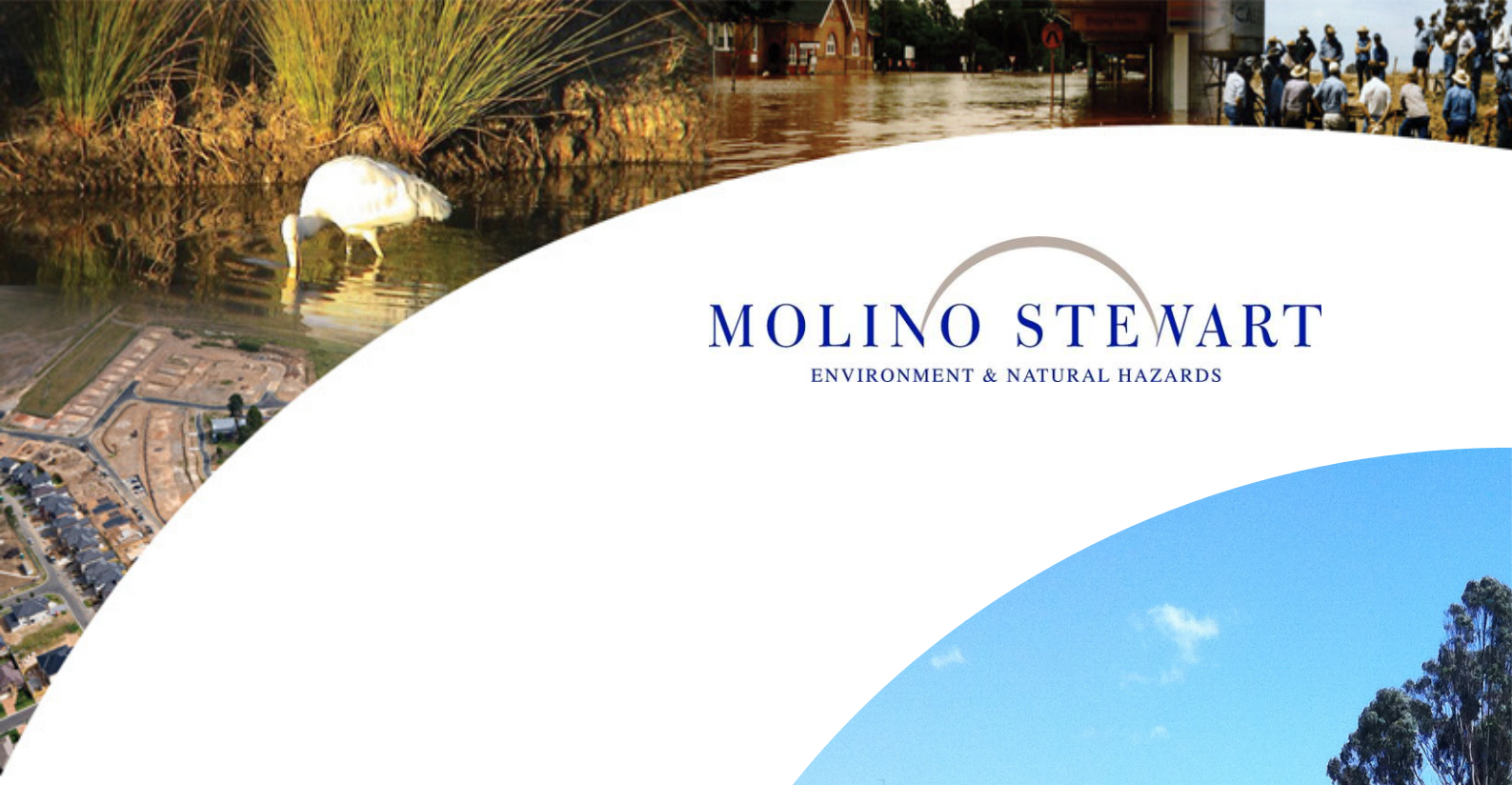

MOLINO STEWART

ENVIRONMENT & NATURAL HAZARDS

Glenelg Hopkins CMA

Glenelg Hopkins Catchment Management Authority

Russells Creek Total Flood Warning Scoping Study Project

Report

MOLINO STEWART
ENVIRONMENT & NATURAL HAZARDS

Russells Creek Total Flood Warning Scoping Study Project

REPORT

for

Glenelg Hopkins Catchment Management Authority

by

Molino Stewart Pty Ltd
ACN 067 774 332

JULY 2013

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DOCUMENT CONTROL

Document Reference	0553 final Russells Creek Report
Project	Russells Creek Total Flood Warning Scoping Study Project
Document Type	Report
Author	Neil Dufty

REVISION HISTORY

Date	**Version**	**Name**	**Comments**
09/05/2013	Ver 1	Neil Dufty	First draft of project report
10/05/2013	Ver 1	Steven Molino	Review of first draft project report
27/06/2013	Ver 2	Neil Dufty	Final draft

DOCUMENT APPROVAL

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EXECUTIVE SUMMARY

Russells Creek is a relatively small tributary of the Merri River that passes through the north Warrnambool urban area (south-west Victoria).

The number of flood prone properties (even after planned mitigation works are completed) within the 100 year ARI flood extent of the Russells Creek catchment, coupled with the potential damages that could be experienced by the community, necessitates the investigation of a Total Flood Warning System (TFWS) for this location.

The Glenelg Hopkins CMA, in partnership with the Warrnambool City Council, received Victorian and Australian Government funding to undertake the Russells Creek Total Flood Warning System Scoping Study. Funding for the investigation was made available through the Victorian Coalition Government's Flood Warning Network – Repair and Improvement Initiative (delivered through Flood Zoom) and the Australian Government's Natural Disaster Resilience Grants Scheme.

The flood warning service needs assessment for Russells Creek was conducted by Molino Stewart Pty Ltd in liaison with a Technical Steering Committee consisting of:

- Glenelg Hopkins CMA
- Warrnambool City Council
- DEPI Floodplain Management Unit
- VICSES
- BoM
- Local community stakeholders.

The assessment examined the components of the Total Flood Warning System (TFWS) based on the Australian Government's Manual 21 – Flood Warning. The TFWS components examined were:

1. Understanding of flood risks and hazards
2. Emergency management planning
3. Community flood education
4. Data collection
5. Flood prediction and interpretation
6. Message construction
7. Message communication
8. Response
9. Review of the TFWS
10. Community and stakeholder consultation

The assessment found that due to a very short warning time of up to one hour it is not possible to build a TFWS across all of the above components. The best that can be achieved is to build a system to alert residents of possible danger that triggers their pre-learned actions for safety and, if possible, to reduce damages.

The assessment considered several alert mechanism options. However, it found these are limited due to the very short warning time.

As a result of the assessment, the following integrated package of options is recommended for a Russells Creek flood warning system:

- Use of the existing BoM warning services and products including severe weather warnings, severe thunderstorm warnings and radar information and maps.
- Data collection provided by the installation of two rain gauges and telemetry in the Russells Creek catchment.
- An opt-in alert system linked to the rain gauges providing SMS messages to the mobile phones of flood-affected residents.
- Tailored community flood education that provides pre-learning for the impacted residents including appropriate responses in relation to cues such as the BOM warning services and SMS alerts triggered from rain gauges.
- A completed Warrnambool Municipal Flood Emergency Plan that addresses the proposed Russells Creek flood warning system.
- Emergency management plans (including flood response appropriate actions) for the Goodstart Early Learning Childcare and the St Joseph's Primary School.
- Ongoing community consultation through a Russells Creek Flood Warning Committee to establish, test, implement and evaluate the flood warning system.

Five suggestions for improving the Russells Creek flood warning service were also identified as a result of the assessment.

1. Additional river level gauge component to enable review of the hydrological and hydraulic data related to a flood event.
2. Use of a local social media site (e.g. Facebook) that provides warning information and allows people to warn others and emergency agencies.
3. A social research study to examine aspects of the potential response of residents with possible resultant actions for emergency planning, community flood education and community development.
4. A vulnerable persons register be developed for those at-risk properties in the Russells Creek catchment.
5. Use of a flood warden or similar program to encourage community leadership to help others in the catchment.

A plan was prepared to implement actions leading to the development of the recommended flood warning system options. The recommended actions in the plan are:

1. Commence a Russells Creek Flood Warning Committee for the governance of the following actions.
2. Consult with the Russells Creek flood-affected community regarding its interest in opting in to the SMS alert service.
3. Seek financial support for the SMS alert system if there is community support.
4. Develop, test and implement the SMS alert system.
5. Develop, test and implement the community education program in relation to the BoM's warning services and the alert system.
6. If there is no or little support for the SMS alert system, use the remaining options to build a system based on situational awareness using existing services.
7. Consider the other suggestions to improve the flood warning service for Russells Creek that are listed in the Molino Stewart report.
8. Develop and implement a flood warning system monitoring and evaluation plan to review and improve the flood warning system as required.

1 INTRODUCTION

1.1 THE TOTAL FLOOD WARNING SYSTEM (TFWS)

1.1.1 Flood warning systems

"Flood warning systems are developed with the fundamental aim of increasing safety and reducing the harmful effects of floods (referred to as 'damages' or 'losses'). The extent of losses avoided as a result of a warning is therefore the key measure of warning system effectiveness." (Molinari and Handmer, 2011, p. 23)

Mileti and Sorenson (1990, p.1) identify warning systems within the tools used to minimise the risks and effects of hazards and disasters. They note that "warning systems bear an interesting relationship to other hazard management tools. They are the last lines of defence after, for example, engineered solutions are applied to reduce the probability of an event below an acceptable level."

This value of warning systems 'as a last line of defence' can be visualised as in Figure 1. Related to floods, warning systems are a critical conduit between emergency management (and its emergency service providers) and affected communities immediately prior to and during a flood event. This relationship operates within the 'residual risk' afforded by structural and non-structural floodplain risk management options.

Mileti and Sorenson add that "warning systems for low-probability events often do not make cost-benefit sense. Warning systems are economically rational only when a risk becomes an actual event and when having inadequate or no warning systems is politically and socially unacceptable."

In practice, flood warning systems provide individuals and communities with time to carry out actions to protect themselves, and if possible, their properties.

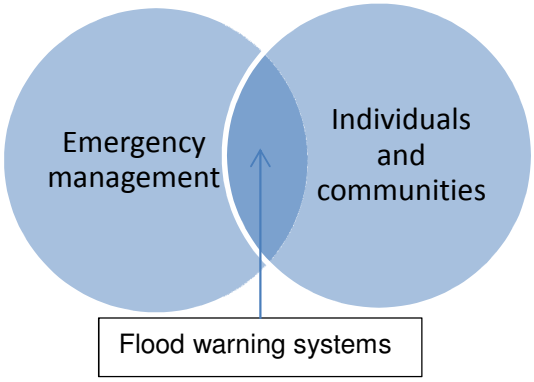

Figure 1: Flood warning systems are a critical link between emergency service providers and communities

According to Carsell, Pingel and Ford (2004, p. 132), a flood warning system "gives property owners and floodplain occupants and those responsible for their safety more time to respond to a flood threat before the threshold is exceeded. With this increased time, lives and property are protected." Not only is time of the essence, but also good warning advice to those impacted. Even if warnings are timely and accurate, individuals and communities also need to be responsive to the warnings.

1.1.2 Manual 21 Flood Warning

In Australia, the concept of the 'total flood warning system' (TFWS) has been developed to describe the full range of elements that must be developed if flood warning services are to be provided effectively.

The lead guiding document for the development of the TFWS in Australia is Manual 21 – Flood Warning (Attorney-General's Department, 2009).

According to Manual 21 (page 6), at its simplest, the TFWS consists of six components:

1. Prediction - Detecting changes in the environment that lead to flooding, and predicting river levels during the flood.
2. Interpretation - Identifying in advance the impacts of the predicted flood levels on communities at risk.

3. Message Construction - Devising the content of the message which will warn people of impending flooding.
4. Communication - Disseminating warning information in a timely fashion to people and organisations likely to be affected by the flood.
5. Response - Generating appropriate and timely actions from the threatened community and from the agencies involved.
6. Review - Examining the various aspects of the system with a view to improving its performance.

Manual 21 (page 7) stresses that for the TFWS to "work effectively, these components must all be present and they must be integrated rather than operating in isolation from each other."

When designing a TFWS, Manual 21 (pages 7-8) advises that the following points need to be addressed:

- The system must meet the needs of its clients including identifying:

  - levels of flooding at which warnings are required

  - the impacts at the different levels of flooding

  - warning time community requires and what can be provided

  - appropriate subject matter content for warning messages

  - the ways in which warning messages are to be disseminated

  - the frequency of warning updates
- The system must be part of the emergency management arrangements established by the relevant State or Territory as defined in disaster or emergency management plans.
- The review of the system must be carried out by all emergency agencies and by the community itself.
- The roles of the emergency agencies must be clearly defined for each component of the system.
- The system must be incorporated into the wider floodplain management.
- The system should be regularly tested and maintained.

1.1.3 A TFWS framework for this project

As noted in Section 1.1.2, Manual 21 advocates six basic components of a TFWS. However, others such as Molino et al (2011) believe that there are more preliminary components required for an effective TFWS, including understanding the residual risk that the TFWS operates under, the impact of prior community flood education and the guidance provided by action plans (e.g. emergency plans for emergency service providers, local government, business, residents). This relationship is shown in Figure 2 and is adopted for the TFWS analysis as required for this project.

In relation to Figure 2, Molino et al (2011) note that "it is important to realise that the diagram is imperfect and does not reflect the significant amount of iteration which is required for each of the components to be done well and properly aligned with the others". They add that "each of these warning system parts can work well or can work poorly or at worst, not work at all. The overall effectiveness of the warning can only be as strong as the weakest link in the chain and, unlike a real chain, errors or weaknesses can accumulate as they are passed along the chain e.g. poor data plus poor interpretation can be worse than either poor data or poor interpretation."

1.1.4 Flash flooding

The study area for this project is a catchment prone to flash flooding (see Section 1.3.3). Flash flooding refers to heavy and often localised rainfall, resulting in both artificial and natural drainage systems exceeding capacity, resulting in water flowing along roads and/or land occupied by houses and other buildings.

Flash flooding can provide only a small amount of 'warning lead time' which according to Manual 21 (page 18), is the "time between issuing a message containing a prediction and the time when the predicted height is reached".

Flash flooding in Australia is defined as flooding that occurs within six hours of the start of rain that causes it (Bureau of Meteorology, 1996).

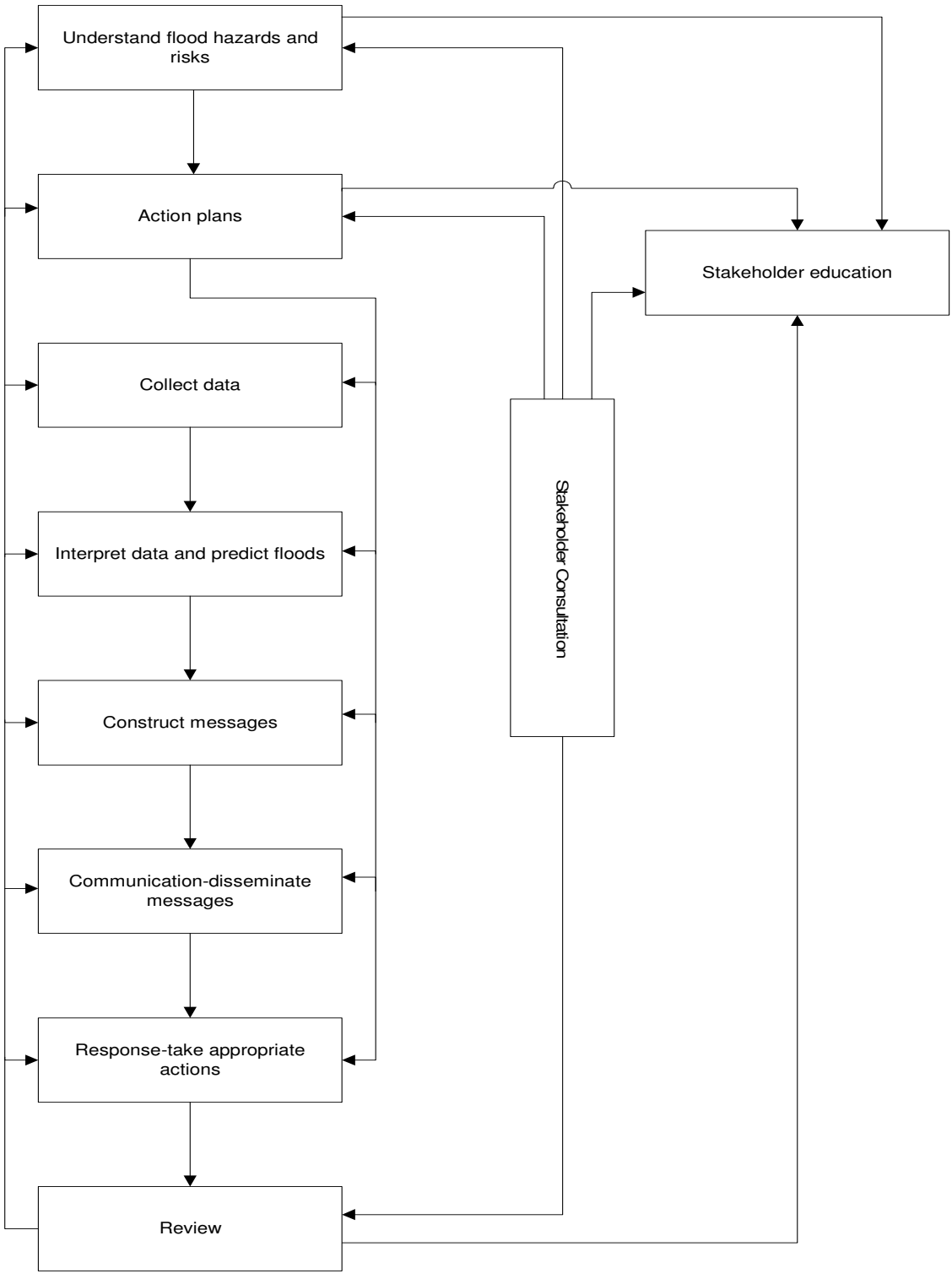

Figure 2: The Total Flood Warning System (source: Molino et al, 2011)

1.2 FLOOD WARNING IN VICTORIA

1.2.1 Legislation, plans and policies

The 1998 Victorian Flood Management Strategy (VFMS) provides the strategic policy framework for flood management in Victoria. The strategy also contains a program of actions to collate the available data on floodplains and implement measures to reduce the flood risk to communities. It also importantly outlines the roles and responsibilities for governments, organisations and communities involved in flood management, including flood studies, mapping, mitigation works and flood warning.

The emergency arrangements in Victoria are regulated through the *Emergency Management Act 1986* (the EM Act), which is intended to ensure an organised structure exists to facilitate planning, preparedness, operational control and coordination as well as community participation in the prevention, response and recovery from an emergency incident.

Specific control and coordination arrangements during an emergency, including flood, are outlined in the Emergency Management Manual Victoria (EMMV). This manual contains procedures for dealing with emergencies of all sizes and includes arrangements that cater for those events requiring multi-agency action, including those requiring participation from both state and commonwealth agencies.

The EMMV identifies the Victoria State Emergency Service (VICSES) as the agency nominated to control response activities to a flood in Victoria. In 2007, the VICSES published the State Flood Response Plan (SFRP) that provides strategic guidance for effective emergency response to flood events in Victoria. The plan also describes the roles and responsibilities of agencies and organisations in flood management and key activities in responding to flood including minimising the threat and impact to people, property and the environment.

The Victorian State Flood Emergency Plan (2012) provides details for emergency agencies relating to flash flood response.

Consistent with any emergency event in the state, Victoria Police (VicPol) retains the responsibility for emergency services coordination during a flood, which includes ensuring that effective control has been established by the control agency and the effective coordination of resources and services. The EMMV also details the responsibilities of several other agencies involved in flood management such as the Bureau of Meteorology (BoM), municipalities, catchment management authorities (CMAs), the Country Fire Authority (CFA), Department of Health (DH), Department of Human Services (DHS) and Department of Environment and Primary Industries (DEPI).

The Victorian Warning Protocol was established in 2009 to provide emergency response agencies with coordinated and consistent direction on advice and/or warnings to inform the Victorian community of a potential or actual emergency event.

“The Protocol is based on the all-hazards approach. Taking such an approach will reassure the community that regardless of the emergency type, any alerts or warnings disseminated will be authoritative, consistently constructed, timely and appropriate.” (Victorian Warning Protocol, page 7)

The Protocol is in line with national warning guidelines and consists of seven elements which are similar to those in Manual 21 (Section 1.1.2) and the extended TFWS framework (Section 1.1.3) used in this report. The seven elements are:

1. Community preparedness
2. Situational awareness and analysis
3. Decision-making and authorisation
4. Message construction and dissemination
5. Management of warning consequences
6. Real-time monitoring
7. Real-time closure.

There are several Standard Operating Procedures (SOPs) derived from the Protocol which guide warning activities particularly in the state, regional and local Incident Control Centres (ICCs).

1.2.2 Flood warning arrangements

The arrangements for flood warning networks are outlined in the VFMS and Arrangements for Flood Warning Services in Victoria 2001.

The responsibility for issuing flood related warnings clearly remains with the BoM and VICSES. Under the current institutional arrangements, the BoM is the organisation charged with the primary responsibility for weather forecasting and flood prediction except within the Port Phillip and Westernport area where the responsibility for flood prediction rests with Melbourne Water. The BoM constructs flood warning messages for selected streams throughout Victoria with the exception of those streams within the area delegated to Melbourne Water. The nature of these predictions or warnings depends on the quality of the information available to the BoM or Melbourne Water, including data from rainfall and stream gauges owned by others (water corporations, local government, DEPI) throughout Victoria. VICSES issues subsequent information as Flood Bulletins which relate flood predictions to possible impacts on communities.

In Victoria, two state-wide flood committees operate to ensure integration of all levels of government to deliver on flood management objectives, including establishment, evaluation, and maintenance of flood warning systems.

1. The State Flood Policy Committee (SFPC) which provides advice on flood policy to government
2. The Victorian Flood Warning Consultative Committee (VFWCC) which identifies requirements and coordinates the development and operation of flood warning services in Victoria.

1.2.3 The Victorian Floods Review

Although there had been planned improvements to the TFWS in Victoria over at least the past decade, the widespread and devastating floods between September 2010 and February 2011 highlighted some major deficiencies.

The Review of the 2010-11 Flood Warnings and Response led by Neil Comrie AO made 93 recommendations to improve flood warning systems throughout the state. Recommendations were made under the following aspects of the TFWS:

- The adequacy of flood predictions and modelling
- The timeliness and effectiveness of warnings and public information
- Emergency services command and control arrangements
- The adequacy of evacuations of people most at risk, including those in health and aged care facilities
- The adequacy of clean-up and recovery arrangements
- The adequacy of service delivery by federal, state and local governments
- The adequacy of funding provided by state and federal governments for emergency grants
- Community resilience.

Although the floods of 2010 and 2011 were largely riverine in nature, the Review made extensive comment about flash flood warning services and systems in Victoria. It clarified the role of the BoM in providing flash flooding warning services and the roles of state and local government in the purchase, installation and maintenance of flash flood warning systems.

The Review identified five core issues underpinning flash flood warning systems in Victoria:

1. The lack of definitive state policy and direction on roles and responsibilities – the role of the BoM and of other TFWS stakeholders in the delivery of forecasts and warnings of conditions likely to lead to and of actual flash

flood events is not as clear as it needs to be.

2. Local government's ability, in terms of both financial and technical capacity, to establish, maintain and operate an effective flash flood warning system with regard for both technical and social aspects (all TFWS elements); unless there is active participation from local government, the framework breaks down.
3. A key tool in extending the warning lead time available in flash flood catchments is weather radar and timely local (community and agency) access to (as a minimum) raw information on the likelihood of rainfall likely to lead to flash flooding.
4. Awareness within the at risk community that flash flooding is a credible risk and the circumstances that may give rise to an event.
5. Dissemination of meaningful and timely pre-scripted warning messages (that impart essential information in a way that is understandable and elicits appropriate responses) to those at risk from flash flooding.

1.2.4 Victorian Emergency Management Reform – White Paper

The Victorian Government is undertaking major reform to the State's crisis and emergency management arrangements to create a more disaster resilient and safer Victoria.

The Government's White Paper on Victorian Emergency Management Reform was released in December 2012. It provides a 'road map' for emergency management reform over the next ten years. The proposals in the White Paper are informed by the Final Report of the 2009 Victorian Bushfires Royal Commission, the Final Report of the Review of the 2010-11 Flood Warnings and Response, submissions on the Green Paper 'Towards a More Disaster Resilience and Safer Victoria' and the Fire Services Reform Action Plan.

In the White Paper there are several actions for improving warning systems in Victoria. In relation to making information available during emergencies there are the following actions (page 8 of the White Paper):

- Develop a single emergency management web portal to provide information and advice to help people prepare for, respond to, and recover from emergencies
- Continue to develop the current multi-agency, multi-hazards and multi-channel approach to providing community warnings and information, focusing more on understanding and responding to the various ways communities choose to access information
- Expand the reach of official emergency broadcasts to include more commercial television and culturally and linguistically diverse media in partnership with emergency broadcasters, and in line with the Floods Review recommendations
- Where possible, memoranda of understanding with broadcasters will include provision for broadcast of community meetings and dissemination of warnings across a range of communication channels (such as internet-based media)
- Develop a single all-hazards telephone hotline for the community to access information during emergencies.

In relation to agency collaboration (page 25 of the White Paper), the Emergency Management Commissioner (EMC) will be responsible for ensuring appropriate warnings are issued to the public, and keeping relevant ministers and secretaries informed on the management of the emergency and its consequences.

In relation to capability (page 38 of the White Paper) there is a vision for Victoria's emergency communication systems and information to be characterised by:

- high transmission capability and flexible platforms able to support diverse applications
- control centres with systems needed to collect information from diverse sources, including emergency workers and members of the public. These will also be

capable of processing, analysing and disseminating acquired knowledge

- field workers with access to information and equipment that is simple and intuitive. Equipment will support the transfer of large volumes of data and communicate (by voice or data transfer) directly with field personnel from other agencies
- community members with access to sophisticated, timely and accurate information (via diverse media) before, during and after emergencies.

There is a subsequent action in the White Paper to "continue developing a long term strategic plan for emergency information and communications, including the integration of the Information Interoperability Blueprint to deliver a common operating platform."

1.3 THE RUSSELLS CREEK CATCHMENT

1.3.1 The catchment

Russells Creek is a relatively small tributary of the Merri River, with a total catchment area of 32.7 km². The Creek passes through the north Warrnambool urban area (in south-west Victoria) to its confluence with the Merri River.

The catchment is primarily urbanised with some agricultural land in the upper sections (see Figure 3). The predominant land use in the urban part of the catchment is residential, with a few businesses (e.g. Centro shopping centre, sporting centres). Other significant land uses within the Russells Creek floodplain are:

- St Joseph's Primary School located along Botanic Road
- Goodstart Early Learning Childcare (formerly ABC) located on the corner of Wares Road and Whites Road.

A photograph of part of the Russells Creek channel is provided as Figure 4.

1.3.2 The community

A detailed small area community analysis was conducted of the residential areas along the Russells Creek catchment (note that not all the population is necessarily flood-prone). The analysis was conducted using Warrnambool City Council's Social Atlas based on 2011 Census Data. The Social Analysis is available at http://atlas.id.com.au/warrnambool/.

The analysis found the following demographic characteristics of the Russells Creek catchment that are relevant to this study:

- The average age of people living in the catchment was 37 years (this was identical to the average age of all Victorians). There was a slight tendency for a younger population in the upper parts of the catchment with one area having an average age of 32 years.
- Approximately 14% of the catchment were 65 years or older. The figure fluctuated along Russells Creek with the upper reaches having lower percentages and an area immediately east of Mortlake Road having 24% over 65 years and over.
- The average number of persons per household was 2.5 (compared with the Victorian average of 2.6).
- Approximately three percent of the population speak a language other than English at home.
- Approximately four percent of the catchment population require some form of assistance due to disability. The percentages are higher in the lower part of the catchment and lower in the upper part (possibly reflecting the younger population there).
- The average across the catchment for the SEIFA Index of Relative Socio-economic Disadvantage was 1,010 (about the national average)
- Approximately 82% of all dwellings in the catchment were separate one-story houses (the area immediately west of Mortlake Road has only 59% of dwellings as separate houses with 41% being high density housing in this area).
- Most of the homes were owned/being purchased, with 21% of all dwellings rented.

The above characteristics are discussed in Sections 3.2.3 and 3.2.8.

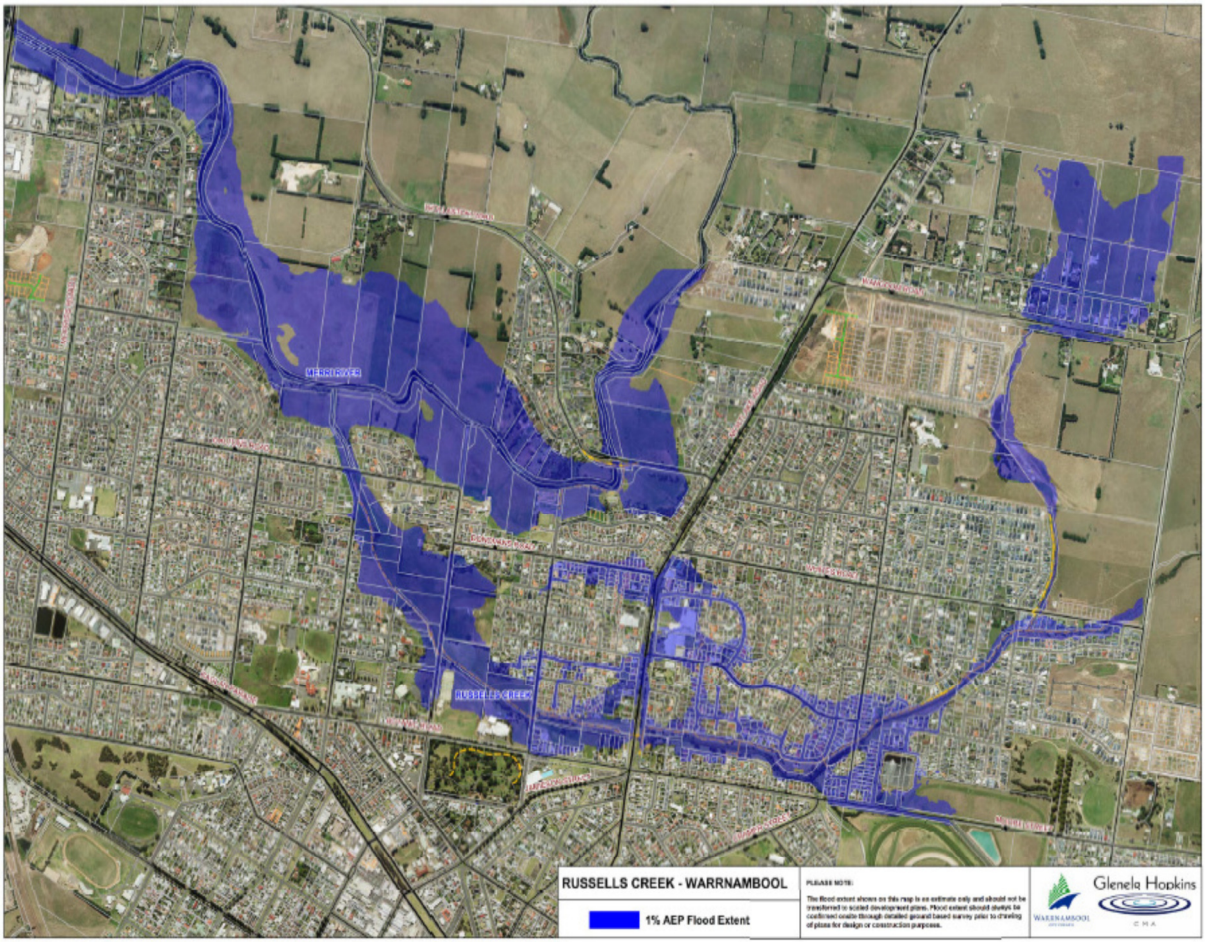

Figure 3: Aerial photograph showing the extent of the 100 year ARI flood along Russells Creek (source: Glenelg Hopkins CMA)

Figure 4: A section of Russells Creek near Mortlake Road (photo: N.Dufty)

1.3.3 Flood risk

The nature of the flooding along Russells Creek is characterised by relatively short term and intense flash flooding, typically following significant storm events.

In some areas along Russells Creek dwellings have been built within five metres of the top of the bank; consequently flash flooding poses a real and significant risk to occupants of these homes.

A North Warrnambool Flood Study was completed in 2003 (GHD, 2003) and revised in 2010 (Cardno, 2010). This study modelled flood level up to and including the 100 year Annual Recurrence Interval (ARI) flood event. A property hazard assessment undertaken at this time indicated that an estimated 146 properties would experience above floor flooding during 100 year ARI events and a further 842 properties are within the 100 year flood extent (Table 1). The annual average damages were estimated to be $491,783. The extent of the 100 year ARI flood event is shown in Figure 3.

Table 1: Properties flooded in the Russells Creek catchment for different events

ARI	Properties Flooded Above Floor	Properties Flooded Below Floor	Total Properties Flooded
5 year	3	292	295
10 year	7	353	360
20 year	16	407	423
50 year	44	551	595
100 year	146	696	842
200 year	236	828	1,064

Source: Cardno (2010)

A subsequent study of mitigation options for the Russells Creek catchment was conducted by Cardno (2012). In February 2013, Warrnambool City Council announced that it would commence mitigation works recommended from this study.

The mitigation works consist of:

- Installation of three additional Mortlake Road culverts
- Levee at La Bella Ct
- Levee bank on the north side of Russells Creek north of Garden Street
- Levee bank on the south side of Russells Creek.

Warrnambool City Council's planned mitigation works will benefit 763 properties including 356 buildings.

The Cardno (2010) study showed that in the 100 year ARI flood, 146 buildings would have water above floor level. Following mitigation works, 99 of these buildings will no longer be at risk of flooding above floor level.

The mitigation works will reduce the annual average damages from $491,783 to $247,773.

According to a Council media release, Council will undertake the improvement works in summer 2013-14, and expects to take about 20 weeks to complete the work.

1.4 THIS PROJECT

1.4.1 Background

Russells Creek is ungauged and does not lend itself to a conventional flood warning system.

Similarly, the catchment is poorly represented with meteorological weather stations and other monitoring data. There is an automated weather station (AWS) at Warrnambool airport.

The number of flood prone properties (even after the mitigation works) within the 100 year ARI flood extent of the Russells Creek catchment, coupled with the potential damages that could be experienced by the community,

necessitates the investigation of a TFWS for this location.

The Glenelg Hopkins CMA, in partnership with the Warrnambool City Council, received Victorian and Australian Government funding to undertake the Russells Creek Total Flood Warning System Scoping Study. Funding for the investigation was made available through the Victorian Coalition Government's Flood Warning Network – Repair and Improvement Initiative (delivered through Flood Zoom) and the Australian Government's Natural Disaster Resilience Grants Scheme.

The CMA engaged the services of Molino Stewart Pty Ltd to assess current and available warning services and guide the development of a TFWS for Russells Creek. This is Molino Stewart's report for the project.

1.4.2 Project objectives

The objectives of the project were to:

1. Investigate and report on the flood warning service need for the study area.
2. Prepare a report that details a development plan for a preferred total flood warning system to meet the determined flood warning need.

To achieve this, the project was divided into three parts:

1. Flood warning service needs assessment
2. TFWS options analysis
3. TFWS Development Plan.

1.4.3 Project scope

a) Part 1 – Flood warning service needs assessment

The consultant in conjunction with the Technical Steering Committee was to assess the flood warning service need for Russells Creek. This assessment will determine the potential benefits of a TFWS to reduce flood impacts.

The methodology for this part of the project is outlined in Section 2.2 and the findings provided in Section 3.

b) Part 2 – TFWS Options Analysis

The consultant was to evaluate the effectiveness of each element of the TFWS to achieve a reduction in flood impacts.

The flood impacts examined should include direct and indirect impacts, and social/intangible aspects. The consultant should assess the range of potential benefits for various TFWS configurations.

The consultant was to consider:

- Data collection: rainfall and river height gauges
- Flood forecasting approaches
- Flood interpretation requirements
- Community education and awareness material
- Flood response

Through discussions with the Technical Steering Committee, the consultant was to propose a preferred TFWS configuration.

The methodology for this part of the project is outlined in Section 2.3 and the findings provided in Section 4.

c) Part 3 – TFWS Development Plan

From the flood warning service needs assessment and TFWS options analysis, the consultant was to prepare a development plan for the preferred total flood warning system configuration. The plan should outline the nature of each element of the TFWS.

The consultant was to prepare a report detailing a development plan for the preferred total flood warning system configuration for consideration by the Technical Steering Committee.

The development plan is provided in Section 5.

2 METHODOLOGY

2.1 STEERING COMMITTEE

As mentioned in Section 1.4, a Technical Steering Committee was established to provide assistance and technical guidance to the consultant throughout the course of the project. The Committee consisted of representatives from:

- Glenelg Hopkins CMA
- Warrnambool City Council
- DEPI Floodplain Management Unit
- VICSES
- BoM
- Local community stakeholders.

2.2 PART 1 – FLOOD WARNING SERVICE NEEDS ASSESSMENT

As noted in Section 1.4.3, Molino Stewart, in consultation with the Technical Steering Committee, was required to assess the flood warning service need for Russells Creek. This assessment will determine the potential benefits of a TFWS to reduce flood impacts.

To assess the flood warning need, it is important to firstly understand the types of benefits that a flood warning system can offer. USACE (1994) identifies four categories of benefits:

1. Direct tangible benefit. Tangible benefits are those to which monetary value can be assigned, and direct benefits are those that accrue to people and property who are 'protected' by the system. Examples of direct tangible benefits include moving belongings, temporarily raising items, temporary flood proofing (e.g. sandbags), traffic control, early notification of emergency services (e.g. establishing evacuation centres)
2. Direct intangible benefit. Intangible benefits are those accrued within the floodplain that cannot be readily expressed in monetary terms. Examples of direct intangible benefits include protection of human health and safety (e.g. timely and orderly evacuation of a floodplain which reduces risks to evacuees), reduced stress, reduction in family disruption.
3. Indirect tangible benefit. These are economic benefits to those who are outside the area protected by the flood warning system. Examples include companies that may have their fate tied to commercial activity within the floodplain, and consumers who shop, recreate in or otherwise use the floodplain benefit from a flood warning system.
4. Indirect intangible benefit. These are non-economic benefits that accrue to those outside the floodplain as a consequence of reduced stress. For example, the effective and widespread communication of warning messages can benefit the mental health of families and friends located outside the floodplain.

2.2.1 Calculating the benefits of a flood warning system for Russells Creek

There have been numerous methods developed that estimate the benefits of a flood warning system and its components.

A key relationship is that of 'warning time' (see Flood Time Line - Figure 5) and the 'damages' incurred from a flood. A rudimentary, yet universally accepted, way of estimating tangible benefits of a flood warning system is the Day curve (Day, 1970). The Day curve (see Figure 6), based on a series of tests in floods, proposes that the tangible benefit of a flood warning system can be estimated as a function of warning time due to the system.

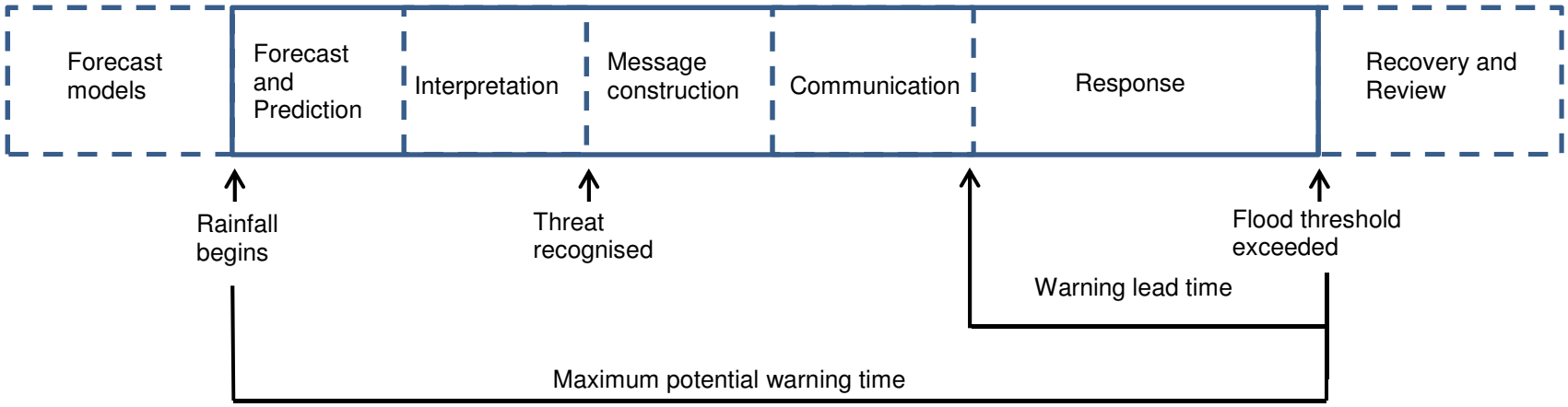

Figure 5: Flood timeline (based on Manual 21 Flood Warning)

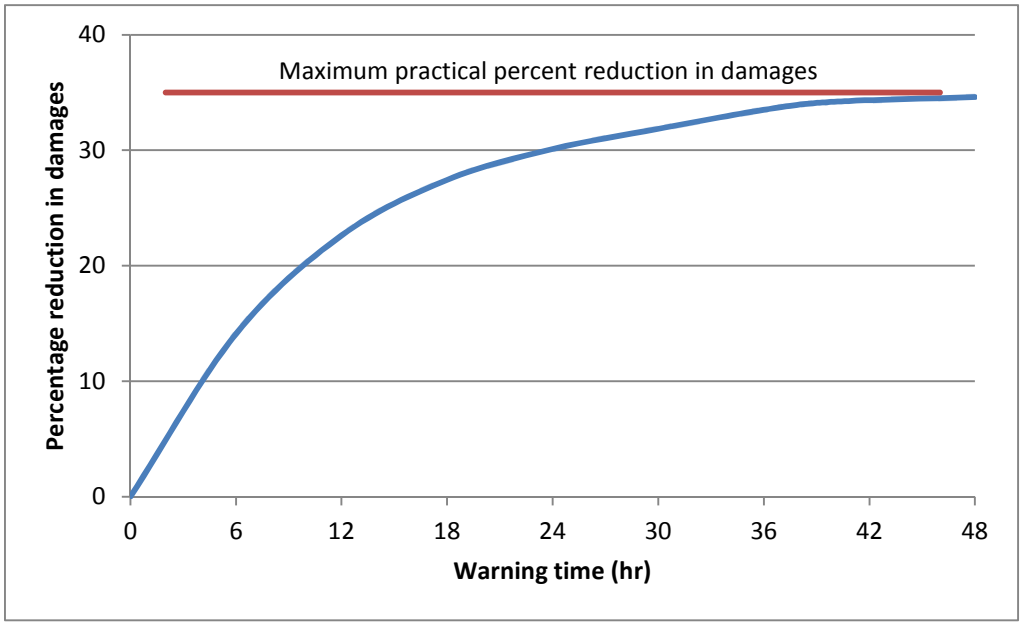

Figure 6: Day curve (Day, 1970)

The Day curve is used in this report (Sections 3.1 and 4.1) to provide an indication of the benefit of having not only a flood warning system but also a TFWS. It also provides a basic understanding of the benefits of each option suggested for a TFWS at Russells Creek (Section 4.1). The damage estimations made by Cardno (2010) are used as a baseline in these calculations.

Warning time as used in the Day curve is mitigation time or 'warning lead time' i.e. the time that people can respond to warning messages (refer to Figure 6).

However, the damage reduction predicted by the Day curve is optimistic as it presumes that when notified, property owners will act rationally and efficiently. To factor in human response, the following equation (Parker, 1991) is used in conjunction with the Day curve:

FDA = PFA x R x PRA x PHR x PHE

where:

FDA = Actual flood damage avoided

PFA = Potential flood damage reductions (as per Day curve)

R = Reliability of the flood warning process (i.e. the proportion of the population at risk which is warned with sufficient lead time to take action)

PRA = Proportion of residents available to respond to a warning

PHR = Proportion of households able to respond to a warning

PHE = Proportion of households that respond effectively

There are sliding scales provided for each of R, PRA, PHR and OHE (Carsell, Pingel and Ford, 2004, p. 137) from which coefficients can be chosen for catchments such as Russells Creek.

This approach to calculating damage reduction is used by the UK Government (SNIFFER, 2006).

It should be noted that there are other methods for calculating the benefit of flood warning systems including using the residential content depth-damage relationship (USACE, 1991) and attempting to factor in intangible benefits (SNIFFER, 2006). The choice of the abovementioned method was based on prior data available (e.g. Cardno report) and the requirement to empirically clearly demonstrate the benefit of each component of the TFWS.

2.2.2 Assessing what is needed for a TFWS at Russells Creek

There is an existing 'flood warning system' for Russells Creek; however, it may not have all the attributes of a TFWS (see Section 1.1.3). A qualitative gaps analysis was conducted by comparing the components of the existing flood warning system with a possible TFWS.

Suggested options for the development of a Russells Creek TFWS were identified for further analysis (Section 2.3).

2.3 PART 2 – TFWS OPTIONS ANALYSIS

2.3.1 Benefit -cost analysis of components

A benefit-cost analysis was conducted to compare the options suggested for each TFWS component (see Section 2.2.2). This was carried out using the empirical methodology explained in Section 2.2.1 in relation to an estimation of initial and maintenance costs for the option. Central to this was the notion of using options to increase warning lead time (see Figure 6) and improve community response (Section 2.2.1).

2.3.2 Analysis of options in relation to other factors

A qualitative analysis of other factors (e.g. reliability) was conducted (see Table 2) for the suggested options in addition to the benefit-cost analysis.

2.3.3 Identifying preferred options

Based on the findings related to the methodology described in Sections 2.3.1 and

2.3.2, a set of preferred options for a TFWS at Russells Creek was identified.

2.3.4 Benefit of a new TFWS for Russells Creek

A benefit-cost analysis (using the methodology described in Section 2.2.1) was conducted for the suite of TFWS preferred options outlined in Section 2.3.3. This result was then compared with the benefit-cost of not having these developed components of a TFWS for Russells Creek.

2.4 PART 3 – TFWS DEVELOPMENT PLAN

Using the preferred options identified, a development plan (business plan) was prepared that could be submitted to the relevant authorities. The development plan consisted of:

- Brief background to provide context
- Priorities for the design of an effective TFWS for Russells Creek
- Costing of each option and suite of options
- An action plan for implementation.

2.5 LIMITATIONS

- The revised North Warrnambool Flood Study (Cardno, 2010) and mitigation works study (Cardno, 2012) were used as a basis for many of the calculations in this report. It was not the intention of this project to review these reports and all of their findings were accepted.
- In this report, there is a focus on warning lead time to gauge the benefits of a flood warning system (Section 3) and calculate the benefit-cost ratios of TFWS options (Section 4). This approach is justified based on current research (Section 2.2.1). However, in practice, there is a dilemma for forecasters and emergency managers between the timeliness and accuracy of warning messages. As Manual 21 (page 16) notes “usually a flood can be predicted with high accuracy only in the later stages of its development when more information such as observed rainfall becomes available. Therefore, in order for sufficient warning time to be provided it is often necessary to accept a less accurate prediction. Thus there is a trade-off between prediction accuracy and warning time.”

  This issue is particularly acute for flash flooding where the warning time is unavoidably short. The dilemma is shown in Figure 7 and is further discussed in Section 3.

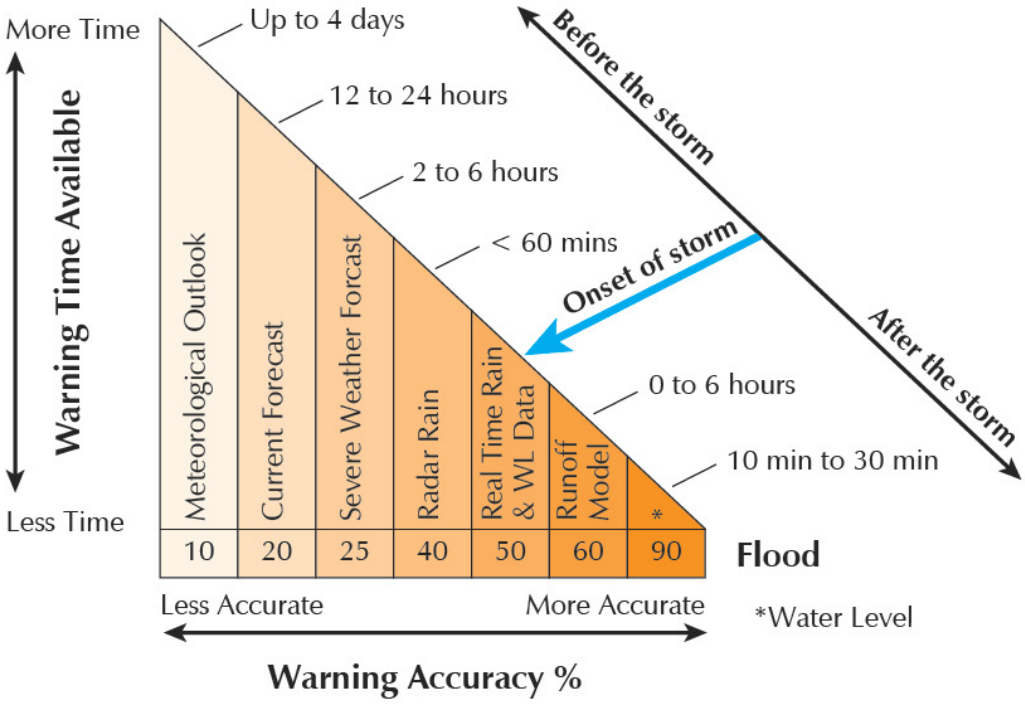

Figure 7: Trade-off between warning time and accuracy for flash floods (Wright, 2001)

3 PART 1 – FLOOD WARNING SERVICE NEEDS ASSESSMENT

3.1 CURRENT WARNING BENEFITS AND ISSUES

As outlined throughout Section 3.2, there are components of an existing rudimentary flood warning system for the Russells Creek catchment. These components include:

- Severe Weather Warnings and Severe Thunderstorm Warnings issued by the BoM (refer to Section 3.2.5)
- Radar services provided by the BoM to detect severe thunderstorms (Section 3.2.5)
- Community education activities (Section 3.2.3)
- Understanding of flood risk and behaviour in the catchment (Section 3.2.1)
- Emergency management plans (Section 3.2.2).

To estimate the damages cost reduction using this 'existing flood warning system', the warning lead time for the Russells Creek catchment was calculated.

Using the RORB model for Russells Creek (Cardno, 2010), Figures 8 and 9 were prepared. It is important to note that the trigger signifying initial property flooding has been set at the 5 year ARI flood, which at Mortlake Road is a flow of 25 cumecs or 2,160 ML/day.

Figure 8 is the rainfall-flow graph for the 100 year ARI 3 hour duration design storms; Figure 9 is the rainfall-flow graph for the 100 year ARI 9 hour duration design storms.

In both cases (and for the 6 hour duration curve), the RORB model generated a flow hydrograph in the lower part of the catchment at Mortlake Road that peaked before the rural runoff had peaked upstream at Aberline Road.

The 100 year ARI 3hr storm produced a subtle, double peak hydrograph at Mortlake Road.

However, the downside of this is that the potential warning time is even less than it might initially have been expected, simply looking at the total size of the Russells Creek catchment.

From this analysis the following observations were made:

1. In each case (3 hour, 6 hour and 9 hour), the 5 year flow at Mortlake Rd (25 cumecs) was reached when only 2/3 of the 100 year rainfall had occurred.
2. Again in each case, only about 0.5 to 1 hour warning time is available for the 5 year flow at Mortlake Rd and that occurred when less than half the rain had fallen for the 3 hour storm and about 35% of the total rain fallen in the case of the 6hr and 9 hour storms.
3. There is virtually no way of providing any more than 0.5 hours of warning for any degree of flooding in the case of the 3 hour storm.
4. In order to provide 1 hour of warning time for the peak flood level at Mortlake Rd an estimate would need to be made when about 70% of the total rain had occurred.

Therefore, it appears that the maximum potential warning time (refer to Figure 5) is only up to **one hour**. Assuming this was available as warning lead time, the formula outlined in Section 2.2.1 can be applied to calculate damage reduction.

For the Average Annual Damage (AAD), under existing conditions (i.e. pre-mitigation works) the potential flood damage reductions (as per the Day curve) for Russells Creek would be $14,753 based on Cardno (2010) estimates (Section 1.3.3). Over a 20 year life span of the system (7% discount rate) this would amount to a damage reduction with a present value of $156,293.

Factoring in the response coefficients (Section 2.2.1), which were at the lowest ends of the scales due to the minimal parts of existing warning system available and its reliability, the flood damage reduction over the 20 years under existing conditions only has a present value of $13,538. This figure would be further reduced by the mitigation works (Section 1.3.3) to an estimate of present value of only $1,364 in damage reduction over 20 years.

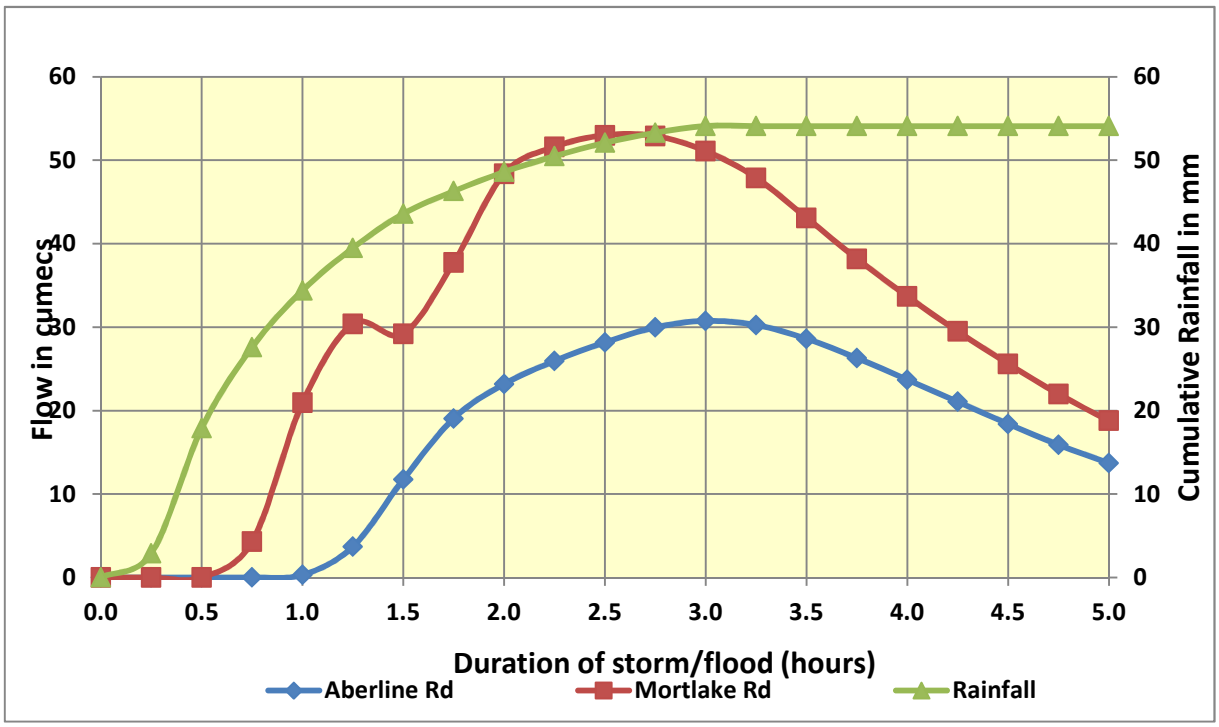

Figure 8: Russells Creek 100 year ARI 3 hour rainfall and flows

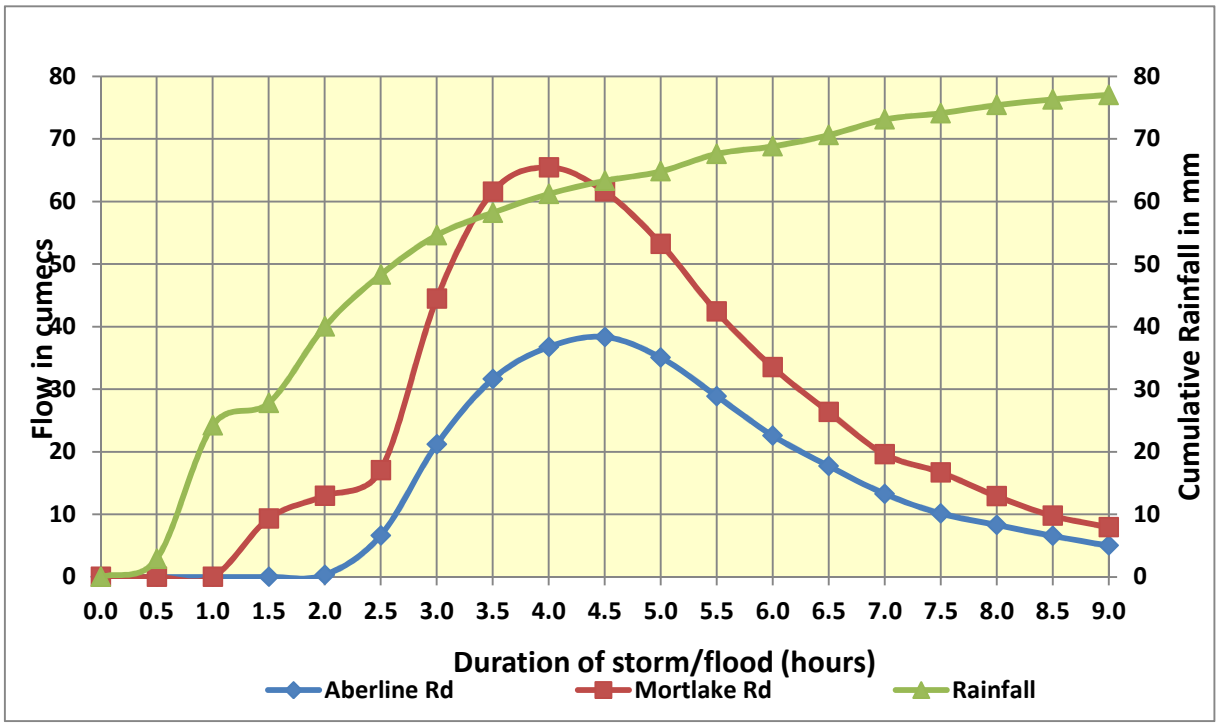

Figure 9: Russells Creek 100 year ARI 9 hour rainfall and flows

As shown in the above analysis, there is little warning time at Russells Creek, and coupled with the limited ability of the community to respond, there is negligible economic benefit with the warning options currently available. There is little time to resolve the dilemma with accuracy (Section 2.5), and timeliness of the warning is thus paramount (meaning that there may be 'false alarms' and inaccurate warning messages).

There is also little time to warn people in the catchment for safety purposes unless they use pre-storm situational awareness (e.g. monitor potential rainfall through the BoM radar) or have some way of being alerted to the impending risk. Of particular concern for safety is that there are three buildings in the catchment that experience maximum above floor flooding depths of more than one metre for a 100 year ARI event even after the mitigation works. However, most buildings only receive up to 0.5 metres depth of maximum flooding during the 100 year event.

Apart from the residential areas, as noted in Section 1.3.1, there are other potentially vulnerable land uses. Of particular concern in terms of safety is the Goodstart Early Learning Childcare (formerly ABC) located on the corner of Wares Road and Whites Road and the St Joseph's Primary School located along Botanic Road. Both do not experience above floor flooding up to the 100 year flood, but their land can be inundated and nearby roads cut off.

The Centro shopping centre and nearby sporting centres will be protected from flooding by the mitigation works up to the 100 year ARI level.

3.2 ASSESSMENT OF REQUIREMENTS FOR A TFWS AT RUSSELLS CREEK

With the very limited warning time available for the Russells Creek catchment, it is not possible to implement all components of a TFWS as outlined in Section 1.1.3. However, it is important to assess the components that are available and could be used prior to identifying warning system options.

3.2.1 Understanding flood hazards and risks

There is a good understanding of the flood hazards and risk for the Russells Creek catchment through the flood studies completed including Cardno (2010) and Cardno (2012).

However, at this stage there is no hydrological study for floods greater than the 200 year event and up to the Probable Maximum Flood (PMF) and the impacts of these larger floods should be investigated.

Warrnambool City Council informs property purchasers of flooding through their Section 32 certificates. According to Council, the information provided based is on the best information it has, irrespective of whether it is in the Council Planning Scheme or not i.e. the Planning Scheme may indicate it is not in a flood zone, but Council informs purchasers that the land is liable to flooding with an appropriate level given as required in the Section 32 statement.

3.2.2 Emergency management planning

The Warrnambool Municipal Flood Emergency Plan (MFEP) is a sub-plan of the Warrnambool Municipal Emergency Management Plan. The MFEP covers all flood risks in the City including in the Russells Creek catchment.

The MFEP is in the early stages of being drafted using the VICSES template and will include an Appendix E relating to flood warnings including using this report for warnings relevant to the Russells Creek catchment.

Further work is therefore required to align the MFEP with the preferred warning option from this report.

Although the flood study maps (e.g. Cardno, 2010) show areas that are isolated as flood levels rise, this needs to be considered in emergency management, and particularly if evacuation is possible.

Each of the main non-residential land uses in the catchment should have an emergency management plan (EMP) to help ensure safety and as part of business continuity planning.

The Goodstart Early Learning Childcare (formerly ABC) has an EMP, although it mostly covers fire and mentions little about flooding.

3.2.3 Community flood education

Community flood education should include guidance for residents and businesses in terms of flood risk, what precautions to take prior to a flood and what to do if a flood is imminent and then occurs.

The VICSES FloodSafe program is designed to inform people about their flood risk, and how to prepare, respond and recover from flooding. It encourages flood-affected residents and businesses to develop emergency plans that include responses to warning triggers.

There is an existing FloodSafe Guide for the Merri River, Hopkins River and Russells Creek Catchments. The Guide does not specifically relate flash flooding risk to Russells Creek, although it notes that “Severe Weather or Thunderstorm Warnings are issued when Flash Flooding is expected". It also describes flash flooding as follows:

“Flash Floods can happen after very heavy rain. Flash Floods can be very powerful and fast moving, easily washing away people, cars, roads or bridges. They can happen quickly, sometimes in just minutes, so there may be little or no time to warn you. BoM cannot normally predict the arrival time or how deep Flash Floods will be, so you need to be prepared and ready to take action to keep you safe.” The Guide provides little indication of how to prepare for flash flooding (although much is related to actions with the time afforded to riverine flooding), although it does warn about never walking, diving or riding through floodwater (the cause of at least half the flash flood-related deaths in Australia).

VICSES has issued flood packs to residents in the Russells Creek catchment. A new Flood Guide covering the Russells Creek catchment is being produced by VICSES. There will be community engagement by VICSES after the mitigation works are completed.

There is a need to provide a tailored flood education program specifically to the needs of the Russells Creek catchment. The program should be geared towards the preferred warning option identified in this report.

As shown in Section 1.3.2, there are some demographic characteristics that should be considered in the development of a tailored community education program. These include the relatively small proportion of people that speak English as a first language, the need for both home owners and renters to be educated, and the need for learning relating to helping others including older people and those with disabilities.

3.2.4 Data collection

As described in Section 3.2.1, there is a relatively large amount of data relating to the flood hydrology and hydraulics, and the impact of flood on properties and buildings. This can be used more effectively in the preparedness for floods by providing data for the MFEP and emergency management plans (Section 3.2.2) and tailored community flood education for the catchment (Section 3.2.3).

As noted in Section 1.4.1, Russells Creek is ungauged and does not lend itself to a conventional flood warning system.

Similarly, the catchment is poorly represented with meteorological weather stations and other monitoring data. There is an automated weather station (AWS) at Warrnambool airport.

However, the use of a rainfall gauge in the catchment would provide data that could be used as a trigger for flood warning. Manual 21 (page 46) touches on the subject of pre-determined threshold rainfalls likely to cause flooding saying, “Using pre-designed messages in flash flooding environments can be triggered by decision rules determined beforehand (e.g. threshold rainfalls exceeded, with further heavy rain forecast), the messages going automatically to radio stations when the appropriate conditions are fulfilled.”

The determination of a threshold rainfall trigger requires several considerations, the initial one being what is the minimum level of flooding which the flash flood warning is aimed at targeting.

For Russells Creek the trigger signifying initial property flooding has been set at the 5 year

ARI flood (refer to Section 3.1) , which at Mortlake Road is a flow of 25 cumecs or 2,160 ML/day.

The RORB model for Russells Creek (Cardno, 2010) was run a number of times using the adopted parameters and continuing loss of 3.5 mm/hr for design rainfalls from 2 year ARI to 200 year ARI.

The results are presented in Figure 10 with each curve representing the different storm rainfall duration modelled from 2 hours to 9 hours.

A line from the 5 year ARI minimum flood trigger of 25 cumecs is projected, with increasing rainfall intensity bisecting each curve and defining the corresponding rainfall required for each duration to produce the minimum flow of 25 cumecs in Russells Creek at Mortlake Road.

In the case of the 2 hour storm, the threshold rainfall intensity over that period equates to 18.5 mm/hr or 37 mm in total.

In order to provide a rainfall-based flash flood warning system for Russells Creek, a minimum of one automatic real-time rain gauge is required to be strategically located in the catchment.

While the RORB design flood modelling assumed uniform rainfall across the catchment this is seldom the case, particularly in the shorter duration storms.

If only one rain gauge is to be installed then it needs to be located in the most strategic part of the catchment where it will provide the most representative rainfall likely to contribute to the stormwater runoff.

The catchment map (Figure 11) shows the RORB model sub-catchment with the proposed rain gauge location marked on the junction of sub-areas C, D and G.

Given the shape and size of the 32 km² Russells Creek catchment, about two thirds of the upper catchment consisting of rural farmland and medium sized pastoral holding and the lower third being largely urbanised, an additional rain gauge to improve the representative rainfall coverage is highly recommended.

The additional rain gauge could be located anywhere in the lower catchment within sub-areas K, L, M, N, Q or P providing a suitable location can be found that complies with the BoM's 'Observation Specification No. 2013.1 – Guidelines for the siting and Exposure of Meteorological Instruments and Observing Facilities, January 1997'.

However, it would be advantageous and cost-effective if a combined automatic real-time rain gauge-level gauge was located on Russells Creek at Mortlake Road to provide vital real-time monitoring of the level in Russells Creek during significant flood events but also to provide a future historical record of significant floods in the catchment.

The existing staff gauge on Russells Creek at Mortlake Road would be an obvious location for an automatic real-time level gauge installation that also provides a suitable location for an automatic real-time rain gauge.

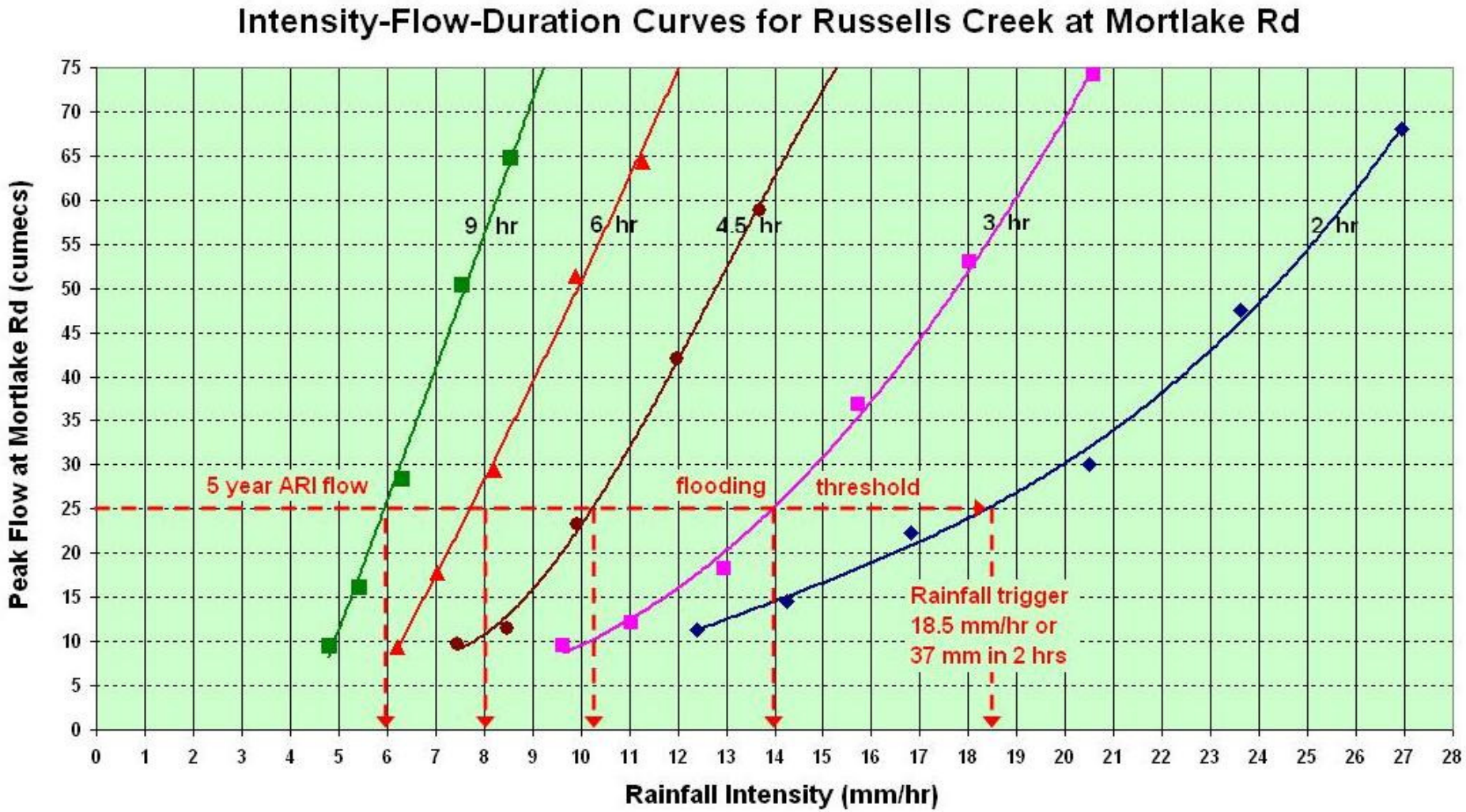

Figure 10: Intensity flow duration curves for Russells Creek at Mortlake Road

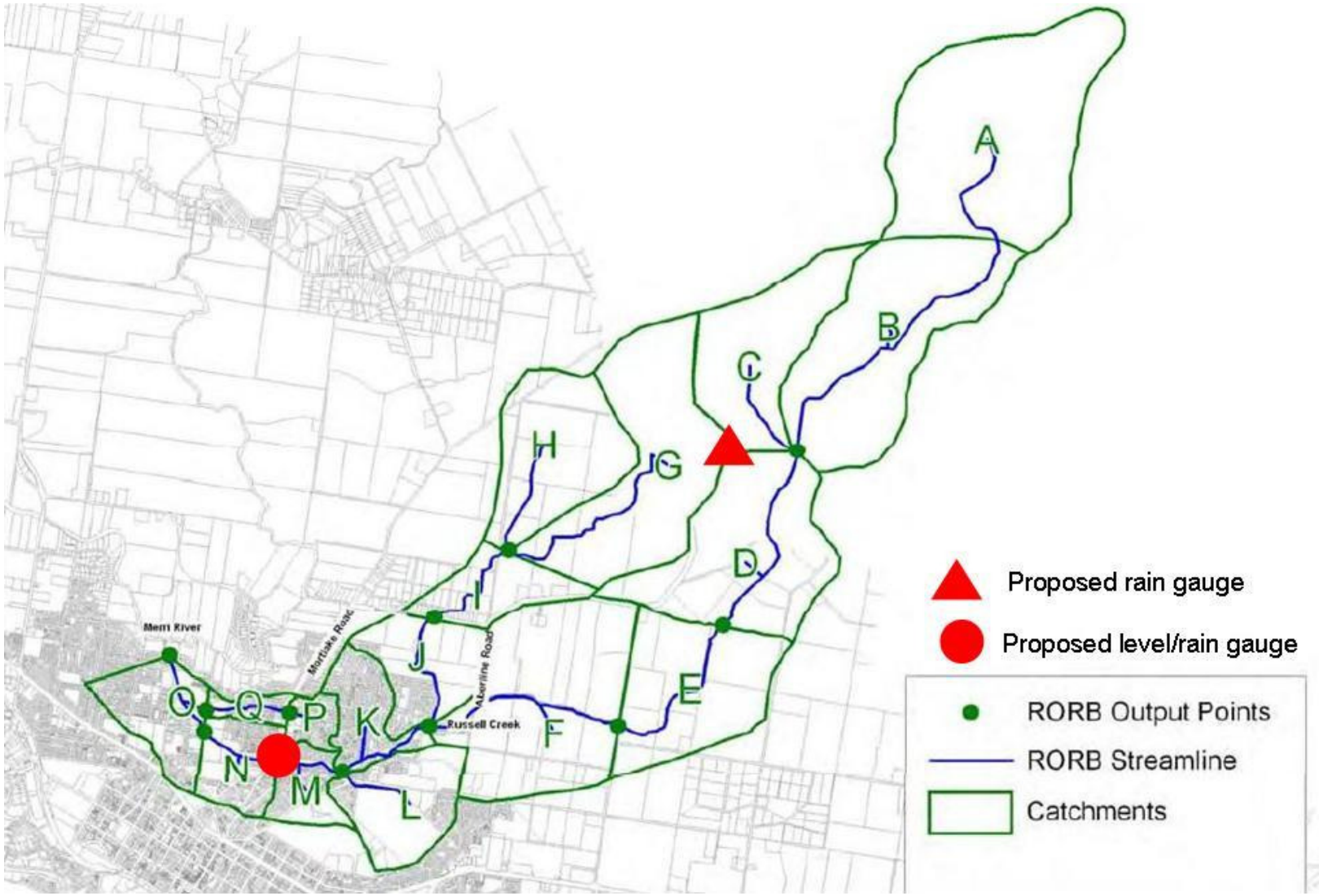

Figure 11: Recommended locations of rain gauges in the Russells Creek catchment

3.2.5 Flood prediction and interpretation

The BoM does not provide warnings for flash flooding for specific creeks and locations such as Russells Creek (i.e. where the catchment response, the time between rainfall and flooding, is less than six hours). Rather, it provides generalised warnings of weather conditions likely to lead to flash flooding.

While the task of issuing warnings of weather conditions likely to lead to flash flooding is a BoM responsibility, the task of issuing catchment or location specific flash flood warnings to the at risk community, the media or other entities is a local government responsibility.

The Review of the 2010-11 Flood Warnings and Response (page 45) stresses that the forecasting of flash flooding is not a trivial task. "Such flooding is often associated with severe thunderstorms or small scale weather systems that are locally intense and slow moving. The BoM can forecast the environment in which these types of weather events may occur and provides a generalised service to that effect. However, the VFR understands that it is not yet scientifically possible to predict individual flash flooding events, except on time scales of ten minute multiples at the very best."

The Victorian Flood Warning Consultative Committee also refers to the provision of flash flood warning services and makes it clear that the BoM does not have an exclusive role. Responsibility for the purchase, installation and maintenance of flash flood warning systems, including the development and operation of flood response plans, became a shared state and local government responsibility with technical assistance to be provided by the BoM.

The BoM role is described in the 1996 *Policy on the Provision of the Flash Flood Warning Service* as primarily "maintaining a central source of expertise and development capability and providing specialist advice on the establishment of locally based warning systems". The policy document also indicates that the BoM accepts "a continuing responsibility for the provision of real-time forecasting and monitoring of regional flash flood producing conditions". The policy document further states that "...the objective of the flash flood warning service is to minimise the potential for loss of life and damage associated with such events by providing information to the public, emergency management organisations and other authorities of the timing and spatial distribution of flash flood situations."

Relevant BoM services comprise four components that depend on the sophistication of available monitoring and forecast capabilities as follows:

1. Generalised warnings (issued to the general public and emergency management organisations, generally as a regional severe weather warning) associated with the onset of heavy rainfall.
2. Radar based warnings of rainfall (issued to identified agencies and user groups as a severe thunderstorm warning at a space scale, where feasible according to BoM, of a typical local government area) that could lead to flash flooding within specific areas, but only where those areas are covered by suitable weather watch radar and where a threshold intensity, chosen such that its exceedance will produce flash flooding irrespective of existing antecedent catchment conditions, is expected to be equalled or exceeded.
3. Area-specific predictions of rainfall intensities (issued to local flash flood warning groups where a local warning system has been established) but only in limited areas covered by suitable weather watch radar.
4. Support and advice to local authorities in the establishment of automated flash flood warning systems (for example, ALERT systems) and related matters.

For Russells Creek, this means that although the BoM will provide these general prediction services including severe weather warnings and severe thunderstorm warnings, in the absence of an ICC (due to

short warning times) local catchment-based interpretation has to be conducted by automated means and/or by people's situational awareness.

3.2.6 Message construction

As there will be no localised warnings issued by the BoM and an ICC constructing localised messages for the Russells Creek catchment is unlikely, there is little option for detailed messages.

With such little warning time available for the Russells Creek catchment, warning 'messages' need to be succinct and call into action pre-learned response behaviours.

Manual 21 (page 45) suggests that due to the limited warning time, "the practice of setting up messages before flooding occurs is especially valuable when warnings of flash flooding are being considered."

3.2.7 Message communication

There are several communication options that could be considered for a warning system at Russells Creek. These options are listed and analysed in Table 2 and discussed below.

Due to the short period of warning time for flash flooding, an ICC most likely will not be in place and thus the use of One Source One Message (OSOM) and Emergency Alert issued by an ICC cannot be used in a warning system for Russells Creek. Other local personalised communication methods such as doorknocking by emergency agencies, community meetings and community newsletters used for riverine floods are also of little use at Russells Creek due to the very short warning time available.

It should be noted that as described in Section 3.2.5, the BoM provides generalised warnings of weather conditions likely to lead to flash flooding which are communicated through its website and through the media (e.g. ABC regional radio). However, it does not provide specific services that communicate local warnings to small urban catchments.

There have been numerous local flash flood warning systems established throughout Australia and the world that use a range of communication methods.

In Victoria, there are several examples. At Moolap in the City of Geelong, a flash flood warning system was established using Event Reporting Radio Telemetry System (ERRTS) to monitor rainfall within the 12km² Moolap catchment. Rainfall details and stormwater levels in the open drain are transmitted to the base station computer. This data is processed by the Automated Local Evaluation in Real Time (ALERT) flood warning software and can also be accessed by the BoM. The Council then makes a decision to notify residents using a 'telephone tree'.

Melbourne Water has trialled flash flood alert systems in two urban Melbourne catchments over the past five years (Rasmussen, 2013).

Melbourne Water established a Supervisory Control and Data Acquisition (SCADA) system in the mid-1970s. This system has progressively grown since this time to about 220 water level and rain gauge stations. It uses schematic diagrams and maps enabling real-time monitoring of water levels, rainfall and other parameters across the Melbourne Water catchment areas, on a continuous basis. The system has the ability to alarm when pre-set thresholds are breached by water levels, flows and rainfall volumes or intensities. The alarms are monitored through a control room and forwarded to the Hydrology and Flood Warning team during business hours and to a Flood Warning Duty Officer (FWDO) out of hours.

In the situation of potential flash flooding, there is minimal time for the FWDO to announce that a flash flood is likely. The development of a flash flood alerting system was initiated to enable direct transfer of any alarms from SCADA for a given location or area, by SMS messages.

The SCADA alarms were configured to provide the water level and intense rainfall alarms. These alarms are sent directly to the resident's mobile phones (who have opted in to the service) as an SMS. The SMS contains details of the alarm that has been generated e.g. "Surrey Hills Tank Rain Gauge Station: Intense Rainfall Recorded".

Phase 2 of the SMS Flash Flood Alerting system was developed in consultation with Telstra. The system is an existing Telstra product that was modified to meet Melbourne Water needs.

A similar flash flood warning system is being developed for urban catchments in the northern beaches of Sydney (Millener et al 2013). There, rainfall and stream gauges are being installed to feed real-time information to the BoM which sends SMS alerts using a Telstra platform to emergency agencies and local councils once trigger levels are reached. The system has not yet been extended to providing alerts to residents.

After the devastating floods of 2011 Lockyer valley floods in which 23 people lost their lives, a set of flash flood warning systems are being installed. The cutting-edge system uses radar and satellite technology which can alert emergency services to pre-determined rising water levels within 20 seconds. The Flood Early Warning System can provide real-time video feeds and has an infra-red measuring system that is accurate to three millimetres.

A guidebook of international early warning systems (University Corporation for Atmospheric Research, 2010) provides a review of communication methods used internationally. These methods include websites, direct alert messages to residents, first responder networks (e.g. pagers to emergency services) and community alert sirens.

Social media can also provide real-time unofficial warnings. White (2012) and other researchers explain the virtues of social media to quickly warn others and mechanisms to use them.

With the very short warning time in the Russells Creek, some of the above described options are excluded (see Table 2) as they are more appropriate for the longer duration flash floods (i.e. closer to the six hours maximum). For example, the use of alerting emergency managers is not appropriate as it would involve first responders to then react and then enter potentially dangerous rising flood waters in the short time available. Even the phone tree message approach used at Moolap may take too long to enact if used at Russells Creek.

The option that appears most appropriate for Russells Creek coupled with the installation of the rainfall gauges (Section 3.2.4) is the use of an opt-in system of SMS alert messages similar to that being developed by Melbourne Water. This system has already been trialled in two urban catchments in Melbourne through extensive consultation with local residents.

This system delivers speedy alerts to residents that carry out pre-learned actions for safety and damage reduction.

Another possibility is the use of rainfall gauge levels to trigger sirens. The technology for this is possible based on trials by the Office of the Emergency Services (OESC) for Yarra Ranges, Dandenong Ranges and at Lorne. However, the trials showed that the use of automated technology is costly, and the range of the sirens was greatly influenced by wind and terrain. Sirens are also a ‘dumb’ warning (i.e. contain no message) and need to be used as a call to seek further information (which may require time that is not available at Russells Creek). In an elongated catchment such as Russells Creek, at least two sirens may need to be installed.

A supportive option is the use of social media to warn others. This could be done through a Facebook or Twitter site (or even a local flood warning app) that is linked to BoM RSS feeds and possibly local SMS alerts. However, the use of social media would require further investigation to assess community use of social media and interest in this warning option.

Table 2: Analysis of possible TFWS communication options for the Russells Creek catchment

Option	Description	Use for Russells Creek	Usefulness rating
Localised SMS phone alerts	Used by Melbourne Water, elsewhere in Australia and overseas.	Rain gauges message SCADA or similar system which then sends SMS messages to residents through phone system. Can provide quick response to real-time rainfall data. Can break down and send false alarms. Need residents to opt-in.	High
Bureau of Meteorology Website	Provides generalised warnings (e.g. regional severe weather warning) and radar based warnings	Used for people to gain situational awareness of impending rainfall	High
Social media	Used in OSOM but there are also local catchment Facebook and Twitter pages (e.g. managed by local councils) plus unofficial pages	A local Russells Creek Facebook or Twitter page could be established (e.g. managed by Council). This could be used to help warn residents (and themselves) and educate and engage with them prior to, during and after a flood. Dependent on the social media usage of affected residents.	Medium
Community alert sirens	CFA sirens now used for community bushfire warning throughout Victoria. Sirens also set up in other locations such as in Yarra Ranges and Dandenong Ranges mainly for bushfire warning. Sirens used elsewhere in the world e.g. 'tornado alley' in the USA.	Of possible value. Use of automated siren technology is relatively costly. At least two sirens would need to be installed due to elongated Russells Creek catchment. Sirens provide a 'dumb' warning i.e. no information.	Low

Doorknocking	Used by emergency authorities to warn people personally about floods and/or request that they evacuate	Difficult as flood warning time is minimal although local SES could doorknock the most vulnerable people (e.g. older people, those with disabilities) if possible	Low
Telephone tree	Used in Australia and overseas. Rainfall and drain levels sent to an authority (e.g. local council) which triggers a phone tree where people ring several others to warn them	Of little use as flood warning time is less than where it is used in Australia and elsewhere in the world. Requires rain gauges and alerting infrastructure (e.g. ALERT) needs to be installed.	Nil
One Source One Message (OSOM)	VICSES, CFA, DEPI use automated process to send flood warning messages from the SCC, RCC or ICC to their respective websites, social media, VICSES Flood and Storm Information Line and to the media	Of no use as flood warning time is minimal and ICC will most likely not be in place	Nil
Emergency Alert	National emergency alerting system using phone SMS and landline messages that are activated by the SCC, RCC or ICC	Of no use as flood warning time is minimal and ICC will most likely not be in place	Nil
Community meetings and newsletters	Used by VICSES to inform and educate people about impending or existing floods and discuss any issues about response	Of no use as flood warning time is minimal	Nil
Alerting emergency agencies	There are systems throughout the world that warn emergency agencies (e.g. through automated messages triggered by rain gauges and drain telemetry). Agencies can warn people by doorknocking, sending phone messages etc.	Of little use as flood warning time is minimal and this is an extra (time consuming) step. Warnings need to be sent directly to those at risk	Nil

3.2.8 Response

The Victorian State Flood Emergency Plan (Victorian Government, 2012, page 36) provides details for emergency agencies relating to flash flood response.

The Plan stresses that pre-event planning for flash floods should commence with an assumption that evacuation is the most effective strategy. However, given the likelihood of some proportion of the population failing to evacuate, either by choice or impediment, a rescue contingency must also be planned for.

"When conducting pre-event planning for flash floods the following steps should be followed, and in the order as given:

1. Determine if there are barriers to evacuation by considering warning time, safe routes, resources available, etc;
2. If evacuation is possible, then evacuation should be the adopted strategy and it must be supported by a public information capability and a rescue contingency plan;
3. Where it is likely people will become trapped by floodwater due to limited evacuation options safety advice needs to be provided to people at risk advising them not to attempt to flee by entering floodwater if they become trapped, and that it may be safer to seek the highest point within the building and to telephone 000 if they require rescue. This advice needs to be provided even when evacuation may be possible, due to the likelihood that not all community members will evacuate.
4. For buildings known to be structurally unsuitable an earlier evacuation trigger will need to be established (return to step 1 of this cycle).
5. If an earlier evacuation is not possible then specific preparations must be made to rescue occupants trapped in structurally unsuitable buildings either pre-emptively or as those people call for help."

As an evacuation centre may not be able to be set up, evacuees should find alternative safe places (e.g. friends, family) outside the floodplain until it is safe to return.

The above advice should be converted to appropriate response behaviours as part of pre-learning (through community flood education) at Russells Creek. With such short warning time, it will be important to convey the idea of staying out of the floodplain (e.g. not going home) and what to do if trapped in homes, offices and schools.

Emergency agencies (VICSES, CFA, DEPI) and Warrnambool City Council have good local capacity to assist people with floods in the Russells Creek catchment. There are over 50 volunteers available with a SES unit and CFA station at Warrnambool.

Melbourne Water promotes three levels of response actions in relation to its flash flood alert system (Rasmussen, 2013) that could be considered for the Russells Creek catchment. The actions included in resident response plans are:

1. Monitor. Close monitoring is an important component leading up to any alarms being received e.g. rainfall alerts and/or level alerts. An action in some residents' plans may be to relocate their car to higher ground.
2. Standby. As the storm moves through the area and heavy rain is falling, as rainfall alerts are received, then the residents move their plan to 'Standby'. At this stage, they need to consider other specific actions such as raising valuable belongings, block doors and openings with plastic and continue to observe what is happening locally.
3. Action. The SMS alert triggered residents to move their plan to 'Action'. At this stage, residents would need to take specific actions such as check water levels at drainage pipe inlets within the boundary of their properties. This enables them to get a good feel of the response of the drains and put any other actions quickly into plan.

Residents are able to make decisions themselves about the actions that they believed were necessary for their safety.

The above outlines appropriate response as conducted and promoted by emergency authorities; the other issue with 'response' is how responsive is the local community during a flood event.

Awareness of flood risk is an important precursor to people taking appropriate safety and damage reduction actions as a result of flood warnings. People that do not know their property floods will not take action.

Community education is required to inform people of their flood risk and the need to prepare an emergency plan.

However, a large body of research (e.g. Paton, 2006; Grothmann and Reusswig, 2006) shows that risk awareness is a poor causal indicator of preparedness and response to warnings. In other words, it cannot be assumed that those aware of flood risk will do anything about it. There are other factors also at play including flood experience, self-efficacy and action coping.

Furthermore, there appears to be three main types of psychological profiles related to flood preparedness and response – people that respond proactively (e.g. self-evacuate), people who are apathetic and will only act when told to do so directly by authorities, and those that will not respond to warnings and stay put (Dufty, Taylor and Stevens, 2012).

Without social research into these psychological factors it is impossible to fully understand the potential response to a flood warning system. The social research would identify response issues that could be addressed through tailored community education and community development (e.g. capacity-building, leadership).

There is also a growing body of evidence (e.g. Aldrich, 2012; Chamlee-Wright, 2010) that shows that social capital (networks, norms, trust) is a critical component of appropriate response and recovery that leads to social resilience. Social network analysis (a form of social research) would give an indication of social capital in relation to warnings and possible gaps that could be filled by community development activities.

A relatively small social research project is recommended for Russells Creek to better understand the psychological and sociological aspects relating to potential community response as this is the true indicator of success of the warning system. This will feed into emergency planning, tailored community flood education and community development including by Council.

Some indication of possible community response vulnerabilities can be gleaned from the 2011 census data and the Warrnambool Social Atlas data (see Section 1.3.2). For example, there is an older population of residents immediately east of Mortlake Road that could be vulnerable during a flood. There are also pockets of residents requiring assistance due to disabilities. It is suggested that a vulnerable persons register be developed for those at-risk properties in the Russells Creek catchment so that VICSES can target these people if it has time and the resources to do so.

3.2.9 Review of the TFWS

According to Manual 21 (page 67), "flood warning systems need regular attention to ensure they will function as intended and to continue to improve their performance". It adds that review should be conducted both at the strategic and operational level.

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

A possible governance model for review of the Russells Creek flood warning system is through the continued use of the Technical Steering Committee for this project (Section 2.1).

There is a need to develop a Russells Creek flood warning system monitoring and evaluation plan, possibly using the guidance in pages 71-72 of Manual 21. As Molino and Dufty (2013) stress, as part of this plan it is important to have a mechanism for post-flood review of all aspects of the TFWS to enable continual improvement.

3.2.10 Community and stakeholder consultation

Community consultation is critical to the establishment and ongoing use of a flash flood warning service. Manual 21 advocates the use of community and stakeholder consultation in the review of the TFWS. It also encourages consultation in the development and implementation of other aspects of the TFWS.

It is important to consult with the Russells Creek flood-affected community regarding the appeal of the flood warning system recommended by this report. As suggested in Section 3.2.9, community participation is also required for review possibly through a flood warning committee that includes members of the local community.

One way that people can assist with flood warnings is through a flood warden or similar program. The flood warden program involves trained community 'leaders' alerting people to a warning and helping organise property-related and evacuation actions based on guidance from authorities such as VICSES.

3.3 RECOMMENDED OPTIONS

Although a TFWS is not able to be fully established for Russells Creek due to the limited warning time, it is important to establish an alternative balanced alert system. The Review of the 2010-11 Flood Warnings and Response (page 45) noted that "a flood warning system (and investments in their implementation) that overemphasises the collection of input data and/or the production of forecasts relative to the attention given to other elements (such as message construction, the information provided in the messages and the education of flood prone communities about floods and flood warnings) will invariably fail to fully meet the needs of the at risk communities they have been set up to serve."

The primary aim of a Russells Creek flood warning service is safety, although there may be some protection of property available within the limited warning lead time.

In Section 3.2, consideration has been made of several factors including successful trials of flash flood warning services, the time available to implement the warning options, and the appropriate technology available. Based on this, the following package of options is recommended for the Russells Creek catchment:

- A completed Warrnambool MFEP that relates to the Russells Creek flood warning system (Section 3.2.2)
- Emergency management plans (including flood response appropriate actions) for the Goodstart Early Learning Childcare and the St Joseph's Primary School (Section 3.2.2)
- Tailored community flood education that provides pre-learning for the community including appropriate responses in relation to cues such as the BOM warning services and SMS alerts triggered from rain gauges (Section 3.2.3)
- Use of the existing BoM warning services and products including severe weather warnings, severe thunderstorm warnings and radar information and maps. (Section 3.2.5)
- Data collection provided by the installation of two rain gauges and telemetry in the Russells Creek catchment (Section 3.2.4)
- An opt-in alert system linked to the rain gauges which provides SMS messages to the mobile phones of flood-affected residents (Section 3.2.7)
- Ongoing community consultation through a Russells Creek Flood Warning Committee to test, establish, implement

and evaluate the flood warning system (Section 3.2.8).

Some other ideas were identified in Section 3.2 for consideration:

- Additional river level gauge component (Section 3.2.4)
- Use of a specific social media site (e.g. Facebook) that provides warning information and allows people to warn others and emergency agencies (Section 3.2.7)
- A social research study to examine aspects of the potential response of residents with possible resultant actions for emergency planning, community flood education and community development (Section 3.2.8)
- A vulnerable persons register be developed for those at-risk properties in the Russells Creek catchment (Section 3.2.8)
- Use of a flood warden or similar program to encourage community leadership to help others in the catchment (Section 3.2.10).

4 PART 2 – TFWS OPTIONS ANALYSIS

4.1 OPTION EVALUATION

4.1.1 Benefit-cost analysis of options

None of the options recommended in Section 3.3 will necessarily increase the warning lead time which appears to be one hour at the most. The options cannot be compared against each other as they are part of a package of options that are interlinked. As Manual 21 (page 7) stresses, "For a flood warning system to work effectively, these components must all be present and they must be integrated rather than operating in isolation from each other. The view that any one component of the system represents all of it, or is an end in itself, impairs the system's effectiveness".

It is apposite here that the recommended flood warning system is assessed in terms of damage reduction (albeit given that the main aim is public safety). Although there will be no 'savings' in terms of warning time, there will be improvements in the response factors in the equation provided in Section 2.2.1 in relation to the sliding scale for community response.

As a result, the reduction in damages was estimated if the recommended system is implemented. The estimated present value of reduction in damages for the recommended options over a 20 year life span is $58,518 compared with the $13,538 using the 'current' system for the 100 year ARI flood under existing conditions.

The estimated cost of installing and maintaining the recommended packages of options is as follows:

- Complete Warrnambool MFEP (in-kind Council)
- Complete flood emergency management plans for the Goodstart Early Learning Childcare and the St Joseph's Primary School (in-kind for these facilities)
- Tailored community flood education project ($20,000 to design and establish, plus VICSES and Council in-kind to maintain)
- Use of the existing BoM warning services and products (no cost)
- Data collection provided by the installation of two rain gauges and telemetry in the Russells Creek catchment ($20,000 installation plus $7,500 O&M per year)
- An opt-in alert system for SMS messages to mobile phones of flood-affected residents triggered by rainfall alerts from the rain gauges connected to a local Enviromon system at Warrnambool interfaced to a telephone alerting system (no cost to install for the telephone alerting system, 10 cents per call thereafter)
- Ongoing community consultation through a Russells Creek Flood Warning Committee to test, establish, implement and evaluate the flood warning system (in-kind from agencies and Council, voluntary for community members).

Using a seven percent discount for O&M, over a 20 year life cycle the total present cost of the recommended system is estimated to be $119,455 (plus the cost of any SMS alert calls over the 20 years).

Based on this costing, the benefit-cost ratio for the recommended suite of options is 0.37 which although appears a poor result, masks the primary need to ensure public safety in a fast rising flood.

4.2 SUMMARY OF PREFERRED TFWS OPTIONS

A package of integrated options is recommended (Section 3.3); however, it largely depends on the efficacy and efficiency of the rain gauge and SMS setup to alert residents.

One means of providing fully automated rainfall-based community flood alerts for the Russells Creek catchment is by connecting the proposed new ERTS real-time telemetry rain gauges to the Enviromon system via a base station located at Warrnambool City Council.

Enviromon is the system used by the BoM to provide alerts based on rainfall rates over specified periods. Figure 12 is a screen grab of the graphical user interface (GUI) of the BoM's Enviromon system.

The BoM already has sharing arrangements for Enviromon with local and state agencies, but this would require further discussion with the BoM's Regional Flood Warning Manager to confirm details of this and to work through several policy and governance implications.

One of these key considerations is the service level assurance and the liabilities involved in case an alert is not received or Enviromon did not detect, or had a system failure.

Enviromon could be interfaced with Telstra's Integrated Messaging (TIM) system powered by Soprano Multimedia Messaging Service (MMS) in much the same way as Melbourne Water's SCADA system interfaces with the TIM (Rasmussen, 2013).

MMS on Telstra Integrated Messaging is a simple but highly useful online tool for broadcasting rich multimedia (text, image, audio, and video) messages to a contact or number of contacts simultaneously.

Figure 13 provides a schematic overview of how the automatic real-time gauges could report rainfall data to the Enviromon base station where rainfall intensity alarms are configured and triggered to initiate pre-determined notifications and external messages via the TIM web-based system.

The Telstra TIM (Soprano) system receives a short message peer-to-peer (SMPP) from Enviromon which initiates the multiple SMS messages to nominated phone numbers.

Another aspect of this system is the need for opt-in by the landholders that would experience above floor flooding. If these people are not interested (or only a few are interested), there may be little value in developing the SMS system and leave people to use situational awareness based on the BoM's generalised warnings of weather conditions and their own observations. Either way, pre-learning (community flood education) is critical so that people react quickly to triggers to ensure safety and, if possible, reduce damages (e.g. lift valuable items, take key documents if evacuating).

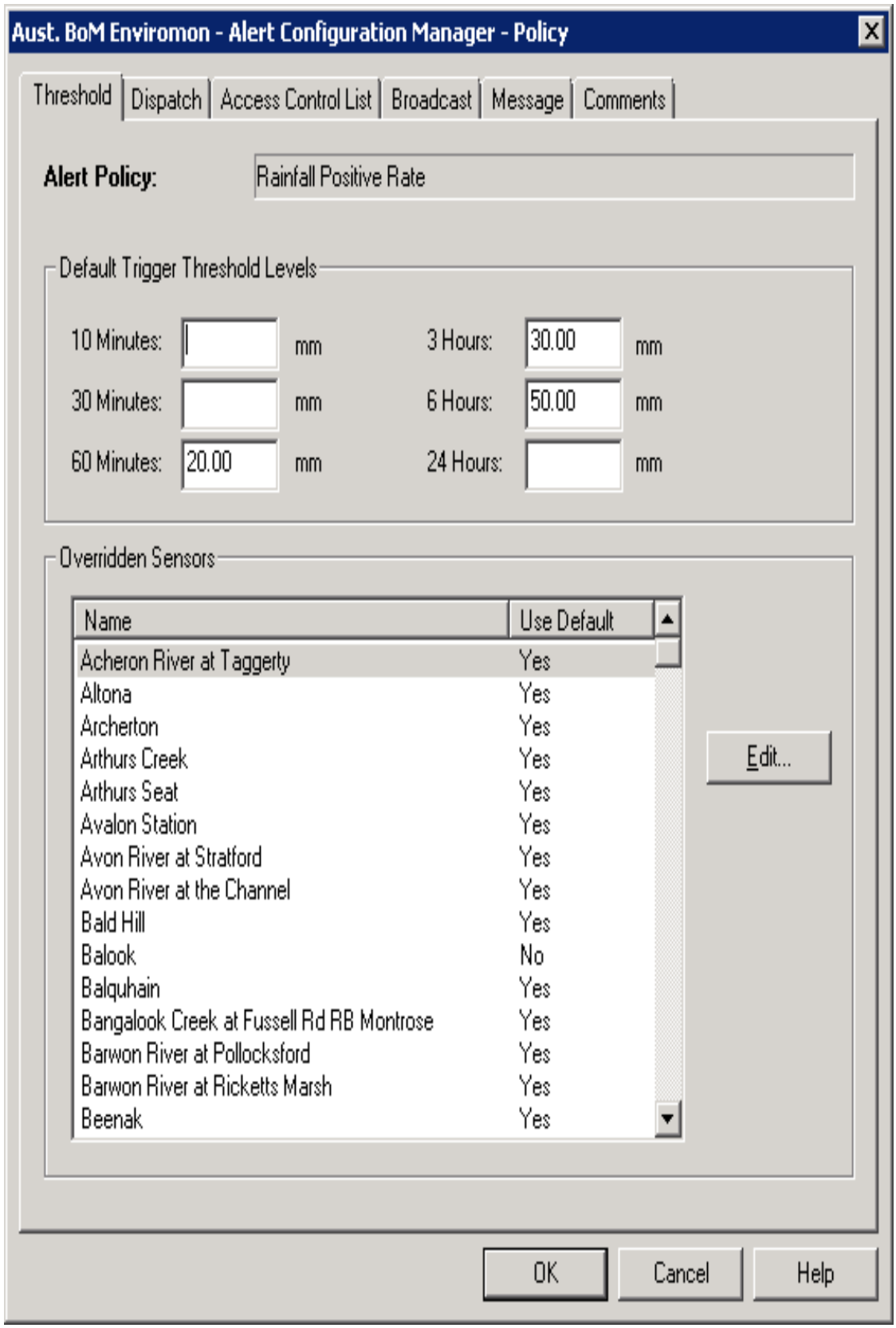

Figure 12: Screen grab of the graphical user interface (GUI) of the Enviromon system.

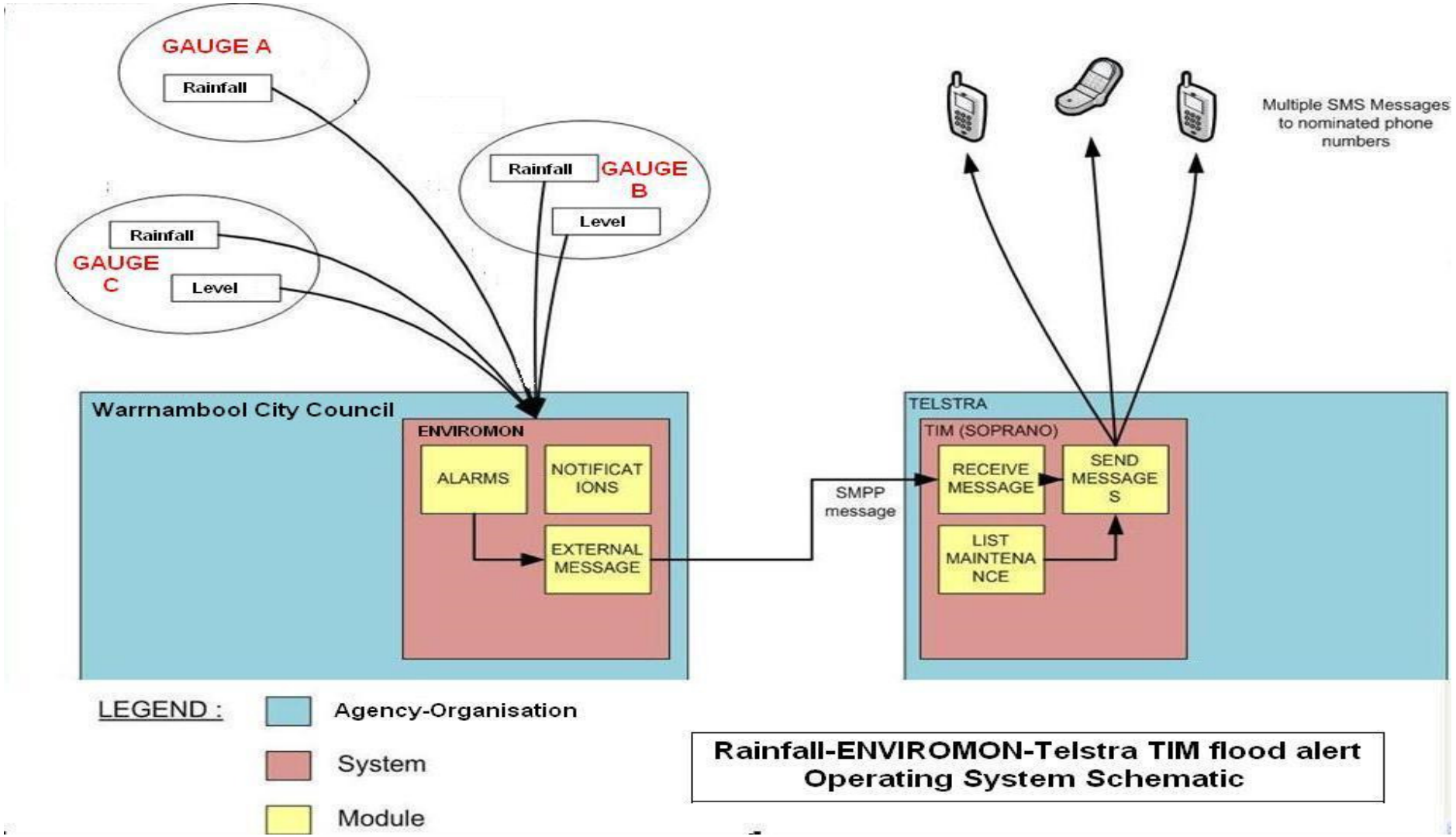

Figure 13: Schematic overview of how the automatic real-time gauges report rainfall data to the Enviromon system and to Telstra's TIM system for SMS alerts (after Rasmussen, 2013)

5 PART 3 – DEVELOPMENT PLAN

5.1 BACKGROUND

A flood warning service needs assessment was conducted for the Russells Creek catchment located in north Warrnambool. The assessment was conducted by Molino Stewart Pty Ltd in liaison with a Technical Steering Committee consisting of:

- Glenelg Hopkins CMA
- Warrnambool City Council
- DEPI Floodplain Management Unit
- VICSES
- BoM
- Local community stakeholders.

The assessment examined the components of the Total Flood Warning System (TFWS) as per the Australian Government's Manual 21 – Flood Warning. The TFWS components examined were:

1. Understanding of flood risks and hazards
2. Emergency management planning
3. Community flood education
4. Data collection
5. Flood prediction and interpretation
6. Message construction
7. Message communication
8. Response
9. Review of the TFWS
10. Community and stakeholder consultation

The assessment found that due to a very short warning time of up to one hour it is not possible to build a TFWS across all of the above components. The best that can be achieved is to build a system to alert residents of possible danger that triggers their pre-learned actions for safety and, if possible, to reduce damages.

The assessment also found that the alert mechanism options are limited due to the very short warning time.

As a result of the assessment, the following integrated package of options was identified for a Russells Creek flood warning system:

- Use of the existing BoM warning services and products including severe weather warnings, severe thunderstorm warnings and radar information and maps.
- Data collection provided by the installation of two rain gauges and telemetry in the Russells Creek catchment.
- An opt-in alert system linked to the rain gauges providing SMS messages to the mobile phones of flood-affected residents.
- Tailored community flood education that provides pre-learning for the impacted residents including appropriate responses in relation to cues such as the BOM warning services and SMS alerts triggered from rain gauges.
- A completed Warrnambool Municipal Flood Emergency Plan that addresses the proposed Russells Creek flood warning system.
- Emergency management plans (including flood response appropriate actions) for the Goodstart Early Learning Childcare and the St Joseph's Primary School.
- Ongoing community consultation through a Russells Creek Flood Warning Committee to establish, test, implement and evaluate the flood warning system.

Five suggestions for improving the Russells Creek flood warning service were also identified in the assessment.

- Additional river level gauge component to enable review of the hydrological and hydraulic data related to a flood event
- Use of a local social media site (e.g. Facebook) that provides warning information and allows people to warn others and emergency agencies
- A social research study to examine aspects of the potential response of residents with possible resultant actions for emergency planning, community flood education and community development

- A vulnerable persons register be developed for those at-risk properties in the Russells Creek catchment
- Use of a flood warden or similar program to encourage community leadership to help others in the catchment.

5.2 PRIORITIES

Although the integrated package of flood warning options is recommended for Russells Creek, the alert system is the most vital as the other elements feed into it.

For the alert system it is suggested that a means of providing fully automated rainfall-based community flood alerts for the Russells Creek catchment is by connecting the proposed new real-time telemetry rain gauges to a locally-based Enviromon system via the ERTS communication protocol.

Enviromon could then be interfaced with Telstra's Integrated Messaging (TIM) system powered by Soprano Multimedia Messaging Service (MMS).

5.3 COSTINGS

A costing for the recommended package of flood warnings is as follows:

- Complete Warrnambool MFEP (in-kind Council)
- Complete emergency management plans for the Goodstart Early Learning Childcare and the St Joseph's Primary School (in-kind for these facilities)
- Tailored community flood education project ($20,000 to establish, plus VICSES and Council in-kind to maintain)
- Use of the existing BoM warning services and products (no cost)
- Data collection provided by the installation of two rain gauges and telemetry in the Russells Creek catchment ($20,000 installation plus $7,500 O&M per year)
- An opt-in alert system for SMS messages to mobile phones of flood-affected residents triggered by rainfall alerts from the rain gauges connected to a local Enviromon system at Warrnambool interfaced to a telephone alerting system (no cost to install for the telephone alerting system, 10 cents per call thereafter)
- Ongoing community consultation through a Russells Creek Flood Warning Committee to test, establish, implement and evaluate the flood warning system (in-kind from agencies and Council, voluntary for community members).

The total cost estimate for a 20 year cycle is therefore $119,455 (plus the cost of any SMS alert calls over the 20 years).

5.4 ACTION PLAN

The following actions are recommended to establish and implement an effective flood warning system for the Russells Creek catchment:

1. Commence a Russells Creek Flood Warning Committee for the governance of the following actions.
2. Consult with the Russells Creek flood-affected community regarding its interest in opting in to the SMS alert service.
3. Seek financial support for the SMS alert system if there is community support.
4. Develop, test and implement the SMS alert system.
5. Develop, test and implement the community education program in relation to the BoM's warning services and the alert system.
6. If there is no or little support for the SMS alert system, use the remaining options to build a system based on situational awareness using existing services.
7. Consider the other suggestions to improve the flood warning service for Russells Creek that are listed in the Molino Stewart report.
8. Develop and implement a flood warning system monitoring and evaluation plan to review and improve the flood warning system as required.

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