

PYRENEES SHIRE

North Central CMA



Cover image courtesy of ABC (2010), Avoca River floods in Victoria, https://www.abc.net.au/news/2010-09-04/avoca-river-floods-in-victoria/2248938

Upper Avoca River Flood Investigation

Project No:	IS297900
Document Title:	Flood Warning Feasibility Assessment Report
Document No.:	IS297900-RPT-006-Warning-RevB
Revision:	B
Document Status:	Draft
Date:	14 May 2021
Client Name:	Pyrenees Shire Council
Client No:	
Project Manager:	Michael South
Author:	Michael Cawood (HARC)
File Name:	IS297900-RPT-006-Warning-RevB.docx

Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
Floor 11, 452 Flinders Street
Melbourne VIC 3000
PO Box 312, Flinders Lane
Melbourne VIC 8009 Australia
T +61 3 8668 3000
F +61 3 8668 3001
www.jacobs.com

© Copyright 2019 Jacobs Group (Australia) Pty Limited. The concepts and information contained in this document are the property of Jacobs. Use or copying of this document in whole or in part without the written permission of Jacobs constitutes an infringement of copyright.

Limitation: This document has been prepared on behalf of, and for the exclusive use of Jacobs' client, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and the client. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this document by any third party.

Document history and status

Revision	Date	Description	Author	Reviewed	Approved
A	19/04/2021	Final	MC	MS	PP
B	14/05/2021	Final	MC	MS	PP

Contents

List of Figures

List of Tables

Definitions

Annual Exceedance Probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 cubic metres per second has an AEP of five per cent, it means that there is a five per cent chance (i.e. a 1 in 20 chance) of a peak discharge of 500 cubic metres per second being equalled or exceeded in any one year (also see average recurrence interval).
Australian Height Datum (AHD)	National survey datum corresponding to about mean sea level.
Average Annual Damages (AAD)	The average annual damage is the average cost in dollars per year that would occur in a particular area from flooding over a long period of time.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, flood with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Benefit-cost ratio	Measure used to assess the economic viability of a mitigation measure.
Catchment	The catchment at a particular point is the area of land that drains to that point.
Design flood	A theoretical flood representing a specific likelihood of occurrence (for example the 1% AEP flood).
Flash flood	Flooding within 6 hours of causal rain.
Flood behaviour	The pattern / characteristics / nature of a flood.
Flood depth	The height or elevation of floodwaters above ground level.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum).
Hydraulics	The term given to the study of water flow in rivers, estuaries and coastal systems.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrology	The term given to the study of the rainfall-runoff process in catchments.
LiDAR	Remote (airplane) sensing method that uses light in the form of a pulsed laser to measure distance to the Earth. This is used to generate detailed 3D topographical information across an area.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event at a particular location.
RORB	Runoff routing computer model for hydrologic analysis of catchment runoff.
Total Flood Warning System (TFWS)	A flood warning system made up of the following components; Data, Forecast, Modelling, Alert and Response (as defined by the Victorian Floodplain Management Strategy).
TUFLOW	Fully two-dimensional and one-dimensional unsteady flow hydraulic computer modelling software.
Velocity	The speed at which the floodwaters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged

velocity, i.e. the average velocity across the whole river or creek section if a one-dimensional solution is used; and depth average if a two-dimensional solution is used.

Abbreviations

AAD	Average Annual Damages
ARR 2019	2019 release of Australian Rainfall & Runoff
BCR	Benefit-cost ratio
BoM	Bureau of Meteorology
Council	Pyrenees Shire Council
CMA	Catchment Management Authority
DELWP	Department of Environment, Land, Water and Planning
DEM	Digital Elevation Model
DTM	Digital Terrain Model
EIA	Effective Impervious Area
EMV	Emergency Management Victoria
ERTS	Event-Reporting Radio Telemetry System
GSAM	Generalised Southeast Australia Storm Method
GSDM	Generalised Short-Duration Method
m AHD	meters Australian Height Datum
FFA	At-Site Flood Frequency Analysis
FFWS	Flash Flood Warning System
LiDAR	Light Detection and Ranging
LGA	Local Government Area
m/s	Metres per second (a measure of speed / velocity).
m^3/s	Cubic metres per second (a measure of flow).
MFEP	Municipal Flood Emergency Plan
NCCMA	North Central Catchment Management Authority
NDRGS	Natural Disaster Resilience Grant Scheme
PALS	Portable Automated Logger System
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PRG	Project Reference Group
RCP	Representative Concentration Pathway
RFFE	Regional Flood Frequency Estimate
RRV	Regional Roads Victoria
The Investigation	Upper Avoca River Flood Investigation
The Catchment	Upper Avoca River catchment to the Investigation downstream boundary
TIA	Total Impervious Area

TFWS	Total Flood Warning System

1. Introduction

A flood warning or alerting system does not currently exist for the Upper Avoca River other than in a very generalised form. For example, all communities in the area receive the Bureau of Meteorology's Flood Watch and Severe Weather warnings, as well as messaging from VICSES. While these warnings and messages are important, they have been described as too broad and not very useful for the Investigation area.

As an input to development of the North Central Regional Floodplain Management Strategy 2018-2028 (NCCMA 2018), the service level of the Total Flood Warning System (TFWS) in place for upper Avoca communities (i.e. Amphitheatre, Avoca and Natte Yallock) was evaluated for adequacy against the assessed flood risk level. It was determined that the service levels for these communities was lower than appropriate for the flood risk but that development of detailed flood maps that were then disseminated to the relevant communities, and the collation of flood intelligence (e.g. consequences and likelihoods) would be the most effective response to address the gap.

Some of the essential building blocks (elements) of a TFWS have been delivered by other outputs from the Upper Avoca River Flood Investigation (The Investigation). These include:

- Flood inundation and related mapping
- Updated Municipal Flood Emergency Plans (MFEPs) for the Pyrenees Shire Council (and Central Goldfields Shire Council) with flood consequence information for the Upper Avoca River
- Indicative flood guidance tools
- Information suitable for inclusion in Local Flood Guides (LFGs)

This Flood Warning Feasibility Assessment Report details flood warning feasibility assessment for the Upper Avoca River and more particularly for the three main townships of Amphitheatre, Avoca and Natte Yallock. It identifies feasible options for improving local capability to act in a timely manner and improving future response to impending floods in the upper catchment, thereby potentially reducing future flood risk through the reduction of consequences. It identifies feasible options for improving local capability to act in a timely manner as well as improving future response to impending floods in the upper catchment, thereby potentially reducing the costs (and consequences) of future flooding. The identified options range from making better use of existing rainfall information in conjunction with deliverables from the Upper Avoca River Flood Investigation (i.e. no / low cost options) through to investment in a monitoring and messaging system with automated system elements outcomes (i.e. an option requiring more substantial investment of time and money to setup and maintain), that if implemented, could lead to more reliable and substantive outcomes. Guidance is provided as to how such a system may operate.

This report builds on the project inception and site visit, data review and validation, and existing conditions flood modelling and mapping tasks of the Investigation as documented in:

- Data Review Report (Jacobs 2020a)
- Flood Modelling Report (Jacobs 2020b)
- Flood Mapping Report (Jacobs 2020c)

1.1 Investigation background

The Upper Avoca River area has a long history of flooding, including experiencing three significant flood events in the recent past: 2010, 2011 and 2016. However, to date, there has not been a detailed flood assessment completed for this area. To address this a flood study of the Upper Avoca River to inform flood intelligence and planning scheme maps for Amphitheatre, Avoca and Natte Yallock and the rural areas in between was identified as a high regional priority in the North Central Regional Floodplain Management Strategy 2018-2028 (NCCMA 2018).

In response the Pyrenees Shire Council (Council) has received funding from the Victorian and Commonwealth Governments through the Natural Disaster Resilience Grants Scheme (NDGRS), and in partnership with the North Central Catchment Management Authority (NCCMA) have engaged Jacobs to undertake the Upper Avoca River Flood Investigation.

The focus of this Investigation is to assess riverine flooding in the Upper Avoca River catchment with the main objectives to:

- Define flood related controls in the Pyrenees Shire Council Planning Scheme
- Develop flood intelligence products and inform emergency response planning
- Investigate opportunities for flood mitigation works and activities
- Assist in the preparation of community flood awareness and education products
- Assess feasibility for improved flood warning arrangements – the focus of this report
- Support the assessment of flood risk for insurance purposes

1.2 Catchment and investigation area description

The Investigation area (Figure 1.1) is located in the upper reaches of the Avoca River where it flows from the hills of the Great Dividing Range ranges onto the Avoca River floodplain where it remains relatively confined until it breaks out into the wider floodplain north of Charlton. To Archdale Junction (the downstream limit of the Investigation), there is contributing catchment of approximately 1,000 km^2.

The Avoca River is the primary waterway in the catchment area, forming in the hills south of Amphitheatre and flowing north, with several tributaries that join it prior to Archdale Junction, including:

- Homebush Creek
- Brown Hill Creek
- Cherry Tree Creek
- Middle Creek
- Redbank Creek
- Mountain Creek
- Wild Dog Creek
- Sardine Gully
- Fiddlers Creek
- Number One Creek
- Number Two Creek
- Sugarloaf Creek
- Rutherford Creek
- Green-hill Creek
- Forrest Creek
- Glenlogie Creek
- Amphitheatre Creek

In total the Investigation covers an area of approximately 300 km^2 from upstream of Amphitheatre to Archdale Junction, covering the townships of Amphitheatre, Avoca and Natte Yallock as shown in Figure 1.1. These towns have populations of 248, 1,193 and 188 respectively as of the 2016 census. High-resolution modelling was undertaken for the townships (which are referred to as town models), with coarser modelling adopted for the broader area (which is referred to as the regional model).

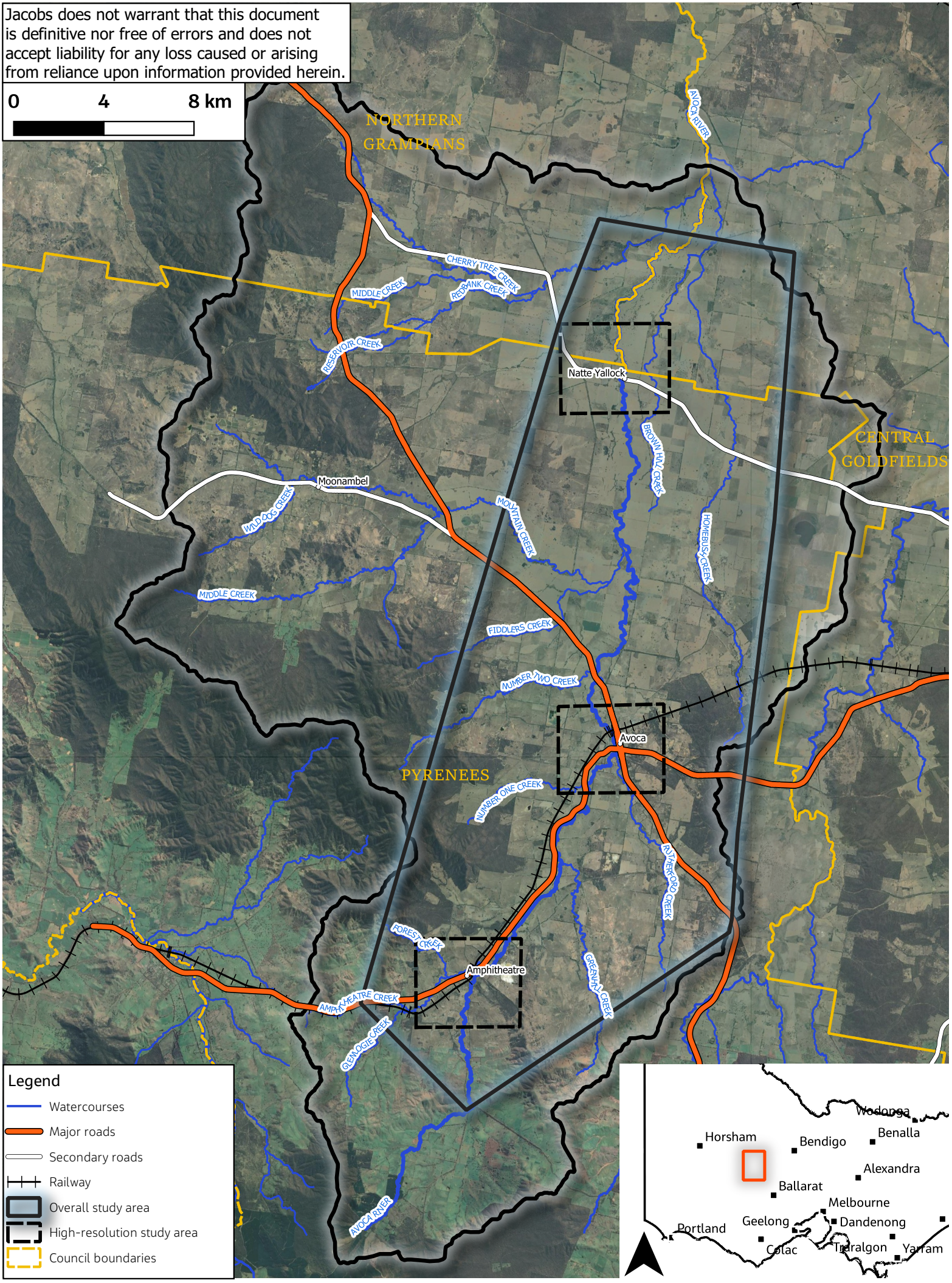


Figure 1.1: Upper Avoca Flood Investigation Overview

Jacobs

2. Estimated effective flood warning time

How quickly a catchment responds to rain and thus how much flood warning time is available varies significantly for individual flood events as a result of several factors including:

- Storm characteristics - the time distribution of rainfall within a storm and the location of a storm within a catchment noting also that flooding from intense short duration storms is likely to develop more quickly than from longer less intense storms
- Catchment and watercourse antecedent conditions - floods tend to develop quicker on wetter catchments and generally travel quicker on a "wet" watercourse than on a 'dry' watercourse (e.g. the first flood after a dry period will usually develop and travel more slowly than the second flood in a series of floods due to the filling of soil stores, off-stream storage and related factors)
- Size of flood - big floods tend to travel faster than small floods due in part to greater stream energy

Having regard for the above, it is suggested in the Flood Modelling Report (Jacobs, 2020b) that the response time for a major flood at Amphitheatre and Avoca is estimated at around 5 to 7 hours and around 10 to 13 hours at Natte Yallock. Response times are estimated to be a few hours longer for smaller flood events. This places Amphitheatre and Avoca close to the flash flood category as per Bureau of Meteorology (BoM) definitions in BoM (1996) and as discussed in VFWCC (2001) and BoM (2020).

Under severe flood conditions and having regard for the current consequences of flooding in the upper catchment , the effective flood warning time for the Upper Avoca River communities is currently estimated to be around 2 to 4 hours as in effect there are no flood warning system elements in place.

With the benefit of the indicative flood guidance tools provided in Appendix C4 of the Pyrenees Municipal Flood Emergency Plan (MFEP) in concert with the flood intelligence and mapping delivered by this study, it is estimated that effective flood warning time could be extended by at least 4 hours for Upper Avoca River communities. The indicative flood guidance tools are included herein as Figure 5.1 through to Figure 5.4.

In view of the estimated effective flood warning time, emergency services driven flood response actions across the Upper Avoca River in the lead up to flooding are currently likely to be severely limited. There is insufficient time available to mobilise emergency services, for roads to be closed and for buildings most at risk of being flooded over-floor to be prepared (e.g. relocate or lift valuables and other items, sandbag openings, etc). Even with the benefit of the deliverables and additional available time that could result from this study, it is suggested that with due regard for other regional flooding issues and the need to prioritise calls for assistance, there would be limited opportunity to mobilise emergency services to assist local flood response (i.e. damage reducing) activities. Residents however, armed with the indicative flood guidance tools and ready access to rain and water level data, may be able to undertake appropriate actions aimed at reducing damage and risk to life. Key to this is awareness of the flood risk, recognition of the likelihood and scale of imminent flooding, and knowing what to do to reduce damage and risk.

While not canvassed with VICSES, Emergency Management Victoria (EMV) or BoM, it is suggested that there may also be future opportunities, in the context of successful proof-of-concept trials at Natimuk (see Section 4.1), for a VicEmergency warning of likely flooding to be issued for the Upper Avoca River communities during severe rain events. However, those opportunities are unlikely to be available until after successful implementation of protocols and after some adjustments to how data from local rain and river gauges is managed. The VicEmergency warning could be augmented by an Emergency Alert if it was assessed that there was a risk to life.

3. Flood warning systems

Flood warning is an effective and credible non-structural flood mitigation or flood risk reduction measure. Successful system implementation requires attention to all system elements as well as the striking of a balance between each of those elements appropriate for the community it will serve. A "one size fits all" or standard approach is not appropriate. What works for one community may not necessarily be appropriate for another.

In relation to the Upper Avoca River, any system established must meet the needs of the at-risk community with appropriate emphasis on the various system elements while also accounting for the constraints imposed by the effective flood warning time. Consideration of the benefit to cost ratio is also important. This is because to secure funding, the benefits of establishing a flood warning system would ideally outweigh the costs.

3.1 Aim and function

Put simply, flood warning systems provide:

- A means of gathering information about impending floods
- Communicating that information to those who need it (those at risk)
- Facilitating an effective and timely response

Thus, flood warning systems aim to enable and persuade people and organisations to take timely action to increase personal safety and to reduce the damage caused by flooding. Key to this for those at risk is:

- The availability of information about flood risk
- Easy access to relevant and timely real time rainfall and water level data/information
- Knowing what needs to be done in the lead up to and during a flood event

Flood warning systems (and investments in their implementation) that over-emphasise the collection of input data and/or the production of (highly accurate) flood forecasts relative to the attention given to other elements, often fail to fully meet the needs of the at-risk communities they have been set up to serve. Put another way, it is essential that those parts of the flood warning system that work to build resilience within a community while also increasing warning lead time are given due emphasis and attention.

3.2 The Total Flood Warning System concept

In 1995 the Australian Emergency Management Institute published a best-practice manual entitled Flood Warning: an Australian Guide (AEMI 1995), and in so doing, introduced the concept of the TFWS. While the original manual has been updated and republished as Manual 21 of the Australian Disaster Resilience Handbook Collection (AIDR 2009), the concepts, practices and key messages from the original manual endure.

The Victorian Floodplain Management Strategy (DELWP 2016) also promotes the TFWS concept and provides clarification on roles and responsibilities for system development and operation in Victoria.

3.3 Total Flood Warning System building blocks

An effective flood warning system is made up of several building blocks depicted in Figure 3.1. Each building block represents an element of the TFWS.

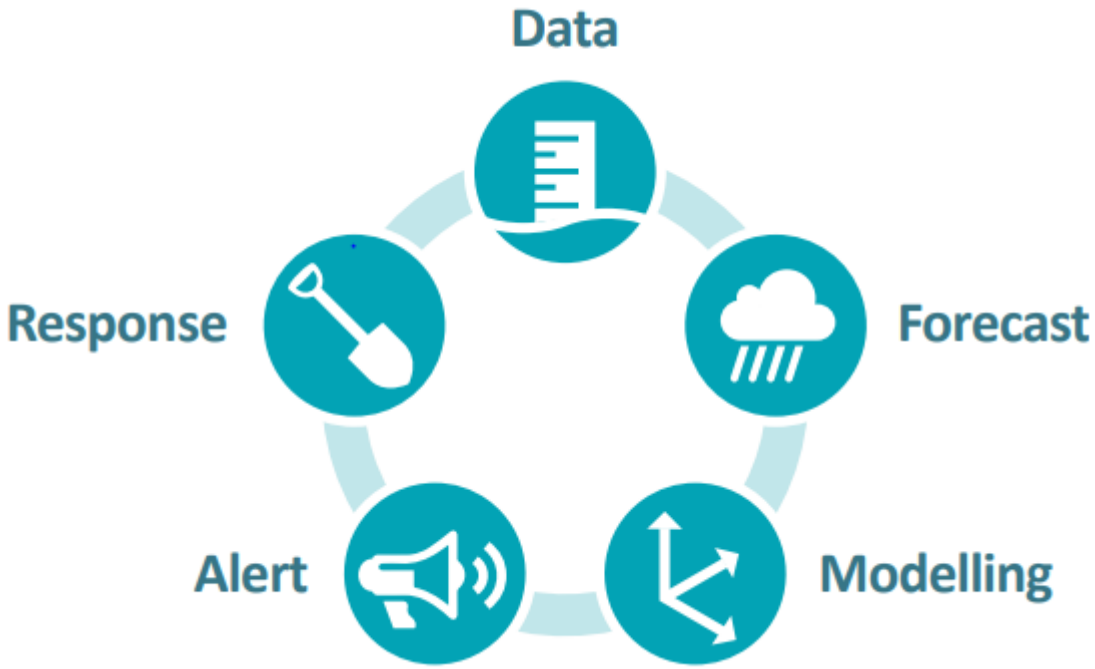


Figure 3.1: Elements of the Total Flood Warning System (DELWP 2016)

An appropriately developed and integrated system considers not only the production of a timely and informative alert of a potential flood, but also the efficient dissemination of that alert to those who need to respond in an appropriate manner, most important of whom are the threatened community. A community that is informed, flood aware and prepared (i.e. flood resilient) is more likely to receive the full benefits of a warning system.

It follows that actions to improve flood response and community flood awareness using technically sound data (such as that produced by the Investigation) will by themselves result in some reduction in flood losses.

3.4 FLARE

As identified in Section 2, parts of the Upper Avoca River are subject to flash flooding. While BoM does not currently provide flash flood warning services, it has developed FLARE, the national flash flood warning advisory resource. FLARE acts as a repository of technical information and guidance in relation to flash flood warning systems (FFWS). It provides:

- Historical information on flash flooding
- An overview of some of the systems operating in Australia (i.e. case studies)
- Details of BoM services available to support flash flood warning systems
- Some suggestions on flash flood warning system elements
- Selected advice on relevant standards and guidelines (e.g. on data sensing and measurement, telemetry, data collection systems, metadata management, etc)
- An office hours help line to respond to questions

A guide to flash flood warning system considerations and design is also provided, as a supplement to jurisdictional approaches and methods. The guide steps the user through the use of the FLARE resources as part of system design (refer to Figure 3 2). FLARE was consulted during preparation of this flood warning feasibility assessment.

Figure 3.2: Guide to FFWS design (FLARE)

4. Task for the Upper Avoca River

The North Central Regional Floodplain Management Strategy 2018-2028 proposes a strategic direction that articulates the need for community and regional resilience as a key and sustainable response to flood risk. This is consistent with State and Federal Government policy. This report and the suggested approach to flood warning for the Upper Avoca River catchment community is similarly consistent. It is aimed at a system that will provide information to enable individuals to make informed decisions about risk and what they need to do. The emphasis is therefore on "what works best for communities in the Upper Avoca River catchment" with due regard for flood risk, available flood warning and response times, available rain and water level data, and the funding and other responsibilities associated with implementing and maintaining elements of a (flash) flood warning system.

The analyses that underpin the North Central Regional Floodplain Management Strategy 2018-2028, identified the need the Investigation, in part, deliver detailed flood maps and inform flood intelligence. The analyses also had regard for:

- The existing rain and water level data collection network and opportunities for regional improvements
- Access to locally relevant near real-time flood information and improved methods of sharing that information
- Improved local flood awareness as a result of LFGs and ready access to information about local and regional flooding consequences
- Opportunities to update the Planning Scheme to better reflect what is known about flooding across the region

The current study shows that out-of-bank flows and flooding of roads commences during quite frequent floods across the Upper Avoca River catchment. It also shows that over-floor flooding of dwellings is not an issue at Amphitheatre, does not occur until near the 2% AEP flood at Avoca but occurs during floods more frequent than the 20% AEP event at Natte Yallock. Depths and velocities within the main channels of the area's streams, particularly through Amphitheatre and Avoca, do present as high (or greater) hazard from quite frequent events. Flood depths and velocities within the overbank floodplain (including through the townships) are in general, low hazard. The exception to this is a broad area of high hazard flooding immediately to the west of the main township area of Natte Yallock that becomes wider as flood severity increases.

4.1 Policy and strategy considerations

The division of responsibilities associated with the establishment, maintenance and operation of flood warning systems as documented in VFWCC (2001) have been endorsed by the relevant Ministers at both State and Federal level. More recent developments have seen the BoM establish a Service Level Specification (SLS) (BoM, 2020) that details the flood forecast and warning service BoM will provide for specific locations across the State. The SLS is updated as data collection network configurations and designations, and flood forecasting capabilities change. The BoM has established a fee-for-service approach to the development (on a priority basis) of flood forecasting tools for locations not included in the SLS (see below). In relation to flash flood warning services, BoM will continue to provide generalised warnings of weather conditions likely to lead to flash flooding but it is understood that there are no current plans to provide flash flood warnings for specific streams or locations.

The Victorian Floodplain Management Strategy (DELWP 2016) provides clarification on roles and responsibilities for TFWS development and operation in Victoria. Policy 16a is directed at flood warning in general while Policy 16d is directed specifically at flash flooding.

Victorian Floodplain Management Strategy Policy 16a (outlines the future arrangements for flood warnings in Victoria):

- BoM will develop new flood prediction services using a cost-recovery model that involves DELWP covering the capital cost of initial model development and BoM the cost of operating, maintaining and continually improving those models.

- Existing flood prediction services will continue to be operated, maintained and improved by BoM.
- Where a flood study identifies the need for new rain or stream monitoring gauges to support a TFWS for a community within Melbourne Water's region, Melbourne Water will cover the capital and maintenance costs of those gauges.
- Where a flood study or regional floodplain management strategy outside Melbourne Water's region identifies the need for a TFWS and that service has community support, the capital costs for new rain or stream monitoring gauges will be shared between the Victorian and Australian Governments. The local community, through its Local Government Area (LGA), will fund ongoing maintenance costs for the gauges.
- Where existing rain and stream monitoring gauges are providing flood warning services, the Victorian Government expects existing cost-sharing arrangements to continue until a regional floodplain management strategy or local flood study assesses the need for a TFWS service.
- Where existing gauges are assessed as being an essential component of a TFWS, the costs of maintaining those gauges will be shared between the LGA and the CMA if it is also used for water quality monitoring, or with a water corporation if it is also used for water resource assessments. In some cases, the costs may be shared between all three agencies.

Policy 16d:

- The CMAs and Melbourne Water, with the support of VICSES and LGAs, will progressively identify areas with a history of flash flooding and include them in their Regional Floodplain Management Strategies and implementation plans.
- Cost-sharing arrangements for flash flood warnings will be the same as for riverine flooding (Policy 16a).

A flood warning system established for a stream or location considered to be subject to flash flooding is, in general terms, the responsibility of the LGA. This includes the installation, operation and maintenance of the technical elements. BoM will maintain delivery of existing severe weather and riverine flood warning related services. Delivery on other TFWS elements including alerting / warning, the development and application of flood response plans as well as flood education and awareness programs, is a shared state and local government responsibility.

Looking ahead and as an out-working from the Services Standardisation Project, BoM has been working in Victoria with EMV and VICSES on scoping and trialling an Automated Alerting Project at Natimuk. The project involves BoM systems automatically identifying exceedance of critical levels on data ingested from selected telemetered rain and river gauges and alerting of that exceedance to EMV. It is understood that those alerts then generate warnings of potential or actual river level rises as a push to the VicEmergency website and App and as more formal public issue warnings from VICSES. The work offers exciting potential to alert and warn at-risk communities of developing (flash) flood events. While it is not suggested that the project offers a ready-made solution for Upper Avoca River catchment communities, subject to further development and adoption as outcomes from the proof-of-concept trials with the Natimuk community, the future potential for benefits to communities in the Upper Avoca River catchment and elsewhere is evident.

There are a number of decisions required in relation to how each of the TFWS elements can be developed and implemented for the Upper Avoca River communities. Regardless, the main messages from the 2005 Flood Warning Service Development Plan for Victoria (VFWCC 2005) remain valid. Those applicable to the Upper Avoca River include:

- Making existing data and information / flood intelligence easily accessible to the at-risk community
- Assisting at-risk communities use that data and intelligence (for example, personalised "what does it mean for me" letters, pamphlets and related information)
- Developing and providing tools that add value to or drag value from available data and intelligence (e.g. indicative flood guidance tools)

- Developing a (local) means of providing an indication of likely flooding with some lead time for the many communities for which the BoM does not currently provide a flood warning service
- Driving maximum value from flood mapping and other study outputs for local community benefit
- Focussing on delivering and / or making available those things that will achieve a reduction in damages (i.e. focussing on facilitating the availability of relevant information with some lead-time and a degree of accuracy and consistency)
- Providing the data, information and indicative flood guidance tools to enable at-risk communities build resilience

4.2 The challenge for the Upper Avoca River communities

In view of what TFWS elements have been delivered by the current study (see Section 1), the key issue for the Upper Avoca River communities is how a potential flood will be detected ahead of the onset of flooding and how the at-risk communities of Amphitheatre, Avoca and Natte Yallock will be alerted, ideally with sufficient lead time to enable completion of effective response actions.

A range of systems, equipment and approaches are available. The dilemma is "which of these are appropriate and sufficient" given that the time between the beginning of heavy rain and the start of water level rises is estimated (see Section 2) at around 5 to 7 hours at Amphitheatre and Avoca and at around 10 to 13 hours at Natte Yallock. Flood peaks are estimated to occur around 17, 18 and 24 hours respectively after the start of heavy rain and around 10 to 14 hours after the start of rise. However, roads are inundated, and the first building is flooded over-floor at Natte Yallock well before the peak of a big flood is reached: around 5 to 6 hours after the start of rise. In this situation under current conditions as discussed in Section 2, the effective flood warning time for the Upper Avoca River is estimated to be around 2 to 4 hours.

Allowing time for information to be made available to the community through a flood warning system and for event severity to become evident (say half way through a heavy rain event) plus time required by the community to confirm that information, the time available to respond (i.e. lift furniture and other household goods off the floor, move vehicles and other assets to dry ground, close roads, etc) is estimated to increase to around 6 to 8 hours or more during a large flood and a couple of hours longer for a small flood. With such a short effective warning time and the increase in time estimated to be achievable with a flood warning system, it is apparent that delivery of information to the local community as quickly as possible is paramount.

4.3 A TFWS for the Upper Avoca River communities

Having regard for first level achievements only, gives rise to the following functional requirements:

- Monitoring of rainfall (and perhaps also water levels), possibly for exceedance of triggers that indicate that flooding may occur
- Ready public access to rainfall data
- Alerting the community, VICSES and the Pyrenees and Central Goldfields Shire Councils to potential flooding as quickly as possible
- Ready public access to flood intelligence (i.e. mapping perhaps as soft copies or through an interactive GIS hosted by the Councils and/or NCCMA, flood information card, etc) so that the community can determine likely impacts and individual consequences and initiate appropriate response actions
- Low setup and operating costs with (ideally) a positive benefit-cost ratio
- Acknowledgement and acceptance that a formal flood warning service is unlikely to be provided for the upper catchment communities

Most of the above can be achieved with minimal cost. Opportunities do exist for local governments to seek and secure Commonwealth and State funding to assist with system set up. Operational and ongoing costs do however remain a local government responsibility as outlined in Section 4.2.

5. Flood warning system considerations

It is suggested that consideration of a flood warning system for the Amphitheatre, Avoca and Natte Yallock communities should have regard for the:

- Existing rain and water level data collection network
- Potential for rapid development and progress of floods within the upper catchment and the limited lead time available between heavy rain and stream rises
- Character of the flood risk (i.e. rapid onset, roads flooded and impassable, high likelihood of over-floor flooding at Natte Yallock from a little below the 20% AEP flood level)
- Modelling completed as part of the Upper Avoca Flood Investigation which shows that there is minimal benefit in installing water level measuring equipment at Natte Yallock
- Economic metrics (i.e. likely benefit-cost based on consideration of the contribution of avoidable damages to the value of average annual damages)
- Policy drivers and financial implications

The following sections outline how each of the TFWS elements could be addressed to implement an effective, low maintenance, scalable flood warning system that has some utility to the Upper Avoca River communities, at minimal cost.

5.1 Data collection and collation

There is a wide range of equipment that will variously collect, collate and/or undertake assessments on rain and/or stream level data and make it available to a single entity or to a group of entities. Data can be pushed either directly from the equipment at site, through a post box or website, or following delivery to a predetermined digital address. The focus here is on what is best for the Upper Avoca River communities.

There are already several permanent and fully operational telemetered rain and stream gauges located in or in close proximity to the Upper Avoca River. There are four stream gauges located in the catchment, and eight relevant rain gauges in or near the catchment. The location of the gauges are shown on Figure 2.4 of the Data Review Report (Jacobs 2020a).

The eight rain gauges are located at:

- Bet Bet Creek @ Lillicur (407288), approx. 10km east of Amphitheatre and approx. 12km south of Avoca
- Doctors Creek @ Lexton Reservoir HG (407326), approx. 17km south-east of Amphitheatre and approx. 22km south of Avoca
- Forrest Creek @ Amphitheatre Reservoir HG (408216), approx. 2km west of Amphitheatre and approx. 13km south-west of Avoca
- Bet Bet Creek @ Norwood (407220), approx. 18km north-east of Avoca and approx. 17km south-east of Natte Yallock
- Bung Bong (408801), approx. 8km south-east of Avoca
- Avoca Water Treatment Plant (408800)
- Avoca (81063), recently brought back online in 2020
- Redbank Creek @ Redbank Reservoir HG (408218), approx. 14km west of Natte Yallock
- Avoca River @ Archdale Junction (408206), approx. 7km north-east of Natte Yallock

The four stream gauges are located at:

- Avoca River @ Amphitheatre (408202)

- Forrest Creek @ Amphitheatre Reservoir HG (408216), approx. 2km west of Amphitheatre and approx. 13km south-west of Avoca (Forrest Creek joins the Avoca River immediately upstream of Amphitheatre)
- Sugarloaf Creek @ Sugarloaf Reservoir HG (408217) (Sugarloaf Creek is a tributary to Number One Creek which joins the Avoca River approx. 1.5km upstream of Avoca)
- Avoca River @ Archdale Junction (408206), approx. 7km north-east (downstream) of Natte Yallock

Data is only publicly available from the BoM website for the following gauges:

- River level at Avoca River @ Archdale Junction at 15 minute intervals
- Rainfall at Bet Bet Creek @ Lillicur, Avoca and Avoca River @ Archdale Junction at 3 hourly intervals
- Rainfall at Bet Bet Creek @ Norwood at 24 hourly intervals

Data from all of the above gauges are available through the Regional Water Monitoring Partnership at 15 minute intervals.

It is suggested that with near real-time access to rainfall data from all eight rain gauges listed above and an indicative flood guidance tool (see Section 5.3) there exists a strong basis exists for a local community-based flood warning system. However, data from those gauges would need to be made publicly available in near real-time (say updated every 15 minutes). The BoM website is an obvious choice to achieve this.

It is suggested that the Pyrenees Shire Council:

- Approach BoM (with support from VICSES, NCCMA, DELWP and the Central Goldfields Shire Council) to request necessary changes to enable near real-time public access to rain data from the above rain gauges and stream gauges via the BoM website (e.g. 15 minute updates).
- Arrange for the installation of a set of staff gauges on the upstream side of the Pyrenees Highway Bridge in Avoca. The staff gauges should be installed such that the gauge boards can be read from the road for small and larger (i.e. 1% AEP) floods so that local residents and emergency services can confirm water levels and rates of rise in the Avoca River.
- As an additional source of information, arrange for the installation of a set of staff gauges on the upstream side of the Sunraysia Highway Bridge downstream from Avoca. The staff gauges should be installed as described in the bullet immediately above.
- Following a successful approach to the BoM regarding data accessibility and in concert with VICSES, consider providing guidance to the upper Avoca communities (through a locally focussed flood awareness brochure or similar) on how to access and interpret data from the various rain and stream gauges together with instruction on the use of that data with the indicative flood guidance tools. Information about other elements of the flood warning system and how it will assist in reducing risk could also be included.
- Consider developing and maintaining a website (and social media) presence for the FWS. As a minimum, this website could contain the indicative flood guidance tools and the associated flood mapping and intelligence outputs from this study.

In addition to the above, consideration was given to installing a set of staff gauges on the upstream side of the Maryborough – St Arnaud Road Bridge. However, the hydraulic modelling undertaken as part of this investigation shows that there is very little difference (approximately 100 mm) in water levels for small and large floods at this bridge. As this difference is too small to allow discrimination between small and large floods and thus facilitate reliable estimates of flood size and likely consequences, there is little value in installing a gauge. The nearest upstream bridge is at the Sunraysia Highway around 3km downstream from the Pyrenees Highway Bridge in Avoca and around 13 km upstream from Natte Yallock but only around 7 km upstream of where breakouts that flow to the west of Natte Yallock begin during large floods. An installation at this bridge has already been included in the suggested list of actions above. An alternative would be to install a new stream gauge station on the approx. 2km section of the Avoca River between where Mountain Creek joins the Avoca River and flood breakouts begin. This would be an expensive undertaking and is unlikely to deliver any

significant additional benefits over a gauge at the Pyrenees Highway Bridge and the indicative flood guidance tools provided in Appendix C4 of the Pyrenees MFEP.

If a greater level of confidence in the likelihood of flooding is required, it is suggested that the Pyrenees Shire Council consider:

- As a first step, purchase of an Event-Reporting Radio Telemetry System (ERTS) river (or rain-river) gauge and its installation on the upstream side of the Pyrenees Highway Bridge in Avoca alongside the staff gauges mentioned above. As above, the Pyrenees Shire Council, with support from VICSES, NCCMA, DELWP and the Central Goldfields Shire Council, would need to approach BoM to provide near real-time public access to data from the gauge via its website.
- As a second step, purchase of an additional ERTS river gauge and its installation on the upstream side of the Sunraysia Highway Bridge downstream from Avoca alongside the staff gauges mentioned in the list above. BoM would need to be approached regarding near real-time public access to the data.
- Alternatively, and instead of ERTS equipment, arranging purchase and installation of different commercially available rain and/or rain-river monitoring equipment (such as DipStik, telemetered cameras) in the locations described in the above bullet. BoM has to date been reluctant to accept such data into their database for website display and archival.
- The addition of "sirens and/or flashing lights" options (triggered by exceedance of pre-set rainfall rates and depths, and river levels and rates of rise) for the automated gauges installed at the bridges as an alternative or additional means of alerting the community to imminent flooding.
- As appropriate and dependent on the monitoring and alerting equipment installed, invite Upper Avoca River residents, along with VICSES, local CFA, Police and Council, to opt-in to receive SMS alert messages direct from installed equipment.
- Provide guidance to the local community (through a locally focussed flood awareness brochure and website) on how to interpret and use available rain and water level data and the indicative flood guidance tools, along with information about the flood warning system and how it will assist in reducing risk.
- Decide whether to establish proposed water level gauges to local datum or to AHD.

Importantly when contemplating the installation of new rain and / or river gauges for flood forecast and warning purposes, current policy on financial contributions and commitments and on ownership, along with the role of the Regional Water Monitoring Partnerships, must be considered. As outlined in Section 4.2, the Victorian Floodplain Management Strategy is clear that capital costs for new rain or stream gauges will be shared between the State and Federal governments but that all ongoing maintenance costs must be met by the local community through the local Council.

While there is the possibility that the two bridge sites identified above could be used as Portable Automated Logger System (PALS) installation sites, catchment response times indicate that in most situations there would be insufficient time to install the equipment ahead of a likely flood. Further, while the PALS would provide useful data for post-event analyses, there are restrictions to public access to the real-time data they provide. Local access to data is key to effective flood warning for the Upper Avoca River. There is also no certainty that PALS would be available when needed as there are a limited number of the units available across the state.

5.2 Flood detection and prediction – Indicative Flood Guidance Tools

5.2.1 Capability following completion of this Investigation

The indicative flood guidance tools provided in Appendix C4 of the Pyrenees MFEP (included here as Figure 5.1 to Figure 5.4) provides some guidance on the likelihood and severity of expected flooding in the Upper Avoca River from upstream of Amphitheatre, through Avoca to downstream of Natte Yallock with an estimated lead time of 6 hours or more during a large flood on a wet catchment.

Rainfall data from the Upper Avoca River and the nearby Bet Bet Creek catchment should be used to drive the rainfall based indicative flood guidance tool at Figure 5 1. However, the tool may not perform to expectations in severe thunderstorm situations, when there are locally heavy falls embedded in more general rain and when the catchment is dry.

River level data from the gauge at Amphitheatre (or from an intermediate location) should be used to drive the water level based indicative flood guidance tools at Figure 5.2, Figure 5.3 and Figure 5.4. It is stressed that these three tools are indicative only. They are underpinned by a number of gross assumptions and tend to be (but will not always be) conservative.

It is suggested that the indicative flood guidance tools are adopted by VICSES, local CFA and Councils for routine use. It is also suggested that the tools and instructions for their use could be shared with the Upper Avoca River communities and key community members instructed on use.

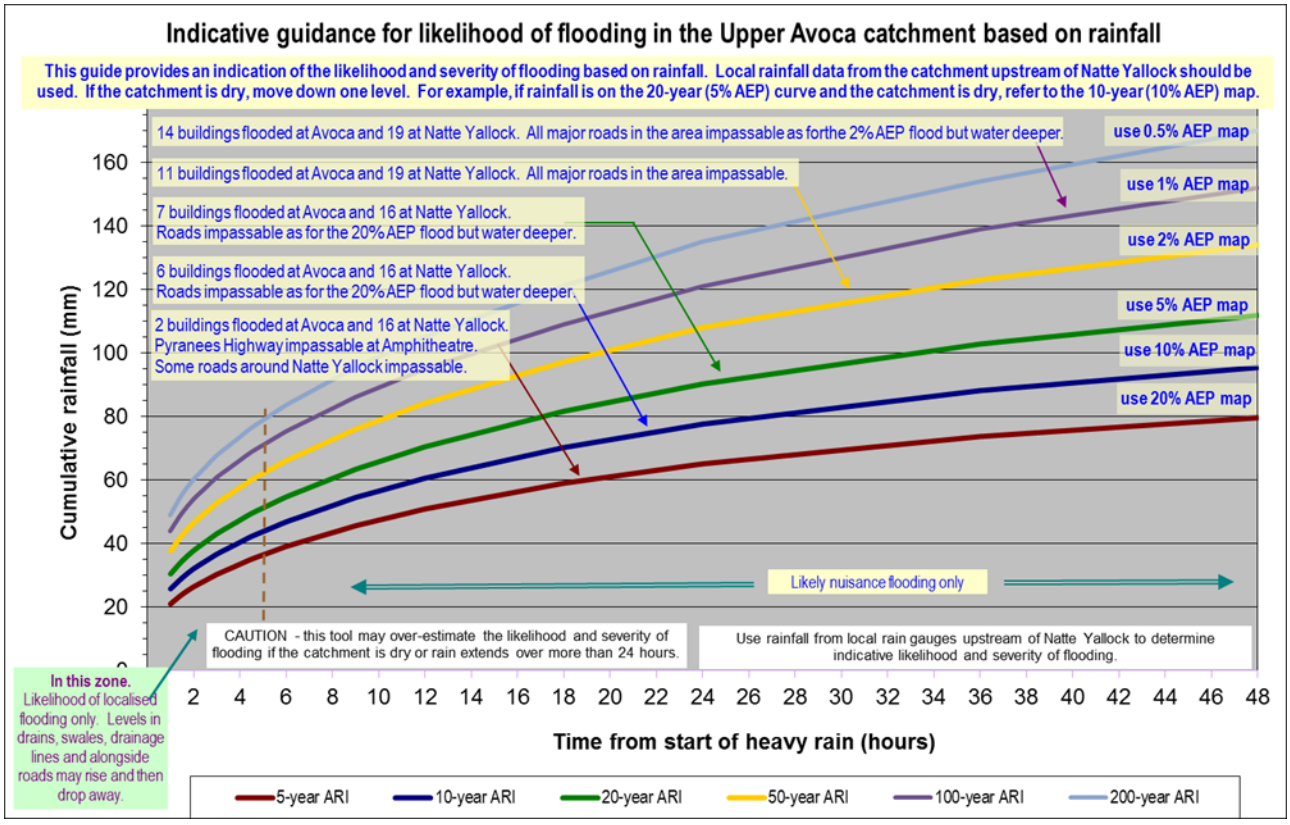


Figure 5.1: Indicative Flood Guidance Tool – likelihood of flooding based on rainfall

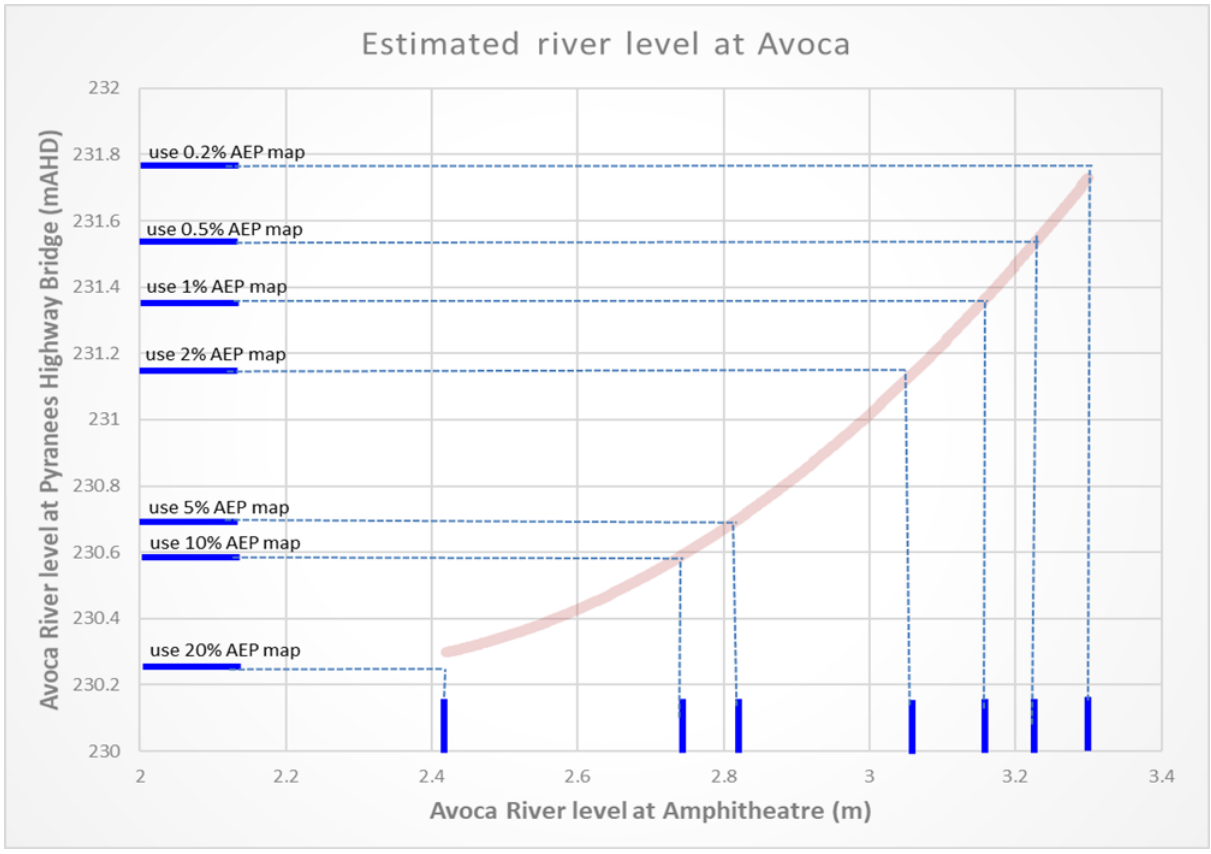


Figure 5.2: Indicative Flood Guidance Tool – likely flood severity at Avoca based on upstream river levels

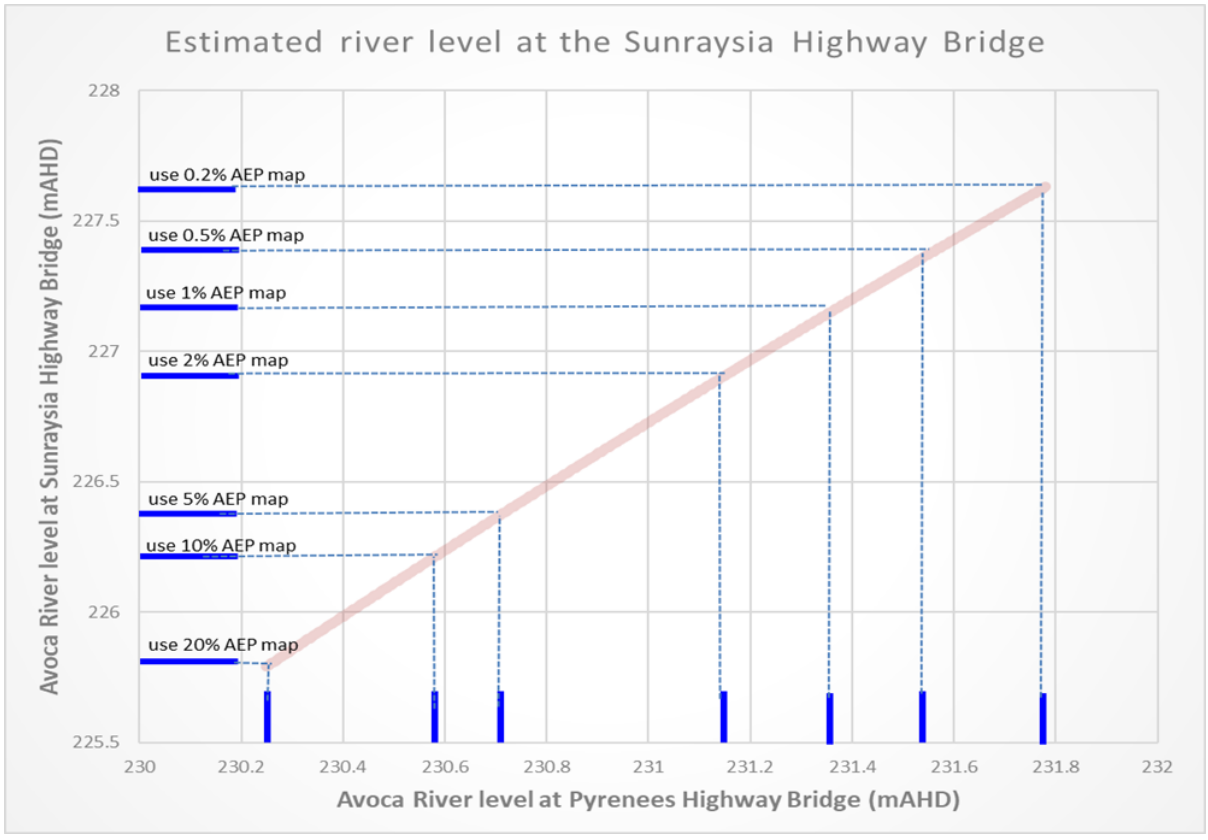


Figure 5.3: Indicative Flood Guidance Tool – likely flood severity Avoca to Natte Yallock based on upstream river levels

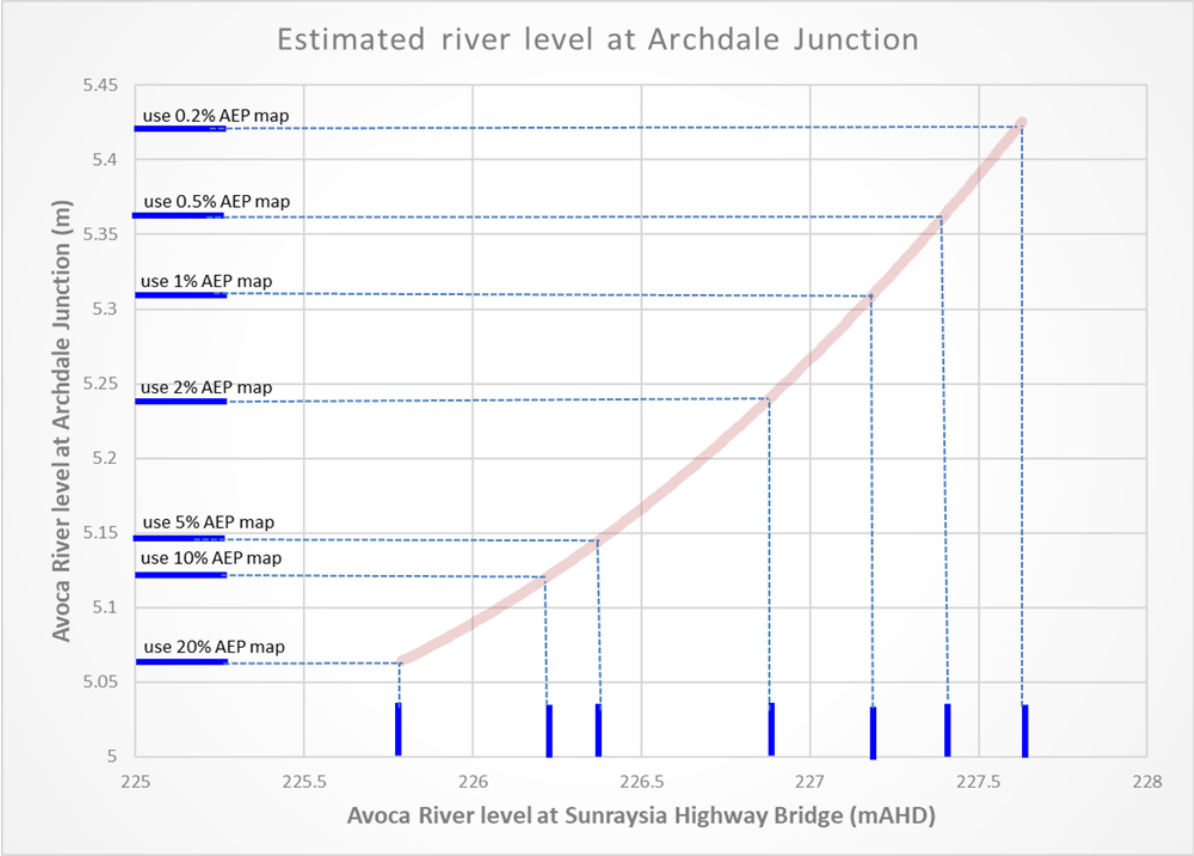


Figure 5.4: Indicative Flood Guidance Tool – likely flood severity around Natte Yallock and downstream based on upstream river levels

5.2.2 Potential capability pending investment in improvements

It is suggested that in the context of State-wide and Regional priorities and the relative scale of flood damages across the Upper Avoca River, investment in a more sophisticated and technically demanding forecast tool that would need to be established, operated and maintained by Pyrenees Shire Council (DELWP 2016 and VFWCC 2001) is probably not warranted.

With a view to the longer term and subject to the programming of alerts for exceedance of pre-determined rainfall rates and depths at (a sub-set of) the eight nearby rain gauges and the Amphitheatre river gauge, the Automated Alerting Project (see Section 4.1) appears to offer potential as the basis for a robust initial flood alerting and warning system. It is suggested that Pyrenees Shire Council maintain contact with VICSES on project progress with a view towards implementation for Natte Yallock initially followed by Avoca and Amphitheatre.

5.2.3 Flood Class Levels

Flood class levels, determined against standard definitions, are used to establish a degree of consistency in the categorisation of floods. In order to assist the flood warning process and increase awareness of flooding within the community, it is suggested that the Council give consideration to establishing flood class levels for Amphitheatre and at the Pyrenees Highway Bridge at Avoca and the Sunraysia Highway Bridge downstream from Avoca. The process would involve coordination between Council, VICSES, NCCMA and BoM and is relatively straight-forward. Note: can only be established for locations with a permanent water level gauge.

5.3 Interpretation

The flood mapping and Pyrenees and Central Goldfields MFEP Appendices developed as part of the Investigation provide the base information to enable the community and stakeholder agencies to determine the

likely effects of a potential flood. This means however that the flood inundation maps and relevant Appendices of the MFEP, and more specifically the flood information cards for the Upper Avoca River, would need to be readily available to the at-risk communities.

5.4 Message construction and dissemination

There are a number of alerting and notification tools, technologies and service providers available, some of which both alert (make people aware of an imminent hazard) and notify (provide a warning message). A summary of those that might be suitable for the Upper Avoca River has not been included herein as the approach proposed does not include the construction and/or dissemination of formal warning messages, other than as may occur as a result of the Automated Alerting Project (or similar) described in Section 4.3. This is because of the short effective flood warning time in combination with the dependencies between the alerting and notification functional requirements and decisions regarding the data collection network equipment and locations to be instrumented.

If a flood was to occur soon after delivery of the maps and indicative flood guidance tools arising from this study to the Upper Avoca River communities, it is likely that for most residents, the initial alert of likely flooding will be personal (or perhaps from a neighbour within the community) and will come from a combination of environmental indicators (e.g. observance of heavy rain, local runoff, etc) and the resident's consideration of the flood inundation maps in conjunction with the relevant Appendix of the MFEP. If an alternate commercial monitoring system such as DipStik was installed, the initial (or confirming) alert may come from the unit's SMS'ed message and / or siren, as rain and / or stream levels exceeded triggers with the above acting to reinforce and add value to resident's assessments and decision processes. Alternatively, and subject to resolution of VICSES and EMV roles in the initiation and dissemination of (flash) flood warnings, the initial alert may come via electronic and social media.

If a marginally more formal alerting system was deemed appropriate and viable for the upper Avoca communities, regardless of whether additional permanent rain and water level monitoring equipment (e.g. ERTS, DipStik, other) was installed, the communities could be encouraged to be more involved in the TFWS by sharing information about the (likely or actual) on-set of flooding and to then back this up with information about likely consequences (e.g. from the MFEP and local knowledge / observations). Social media provides a suitable vehicle. A Twitter and/or Facebook account could be established for the Upper Avoca River TFWS. This would require the Pyrenees Shire Council (in conjunction with VICSES) to champion the formation of an Upper Avoca River flood action group (or similar). The Landcare Group at Natte Yallock are already established and functional and may be in a position to take on this role.

Members of the (proposed) flood action group could play a key role in local flood warning operations and review. In particular, via social media, they could share information initiated within the community, following application of the indicative flood guidance tools and by VICSES on likely flood severity, impacts and appropriate actions.

5.5 Response

The Pyrenees and Central Goldfields MFEP Appendices have been populated for the Upper Avoca River as part of the Investigation. Information in the MFEPs includes available intelligence relating to flooding from the upstream catchment along with the indicative flood guidance tools provided in Figure 5.1 to Figure 5.4. Instructions for the tools' use have also been included in the MFEPs. Flood inundation extent and depth maps have been added together with a list of areas and roads likely to be flooded. A table of properties and key infrastructure likely to be flooded along with the likelihood and depth of over-ground and over-floor flooding at each property (where available) is also included along with flood information cards for the area.

The availability of this flood intelligence will improve the situational awareness of the emergency service agencies and the Upper Avoca River communities while also increasing their potential to respond in a more timely and appropriate manner.

Following (or perhaps in concert with) acceptance of the updated MFEPs by the Pyrenees and Central Goldfields Shire Councils and by VICSES, a program to encourage and assist residents and businesses to develop individual flood response plans should be developed and delivered. A package that assists businesses and individuals is available from VICSES and provides an excellent model for community use.

5.6 Community flood awareness

LFGs that draw on the flood intelligence collated to the Pyrenees MFEP should be developed for and made available to the Amphitheatre, Avoca and Natte Yallock communities. LFG development and maintenance are a VICSES responsibility.

Looking further ahead, it is suggested that VICSES, in partnership with Council, develop activities and materials for the Upper Avoca River communities that emphasise personal safety, how available rain and stream level data can be used, what any warnings/alerts mean and what individuals can do to stay safe and protect their property including how to fill and lay sandbags. This should extend to also making relevant parts of the MFEPs publicly available (e.g. Council offices, library, website, etc). Such investments will assist in maintaining and renewing flood awareness within the local community.

5.7 Funding opportunities

Opportunities do exist for local government to seek and secure Commonwealth and State funding to assist with flood warning system set up. Generally, the benefits of establishing the system need to outweigh costs in order to secure funding support. Regardless of the support received, operational and ongoing costs remain a local government responsibility as outlined in Section 4.1.

It is suggested that having determined the desired elements of the flood warning system to be established for the Upper Avoca River communities and a timetable for the establishment of each element, Council (with support from NCCMA and VICSES) should scope and submit an application for funding under the Commonwealth-State National Partnership Agreement on National Disaster Risk Reduction (i.e. the Risk and Resilience Grants Program) or successor funding programs.

6. Recommendations

Currently achievable response actions across the Upper Avoca River, as outlined above and without regard for time of day or night, are limited to what residents can achieve.

It is suggested that an "accurate" forecast is not the key to achieving an increase to personal safety and flood damage reduction within the upper catchment communities. Rather it is timely alerting and access to relevant data and easy-to-use indicative tools that, coupled with robust communications systems supported by sound awareness of flooding consequences (i.e. community resilience), provide the information that triggers those at risk to take timely and appropriate actions: to improve local capability and deliver the benefits sought from a flood warning system.

Further to these specific requirements, this assessment identifies feasible options for improving local capability to act in a timely manner and improving future response to impending floods within the Upper Avoca River, thereby potentially reducing future flood risk. The identified options range from making better use of existing rainfall monitoring resources (i.e. no/low cost options) through to investment in improved rain and/or river monitoring in conjunction with automated messaging, that if implemented, could lead to more reliable and substantive outcomes (i.e. an option requiring more substantial investment of time and money to set up and maintain). Guidance is provided as to how such a system may operate.

Adopting and making best use of the immediate deliverables from this investigation (i.e. making the indicative flood tools, flood intelligence and flood mapping available to both the emergency agencies and the Upper Avoca River communities and being able to make better use of rainfall data that will (hopefully) soon be available in near real-time from BoM), will increase flood awareness and the opportunity for residents to recognise imminent flooding and initiate appropriate response actions. This has been assessed as being achievable in the near term with minimum investment.

With some investment, additional water level monitoring equipment could be installed around Avoca and additional measures implemented to increase flood awareness and community engagement. Together, these measures are estimated to give additional confidence in expected flood severity along with an increase in the time available for damage reducing actions by the upper community's residents (i.e. more reliable and substantive outcomes). This has been assessed as being achievable in the mid-term.

Further increased confidence in the expected severity of a developing flood, along with additional time to undertake damage reducing measures could be achieved if there was investment in additional and more sophisticated instrumentation to monitor water levels and the associated systems to alert emergency services and individuals to the exceedance of trigger values (i.e. improved monitoring and messaging system with automated elements). It is estimated that together these measures would achieve a further increase in effective flood warning time. This has been identified as the fully developed option for communities in the Upper Avoca River and assessed as being achievable in the longer term. Implementation would require significant investment.

The above three paragraphs are presented in Table 6.1 in summary form against the TFWS building blocks as suggested actions aimed at securing a flood warning system for the Upper Avoca River. A reworked version of this table presented in terms of what is achievable now, with a greater level of investment and longer term is provided as Table 6.2. The information in the tables is identical.

Discussions during the community engagement stages of this Investigation did contemplate the possibility of a flood warning system for Natte Yallock that was (almost) totally independent of existing gauge infrastructure and systems and very heavily locally driven and managed. The Landcare Group were seen as a key part of such a system. The Group remains a key part of the approach proposed herein. However, the inability to discriminate between small and big floods based on water levels at the Maryborough – St Arnaud Road Bridge demonstrates that a local river gauges have limited benefits. Similarly, the number and distribution of telemetered rain gauges upstream of Natte Yallock that are managed through the Water Partnership suggests that adding more rain gauges (either manual or automated) is not a robust solution. The key is seeking for BoM to make data from those existing rain gauges available through the BoM website at frequent intervals. The rainfall and upstream

water level based indicative flood tools can then be used locally leading to increased flood warning lead time and community resilience, and a reduction in avoidable flood damages. While it is not quite that simple (as outlined in the paragraphs above), the basis already exists for a robust locally driven flood warning system for communities in the Upper Avoca River.

Table 6.1: TFWS Building Blocks and Suggested Actions for the Upper Avoca River with due regard for the EMV, Commonwealth-State arrangements for flood warning service provision VFWCC (2001), AIDR (2009) and DELWP (2016)

TFWS Building Blocks	Potential Improvement actions for the Upper Avoca River
DATA COLLECTION & COLLATION	Pyrenees Shire Council to approach BoM (with support from VICSES, NCCMA, DELWP and Central Goldfields Shire Council) to request necessary changes to enable near real-time (e.g. with 15 minute updates) public access via the BoM website to: ▪ Rain data from the eight rain gauges located in or in close proximity to the Upper Avoca River and listed in Section 5.1 ▪ River level data from the four stream gauges within the Upper Avoca River as listed in Section 5.1 Pyrenees Shire Council to arrange for the installation of a set of staff gauges on the upstream side of the Pyrenees Highway Bridge in Avoca and on the upstream side of the Sunraysia Highway Bridge downstream from Avoca. The staff gauges should be installed such that the gauge boards can be read from the road for small and larger (i.e. 1% AEP) floods. If a greater degree of confidence in the likelihood of flooding is required, it is suggested that Pyrenees Shire Council: ▪ As a first step, arrange purchase and installation of an ERTS river (or rain-river) gauge the upstream side of the Pyrenees Highway Bridge in Avoca. At the same time, Pyrenees Shire Council with support from VICSES, NCCMA, DELWP and Central Goldfields Shire Council to approach BoM to provide near real-time public access to data from that gauge via its website ▪ As a second step, arrange installation of an additional ERTS rain (or rain-river) gauge on the upstream side of the Sunraysia Highway Bridge downstream from Avoca. As above, Pyrenees Shire Council with support from VICSES, NCCMA, DELWP and Central Goldfields Shire Council to approach BoM to provide near real-time public access to data from those gauges via its website ▪ Alternatively, and instead of ERTS equipment, arrange installation of different commercially available equipment (e.g. DipStik) to monitor (and alert on) rainfall and / or water level in the river at the locations described in the above two bullets ▪ As appropriate and depending on the monitoring and alerting equipment installed, invite Upper Avoca River residents, along with VICSES, local CFA and Police, to opt-in to receive SMS alert messages direct from installed equipment ▪ Consider the addition of “sirens and/or flashing lights” options (triggered by exceedance of pre-set rainfall rates and depths, and river levels and rates of rise) for the automated gauge installed at the bridges as an alternative or additional means of alerting the community to imminent flooding As part of all of the above: ▪ Provide guidance to the local community (through a locally focussed flood awareness brochure and website) on how to interpret and use available rain and river level data and the indicative flood guidance tools, along with information about the flood warning system and how it will assist in reducing risk

TFWS Building Blocks	Potential Improvement actions for the Upper Avoca River
	▪ Develop and maintain a website (and social media) presence for the FWS that includes the above guidance along with (a link to) flood mapping and intelligence outputs from the Upper Avoca River Flood Investigation Pyrenees Shire Council in consultation with NCCMA to decide on the datum to be used for any new river level gauges: AHD or local.
DETECTION & PREDICTION (i.e. Forecasting)	Pyrenees Shire Council to provide the indicative flood guidance tools and instructions for their use to Council staff, VICSES and local CFA for routine use. Provide training in use as appropriate. Pyrenees Shire Council and VICSES to agree who will maintain the tools and how. Pyrenees Shire Council to lead the determination of flood class levels for Amphitheatre and at the Pyrenees Highway Bridge at Avoca and the Sunraysia Highway Bridge downstream from Avoca. Will involve coordination between Council, VICSES, NCCMA and BoM and is a relatively straight-forward process. Pyrenees Shire Council to maintain contact with VICSES on progress with the Automated Alerting Project with a view to implementation for Upper Avoca River communities.
INTERPRETATION (i.e. an ability to answer the question "what does this mean for me - will I be flooded and to what depth".	Mapping and intelligence from the Upper Avoca River Flood Investigation has been captured to the MFEPs. The indicative flood guidance tools together with the MFEPs enable those at risk to determine the likely effects of a potential flood with some lead time. Pyrenees Shire Council to ensure flood inundation maps and relevant MFEP Appendices along with the flood information cards for the Upper Avoca River are readily available to the at-risk communities. If local datum has been chosen for water level gauges, Pyrenees Shire Council to lead update of the MFEP and indicative flood guidance tools. This will assist local interpretation and the determination of likely flood impacts during future events.
MESSAGE CONSTRUCTION	The initial alert within the at-risk communities of potential flooding is likely to come from a combination of environmental indicators (e.g. observance of heavy rain) and from consideration of rain data, the flood inundation maps, the indicative flood guidance tools and the flood intelligence in the MFEP and / or from observing a water level rise in local streams. If monitoring equipment with SMS capability is installed, the initial (or confirming) alert may come from the unit's SMS'ed message as rain and/or river levels exceed triggers with the above acting to reinforce and add value to resident's assessments and decision processes. Alternatively, and subject to resolution of VICSES and EMV roles in the initiation and dissemination of (flash) flood warnings, the initial alert may come via electronic and social media. If a marginally more formal alerting system is deemed appropriate for the upper Avoca communities, Pyrenees Shire Council in conjunction with VICSES to: ▪ Champion formation of an Upper Avoca River flood action group (or similar) ▪ Lead establishment of a Twitter and / or Facebook account for the Upper Avoca River TFWS so that information can be shared within the community and by VICSES (say, following use of the indicative flood guidance tools) on likely flood severity, impacts and appropriate actions

TFWS Building Blocks	Potential Improvement actions for the Upper Avoca River
MESSAGE DISSEMINATION (i.e. Communication and Alerting)	Establish a Pyrenees Shire Council championed community flood action group. The Landcare Group at Natte Yallock may be in a position to take on this role. Use social media. A role remains for the Emergency Alert (EA) during a severe flood event. If an SMS enabled gauge is active, Pyrenees Shire Council to identify/nominate key community members (in addition to VICSES and perhaps CFA) to receive SMS or email alerts on exceedance of alarm trigger values. If alternate commercially available water level (and rain) monitoring equipment is installed, Pyrenees Shire Council to establish and maintain an opt-in system that must be heavily community driven.
RESPONSE	Initiate a community engagement program to communicate how the FWS will work. Following (or perhaps in concert with) acceptance of the MFEP by Pyrenees Shire Council and VICSES, encourage and assist residents to develop individual flood response plans. A package that assists businesses and individuals is available from VICSES and provides an excellent model for community use.
REVIEW	Review and update of local flood intelligence (i.e. flood characteristics, impacts, etc), local alerting arrangements, response plans, local flood awareness material, etc (initially) after every flood that triggers a response. Best driven by Pyrenees Shire Council with input from VICSES, NCCMA, CFA and the Council championed community flood action group. Pyrenees Shire Council to develop review and update protocols; who does what when and process to be followed to update material consistently across all parts of the flood warning and response system, including the MFEP.
AWARENESS	VICSES to prepare and print LFGs for the Amphitheatre, Avoca and Natte Yallock communities. Make relevant parts of the MFEP publicly available (e.g. Council offices, library, website). Develop, maintain and renew flood awareness through activities and materials that emphasise personal safety, where rain, river and rain radar data is available, how to interpret and use that data, what any warnings / alerts mean and what individuals should do to stay safe and protect their property including how to fill and lay sandbags. Pyrenees Shire Council and VICSES to: ▪ Load and maintain material including the MFEP to the Pyrenees Shire Council and VICSES websites with appropriate links to relevant useful sites; ▪ Routinely revisit and update awareness material to accommodate lessons learnt, additional or improved material and to reflect advances in good practice; and ▪ Routinely repeat distribution of awareness material and consider other measures.

Table 6.2: TFWS Building Blocks and Staged Suggested Actions for the Upper Avoca River with due regard for Table 6.1

TFWS Building Blocks	Potential Improvement actions for the Upper Avoca River
Achievable in the NEAR term with minimum investment	
DATA COLLECTION & COLLATION	Pyrenees Shire Council to approach BoM (with support from VICSES, NCCMA, DELWP and Central Goldfields Shire Council) to request necessary changes to enable near real-time (e.g. with 15 minute updates) public access via the BoM website to: ▪ Rain data from the eight rain gauges located in or in close proximity to the Upper Avoca River and listed in Section 5.1 ▪ River level data from the four stream gauges within the Upper Avoca River as listed in Section 5.1 Provide guidance to the local community (through a locally focussed flood awareness brochure and website) on how to interpret and use available rain and river level data and the indicative flood guidance tools, along with information about the flood warning system and how it will assist in reducing risk.
DETECTION & PREDICTION (i.e. Forecasting)	Pyrenees Shire Council to provide the indicative flood guidance tools and instructions for their use to Council staff, VICSES and local CFA for routine use. Provide training in use as appropriate. Pyrenees Shire Council and VICSES to agree who will maintain the tools and how.
INTERPRETATION (i.e. an ability to answer the question "what does this mean for me - will I be flooded and to what depth".	Mapping and intelligence from the Upper Avoca River Flood Investigation has been captured to the MFEPs. The indicative flood guidance tools together with the MFEPs enable those at risk to determine the likely effects of a potential flood with some lead time. Pyrenees Shire Council to ensure flood inundation maps and relevant MFEP Appendices along with the flood information cards for the Upper Avoca River are readily available to the at-risk communities.
MESSAGE CONSTRUCTION	The initial alert within the at-risk communities of potential flooding is likely to come from a combination of environmental indicators (e.g. observance of heavy rain) and from consideration of rain data, the flood inundation maps, the indicative flood guidance tools and the flood intelligence in the MFEP and/or from observing a water level rise in local streams.
MESSAGE DISSEMINATION (i.e. Communication and Alerting)	Establish a Pyrenees Shire Council championed community flood action group. The Landcare Group at Natte Yallock may be in a position to take on this role. Use social media. A role remains for the Emergency Alert (EA) during a severe flood event.
RESPONSE	Following (or perhaps in concert with) acceptance of the MFEP by Pyrenees Shire Council and VICSES, encourage and assist residents to develop individual flood response plans. A package that assists businesses and individuals is available from VICSES and provides an excellent model for community use.

TFWS Building Blocks	Potential Improvement actions for the Upper Avoca River
REVIEW	Review and update of local flood intelligence (i.e. flood characteristics, impacts, etc), local alerting arrangements, response plans, local flood awareness material, etc (initially) after every flood that triggers a response. Best driven by Pyrenees Shire Council with input from VICSES, NCCMA, CFA and the Council championed community flood action group. Pyrenees Shire Council to develop review and update protocols => who does what when and process to be followed to update material consistently across all parts of the flash flood warning and response system, including the MFEP.
AWARENESS	VICSES to prepare and print LFGs for the Amphitheatre, Avoca and Natte Yallock communities. Make relevant parts of the MFEP publicly available (e.g. Council offices, library, website). Pyrenees Shire Council and VICSES to: ▪ Load and maintain material including the MFEP to the Pyrenees Shire Council and VICSES websites with appropriate links to relevant useful sites ▪ Routinely revisit and update awareness material to accommodate lessons learnt, additional or improved material and to reflect advances in good practice ▪ Routinely repeat distribution of awareness material and consider other measures
Achievable in the MID term with a greater level of investment	
DATA COLLECTION & COLLATION	In addition to the above: ▪ Pyrenees Shire Council to arrange for the installation of a set of staff gauges on the upstream side of the Pyrenees Highway Bridge in Avoca and on the upstream side of the Sunraysia Highway Bridge downstream from Avoca. The staff gauges should be installed such that the gauge boards can be read from the road for small and larger (i.e. 1% AEP) floods ▪ Develop and maintain a website (and social media?) presence for the FWS that includes guidance from the previously prepared locally focussed flood awareness brochure (see above) along with (a link to) flood mapping and intelligence outputs from the Upper Avoca River Flood Investigation ▪ Pyrenees Shire Council in consultation with NCCMA to decide on the datum to be used for any new river level gauges: AHD or local
DETECTION & PREDICTION (i.e. Forecasting)	In addition to the above: ▪ Pyrenees Shire Council to lead the determination of flood class levels for Amphitheatre and at the Pyrenees Highway Bridge at Avoca and the Sunraysia Highway Bridge downstream from Avoca. Will involve coordination between Council, VICSES, NCCMA and BoM and is a relatively straight-forward process ▪ Pyrenees Shire Council to maintain contact with VICSES on progress with the Automated Alerting Project with a view to implementation for Upper Avoca River communities

TFWS Building Blocks	Potential Improvement actions for the Upper Avoca River
INTERPRETATION (i.e. an ability to answer the question "what does this mean for me - will I be flooded and to what depth".	In addition to the above: ▪ If local datum has been chosen for river level gauges, Pyrenees Shire Council to lead update of the MFEP and indicative flood guidance tools. This will assist local interpretation and the determination of likely flood impacts during future events
MESSAGE CONSTRUCTION	In addition to the above: ▪ If monitoring equipment with SMS capability is installed, the initial (or confirming) alert may come from the unit's SMS'ed message as rain and / or river levels exceed triggers with the above acting to reinforce and add value to resident's assessments and decision processes. Alternatively, and subject to resolution of VICSES and EMV roles in the initiation and dissemination of (flash) flood warnings, the initial alert may come via electronic and social media ▪ If a marginally more formal alerting system is deemed appropriate for the upper Avoca communities, Pyrenees Shire Council in conjunction with VICSES to: Champion formation of an Upper Avoca River flood action group (or similar) Lead establishment of a Twitter and/or Facebook account for the Upper Avoca River TFWS so that information can be shared within the community and by VICSES (say, following use of the indicative flood guidance tools) on likely flood severity, impacts and appropriate actions
MESSAGE DISSEMINATION (i.e. Communication and Alerting)	In addition to the above: ▪ If an SMS enabled gauge is active, Pyrenees Shire Council to identify / nominate key community members (in addition to VICSES and perhaps CFA) to receive SMS or email alerts on exceedance of alarm trigger values
RESPONSE	In addition to the above: ▪ Initiate a community engagement program to communicate how the FWS will work
REVIEW	As above.
AWARENESS	In addition to the above: ▪ Develop, maintain and renew flood awareness through activities and materials that emphasise personal safety, where rain, river and rain radar data is available, how that interpret and use that data, what any warnings/alerts mean and what individuals should do to stay safe and protect their property including how to fill and lay sandbags
Achievable LONGER term – fully developed option requiring significant investment	

TFWS Building Blocks	Potential Improvement actions for the Upper Avoca River
DATA COLLECTION & COLLATION	In addition to the above: ▪ Pyrenees Shire Council to arrange purchase and installation of an ERTS river (or rain-river) gauge on the upstream side of the Pyrenees Highway Bridge in Avoca. At the same time, Pyrenees Shire Council with support from VICSES, NCCMA, DELWP and Central Goldfields Shire Council to approach BoM to provide near real-time public access to data from that gauge via its website ▪ Pyrenees Shire Council to arrange purchase and installation of an ERTS river (or rain-river) gauges on the upstream side of the Sunraysia Highway Bridge downstream from Avoca. As above, Pyrenees Shire Council with support from VICSES, NCCMA, DELWP and Central Goldfields Shire Council to approach BoM to provide near real-time public access to data from those gauges via its website ▪ Alternatively and instead of the ERTS equipment, Pyrenees Shire Council to arrange installation of different commercially available equipment (e.g. DipStik) to monitor (and alert on) rainfall and/or water level in the river at the locations described in the above two bullets ▪ As appropriate and depending on the monitoring and alerting equipment installed, Pyrenees Shire Council to invite Upper Avoca River residents, along with VICSES, local CFA and Police, to opt-in to receive SMS or other alert messages direct from the installed equipment ▪ Pyrenees Shire Council to consider the addition of "sirens and/or flashing lights" options (triggered by exceedance of pre-set rainfall rates and depths, and river levels and rates of rise) for the automated gauge installed at the bridges as an alternative or additional means of alerting the community to imminent flooding
DETECTION & PREDICTION (i.e. Forecasting)	As above.
INTERPRETATION (i.e. an ability to answer the question "what does this mean for me - will I be flooded and to what depth".	As above.
MESSAGE CONSTRUCTION	As above.
MESSAGE DISSEMINATION (i.e. Communication and Alerting)	In addition to the above: ▪ If alternate commercially available water level (and rain) monitoring equipment is installed, Pyrenees Shire Council to establish and maintain an opt-in system that must be heavily community driven

TFWS Building Blocks	Potential Improvement actions for the Upper Avoca River
RESPONSE	As above.
REVIEW	As above.
AWARENESS	As above.

7. References

(AEMI) Australian Emergency Management Institute (1995), *Flood Warning: An Australian Guide*, Commonwealth of Australia.

(AIDR) Australian Institute for Disaster Resilience (2009), *Manual 21: Flood Warning*, Commonwealth of Australia.

(BoM) Bureau of Meteorology (1996), *Bureau of Meteorology Policy on the Provision of the Flash Flood Warning Service*, Bureau of Meteorology.

(BoM) Bureau of Meteorology (2020), *Service Level Specification for Flood Forecasting and Warning Services for Victoria – Version 3.2*, Bureau of Meteorology.

(DELWP) Department of Environment, Land, Water and Planning (2016), *Victorian Floodplain Management Strategy*, Department of Environment, Land, Water and Planning.

Jacobs (2020a), *Upper Avoca River Flood Investigation Data Review Report*, Doc. Ref: IS297900-RPT-001-DataReview-RevB.docx, Jacobs.

Jacobs (2020b), *Upper Avoca River Flood Investigation Flood Modelling Report*, Doc. Ref: IS297900-RPT-003-Modelling-RevC.docx, Jacobs.

Jacobs (2020c), *Upper Avoca River Flood Investigation Flood Mapping Report*, Doc. Ref: IS297900-RPT-004-Mapping-RevA.docx, Jacobs.

(VFWCC) Victorian Flood Warning Consultative Committee (2001), *Arrangements for Flood Warning Services in Victoria*, Bureau of Meteorology.

Contact Us:

Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
Floor 11, 452 Flinders Street
Melbourne VIC 3000
PO Box 312, Flinders Lane
Melbourne VIC 8009 Australia
T +61 3 8668 3000
F +61 3 8668 3001
www.jacobs.com