Australasian Hydrographer

September 2020

AUSTRALIAN HYDROGRAPHERS ASSOCIATION

AHA

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Contents

Acknowledgement of Country

The AHA acknowledges the Australian Aboriginal and Torres Strait Islander peoples of this nation. We acknowledge the traditional custodians of the lands on which our association is located and where we conduct our business. We pay our respects to ancestors and Elders past, present and emerging. The AHA is committed to honouring Australian Aboriginal and Torres Strait Islander peoples' unique cultural and spiritual relationships to the land, waters and seas and their rich contribution to society.

JACQUIE BELLHOUSE

Editor-In-Chief's Introduction

Welcome to the September 2020 edition of the Australasian Hydrographer. I am quite excited this month, not just because spring is in the air, but rather because our modest Australasian Hydrographer editorial team is growing!

With the Australasian Hydrographer now firmly entrenched as the Australian Hydrographers Association's quarterly publication I find I am forever on the hunt for interesting articles, snippets of information and eye catching photography to present to our readers. I spend quite a bit of time between my work commitments doing this, and trying to ensure the content has appeal for our extremely diverse reader base. Unfortunately as a consequence, at times, I haven't always had the time to review the overall structure of our publication in order to ensure it will continue to not only engage with our readers but also remains relevant and sustainable, in this rapidly changing world.

With this in mind the AHA has convened the *Publications ThinkTank* and with it we welcome two new members to our editorial team, Harry Schofield and Zac Ward CPH. The aim of the ThinkTank, populated by a range of volunteers, is to not only spread the load but to empower the editorial team to find innovative new ways to keep our fellow hydrographers informed within an ever evolving technological industry.

In celebration, and by way of introduction, we will be featuring profiles from each of our Editorial team. This month our editor and AHA committee member Harry Schofield has kindly provided us with a brief profile. Accompanying Harry's piece is a second profile from one of our recent Diploma graduates Andrew Blair CPH.

We also have a couple of great short papers from our members, Mike Lysaght on the highest USA rainfall event for 24 hrs when, in 2018, 49.64" of rain was recorded by a TB4 Tipping Bucket Rain Gauge (*"Historic Rainfall Record Broken in US"*) and Matt Saunders on spiking conductivity readings in an urban creek (*"Conductivity Readings Spike with Flows in Urban Creek"*).

And finally for those who have enjoyed our 2018 Conference series we have also included Nick Boyens paper "*The right message, to the right person, in the right way, at the right time: Review of Greater Wellington Regional Councils Flood Warning Service*".

We hope you enjoy our latest edition. If there is anything you would like to see us include in future editions or if you have a paper you would like to contribute please do not hesitate to contact myself and the team at journal@aha.net.au

Jacquie Bellhouse CPH
Editor-In-Chief

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Looking Forward VEGA

ARRAN CORBETT

From the President

The professional Hydrographer today may face a wide range of monitoring applications and tasks, each bringing their own unique challenges and considerations. Possibly two of the larger tasks that we are typically charged with are natural resource assessment (long term baseline data) and operational hydrometric monitoring (what is the flow/volume/level/quality right now).

Looking more closely at assessment, which has traditionally been carried out by state employees or state contractors, there is a need for a high standard of accuracy, precision and overall quality. Tight quality control measures support high end instrumentation whilst redundant systems ensure the continuity of these often long scale time series records. These records are usually collected to a legally defendable standard.

If we turn to operational water flow / volume / level / quality data we see a lesser requirement for precision but the data is no less important. It is required in order to answer questions such as:-

- Is there enough water present to irrigate?
- Is there water over a road or is my town about to be flooded?
- Is the water safe to drink?

Operational data usually calls for greater granularity at near real time so capital outlay becomes an issue; as does the ongoing operational expense. These factors may force a cost compromise on precision and accuracy but not reliability.

With the above examples of the common challenges we all face, we must endeavour to be explicit from the outset in our dealings with everyone from manufacturers to senior leadership. For the former, if we can clearly explain our requirements, we will receive the right equipment at the right price (and guide future industry development). For the latter, clarity will guide capability expectations and assist in appropriate budget setting. All of these make for a better outcome.

My point with this is simple — we as Hydrographers must be agile and open to change. We must embrace the challenge in front of us and be able to continue to provide the high quality service that we always have, no matter the application.

To help you, the AHA is committed to continuing its work to improve hydrometric skills and knowledge, develop and maintain standards and raise the overall profile of the hydrometric monitoring industry. We strive for a future where the hydrometric monitoring industry is in full control of its future and even more importantly remains both relevant and sustainable, in this rapidly changing world.

And finally... for some (of course depending on where you are in Australia), the wet season is just around the corner. With a 70% chance of La Nina conditions forming in, it appears some parts of the country could be in for a decent season! And for those who are perhaps moving into a dryer (and quieter?) period, now is perhaps the opportunity to cross off some of those maintenance tasks. Whatever phase you are moving into, please take care to ensure your gear is in good order, your PPE is up to scratch and by all means you stay safe!

Arran Corbett CPH
AHA President

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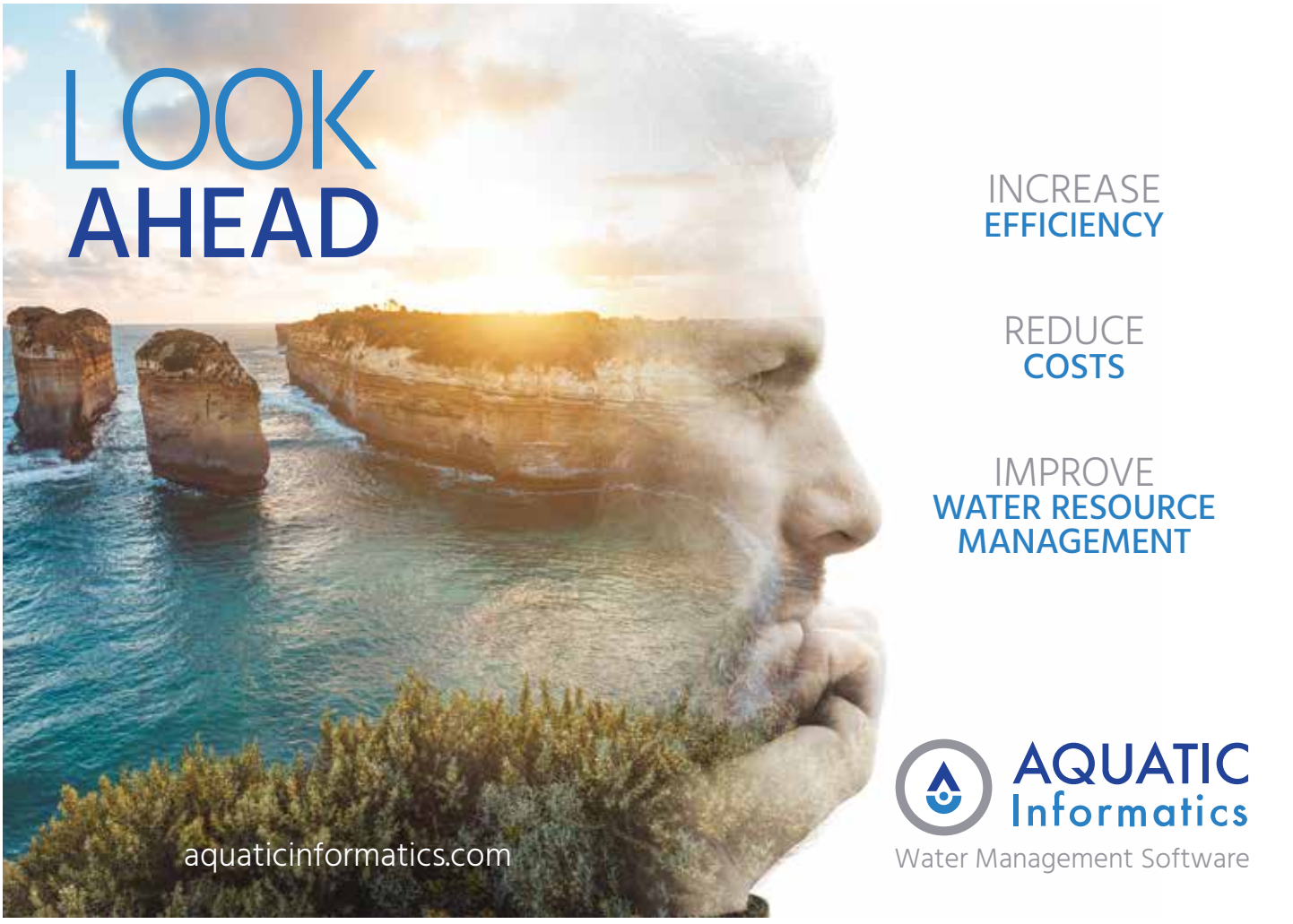

INCREASE
EFFICIENCY

REDUCE
COSTS

IMPROVE
WATER RESOURCE MANAGEMENT

AQUATIC Informatics
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AHA Member Profile: Harry Schofield

Describe your current role.

I am currently employed as the Bureau of Meteorology's (BoM) Flood Warning Networks Lead for the Perth hub. This position involves collecting river and rainfall data from across most of Western Australia (WA) for flood warning purposes. I manage over 100 monitoring stations using varied and resilient data communication methods to ensure data continuity during severe weather events. Due to WA's remote landscapes, many catchments have very limited monitoring and I'm required to design, implement and maintain new flood warning network infrastructure to allow for improved flood warning services to WA communities.

What hydrometric (or other) qualifications relevant to your role do you have?

A *Bachelor of Science (Geosciences)* with Honours and attendance at several AHA short courses.

What do you consider some of your major career achievements to date?

Being awarded the **"Alex Miller Award"** for best presentation at the 2014 AHA Conference, to date is my standout achievement.

But I have also had varied experiences throughout my career working in the following areas of the industry:

- Wastewater (e.g. sewage, drainage) / urban hydrometrics in NSW for Sydney Water
- Traditional 'river or fresh water' (surface water) hydrography in New Zealand at a regional council
- Hydrographer and water resources management at Tasmanian Irrigation, focusing on water storage and extraction measuremnts and water licence compliance
- Hydrography for flood warning purposes at Bureau or Meteorology

Ed: And now Harry can add 'joining both the AHA Committee and the Australasian Hydrographer editorial team' as another career achievement. Welcome to the AHA team Harry!

How did you end up in the hydrometric profession?

Hydrometric data collection including water quality monitoring was my first job out of university. I applied for the position because it was a job that involved working both indoors and out (albeit in sewers) that also had a scientific element.

Where has hydrometry taken you in the world?

In my relatively short career in the industry (~10 yrs.) my work has taken me to awesome places including the far north of New Zealand, into the wild forests and untouched rivers of Tasmania, to Sydney's largest Wastewater Treatment Plants and into remote and vast areas of WA where the catchments of rivers are larger than the overall state of Tasmania.

What has been the most memorable experience (good or bad) in your career?

When undertaking a flow measurement in a remote river in Tasmania's North East a platypus jumped into the water right in front of me and had awesome play not noticing me for some time.

What makes our profession interesting?

Being able to work in the great outdoors, on projects that benefit our community.

What do you do when you are not at work?

Doing my best at raising two young boys, bush waking, playing cricket and watching sports when I get the chance.

How do you think hydrometric monitoring will change in the future?

I believe the industry will become increasingly more important for Australian communities as water resource stresses and unpredictable weather result from a changing climate.

AHA Graduate Profile: Andrew Blair CPH

Describe your current role.

Currently, I am employed by the Water Corporation of Western Australia (WA) in the Asset Monitoring and System Investigations section (AMSI). AMSI provides a range of asset monitoring services and this encompasses our hydrometric monitoring team. I am currently on a hiatus from my original role as a Hydrographer and at this moment manage the Canine Leak Detection Program for the System Investigation side of the business. Essentially, we have trained a young Springer Spaniel to sniff out chlorinated water underground. This allows us to find leaks from the supply scheme in otherwise problematic lengths of pipeline around farmland areas of WA. Traditional leak detection technologies are impractical in many rural areas due to the lack of assets (e.g. air valve, section valve, etc.) and exposed pipeline for acoustic technologies to cost effectively locate water leaks. The scent detection canine has proven to be very valuable to the Water Corporation saving us time, money and most importantly water.

Figure 1. Andrew planning a discharge measurement at Bannister Creek, Western Australia.

Aside from graduating with a Diploma what do you consider your major career achievement to date?

A Pressure Management Program was run on a variety of networks here in the Perth metropolitan area and surrounds. I was responsible for collecting water quality, pressure and flow data in each network. Some of the methods used, to collect the hydrometric data were new to the section. This included learnings for AMSI, e.g. the operation & troubleshooting of a continuous monitoring water quality device (Chloroclams) and Flexim Ultrasonic Flow Meters (clamp on). Learning to install and monitor these instruments taught me a lot about how chlorine behaves in water, how pipe material affects the ultrasonic sensors and most importantly how pressure and flow can impact the level of chlorine at various locations along the supply network. The program was running for at least two years and the data collected was used to better understand and manage the Perth water supply scheme.

How did you end up in the hydrographic profession?

In 2007, immediately after Year 12, I applied for a job with the Water Corporation as a Trainee Engineering Hydrographer in Engineering Data Services (EDS) under Allan Deane. For the next three years I spent the majority of my time maintaining Gauging Stations, Meteorological Stations, becoming familiar with Hydstra, learning the importance of collecting good quality data and finding instruments that are fit for purpose. At this point I took a four year sojourn with the Australian Army as an Infantry Soldier learning the ins and outs of some very different instrumentation. I was deployed to Afghanistan in 2012 and left the military in 2014. After spending two years touring Australia with my brother and my dog through various jobs around the country, I found myself back at the Water Corporation as an Asset Monitoring Officer (the Corporations job title for its Hydrographers) in 2016. I commenced my studies in the *Diploma of Water Industry Operations (Hydrography)* in 2017 and completed this study through the AHA in August 2020. In August 2020 I was also recognised as a Certified Practising Hydrographer (CPH).

Was there anyone who has had a major influence?

Zac Ward has been a major influence on me and has been an inspirational mentor. Zac was a junior Hydrographer when I first started my career back when I was a fresh faced 17 year old. That was 13 years ago and in that time he has worked his way up to be the Supervisor–Asset Monitoring Team. Zac is that kind of manager/supervisor that every worker hopes they get but rarely ever does. His dedication to his team is second to none and the extent of his knowledge in hydrography is enviable. I would not have completed my studies without Zac, and I do attribute my attainment to his expert guidance.

What has been the most memorable experience so far?

My most memorable experience was one of baptism by fire, or in this case by rain. I was with Trevor Barnes (Senior Hydrographer) and on an away on a trip to the South West Region (SWR) of WA, Narrogin, to perform some discharge measurements at the local gauging stations. This was in my first year as a trainee and it was winter in the SWR so why would I bring a rain jacket? Armed only with a thin jumper, Trevor had me holding the OTT C31 current meter in the river all day with the rain pouring down. I could not feel my feet by the end of the day and learned a very valuable lesson in the process.

Figure 2. 609020 Walker Rd Gauging Station, Narrogin.

Figure 3. Walker Rd Gauging Station view downstream.

What do you think makes hydrometric monitoring interesting?

The applications of hydrometric data are seemingly endless. So much can be understood and interpreted from accurate data and I think that in the future the implementation of this information to make decisions on climate change and environmental impacts will be paramount. The longer we can record this quality of data the better the decisions we can make for the generations to follow.

What do you do when you are not at work?

When I'm not at work you may find me in bush with family, camping, exploring, hiking and four-wheel driving. I love spending time training & exercising with my dogs, Loki & Kep. Sport is a big part of my life, my favourites being Archery and Muay Thai. I also love to read all sorts of books including philosophy, history, psychology, biographic, scientific, health and fitness.

Now that you have graduated, where are you hoping your hydrometric monitoring skills will take you?

Environmental management and conservation are some interests of mine and I hope to tie my hydrometric monitoring experience into these areas. In the next few years I will endeavour to learn even more about some of the exciting jobs that seem to be finding their way to our section.

How do you think hydrometric monitoring will change in the future?

There are so many intriguing technologies finding their way into hydrography it is hard to keep up! I believe that the application of open channel ultrasonic flow meters are going to be a game changer and in combination with the Acoustic Doppler Current Profiler (ADCP) there may never be a need to get in the water again!

Historic Rainfall Record Broken in US

Mike Lysaght CPH, Business Development Manager, HyQuest Solutions Pty. Ltd, Warwick Farm, New South Wales, Australia

The highest USA rainfall event for 24 hours was recorded in 2018 when 49.64" (1,262.1 mm) of rain was recorded by a TB4 Tipping Bucket Rain Gauge on the island of Kauai Hawaii. The event officially breaking the previous all-time record for single day rainfall in the U.S. occurred in 1979 in Alvin, Texas during Tropical Storm Claudette.

Figure 1. Garden Kauai Hill (courtesy of Waipa).

On 15 April 2018 a singular weather event occurred on the island of Kauai Hawaii. In a 24 hour period 49.69" (1,262.1 mm) of rain dropped breaking the record for total precipitation ever recorded in the USA. A TB4 Tipping Bucket Rain Gauge was the instrument that recorded the historic rainfall reliably and precisely when it really mattered.

Though Kauai is the rainiest place on Earth, receiving some 400" (10,160 mm) per year with rain on most days, this single day's rainfall was far in excess of even that soggy norm. In total, the event amounted to about one and a half months of precipitation for the world's wettest location falling in just one day! Although some precipitation occurred through most of the period, the primary contributors to the very large 24-hour total occurred in three bursts.

Previous Records

The previous all-time record for single day rainfall in the U.S. occurred in 1979 in Alvin, Texas during Tropical Storm Claudette. This storm dumped 43" (1,092.2 mm) over a 24-hour period. The Kauai event shattered this record, and did not involve a tropical cyclone, just historically high moisture levels over the Pacific colliding with unstable air masses streaming down from the north[1]. This set-up brought radar-estimated rainfall rates of 2 – 4" (50. mm to 1001.6 mm) per hour to the north shore of the island.

While the Kauai event does fall short of the World Record for 24-hour rainfall (71.8" or 1,823.7 mm at Foc-Foc, La Réunion Island, in the South Indian Ocean, on 7 to 8 January 1966, during Tropical Cyclone Denise) it is the world's second greatest 24-hour rainfall from a non-tropical storm event. For those who were not aware the greatest 24-hour rainfall event, not from a tropical cyclone, amounted to 64.17" or 1,629.9 mm over 24 hours on 2-3 November 1999, in Central Vietnam[2].

Valid Measurement

After the event, the TB4 and data logger were put through several calibration tests using equipment designed or adapted for the purpose of analysing gauge performance under high rainfall rates. The tests showed that the gauge performed within expected tolerances.

After considering the observation and the various surrounding factors, the National Climate Extremes Committee (NCEC) determined the observation to be valid, and it now stands as the 24-hour record precipitation for the United States.

[1] Washington Post.
[2] Weather Underground https://www.wunderground.com/cat6/new-us-24-hour-precipitation-record-4969-kauai-hi-april-15

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Conductivity Readings Spike with Flows in Urban Creek

Matt Saunders, General Manager, Unidata Pty Ltd, O'Connor, Western Australia

Figure 1. Cottonwood Creek installation.

Recently a Starflow QSD 6537 loaded with a Starlog V4 Flow Scheme was installed in the extremely flashy Cottonwood Creek in Dallas as a long term test site. The intent was to record the flow activity in an extremely flashy urban creek. A sensor was relied upon to record extremely sharp increases in flow in response to rainfall events. One such event is illustrated below.

The creek cross-section was composed of a flat bottom with sloping sides and a low flow channel towards one side (see profile below).

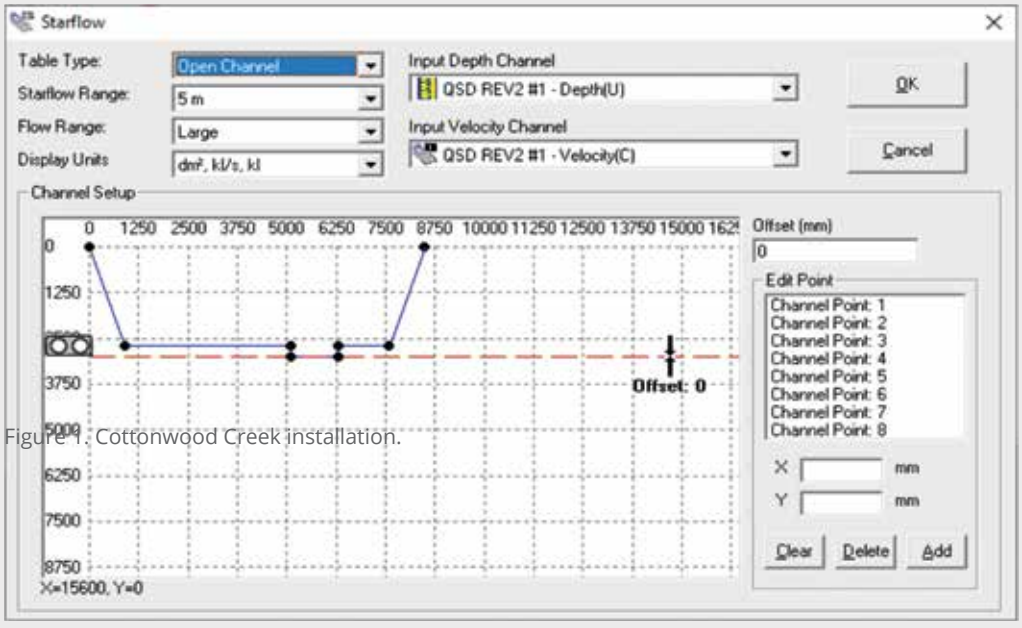

Figure 2. Creek Cross-Section.

The temporary installation consisted of a Starflow QSD 6537 screwed onto a cement slab which had been placed at the bottom of the low flow channel within the creek. The Starflow QSD 6537 was selected as the internal ultrasonic depth sensor has been found to perform very well in turbulent and silt loaded conditions. A solar-powered system, the unit reports back to a central server across the internet.

During one particular event, within 30 minutes, the depth went from 250 to 750 mm; the flow rate from .05 to 4 m^3/s. Over the period 12/4 @ 11:00 to 18:00 a total of 40,000 m^3 of water flowed down the creek. The depth peaked at 1m.

By contrast, the average Australian uses an approximately 100 m^3 of freshwater (per person each year)[3]. That is a lot of water moving down that creek!

What is interesting to note is the conductivity responses during this event. Starting above 1000 µS/cm (representing quite polluted urban run-off) the conductivity dropped almost instantly to below 200 µS/cm (clean water) as the creek is flushed with rainwater. The trend then gradually increased as the flow dropped and the proportion of urban run-off increased.

This would appear to be an excellent example of how, a temporary site can still provide a significant insight into the behavior of a system without incurring the large expense of a more traditional permanent gauging station.

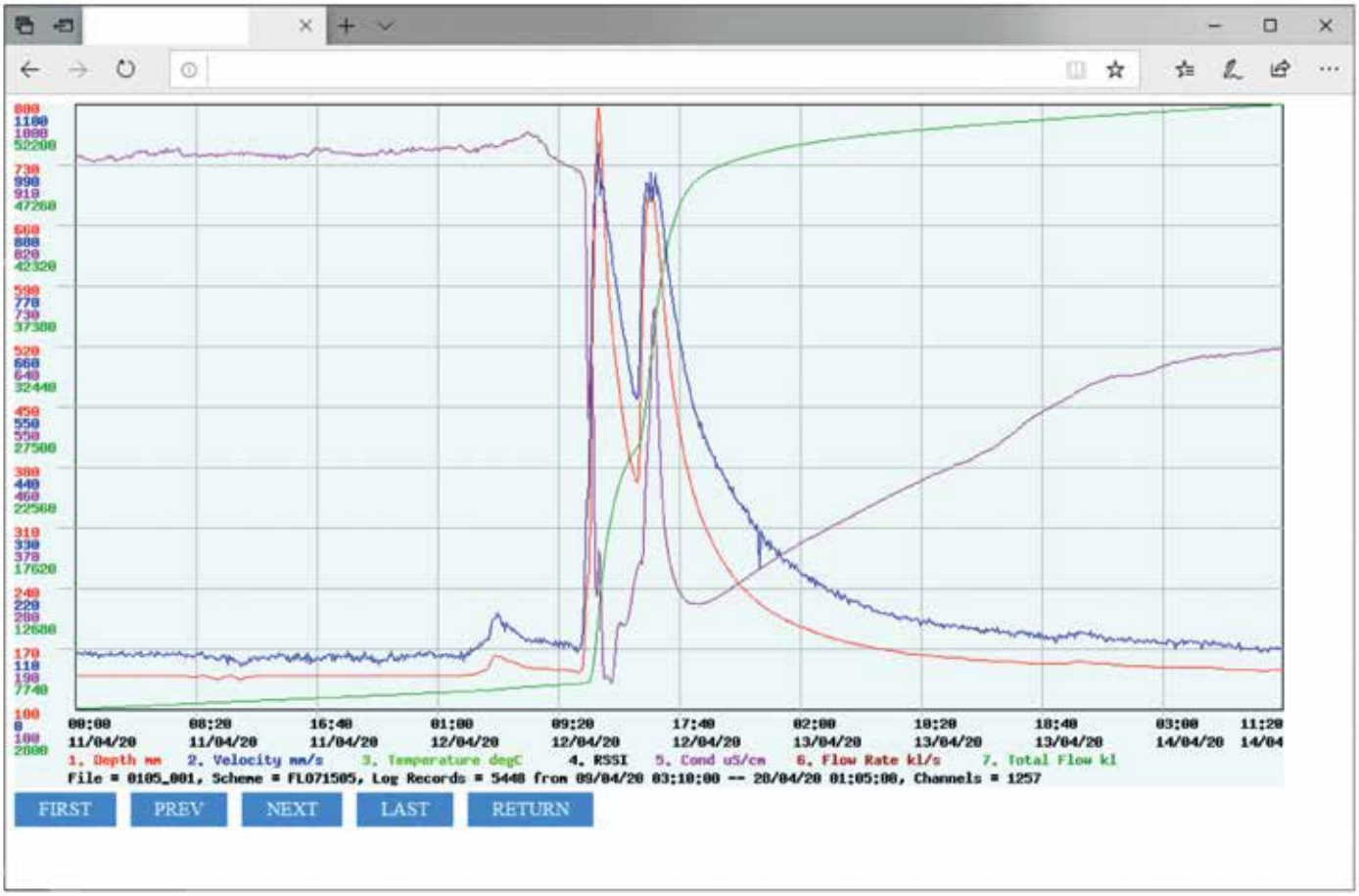

Figure 3. Performance during a recent flash flow event.

[3] https://www.yourhome.gov.au/water

The right message, to the right person, in the right way, at the right time: Review of Greater Wellington Regional Councils Flood Warning Service

Nick Boyens, Greater Wellington Region Council, Wellington, New Zealand
Mark Hooker, Greater Wellington Region Council, Wellington, New Zealand
Craig Hamilton, Greater Wellington Region Council, Wellington, New Zealand
Zoe Ogilvie, Greater Wellington Region Council, Wellington, New Zealand
Graham Leonard, GNS Science, Lower Hutt, New Zealand

Paper presented to 19th Australian Hydrographers Association Conference Canberra. 12-15 November 2018

Abstract

Greater Wellington Regional Council's flood warning service had over time become fractured and involved disparate agencies that were not working in an integrated way. This resulted in potential risks that flood warnings may not be delivered effectively and the consequences of that could be severe. This combined with recent developments in technology and the general thought that the system could be better gave impetus to a full review of the Flood Warning Service. The review involved going back to our stakeholders and asking them how we are doing and what they expect to be getting from us. Information gained from this process was evaluated and resulted in an overarching service level statement of: The right message, to the right person, in the right way, at the right time. The project engaged the expertise of the Risk and Society Department at GNS Science to help develop a picture of what the system should look like when aligned to current best practice and developing trends. The review process has been valuable in that it has allowed the council to re-engage with stakeholders, develop an aspiration for delivering a state of the art service, and garner support from senior management. A plan for implementing the recommendations of the review has been developed and has been successfully funded in Council's long term planning process.

Introduction

Flood warning services in the Wellington Region are provided across three parts of Greater Wellington Regional Council (GWRC): Flood Protection Department, Environmental Science Department and Wellington Region Emergency Management Office (WREMO). WREMO is the joint coordination point across the Wellington region for all the Local Authority emergency management planning and response functions. The current setup predates the establishment of WREMO in 2012. In fact the existing systems, established in the 1970s and 1980s under the Catchment Board Authority, actually predate the formation of Regional Councils. Providing adequate flood warning services is a critical role for GWRC and an area of significant risk if something goes wrong (or if there is a perception that it has not been done properly). The existing

system had not been reviewed recently and has never had a comprehensive review looking at what service is provided and how it is delivered, or why there is a flood warning service.

The purpose of this project was to make sure our flood warning system is aligned against defined levels of service and co-defined with the stakeholders in the service. The outcomes of this project are defined levels of service based on the needs of our stakeholders and a clear and robust set of improvement recommendations. The timing of the project was intended to line up with GWRC long term planning budgeting timelines so that review outcomes would be programmed and funded.

Existing Flood Warning System

The flood warning system that existed prior to this review had developed over a long period of time and in many cases was an artefact of previous local government and organisational structures. There are essentially two different systems operating relatively independently that are based on geographic separation and historic organisational separation. This separation still exists to some extent and is reinforced by staff operating out of GWRC's two main offices in Wellington and Masterton. Described below are the main parts that make up the existing system. Figure 1 describes in a basic sense the information flows in the existing system and where the differences lie and Figure 2 shows the layout of the region and flood related infrastructure and monitoring equipment.

- Rain gauges and river level sites are in place at key locations across the region. These are maintained by the Hydrology Team in the Environmental Science Department.
- These sites are connected by radio or cellular telemetry to our Hydrotel telemetry system that is monitored in Wellington and Masterton. The data is constantly monitored for rainfall intensities and river levels that exceed pre-set alarm thresholds.
- There are two Duty Flood Warning Officers, who are experienced members of the Hydrology team, on duty 24 hours a day, 7 days a week. One is based from Wellington and the other from Masterton. Their roles and responsibilities are:
    - The first point of contact for MetService (New Zealand's official severe weather forecasting agency) who issue official severe weather warnings. They have a direct line of contact with the MetService forecast room;
    - The first person to receive notification of alarms by text and email;
    - They assess the alarm according to their expert knowledge and information available from MetService and then pass on the information to the next person in the chain. This is different between Wellington and Masterton offices:
        - » In Wellington the Duty Flood Warning Officer deals with the Duty Flood Manager who is an engineer from the Flood Protection Department. They in turn deal with the WREMO Duty Officer who deals with Local Authorities, Emergency Services, media and the public;
        - » In Masterton the duty Flood Warning Officer deals with WREMO and also makes calls to the first contacts on extensive landowner phone tree lists.
- There are also a number of stakeholders that receive automated alarms direct from the Hydrotel telemetry system for specific operational purposes usually related to resource consent condition monitoring or for contractors working in river corridors.

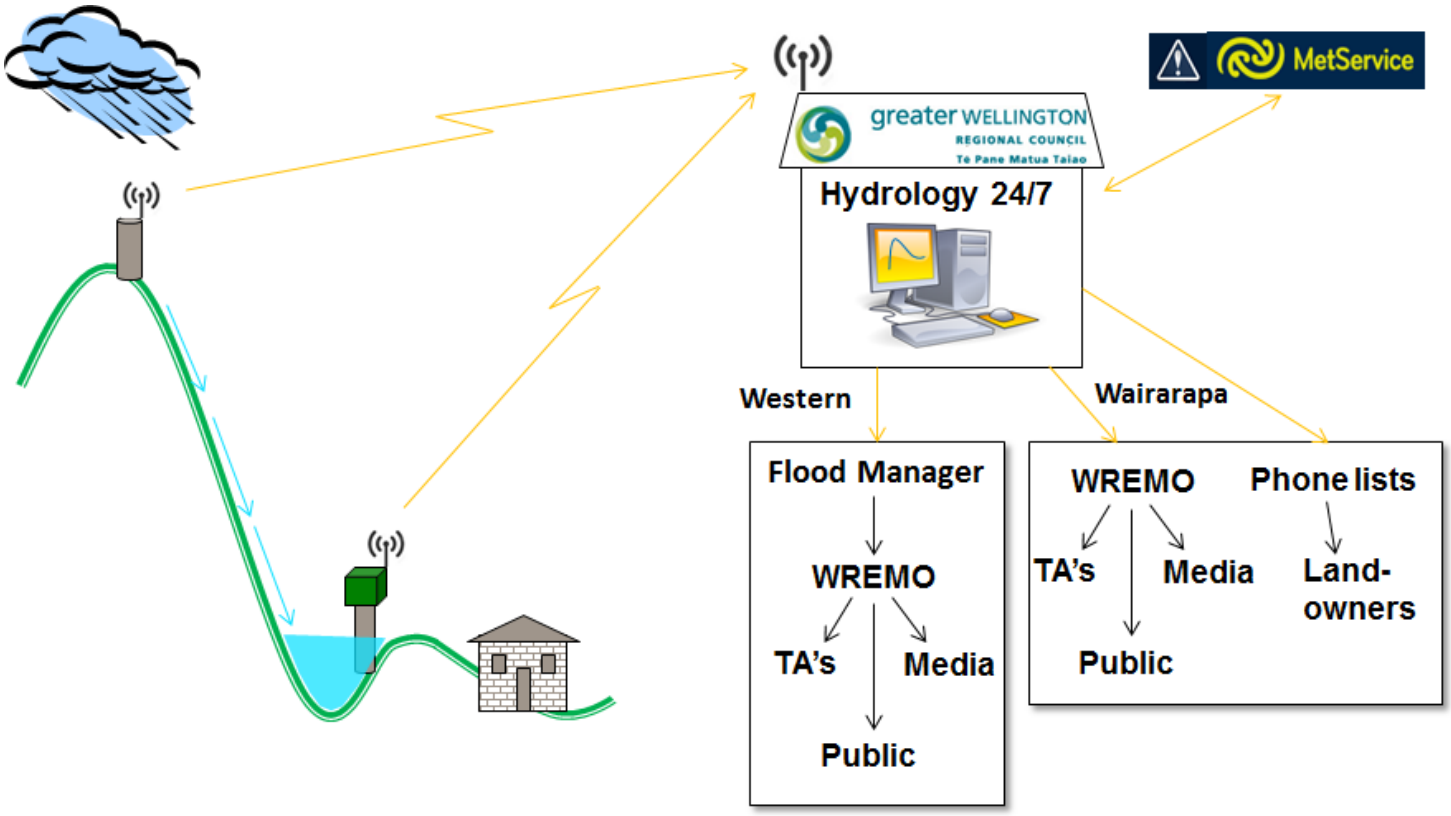

Figure 1. Existing Flood Warning System Information Flows.

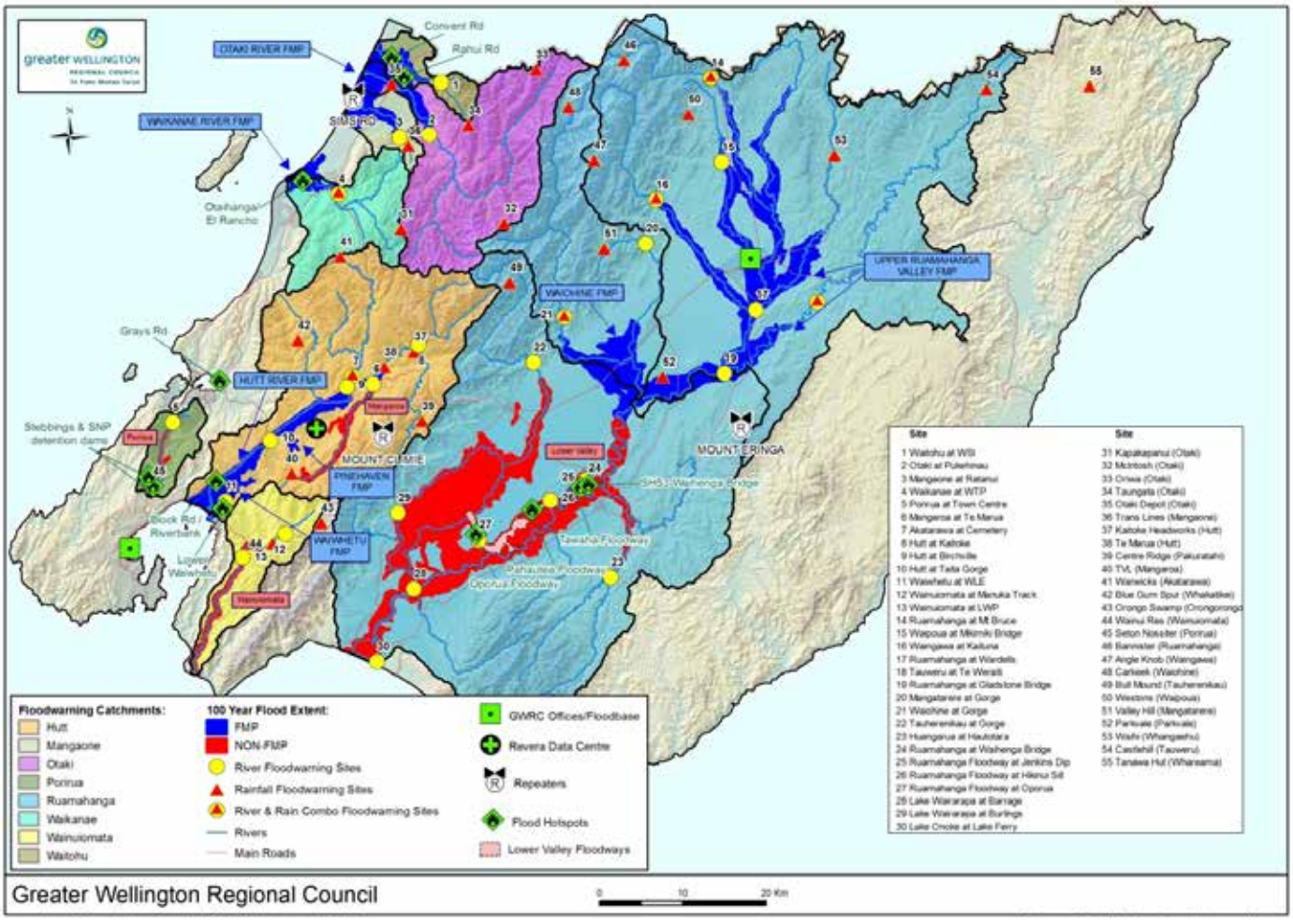

Figure 2. GWRC Flood Related Infrastructure and Monitoring Networks.

Project Structure

The project team was formed and consisted of representatives from the three main areas involved in providing the existing flood warning service: Flood Protection, Environmental Science and WREMO. Through the initial stages of project planning it was quickly recognised that a large part of the project would involve stakeholder engagement and that expertise in this area would be required. This led to the inclusion of a representative from the GWRC Community Engagement Team. This had added benefits of bringing in a view of the communications side of the flood warning process to the project. Where needed, other expertise from within the three organisations was brought in and it was decided that the main analytical part of the project would best be done by a suitably qualified consultancy.

The project was planned out in four phases:

- **Phase 1** involved canvassing internal stakeholders to get an idea of what they think is currently provided by the service and how it is done. This process was also intended to help inform who should be involved in the second round of engagement which was with external stakeholders.
- **Phase 2** involved running stakeholder engagement workshops with external stakeholders to find out what it is they expect of the flood warning service. This included finding out their ideas on how they want to receive the information provided. Following on from those workshops the information gathered was to be analysed to define "Levels of Service" across the region.
- **Phase 3** involved working out how that stakeholder defined level of service is interpreted and how it is implemented across the region. This included consideration of variables such as geographic variability across the region, the type of stakeholder groups, the communication techniques available, etc. The existing system was then reviewed against the desired level of service to identify gaps and improvement opportunities.
- **Phase 4** was taking the information from Phase 3 and converting that to a detailed implementation plan for providing the reviewed service and for taking to the GWRC long term budgeting process.

Stakeholder Engagement

As the aim of this project is to ensure that any flood warning service offered by GWRC is meeting stakeholder requirements it was critical that their input formed the basis of the review. The stakeholder engagement was split into two stages that firstly involved stakeholders that are internal to GWRC and WREMO and then secondly the external stakeholders for whom the service is provided plus the other agencies that have a role in flood warning. During the development of the external stakeholder engagement plan the GNS Science Risk and Society Team, who have expertise in stakeholder analysis, hazard and risk analysis, and alerting systems, were contracted to assist with the engagement feedback analysis and to undertake Phase 3 of the project.

Internal Stakeholders

Engagement of internal stakeholders had two main objectives:

- Ascertaining what this group thinks is currently provided by the service and how it is delivered; and
- Getting wider input into the collation of a list of external stakeholders that need to be engaged with.

Internal engagement was delivered through single facilitated workshop, bringing together all the staff currently involved in the system and others internally that have a stake in or use the information. This covered WREMO Duty Officers and Advisors, Hydrology technical staff, Flood Protection engineers and field operational staff, and public transport advisors. The questions asked of the internal stakeholders are summarised in Table 1.

Table 1. Questions Posed to Internal Stakeholders

Main Question	Supplementary Question
Define and identify Levels of Service – what do we do?	• What is your role? • In regards to the flood warning system what are your associated tasks?
What are the objectives of the flood warning system – why do we do it?	• Why do you perform those tasks? • What would happen if you didn't perform those tasks?
Identify stakeholders – who do we do it for?	• Who do we provide this level of service to? • What do they want?

The first two questions offered interesting results that confirmed the decision to undertake the review based on the potential for confusion in the existing system and the risk of something going wrong. It also highlighted the broad range of tasks performed by the staff operating the system with a particular emphasis on collecting and interpreting data and passing information on to the right people. There is also a general agreement that we perform this role due to the legislated requirement but also because we believe we are in a position to make a real difference by doing so.

Table 2. Internal Stakeholder Roles in Existing System

Tasks Performed	Reasons for Performing Tasks
Run flood models before and during events	Legislated to perform this function
Manage public information dissemination	Community expects it
Data analysis during and after events	Something we can do
Ensure IT systems are running	Prevent damage
Empowering communities	Enable good decisions
Notifications during events	Prevent loss of life
Maintaining monitoring equipment	
Planning and preparation	
Collate and interpret information	
Communicate information	
Liaise with stakeholders	
Collecting good data	
Get more information from other sources	
Operate controllable assets that we maintain	
Timely response	
Work with landowners of assets	
Rostered on to perform duties	
Maintain and update stakeholder lists/ database	

Internal stakeholders were also asked questions intended to understand what the internal view of our current level of service to the stakeholders is. The answers were analysed and the following main themes related to level of service were identified as being considered important to deliver on:

- Preparation
- Reliability
- Timeliness
- Communication
- Robust data
- Resilience

The relative importance of aspects related to these themes is captured in the word cloud presented in Figure 2. There is a definite theme of needing to be timely, accurate, resilient and trusted.

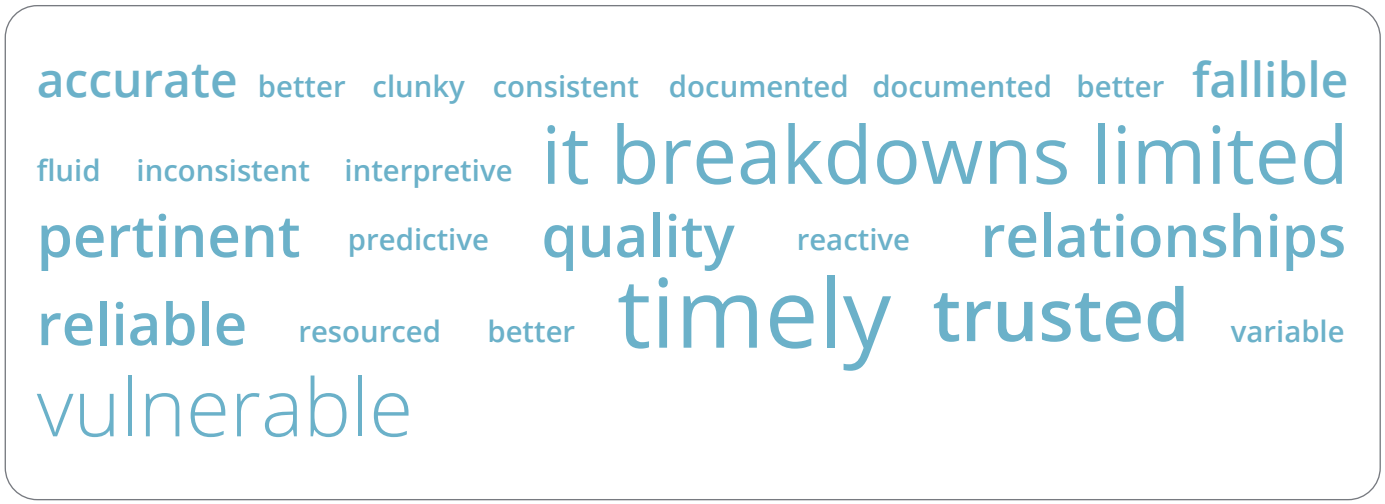

Figure 3. Internal Stakeholder Relative Importance of Level of Service Aspects.

The third piece of information that was to be collected at the internal stakeholder workshops was a comprehensive list of who are all the stakeholders, both internal and external, of the flood warning system. This was a useful exercise in itself in that it helped all involved get a better appreciation of the breadth of stakeholders using this information for decision making. This list was used to inform the selection of stakeholders to invite to the external stakeholder workshops. Table 3 lists the identified stakeholders grouped into their respective system function groups. External stakeholders are identified in *italics.*

Table 3. Flood Warning System Stakeholders List

Information Providers	Data Gathering & Support	Interpreters	Information Users	Response	Post Event
MetService	GWRC Hydrology	Flood Protection	Fonterra	Fulton Hogan	Insurers
Consultants	GWRC IT	People on phone trees	Post/freight companies	Downer	Engineering consultants
Landowners		Landowners	NZ Transport Agency/ Police (Regional Transport Response Team)	Land owners	Flood Protection
Contractors		Central Government	Kiwirail	Flood Protection Operations teams	GWRC Hydrology
Recreational groups		District Councils	Media	Public	Media
District Councils		GWRC	Schools	District Councils	District Councils
Wellington Water Ltd		WREMO	District Health Boards	Media	Community
Media		Emergency Coordination Centres	Welfare support agencies	NZTA	Internal reporting
Public		Emergency services	Specific Communities	Emergency services	
Social media			Metlink (GWRC public transport)	Internal communications	
			Consultants	Asset controllers	

External Stakeholders

Due to the geographic spread of the existing system and its stakeholders' across the region it was decided that two external stakeholder engagement workshops would be held. The first workshop was held in Carterton in the Wairarapa and the other in a middle meeting point for the Western part of the region at Judgeford, in Porirua. Both workshops were identical in the questioning and the format of a prompted, facilitated discussion. An online survey was also made available so that stakeholders that were unable to attend a workshop could still offer their input.

The external stakeholder sessions were designed around an intention to *Discover* from the stakeholders what they believe they currently get from the existing system, *Discover* why they feel it is (or is not) important, and then to get them to *Dream* up what an ideal system could look like, and finally to offer some ideas on how we should *Design* that. The workshops revolved around four main questions, in bold in Table 4, and supplementary questions designed to encourage further discussion.

Table 4. External Stakeholder Workshop Questions

Objective	Questions (main question in bold)
Define and identify levels of service Information gathering DISCOVERY	• What information are you receiving? • How are you receiving that information? • Why are you receiving the information? • What do you use the information for? Is it useful? • What's the most important element of the information? E.g. timeliness, accuracy, breadth, etc.
What are the objectives of the flood warning system DISCOVERY	• In regards to the flood warning system do you have actions you complete or people you connect with? • Why do you perform the actions associated with the flood warning system? • What would happen if you didn't perform those actions?
Define customer needs DREAM	• What information do you want? • How do you want to receive it? • Where are the gaps? • What is your ideal version of this system?
Define customer wants DESIGN	• What improvements could we make? • Are there any solutions you can think of? • What's missing from the current system? • What is the best way for this to work for you?

Feedback from external stakeholders on the existing system was generally positive with regard to the level of service being provided. It was however recognised that this view was coming from a position of little understanding of the full structure and inherent risks of the existing system. It was also interesting to note the feedback from some stakeholders that they didn't realise the GWRC offered any such service. These were generally those we had reached out to that we knew were currently not receiving direct official warnings but could benefit from doing so, such as District Health Boards. Another interesting note was the discovery that one of the local canoe clubs was using raw telemetered river level and flow information accessed directly from the GWRC external facing data server in their own bespoke smart phone application.

Summary of Stakeholder Feedback

The information gleaned from the stakeholder engagement was valuable in providing a good picture of how both internal and external stakeholders perceive the existing system and how they think the service could be improved. Internal stakeholder feedback was mainly of a technical nature or focused on the potential for confusion or failure in the existing system. External stakeholders were grouped into areas of similar interest, risk or impact (Leonard et al. 2016):

1. **Farmers:** Relatively few stakeholders in known locations, relatively frequently flooded with high consequence and high potential for protective action.
2. **Contractors:** Transient, mobile people and equipment that may be operating in the flood channel, often with a critical role in the flood protection, lifeline maintenance or warning response. Need to be able to make plans for when to access the river.
3. **Civil Defence Emergency Management Agencies:** A range of agencies with at-risk assets, planned response actions and alerting obligations, including lifelines. Known agencies with known structures and plans. Need intensive detailed information and need to work in partnership with the flood monitoring team.

4. **Special Interest Groups:** Conduct specific activities in the flood channel (e.g. tourism, tramping, kayaking, fishing, etc.). Changing individuals but a consistent set of high level contacts. Need to be able to make plans for when to access the river.
5. **General Public:** Large number of people over a wide range of locations. Opt-in messaging lists are preferred, as it is difficult to maintain lists of who is where, or what they need from flood warnings. Warnings need to give as specific an impact, a location and timing as possible, because the recipient will need to decide if they will be impacted. Some action will be taken on their behalf (e.g. evacuation by CDEM).

Valuable insight was gained on how warnings were being used and disseminated in the existing system and some idea on how the service might be improved. This is summarised in Table 5.

Table 5. Stakeholder Workshop Results (after Leonard *et al*, 2016)

Stakeholder Group	Existing Use Comments	Improvement Ideas (all groups)
Farmers	• Telephone trees working – somewhat labour intensive to maintain at present. • Not all trees operate at all event-scales. • Those receiving warnings are very happy with the service (note that not all farmers receive alerts).	• Impact based warnings preferred e.g. information on website, graphs indicating specific roads or areas flooded. • Fast updating of data on river monitoring website. • The system should prompt actions for the community to initiate coordinated community actions. • A central repository to access all data and information – a 'one stop shop'. • Opt-in text alerts would be great. • Flood warning information website should be much more visible on GWRC website when a flood is occurring/forecast. • WREMO need to understand the regional picture scaled down to local impacts and be able to relate that to MetService warning information.
Contractors	• Some thresholds for key locations for key contractors, working at the regular-event scale for parts of the catchment (reactive to recent events, known hotspots). • Some vulnerable points already known to need notification, even for regular events.	
Civil Defence and Emergency Management	• Not fully documented at all scales of event. • Generally communicated at district-level.	
Special interest groups	• Regular river users are generally self-interpreting. • Website monitoring data main source of information.	
General public	• Reactive; not particularly planned.	

Development of Co-Defined Level of Service

Information collated from stakeholder engagement and feedback from GNS Science was used by the project team to develop a proposed level of service. In particular the future state thoughts from the external stakeholders were combined with the expert knowledge of the project team and internal stakeholders, especially the insight of the risks of the existing system, to give a comprehensive set of service levels. This was circulated in September 2016 to all stakeholders involved in the workshops for comment. The final version is as follows:

Overall Philosophy:

"The right message to the right person, in the right way, at the right time"

GWRC and WREMO will work towards a flood warning system that is consistent with best practice.

Levels of Service:

- Reliability of delivery:
  - All events that meet agreed thresholds generate an official warning (0% failure rate of GWRC/WREMO warning systems to warn for a flood).
  - Services that provide information only (e.g. GWRC flow graphs) but not an official warning or notification. Can accept a small tolerance for failure.
  - Warning thresholds continue to prioritise safety over avoiding 'false alarms'.
- Consistency of message:
  - Key elements of warnings and information are consistent across delivery methods and agencies.
- Stakeholder coverage:
  - High risk and vulnerable stakeholders are all aware of and have access to the system.
- Impact-based warnings:
  - Official warnings provide information and context about what the likely impacts are and guidance on response.
  - This information will be included at a catchment scale and for certain high risk 'hot spots' or communities but this level of detail will not generally extend down to individual properties.
- Education and feedback:
  - Resources are available for people on warning lists to plan how they will respond to official warnings.
  - The community has the opportunity to be aware of the wider system and of what services are available.
  - GWRC regularly seeks feedback on the performance of the system.
- Suite of options:
  - A range of options are available for people to access official warnings, notifications and data. This will likely include phone warnings, SMS, email, website, social media, and smartphone apps.
  - Notification option suites are tailored across a set of stakeholder categories, each of which share similar characteristics and warning needs. More resource intensive options (e.g. phone calls from a Duty Officer) are prioritised on the basis of risk, but existing telephone tree systems are maintained.
  - GWRC regularly tests the system (e.g. exercises).

Comparison of Existing System to Proposed Level of Service

For Phase 3 of the project the Risk and Society Team from GNS Science were engaged to compare the existing flood warning system to the proposed level of service and to make recommendations on any changes that needed to be made. The GNS team were selected for the review based on their significant experience in natural hazard monitoring, warnings and public alerting from both an operational and theoretical point of view. They also had significant experience in behavioural response to hazards and knowledge of New Zealand local government operations.

This section of this paper is adapted from the GNS Science Report 2016/66: GWRC Flood Warning Review Phase 2 & 3: Recommendations from comparison of existing system to proposed level of service (Leonard et al. 2016).

The GNS Science report includes a summary of the existing warning system which drew on the results of the workshops, meetings with key staff, and the content of the planning documentation. The framework, documentation, and stakeholder experiences of the existing flood warning system for Wellington Region are summarised in the report.

Existing arrangements were compared to the proposed level of service. For this process the following elements were considered and commented on in the context of warnings:

- The wider risk management context,
- Effective impact-based warnings,
- Planning,
- Catchment monitoring, modelling and warning evaluation,
- Warning notification and communication,
- System resilience including site and communications equipment,
- System resourcing – both hardware and human resource,
- Stakeholder evaluation, categorisation and management.

Recommendations for Improvements to Meet Proposed Level of Service (LOS)

Following comprehensive comparison of the existing flood warning system and the proposed level of service in the context of the elements listed above GNS Science provided the following list of recommendations for improvements (Leonard et al. 2016):

- A wider risk-based assessment of all flood mitigation options (land use planning, structural mitigation and warnings) and the risk to affected stakeholders on a catchment by catchment basis is needed to determine the residual risk that should be covered by warnings.
- Base the level of service offered to (a) each stakeholder and (b) each catchment, on risk and agreed risk reduction targets:
  - District Councils, lifelines, emergency services and health agencies need to be included with the wider group on discussion in terms of residual risk reduction targets and therefore level of service to catchments and stakeholder categories,
  - Correlate what's being warned for, to whom, where, and level of risk.
- Set up a 'one stop shop' for all stakeholders to receive their warnings.
- Consider planning, telemetry, alerting, stakeholder relationships, information systems and the 'one stop shop' as one flood warning ecosystem that should be coherent, effective and as streamlined as possible.
- Consider the multi-hazard context — this is one of several warn-able hazards within the region using overlapping alerting technologies to reach many of the same stakeholders.
- Full documentation of all arrangements — complete coverage of all procedures, all scales, all agencies, harmonised, succinct, used, tested, reviewed and updated. Include procedures, communications, notification and welfare.
- Regular exercises should be planned and completed (ideally annually) across a wide range of scales and scenarios. Exercises and real events must be regularly evaluated to enable a culture of continual improvement to be developed.
- Consider and deliver the level of service and needs of stakeholders in five broad stakeholder categories.
- Move to impact-based warnings that consider the optimum messaging needed for response actions for each stakeholder category.
- Use a pilot location to develop, with stakeholders, suitable effective impact-based messages for the Wellington Region.

- Plan for all scales (return periods) within agreed risk reduction targets, and agreed level of service.
- Develop comprehensive cross-agency Public Information Management and communication message planning.
- Adequate system resourcing, in terms of both direct costs and human resources, is critical. Under-resourcing will lead to decreased resilience or functionality and a consequent reduction in LOS delivered.
- Include Wellington Water Limited in planning.
- Include flood warning arrangements for all stakeholder categories in each Floodplain Management Plan (FMP), and complete FMPs for all floodplains.
- Write and maintain a single short interagency master plan that explains:
  - Boundaries of authority (who does what, who monitors what, at what scales, to warn whom),
  - All agencies involved (including partners) and how their plans operate together,
  - Levels of service,
  - Sub-plan-linkage-diagram,
  - Telemetry-notification network diagram,
  - Coverage map,
  - Exercising, review and improvement schedule,
  - Current state and staged strategy for stepwise improvement.

Overall Conclusions Reached by GNS Science

The treatment of risk via warning should be realistic and pragmatic. Some mitigation is in place and appears to be effective — where it has been tested in real events. The existing warning system generally focuses on relatively frequent return periods for a sub-set of stakeholders and catchments. The proposed level of service is ambitious but is appropriate.

GNS Science recommended four key areas of focus for the revised warning system:

1. A combined risk-based approach to combined mitigation across land use planning, structural mitigation and warnings.
2. Alerting coverage needs to be explicitly laid out for all stakeholders in all categories by one or more alerting end-points from one or more of GWRC, WREMO or MetService. Alerts are already provided in some form or another, to everyone, by one or more of these agencies — these need to be rationalised, planned and clear to both these agencies and to stakeholders.
3. A one team, one warning system philosophy across all agencies, supported by integrated overarching planning.
4. Development of a 'one stop shop' for all stakeholders to access warning information.

The final recommendations of GNS Science were adopted by the project team and taken to GWRC/WREMO senior management for endorsement and also presented to GWRC Council for their endorsement. The project and its conclusions were well received by both levels of management.

Implementation of Recommendations

Phase 4 of this project involved taking the information from the GNS Science report and developing a detailed implementation plan for providing the reviewed service. This was intended to not only provide a future work plan but also to inform the GWRC long term budgeting process. As a result of the comprehensive review and strong engagement with the GWRC and WREMO senior management teams throughout the project the implementation plan was successfully funded and adopted in the Long Term Plan approved in June 2018.

Implementation Approach

No warning system can ever be 100% effective, therefore, it is iterative improvement, focussed on discrete projects that will have the greatest impact on the region and drive progress. Using existing catchments that have already been identified through a risk-based approach, it is planned to use pilot projects to develop and test systems, communications and messages, using the approaches recommended in the review.

Complementary to this work, high-priority infrastructure improvements that have been identified through the Hydrology Network Review and Floodplain Management Plans (FMPs) will be implemented. Progress will be reviewed after five years, at which point it will be determined how to implement improvements more widely and develop the next set of improvement projects.

Work Streams

Seven work streams have been identified through the GNS Science review. Due to the overlapping nature and dependencies of the work streams, projects will often contribute to more than one work stream. In order to focus on projects that will deliver the greatest impact not every element of every work stream will be delivered immediately. The implementation plan takes a rolling five year planning and continuous improvement approach.

Work to be undertaken under each of the seven work streams is as follows and summarised in Table 6:

- Risk-based approach:
  - Prioritising our improvements in areas that have an identified risk and need for better flood warning.
  - Understanding our stakeholders and the different levels of risk they are exposed to, and warning them accordingly. This may include consideration of what services will be offered to different catchments and stakeholders based on risk (because resources are not limitless).
  - Concentrating our efforts into planning and warning for major floods (that people may have no experience of) rather than the more frequent events that people know and understand.
- 'One stop shop' for flood warning info:
  - Our vision is a web-based portal where people can access all the information they need about flood warning in the Wellington Region, regardless of the type of flooding or location. They would be able to sign up for warnings, access information about current warnings and be directed to information to help them understand their flood risk and how to prepare.
- Multi-agency coordination:
  - Complete understanding of the roles agencies play in flood warning and the coverage that they provide. Leveraging off each other's related projects and work streams and achieving greater alignment in providing flood warnings. A commitment to collaboration as a tool to increase effectiveness and efficiency.
- Structural/system improvements:
  - Start with reviewing, updating and rationalising all documentation, but also consider what structure would best deliver the outcomes desired by stakeholders. At the moment there are four Duty Officers simultaneously on standby across the region with a role in flood warning. Several GWRC Departments and WREMO are involved in providing warnings but nobody has it as a focus for their day job.
- Improve infrastructure:
  - Understand where our critical sites and infrastructure are, and invest in resilience or redundancy to ensure that we can provide reliable flood warnings. This includes physical monitoring sites, communications telemetry, ICT infrastructure and software.
- Engagement and awareness:
  - Engage with identified high-risk groups who may not be aware of their level of risk or the availability of flood warnings. Consider who we're talking with and how we reach them. Particular focus on vulnerable communities to alleviate risk.
  - Raise awareness of the flood warning system and what's available to different stakeholders/catchments. Develop and carry out exercises to maintain awareness and engagement.

- Warning delivery:
  - Moving towards warnings that communicate the impact of the event and thereby trigger an action. Consider what tools are available to warn people and which tools we should use generally as well as for particular stakeholder groups or catchments.

Table 6. Summary of Implementation Plan Work Streams

Work Stream	Comment/Relevant Recommendations	KPI 5 Years	KPI 10 Years
Risk-based approach	Prioritise areas of highest risk, tailor service based on risk, consider range of mitigation responses i.e. integrate FMP outcomes and findings, plan for a range of scales.	Risk assessment is a core part of decision making.	Risk and its management is well understood region wide.
'One stop shop' for flood warning info	Public interface. Single portal potentially including other agencies. Have people taking responsibility for managing their own subscriptions.	Web portal is up and running.	Portal remains relevant and well utilised.
Multi-agency coordination	Coverage of different agencies/ systems to be explicit and clearly communicated. Develop joint projects. Bring flood warning together across region. Overarching planning. Consider multi-hazard context for warnings. Public Info Mgmt. Interagency master plan.	Multi-agency agreement in place.	Seamless multi-agency integration of systems.
Structural/system improvements	Review, update and rationalise all our documentation. Review current structure and restructure the system/ roles/responsibilities if needed, determine what resourcing is needed.	New structure defined, agreed and adopted.	Continual improvement programme in place.
Improve infrastructure	ICT, hydrometric, flood warning models, autodiallers etc.	Better technologies in place and minimal service disruption.	Continual improvement programme in place.
Engagement and awareness	Identify and make contact with stakeholders, exercises.	Improve stakeholder numbers warned in each group.	Continual improvement programme in place.
Warning delivery	Impact-based warnings, diversify warning methods, notifications project.	Warning delivery aligned with national initiatives.	Warning delivery maintains alignment.

Lessons Learned From this Project

The approach taken to this project was relatively agile and iterative in that it was broadly planned out from the start but each phase was not planned in detail until just prior to start. This allowed the project direction and structure to develop as the project team learnt more about the topic and the work involved in the review, and were informed by each phase of the project. Overall the project was very successful but as with any project we did learn a few lessons along the way:

- Regular project team meetings, including regular reflection on the Project Plan and Risk Register were valuable for this project.
- Using the Project Plan as a live document, and seeking Governance approval of the updated plan at gateways between project phases. This allowed the plan to be developed in more detail for phases in the near future with only outlines of phases further ahead.
- Recognition of the importance of stakeholder engagement, even on an apparently technical project and a service that all stakeholders, in this case end users, seem to be happy with. Early involvement of our Community Engagement Team was valuable.
- Communication internally through GW channels and with external stakeholders throughout the course of the project meant all people were aware and able to take part if they thought it was necessary. Enabled no surprises.
- Involving key expert consultants early in the process was useful in ensuring that their input was able to be considered early and this could inform the data collection through the stakeholder engagement process.
- Keeping project team input time commitment to reasonable and achievable levels helped to keep things moving smoothly without becoming too onerous.

Conclusions

We carried out a review of our flood warning system in 2016/2017 that was initiated by key staff who felt that the system was at risk and needed to be reviewed in light of current methods and technologies. The review involved multiple agencies who have a role in the flood warning system and that will have a key role in implementing the outcomes:

- GWRC (particularly Flood Protection and Environmental Science, but also Communications and Marketing, Public Transport and ICT)
- WREMO (including on behalf of District Councils)
- Wellington Water
- MetService
- GNS Science

The review also strongly drew on input from the key internal and external stakeholders of the flood warning systems to ensure that the customers' needs were considered. This stakeholder input was analysed and distilled into an overarching level of service statement:

> *"The right message to the right person, in the right way, at the right time"*

This new level of service statement was compared to the existing system by experts from GNS Science and a comprehensive report outlining recommendations for bringing the flood warning service up to best practice. This is what will be required to enable GWRC to meet this new level of service. The pathway to achieving this is not short and is strongly focused don interagency cooperation and in particular the harmonisation of processes and understanding across the multiple organisations. There are a number of projects planned in order for this aspiration to be achieved and for the development of an ongoing continuous improvement approach to the maintenance of the systems. This work is planned to begin in 2018/19 and continue for around 5 to 10 years.

Along with the formal outcomes of the review the project has already created positive outcomes by:

- Enabling us to better understand our many stakeholders and customers as well as their varied needs,
- Connecting us better with other agencies working in this space who share our vision for a better public flood warning system for our region,
- Identifying partners that could assist in funding some of the implementation plan,
- Enabling us to better understand our own system and how it interacts with our key partners and stakeholders so that risk is mitigated.

Overall the project has been extremely successful and has put GWRC on the path to developing a state of the art flood warning system that can be maintained an built upon in the future.

References

Leonard GS, Becker JS, Woods RJ and Potter SH 2016 *GWRC Flood Warning Review Phase 2 & 3: Recommendations from comparison of existing system to proposed level of service.* GNS Science Report 2016/66, December 2016.

AUSTRALIAN
HYDROGRAPHERS
ASSOCIATION