GIPPSLAND LAKES FLOOD WARNING SYSTEM – A COLLABORATION OF SCIENCE, PLANNING AND COMMUNITY

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Abstract

There are few opportunities to create a total flood-warning system from scratch, or of creating a purpose built flood-warning system with all agency integration. To do so in such a highly complex and variable environment as an estuarine system with a catchment of over 2 million hectares, seven rivers and a surface area over 300km^2, is even more of a challenge. A challenge to which the Catchment Management Authorities, Bureau of Meteorology, State Emergency Service, Local Government and the community of the Gippsland Lakes have risen.

The Gippsland Lakes in eastern Victoria are a group of RAMSAR recognised coastal lagoons fringed on the seaward side by Ninety Mile Beach, with a single outlet to the sea at the township of Lakes Entrance. These lakes pose a unique flood risk where frequent events (< 5% AEP) cause significant impacts on the ten communities around the lakes' edge. The complex set of variables that influence the lakes has intrigued many a researcher and PhD student over the years. This has provided the opportunity to create a new, fully integrated and innovative estuarine flood warning system requiring a highly complex hydrographic modeling tool, LiDAR mapping, infrastructure, warnings, organisational partnerships, flood intelligence and community information and engagement. The system is centred around a purpose-built flood forecasting tool which takes in a plethora of variables including the inflow volumes and timing of seven different river systems, initial lake levels, wind, tide, waves and coastal ocean levels, in order to produce accurate and timely predictions for use by response agencies and to ensure a thoroughly prepared community.

This paper describes the comprehensive flood warning system developed for the Gippsland Lakes and the agency integration that has underpinned its development.

Introduction

The current community and Government landscape surrounding emergency warning in Australia and Victoria presents both opportunities and challenges.

Following major fire and flood events around the country, Government funding has been granted to upgrade infrastructure and focus on community preparedness and resilience. There is an intensity of focus to 'get it right' in a field of science that is dealing with extreme and somewhat unpredictable events and with community expectations at a pitch not generally experienced in emergency management.

Amongst this pressure of expectation, is a post event momentum that can be harnessed to create change where otherwise there is recognized community apathy.

At present, we are in a space where the community is not only activated and interested in change, but demanding change. A space where Governments at all levels are

cognizant of their risk exposure and their community responsibility, to better manage emergencies.

This culmination of a call to action by both community and Government is the key to making any real change and is most definitively the key to the successful creation and agency integration of the Gippsland Lakes Flood Warning System.

The Total Flood Warning System

We have come a long way from the days of passing information to downstream communities by telegraph to warn of floodwaters. In more recent times, there is a different expectation.

There is much written advice about flood warning systems and in Australia there is an agreed definition of what a flood warning system consists of. The key components are defined in the Australian Emergency Manual: Flood Warning (Attorney-Generals Department: Commonwealth of Australia, 2009) as:

- Monitoring of rainfall and river flows;
- Prediction of flood severity and time of onset;
- Interpretation of the prediction to determine likely flood impacts;
- Construction and dissemination of warning messages describing the expected impact and what actions should be taken;
- Response to the warnings by agencies and community; and
- Review of the warning system after flood events.

But as Chas Keys noted (Keys, 1997), "*the development of warning systems has been Topsy-like… rather than carefully and purposefully planned, and in such circumstances the various elements are likely to have developed to differing degrees and to be only flimsily tied together."*

To be effective, a flood warning system must encompass all components equally and in an integrated fashion. The weather forecasting systems, hydrologic modeling, accurate information about time, depth, velocity and reach of impact, timely and meaningful community messages and, most importantly, a community aware enough to receive those messages and take appropriate actions.

Keys (1997) described an aspirational target of a flood warning system that was multi-dimensional and meshing. One that would reflect the needs of flood prone communities, provide high levels of accuracy and be clearly understood by its clients. He went on to state that it was doubtful if any warning system existed that justified that title.

The agencies and communities of the Gippsland Lakes are on their way to justifying it.

Gippsland Lakes Overview

The Gippsland Lakes is the largest inland network of waterways in Australia, separated from Bass Strait by a series of narrow sand dunes and joining the sea through an artificial entrance at its eastern end.

The Gippsland Lakes system comprises three major water bodies interconnected with complex channels and is fed by seven major river catchments that are large enough for floods not to occur simultaneously. There is a maximum wind fetch of about 50 km exposed to frequent strong wind events and a connection to the Bass Strait subject to significant coastal ocean level variations, due to atmospheric effects and coastally trapped waves.

The Latrobe, Thomson, Macalister, Avon, Mitchell, Nicholson & Tambo Rivers all flow into the Lakes through a varied 20,000km^2 catchment landscape which includes open cut coal mines, power generation plants, timber harvesting and paper production, major water storages, Ramsar wetlands and agricultural pursuits including irrigation, horticulture and grazing.

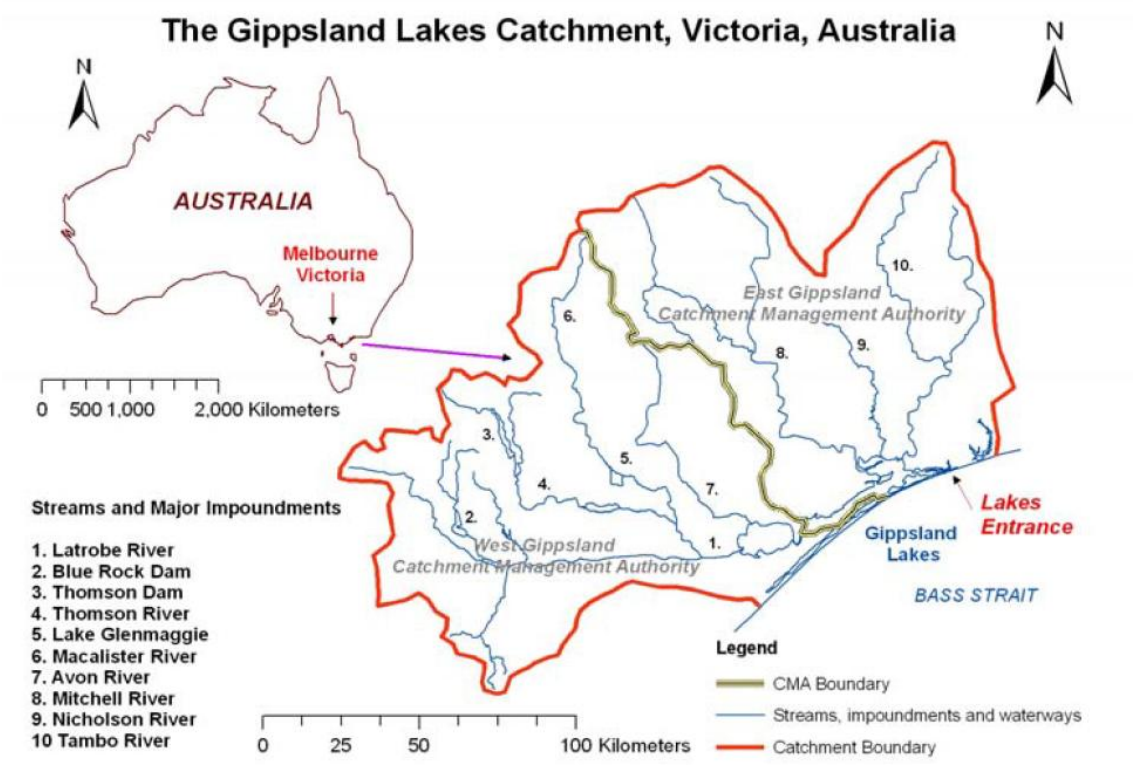

Figure 1 The Gippsland Lakes Catchment, Victoria, Australia (Wheeler, Kunapo, Peterson, & McMahon, 2007)

There are ten communities dotted around the lakes' edge, the largest being the popular tourist and fishing town of Lakes Entrance with a permanent population of approximately 5,500. Many of these communities experience significant flooding every ten years or so (Grayson, et al., 2004).

Over 2000 homes and businesses in the Gippsland Lakes are at risk of flooding within the extent of a 1 in 100 year ARI event, with a further 3000 isolated. Much of the public and private infrastructure in these communities is very low lying, with major impacts and isolation in some towns at less than a 1 in 20 ARI event. Many towns first experience flooding in properties and on roads from lake water back flowing through the stormwater system.

The balance between high tidal levels and flooding is so fine that in Lakes Entrance for example, the difference between levels created from a high tide joined with a strong south westerly wind compared to the classified Minor Flood Level is as little 10cms.

Many of the lakeside communities have felt the sea change phenomenon, which has brought with it both development pressures and a population churn factor. The development pressures from increasing population have created tension between local landholders and government authorities regarding sea level rise and changing planning requirements around land subject to inundation.

Due to the influx of sea changers, many in the community do not have a history of flooding or any local familial support and are of an age where they are likely to be more vulnerable to events through complacency and/or incapacity to self respond. These are key factors in whether a community is resilient in the face of natural disaster (Gissing, Keys, & Opper, Future Challenges and Directions of Flood Emergency Management, 2010).

Gippsland Lakes Flood Level Modelling Project

In 2004, a major study of flood levels in the Gippsland Lakes was completed by the Centre for Environmental Applied Hydrology at the University of Melbourne. This study, the Gippsland Lakes Flood Level Modelling Project, developed a significant amount of new science to combine the effects of the many influences in the lakes system to derive estimates for 20, 50 & 100 year ARI flood levels around the lakes. The project produced a suite of models and technical assessments that could also be utilised as a basis for a comprehensive assessment of climate change scenarios and for real-time forecasting of flood levels (Grayson, et al., 2004).

This project also formed the basis for a further study led by Wheeler which examined the use of digital spatial data handling to create a spatial model to, amongst other things, “integrate information into local emergency services information systems and contingency planning” (Wheeler, Kunapo, Peterson, & McMahon, 2007). Wheeler was able to produce an interactive two and three dimensional visualization model which is now publicly available on the web – e.g. http://sahultime.monash.edu.au/LakesEntrance/ .

It was these two projects that led to predictions being possible during a major flood event in 2007 - Grayson’s modelling to provide the predictions and Wheeler’s visualization tool being used extensively to communicate the translation between lake height and horizontal inundation to emergency services and the community.

2007 Flood Event

In June 2007, a series of intense east coast low pressure systems produced well above average rainfall totals across Gippsland resulting in most rivers approaching record flood levels (Bureau of Meteorology, 2007) which ultimately increased normal water levels in the Gippsland Lakes by over 1.3m (East Gippsland & West Gippsland Catchment Management Authority, 2010).

With an estimated ARI of between 20-30 years, the 2007 event saw more than 100 buildings flooded above floor level (Grayson, et al., 2004). More than 180 homes and businesses were impacted by flooding or isolation in Lakes Entrance, Paynesville and Raymond Island, including Ambulance, Fire Station and Municipal Offices. Many homes were isolated for up to two weeks. (East Gippsland & West Gippsland Catchment Management Authority, 2010)

Flood Warnings were being issued for many towns and rivers in Gippsland at the time but with flooding imminent for many of the towns around the lakes edge, the Bureau of Meteorology had no capacity to monitor or model floods in the Gippsland Lakes nor to provide any warnings.

No warnings had ever been issued for the Gippsland Lakes as no flood warning system existed. However, the West and East Gippsland Catchment Management Authorities were able to provide some level of flood prediction during the event by manipulating the models produced as part of the Gippsland Lakes Flood Modelling Project.

This resulted in general warnings being issued for the Lakes and allowed for VICSES, Local Government and the community to take some actions to mitigate risk, including evacuations, sandbagging and community meetings.

According to Grayson, the Gippsland Lakes also experienced large impact floods in 1998, 1978, 1952 and 1893.

The Gippsland Lakes Flood Warning System

After the 2007 flood event, the Victorian Government funded the development of a flood warning system for the Gippsland Lakes, including the installation and upgrade of river and lake monitoring equipment.

Remembering the key components of a flood warning system are essentially: monitoring, prediction, interpretation, messaging, response and review, the Gippsland Lakes Flood Warning System, while unique, would still have to address all of these components to be effective. Components that did not yet exist, essentially a Greenfield site for further development.

Monitoring of Rainfall and River Flows

The Bureau of Meteorology already monitors rainfall and river flows in the catchment and river basins of the Gippsland Lakes which allows for appropriate flood predictions in those river systems.

However, a need was identified for further monitoring to allow for predictions within the Lakes system. The upgrades that were identified included three river flood hydrograph estimation sites and five new lake level monitoring sites (Sinclair Knight Merz (4), 2011).

These sites are now direct feeding to the Bureau of Meteorology website, providing emergency response agencies and the community with real time data to monitor the emerging situation during a flood event as well as the information required for predictions.

Prediction of Flood Severity and Time of Onset

The flood prediction component of the warning system has a significantly different structure to what is generally found in flood warning systems. Due to the complex interaction of contributing factors, rather than it being based on hydrodynamic models

of inputting rivers, it is based on matching the developing conditions against the suite of models from Grayson's project.

A software tool, the Flood Level Assistant for the Gippsland Lakes (FLAGL) was created by Sinclair Knight Merz (SKM) which utilises a case matching approach to provide predictions. The tool compares current real-time data on the contributing factors to a database of over 300 modelled events which were stochastically generated and validated against historical data. This database provides hourly time step data for the contributing factors, ie volume and timing of tributary inflows, lake levels, wind set up, tidal influence and coastal ocean levels (Sinclair Knight Merz (1), 2011).

The prediction approach varies as the flood event progresses. Initially, with onset several days away, the predications carry a high degree of uncertainty as they rely on forecast data from the Bureau of Meteorology. As the flood event progresses, hydrograph inputs are more certain and lake levels will start to rise, both of which refine the prediction (Sinclair Knight Merz (5), 2011).

Predictions are able to provide lead times of greater than 24 hours from observed hydrograph peaks to observed lake level peaks at Paynesville and Lakes Entrance in 93% of instances. According to SKM, in almost all cases, at all sites, there is more than 18 hours lead time between observed hydrograph peaks and lake level peaks.

Lake level predictions are also able to prove a high level of accuracy with 81% of predictions within 0.1m and 99.7% within 0.3m, with a standard error of 0.086m. This is a higher level of accuracy than is generally experienced, as can be seen in Figure 2.

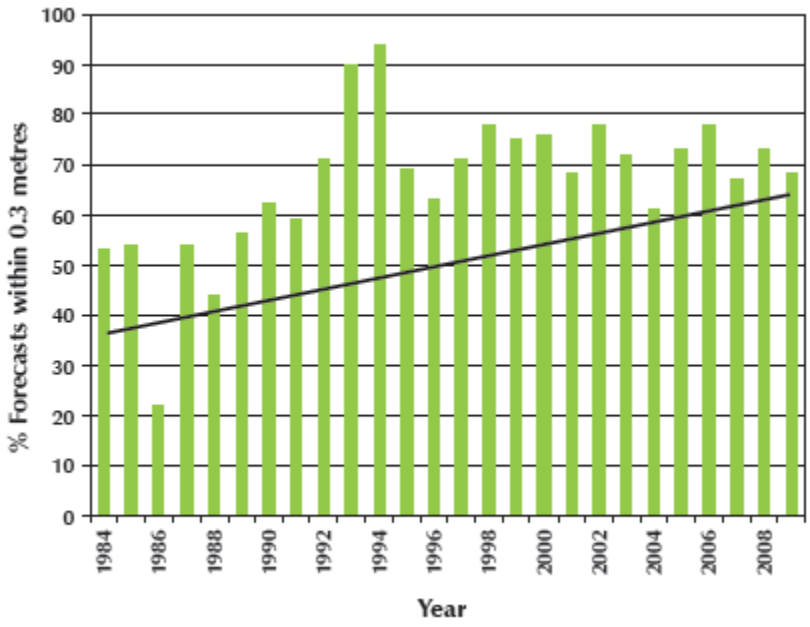

Figure 2: the Trend of Flood-Height Forecast Accuracy in NSW, 1984-2009
(Attorney-Generals Department: Commonwealth of Australia, 2009)

To enable a smooth process of monitoring and prediction, the tool requires integration into the current systems at the Bureau of Meteorology. The tool was utilised for test purposes during the last two Gippsland flood events in July and August of 2011, which highlighted the requirement for minor debugging. The tool is now in a process of development to enable direct data flow from the established monitoring systems at the Bureau into the tool.

The tool will operate under interim arrangements whereby the West Gippsland Catchment Management Authority runs the tool and provides predictions to the Bureau who issues warnings, until such time as the tool is fully integrated and tested.

The two local government bodies with responsibility for the Gippsland Lakes, the Wellington and East Gippsland Shires, are funding the operation and maintenance of the new and upgraded monitoring sites through the Gippsland Regional Water Monitoring Partnership.

Interpreting Flood Predictions

Flood Predictions alone are not meaningful to community members or response agencies. References to ARI measurements or gauge heights are not easily translated by the community. For warning messages to be meaningful, the predictions need to be translated into on-ground impacts.

This process of gathering and analyzing flood related information is referred to as flood intelligence and enables not only meaningful warning messages to be issued during an event, but also enables emergency response managers to determine the actual or likely effects of flooding on a community and to plan appropriately (Gissing, Bewsher, Campbell, Yeo, & Kidd, 2004).

Keys (2007) describes flood intelligence as “detailed information about timing, impact zone, depth, velocity, duration and the expected flood behavior up to, during and after the peak”.

An important component of the Gippsland Lakes Flood Warnings System is the LiDAR mapping that was produced as part of the Victorian Government “Future Coasts” project. The Catchment Management Authority was able to utilise this data to provide detailed flood mapping for the VICSES to create highly detailed Flood Intelligence Cards (FICs) for each locality. The FICs detail specific property, road and critical infrastructure impacts at particular gauge heights.

These FICs are utilised by response agencies, local government and the community before, during and after flood events.

Local Government is including them as part of their Flood Emergency Plans, VICSES is utilising them to form a body of suggested operational considerations for use during an event and some communities have taken the FICs and detailed their own community flood mitigation actions for the different gauge heights. Agencies will also be able to utilise the detailed property listings to assist with rapid impact assessment and recovery processes.

This information will also be used to inform individual property owners of what gauge height their property will be first impacted and when they are likely to become isolated, to enable them to plan appropriate actions to mitigate impact upon their home or business.

Construction and Dissemination of Warning Messages

The Australian Emergency Manual (AEM) for Flood Warnings describes a warning message as the critical link between flood prediction and interpretation on the one

hand, and the taking of protective action on the other; that a flood warning message should be influenced by the needs and characteristics of the community.

The diversity, both physical and social, of the impacted communities around the lakes requires tailored messaging and a multi-faceted and focused community engagement program to ensure the messaging elicits appropriate community responses.

With this in mind, the warnings have been pre-written for use by the Bureau of Meteorology and the VICSES during flood events. They are specific to locations but fall under the umbrella warning of the Gippsland Lakes.

In riverine flood warning systems, a flood warning is issued with a flood class reflective of the highest impact within that river system. The warnings for the Gippsland Lakes however have been written differently, where a flood warning will be issued for the Gippsland Lakes with no flood class level attached. Rather, a flood class will be attached to each town within the lakes.

In many events, different communities will be experiencing different impacts based upon their particular physical characteristics. To issue a Major flood warning for all communities on the Lakes based on a low lying community like Hollands Landing may well create panic in the first instance and then a mistrust of the warnings in the second.

With regards dissemination of warnings, all warnings will utilise the standard Bureau of Meteorology channels, value added messages will then be added by the VICSES and utilise their One Source One Message (OSOM) protocol to disseminate to media, other agencies, the web and provide RSS feeds.

In one instance, the Raymond Island community has instituted a community plan whereby their emergency committee subscribes to the RSS feeds and then on forwards the messages to an email listing of affected residents and door knocks or rings others who are not on email. This same community utilises an SMS alert system they initiated for specific more urgent warnings of evacuation or ferry closure. The community and VICSES has collaborated and produced prewritten warnings for use by VICSES during a flood event to ensure they are meaningful and effective.

Response to Warnings by Agencies and Community Members

According to the AEM on flood response, flooding is a highly manageable hazard where the flood risk can be defined and appropriate emergency preparedness and mitigation strategies developed (Attorney-General's Department, Australian Government, 2010).

Like all other hazards, flood response should use the four elements of a comprehensive approach to emergency risk management, i.e. prevention, preparedness, response and recovery.

Unlike many other hazards, lake and estuarine flooding is relatively easy to determine who and what will be impacted at different flood levels and therefore plan and prepare in advance to ensure response activities are focused and effective.

The flood intelligence cards mentioned earlier form the basis for response by agencies and the community by allowing time to work out in advance what actions should be taken by whom and when, to mitigate any flooding impact.

As part of its multi-agency collaborative approach, the Gippsland Lakes Flood Warning System has assisted in the development of local Flood Emergency Plans for the lakes communities. Local Government has embraced the plans and, with assistance and direction from the VICSES, are co-ordinating their production in a multi-agency approach to maximise the effectiveness of flood response across warnings, evacuations, relief centres, road closures etc.

It is well understood that those involved in the planning process are more likely to understand, accept and use an emergency plan (Gissing, Morgan, & Ronan, Planning for the Inevitable - Emergency Planning for Floods in NSW, 2007) and those who are not, tend to be confused when unable to relate gauge heights to their particular business or home (Gissing, Business in the Macleay, Commerical Flood Damage Kempsey 2001, 2002).

The objective of the multi-faceted and tailored community education and engagement plan was for all communities to collaborate with messaging and produce their own community and home flood emergency plan. With the assistance of local government and the VICSES, many communities around the lakes are in the process of developing these plans.

In addition to these meetings and sessions, the FloodSafe program of the VICSES is being utilised along with direct mail to properties at risk with information about their specific risks.

Review

A component of the flood warning system yet to be addressed is that of review. For any flood warning system to remain alive and current, it needs regular review and exercising. There are flood mitigation works in progress in some of the towns along with changes to the physical environment. These, along with changes in agency staff and community members means community and agency education and engagement must continue, especially during long stretches without flood events.

It may well be appropriate for performance indicators to be set to allow for a formal review process of the flood warning system. With a goal of continuous improvement, the AEM on flood warning provides a useful guide for reviewing the performance of a flood warning system with a suggestion that agencies responsible for the various components of flood warning systems should develop appropriate Key Performance Indicators (KPIs) relevant to the components for which they are responsible (Attorney-Generals Department: Commonwealth of Australia, 2009). It suggests the following KPIs for flood warning systems:

- Prediction accuracy and timelines;
- % of those who were advised to evacuate who actually did; and
- Evidence of community acceptance and comprehension of the warnings.

Collaboration / Agency Integration

From the beginning, the Gippsland Lakes Flood Warning system has been a collaborative effort. Partnerships were already established and the community and agencies identified the need for a flood warning system specifically tailored for the Gippsland Lakes communities. The best way forward was to do what Gippsland does best, collaborate to achieve a common goal.

East and West Gippsland CMAs, VICSES, Wellington and East Gippsland Shires, Bureau of Meteorology and many other emergency agencies are contributers to the flood warning system. Local government, along with their statutory roles, also provides key linkages to their communities.

It was well understood from the beginning that the most important collaboration is that of community. For without understanding their needs from the outset, the flood warning system could not function as effectively. There are 10 separate communities across a large area and with different needs and capacities and impacts. As discussed previously, to be effective, engagement needed to be tailored to each individual community.

Each agency has their particular skill set and area of responsibility, with the Steering Committee established for guidance. As each organisation completed their component, it is discussed and tweaked to allow for full integration and a better understanding of organizations in their roles in preparation, planning and response and recovery.

That's not to say the collaboration has always been easy or the path immediately obvious. If nothing else, the process has highlighted the lack of defined pathways to enable the collaboration required. The project steering committee and those charged with the delivery of the flood warning system have had to feel their way through a winding path of legislation, regulation, privacy issues, data licences, interpretations of responsibility, resourcing capacity and different prioritizations.

The art to good collaborative outcomes is the will of the agencies and the community to achieve the outcome and work through the road blocks. In the case of the Gippsland Lakes Flood Warning System, this has been and is continuing to be achieved. It has paved the way for more success in flood warning systems and flood emergency plans throughout the region.

Conclusion

The Gippsland Lakes pose a unique flood risk and requires a unique flood warning system to be effective at reducing impact and making its communities more resilient in the face of natural disaster.

Although the Gippsland Lakes Flood Warning System may not yet completely justify the aspirational title suggested by Keys, the communities of the Gippsland Lakes were given an opportunity and chose to aim for that aspirational target of a flood warning system that reflects the needs of flood prone communities, provides high levels of accuracy and is clearly understood by its clients.

The Gippsland Lakes Flood Warning System is well on its way to achieving that target as it is responding to a community identified need, provides high levels of accuracy and, through a multi-faceted and focused education and engagement strategy, aims to ensure its clients, the community, understand the outputs and are able to take mitigating actions based on those outputs.

Anything that makes our communities more resilient in the face of natural disasters and makes our organisations more effective adds value to our communities.

Acknowledgement

Andrew Gissing, Director Emergency Management Planning & Communication, Victoria State Emergency Service

Clint Saarinen, Regional Manager, East Region (Gippsland) Victoria State Emergency Service

Anna Larkin, Community Resilience Co-ordinator, East Region (Gippsland), Victoria State Emergency Service

Kate Nelson, Manager Community, East Gippsland Shire Council

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