Australasian Hydrographer

December 2019

AUSTRALIAN HYDROGRAPHERS ASSOCIATION

AHA

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Deep Reach Pool, Millstream National Park, West Pilbara WA

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Contents

JACQUIE BELLHOUSE

Editor's Introduction

This journal marks not only the last for this year but also the last for this decade. This led me to reflect over the highs we have seen over the past ten years. Some of the highlights from my perspective:-

1. Establishment and subsequent revision of the National Industry Guidelines for Hydrometric Monitoring (0 to 10) as facilitated by the WaMSTeC;
2. WaMSTeC, a purely voluntary committee, is now attended by representatives from well over 20 agencies / businesses / bodies involved in the Hydrographic industry. It is phenomenal to see the continued depth of knowledge and ongoing drive to improve how we as a profession collect, quality assure and preserve data on our Water resources;
3. Continued growth in the AHA. We have gone from ~230 members in 2013 to more than 380 this year, our website grows by leaps and bounds and for the first time (since I accepted the editorship) we have been able to publish quarterly journals primarily from member submissions;
4. The continued uptake of Certification (over a quarter of the AHA's members are now certified) and our record number of students learning the art of Hydrometric Monitoring;
5. The ongoing advancements in data collection technology, Rising Bubble Streamflow (note Jeremy's next instalment), Acoustic Doppler Current Profilers (ADCP), Real Time Kinematic (RTK) surveying and Digital Elevation Models (DEM), Internet of Things (IoT)…
6. The increasing diversity within our profession (age, culture, sex, hydrographic discipline take your pick);
7. An ever increasing visibility of the data we are paid to collect be it on the ABC News, the BoM website or even each of the individual agency data portals.

Of course these are just my highlights, I am sure each of you will have your own.

So as the year comes to a close please enjoy the latest submissions from our members and new Association President Arran Corbett.

Jeremy Bulleid from NIWA has a third article covering the *Automation of Rising Bubble Streamflow Measurement using Artificial Intelligence*, Dr Carla Mooney and Dr Richard Hammond from the Bureau of Meteorology have provided an update on the *Flood Warning Infrastructure Framework and Standard* and Luke Donovan, Department of Water and Environmental Regulation in Kununurra has provided details on a recent DWER Hydrographic Technical Forum.

For a little light reading over the silly season I have also included and article from BoM's Janice Green on the new standards for describing the extremeness of an event before, during and after the event. This paper was presented to the 2018 AHA conference and has proven useful to me since then when I have the need to explain the concept to our newer graduate engineers.

Merry Christmas and a Happy New Year and please keep the articles coming in 2020.

Jacquie Bellhouse
Journal Editor

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ARRAN CORBETT

From the President

As the year draws to a close and we approach a new decade it is time to ask ourselves what challenges lay ahead and are we ready for them. In a year that has been bracketed by floods in North Queensland, drought and bush fires In NSW, Southern Queensland, South Australia and parts of WA it is very difficult to speak with certainty about what is next.

One thing we can say with certainty is that these extremes necessitate a greater scrutiny of our resources. We need to operationalise our data collection to protect our precious resources, ensuring that they are put to the most productive use possible while sustaining our environment and quality of life.

Not an easy challenge but one that I am confident the Hydrographers of Australia can rise to. In taking up the role of President of the AHA I asked myself what I hoped to achieve, how I can help our members succeed through change. The answer that I keep coming back to is supporting our people through this new challenge, creating resilience and shaping an adaptable team of professional Hydrographers whose services are in demand.

There are a few factors to consider in building this team of resilient, adaptable Hydrographers. A few of these are:

- Technical – ensuring that we work with industry to develop the best, most practical tools.
- Training – create a stable, fit for purpose training system without reliance on external stakeholders.
- Communication – we need to get better at talking to each other, sharing ideas and experiences. Taking the time to recognise and celebrate our achievements.

While there are undoubtedly many other factors at play, I believe that the ones given above are those that we can achieve the biggest impact in the shortest time.

So my challenge for you is to get involved, speak up and be heard.

Arran Corbett
AHA President

AHA Member Profile – Arran Corbett

Figure 1. Arran Corbett (in his natural habitat).

I am currently Team Leader of the Hydrographic Support Unit (HSU) in the Queensland Department of Natural Resources Mines & Energy (DNRME).

We are small team of seven with two main functions;

1. Manage and deliver the Assets Under Construction capital program. This is a three year rolling program valued at around $1.3M/yr to upgrade the 403 core Gauging Stations of the QLD network. We assemble both gauging huts and data system ready for field deployment.
2. Our second core function is that of Research & Development. This is possibly the most rewarding part of our work as we are given a free run to investigate, test and document for field use all kinds of new monitoring solutions.

Current efforts in the R&D realm include flood gauging with drones, operationalisation of fixed cameras for flow measurements and most excitingly development of lower cost Narrowband Internet of Things (NB-IoT) & Cat M1 ready devices.

I also provide technical representation for Queensland on a number of State and Federal groups such as WaMSTec, BoM Flood Standard Technical Assessment Group, State based Flood Warning Consultative Committee and the Northern Basin Hydrometric Upgrade project. This work is very rewarding as I get to work with some of the best "water people" in the country.

What hydrographic or other qualifications - relevant to your role - do you have?

I took a role of Cadet Hydrographer in 1997 with the then Department of Natural Resources. Part of my cadetship was on going enrolment and completion of the Hydrographic Certificate. The first course I started was written in the 1970s and it was a bit of a challenge to find the drafting pens required to complete the Design Survey Drafting unit. This course was superseded by a new course (I can't recall its title) and I completed most of the units but not all.... The course then changed again to the Cert IV and I thankfully finally finished it in 2001.

It must said that most learning was done in the field and I was lucky enough to have a great mentor in John Ridler (now retired). Being a lowly paid cadet I took every opportunity to work "out bush" because it meant I could live off cans of beans and pocket my Travel Allowance. Good times!

What are your major achievements?

In 2005 I left the saftey of a governement gig and started working for a US based ADCP manufacfruer (SonTek). I provided field training for local customers. Quickly realising the opportunity to expand the sales business, to include service, I presented a business case to the then CEO Gayle Rominger of parent company YSI.

Gayle approved my plan and I returned to Australia to establish YSI Australia with my good friend Mic Sievers (now deceased). Mic and I had unbelivable success and we grew that business to $7M and eight people.

I consider this to be one of my greatest achivements not because of the dollars but because of all the fantastic, rewarding relatiosnhips we created amd the adventures we had.

Where has hydrography taken you in the world?

I have been very fortunate in that Hydrography has taken to just about every corner of the world. Probably one of the most exciting places I have worked is in the Northern Islands of the Solomons. We were contracted in to map the freshwater/saltwater interface in places like the Tukuku River. The job involved lots of jungle treks, hair raising helicopter rides, canoe rides, crocodiles etc. A real Boys Own Adventure.

How did your career related to hydrography commence?

My career in Hydrography started out purely by accident. I had landed in Australia as a nineteen year old fresh out of the British Army where I served as a Combat Engineer (never saw conflict thankfully). I was running out of money and needed a job, given that I was only really qualified as a rigger or security guard I constrained my job search to the small ads in the Courier Mail. But… a full page ad caught my attention – “Do you like working in a natural environment, are you fit and strong (was back then) and are you prepared to commit to training.” Yes, Yes and Yes! So I took myself down to New Farm public library to find out what a Hydrographer was and of course spent the afternoon learning all about our salty cousins who like to map ports and harbours. Undeterred, I bought a St Vinnies suit and proceeded to walk the 5Ks in to the City for an interview, which was not a great idea. By the time I got there I was a puddle of sweat in an ill-fitting wool suit.

Something went very right for me that day and out of 150 candidates Richard Dickfos and I were offered positions. Tricky is still with the Department working out of our Toowoomba office today.

Was there anyone who had a major influence on your career?

There are three people that have really had a big influence on my career:

1. Paul Martin for giving me a go and teaching me how to play the narrow gap between managers’ expectations and practical field realities. Oh and how to have a good time while still achieving results.
2. John Ridler was my party leader from day one. JR took great pride in our work and very thorough in handing on his skills. He also taught me how to speak so Aussies could understand me (“Now Arran go through your vowels again”).
3. John Sloat was the lead trainer for SonTek. We travelled all over the world putting on what he called our “Dog & Pony Show”. John taught a great deal about communicating what can be very dry material in an entertaining and engaging fashion.

What has been the most memorable experience in your career?

The most memorable hydrographic experience for me was having the opportunity to measure the 2011 Brisbane floods from the Jindalee Bridge. We boated in to the bridge through roof tops and around Blockbuster signs while dodging shipping containers etc. There was a real sense of apprehension in the team as we knew this was going to be the biggest test our equipment and ourselves yet.

Thankfully we were up to the challenge, adapting our techniques to accommodate the conditions (depths of around 25 m, velocities up to 4 m/s and lots of odd debris). We measured through to the peak of the king tide and back down until the small hours of the morning. The ADCP we were using was struck by a tumbling tree, the harness broke and $70,000 of equipment floated off down the river. Never to be seen again – or so we thought. Two years later I was called in to the Nundah Police Station where flood debris that looked valuable was stored. And there was my M9! We changed the batteries and put that unit back in to service.

What makes hydrography interesting?

Everything – I love the challenge. Every measurement situation is different; each site has its own quirks. A good hydrographer adapts and overcomes after all coming home without the data is not a good look!

What do you do when you are not at work?

We have a farm South of Tenterfield in NSW on the Deepwater River. We agist to a neighbouring farmer and run a hunting property. The accommodation is a three bedroom barn conversion and we have done most of the work ourselves. I am going to tile the upstairs bathroom over Christmas.

Oh and I am currently teaching the eldest of my four children how to drive...

Where do you see hydrography in 50 years?

Fifty years is a lifetime in Hydrography and if you consider where we were fifty years ago I don't think anyone would be game to speak with confidence on the next fifty years.

In the next ten to twenty years I do see a shift towards remote and non-contact measurement. Hydrography will continue to evolve and I very much look forwards to being part of it.

Automating Rising Bubble Streamflow Measurement with Artificial Intelligence

Jeremy Bulleid, National Institute of Water and Atmospheric Research (NIWA), New Zealand

Introduction

In the July 2019 and October 2019 issues of the AHA Journal, I provided an overview of the Rising Bubble Method (RBM) of streamflow measurement and outlined our progress with the development and implementation of a practical RBM tool to improve the reliable measurement of water flowing in lowland weedy streams. This is part of an MBIE Envirolink Tools project we are carrying out in collaboration with several regional councils.

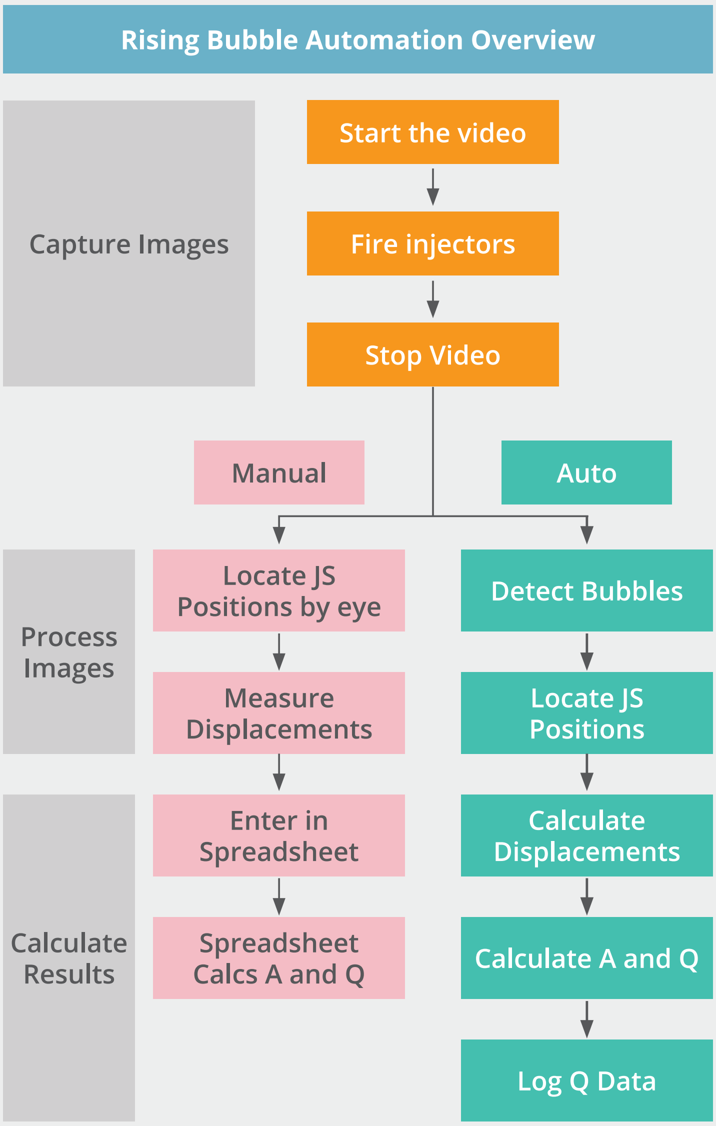
In principle we release 'precision' air bubbles from a streambed to enable direct calculation of Total Discharge. In this article we focus on automation. We have achieved partial automation, where we capture 5 seconds of video at a remote site, telemeter the file and detect surfacing bubbles in the images by eye. Figure 1 provides an overview of the manual and automatic processes.

Total Discharge (Q) is calculated using:

Q = Vr * A,

Where Vr is the bubble rise velocity (measured in the Velocimeter – covered in previous articles) and A is the displacement area on the water surface.

To determine area, we identify the *surfacing location* of each bubble. From this we measure the downstream displacement of each surfacing location, from its origin, and calculate the total displacement area defined by multiple injectors.



Capturing the images

To capture images we have developed a controller that initiates a 300-frame video take, operates the air-valve that simultaneously fires each of the bubble injectors on the stream bed and stops the video after five seconds.

The video clip may be telemetered, from a remote site to the office, for manual processing or for quality verification.

Alternatively, it may be processed automatically, on site, to output and log the results of successive Q measurements. Onsite automation minimises the amount of data (per measurement) that would need to be transferred – one Q value vs 300 0.3 MB image files.

Processing the images

We have developed a reliable bubble detector by creating a multi-layered Artificially-Intelligent Neural Network (NN) that detects surfaced bubbles. We chose Deep Learning (DL), a machine learning technique that does what comes naturally to humans - it learns by example. So, with DL we don't need to understand which features best represent the bubbles we're trying to detect as DL uses training images to extract these features for us. But this process requires literally hundreds of training and verification images. Here, video comes to the rescue, as it is easy to derive lots of labelled data from video taken of the water surface at bubble rise time.

Another reason for the use of DL is that, unlike conventional Machine Learning (ML) where features are manually extracted, if necessary, we can keep training with more and more-diverse images. This strategy can facilitate development of a detector that is more robust and provides better results over a wider range of natural conditions. In contrast, where DL can go on learning indefinitely, ML (with manual feature extraction), requires a lot of human input in order to approach a precision 'ceiling'.

There are three stages in the AI process: creating the NN, training the NN to detect bubbles and creating/using the bubble detector.

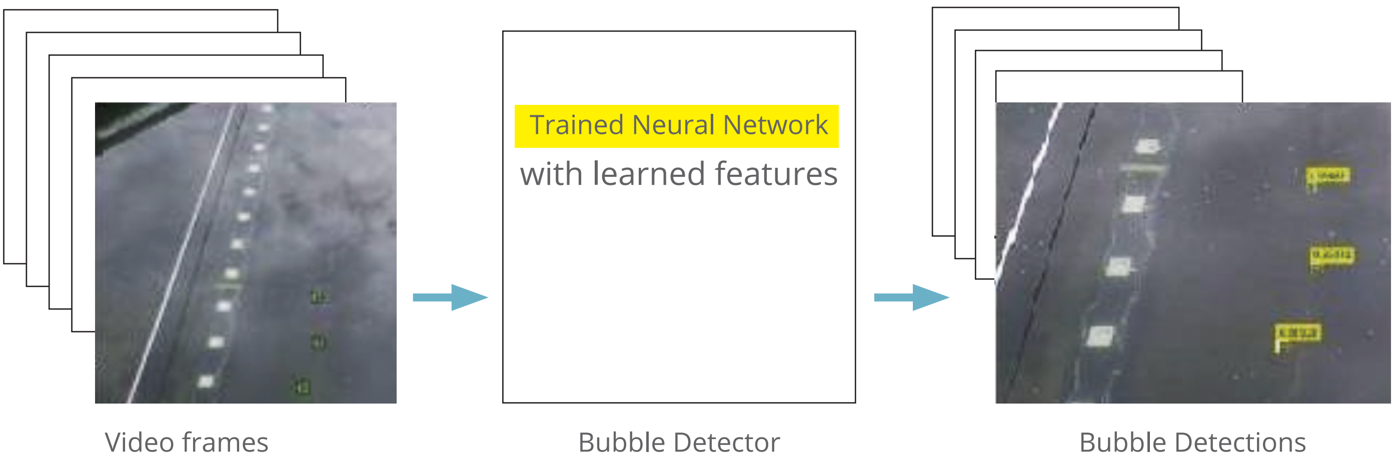


Figure 2: Using the trained bubble detector.

Because of the need for large training datasets, and hence long training times, we needed to exploit the power of a High-Performance Computing Facility (HPCF). Even with this extended capability it took over three days to train the neural network used to obtain the results below. Once trained, the detector software can be compiled into a relatively compact 'Q measurement' firmware application (app) and embedded into a small processor to enable 'stream-side' processing. In comparison to the long training process, the detector portion of the firmware works very fast (minutes) as it uses, just enough features, to uniquely identify its target.

Calculating the results

In the September 2019 issue of the AHA Journal, we examined in detail the results from flow measurements carried out at Raupare Stream in Hawkes Bay. We calculated these manually, by stepping through video frames, measuring bubble surfacing positions on-screen with a ruler and inserting these measurements into a processing spreadsheet. We now use these manual results to compare against the automated results. Figure 3 shows 'surfaced bubble' detections, by the deep learning network, in a single frame of video. The inset bubble image is an actual training image and exemplifies how little resolution is required to obtain valid detections.

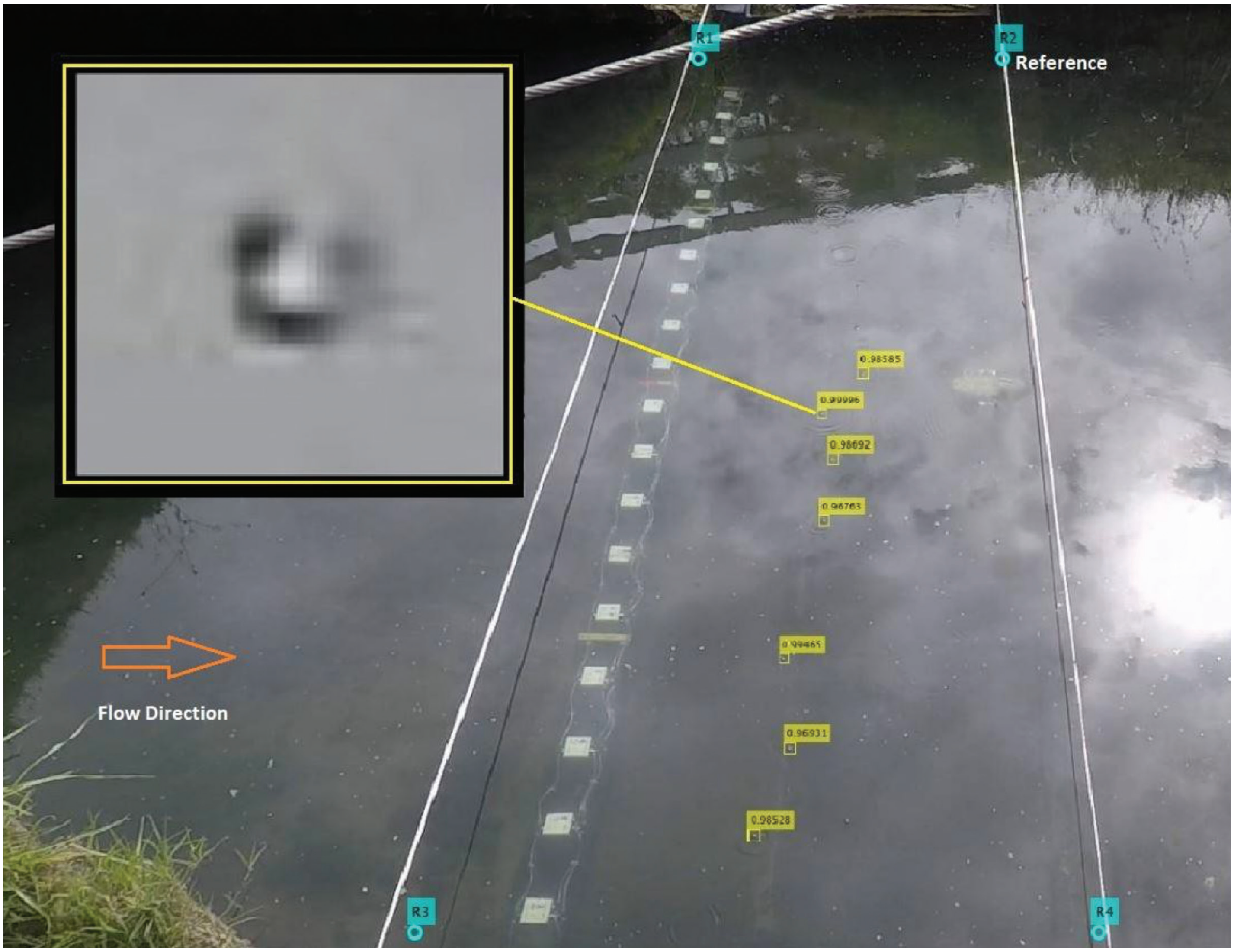


Figure 3. Raupare Stream; view from the Stilling-well Tower and is the location of the video shoot. This shows the detections obtained from a single frame of video. Each annotated bubble shows the detector's confidence in having achieved a correct detection.

There were 20 injectors spaced 0.2 m apart. The injector images are refracted at the air/water boundary so, even though they are visible, we can't use their 'apparent' underwater positions for reference. All measurements are referenced to the plane of the water surface.

From the bubble surfacing displacements, the app calculates the 'just-surfaced' image position (in pixels) relative to the reference (SDR), converts it to true displacement (in metres) and calculates the partial area (pA) and partial discharge (q) contributed by each injector (Table 1). We limited this example to nine injectors.

Table 1. Example of the software structure within which we assemble and store the data used to calculate Total Discharge (Q).

dischargeStruct

1x9 struct with 4 fields

Fields	SDR	TrueDispl	pA	q
1	[]	[]	[]	[]
2	0.3985	0.4901	0.0980	0.0215
3	0.4295	0.5283	0.1057	0.0232
4	0.4108	0.5053	0.1011	0.0222
5	[]	[]	[]	[]
6	0.5558	0.6836	0.1367	0.0300
7	0.4672	0.5747	0.1149	0.0252
8	0.5035	0.6193	0.1239	0.0272
9	[]	[]	[]	[]

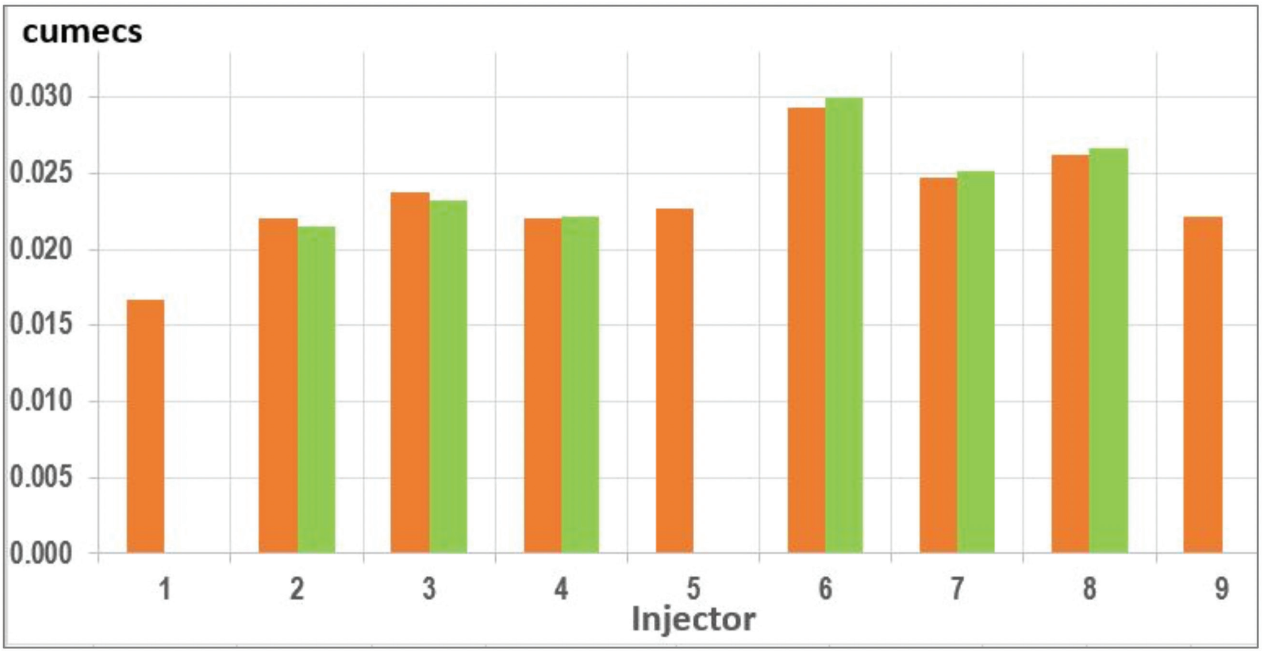


Figure 4. Verifying the automation process.

Verifying the automatic process

The bar graph in figure 4 shows the partial discharge calculated at injector positions one to nine. The results from the automatic calculations (green bars) are shown beside the reference values (orange bars). When the video was taken we were carrying out a 'three-point' FlowTracker gauging (0.482 m^3/s). This took over an hour. The manual RBM calculation was 0.462 m^3/s, taken from a series of 10 'shots' at 1.7 second intervals.

Summing the six partial discharge values gave: manual 0.149 m^3/s, and automatic 0.148 m^3/s.

Conclusions

These initial results indicate that automatic operation of RBM is achievable. To obtain robust operation over a wide range of locations and conditions, significantly more training will be required. However, videos for training purposes are easy to acquire and label.

The next stage will be to increase the diversity of the training, set up the prototype monitoring system at Raupare and to carry out end-to-end trials.

In addition to calculating discharge, we can also calculate depth-integrated and surface velocities using the displacements and the time derived from the camera's frame count at 60 frames per second.

Acknowledgements

MBIE Envirolink for funding;

Thomas Wilding, Hawke's Bay Regional Council;

Andrew Starr, NIWA, for the design and construction of the control box;

NIWA, HBRC, ECan for their support.

New Flood Warning Infrastructure Framework and Standard Endorsed by ANZEMC

Dr Carla Mooney, Bureau of Meteorology, Melbourne, Victoria
Dr Richard Hammond, Bureau of Meteorology, Melbourne, Victoria

Abstract

On 27 August, the Australia-New Zealand Emergency Management Committee (ANZEMC) endorsed the National Framework for Flood Warning Infrastructure and the Flood Warning Infrastructure Standard developed by the National Flood Warning Infrastructure Working Group (the Working Group).

Background

Accurate near-real-time data are essential for preparing effective and specific flood forecasts and warnings. Australian flood forecasting and warning services rely on over 100 different organisations to collect, measure, record, send and receive, store and display rainfall and river level data. In many cases the flood warning infrastructure that supports the service has been adapted from other purposes. Historically, this has posed several difficulties, including incompatibility of instruments and data-communication technologies, ineffectual choice of sites, and inadequate redundancy (BoM, 2019).

The Flood Warning Infrastructure Standard is intended to improve data accuracy, interoperability, resilience and latency, and reduce life cycle costs. Fundamentally, it is expected that the Standard will provide guidance on fit-for-purpose flood warning infrastructure based on non-mandatory industry-recommended performance requirements (BoM, 2019).

The scope of the Standard includes flood warning infrastructure from field instruments and communications equipment, through to the data ingestion software for receiving, storing and displaying real-time flood data. The Standard applies to new and existing infrastructure required for warning services for riverine and flash flooding.

The Framework provides guidance for future flood warning infrastructure planning and investment, based on jurisdictional analyses of their flood warning infrastructure. The Standard presents non-mandatory industry-recommended performance requirements for the design, development and monitoring of fit-for-purpose flood warning infrastructure. These initiatives will guide future flood warning infrastructure investments in an integrated and cost-efficient manner, to enhance flood warnings to the community. The endorsement of the *National Framework for Flood Warning Infrastructure and the Flood Warning Infrastructure Standard* marks the successful conclusion of the time-limited Working Group and is testimony to the collaborative nature of the Working Group and the hard work of all involved.

Standards development

Following Munro (2011) recommendations, ANZEMC established a Bureau of Meteorology Hazards Services Taskforce (the Taskforce) in October 2013. The Taskforce reported to ANZEMC in May 2015 and recommended the formation of the Working Group.

The Working Group was established in 2016 to address the limitations and inconsistencies of flood infrastructure and standards across Australia. The Working Group involved extensive collaboration and inter-agency cooperation to standardise national flood warning services and infrastructure; an ambitious undertaking given the wide variety of climates, jurisdictions, and agencies involved. The Working Group was a time-limited project, working to deliver a Flood Warning Infrastructure Standard, Infrastructure reports for each jurisdiction, and a National Framework for Flood Warning Infrastructure by 2019.

Figure 1. National Flood Warning Infrastructure Working Group.

Figure 2. National Flood Warning Infrastructure Working Group Chairs.

The Flood Warning Infrastructure Standard was developed by the Standards Technical Advisory Group (TAG). The TAG was established to provide expert advice to the National Flood Warning Infrastructure Working Group (BoM, 2019).

The development process included two periods of consultation.

The draft standard was made available for initial industry consultation from 1st June to 31st August 2018. The consultation was formally launched at the 2018 Floodplain Management Association Conference. The draft Standard was also made available on the Bureau website and various activities undertaken to make industry aware that it was available for comment.

Written submissions were received from 17 parties. A number of these were consolidated responses from organisations with multiple contributors. In total 272 individual comments were provided. These can be viewed via the Consultation report: http://www.bom.gov.au/water/standards/documents/Consultation_feedback_log_and_response.pdf

The Standard was substantially revised in response to feedback. This included resolving technical/factual matters, reformatting, improving examples and simplifying language. The revised draft standard was then made available for public comment from 10 May to 10 June 2019. Minor comments were received, and the draft standard was revised accordingly.

This enabled ANZEMC to endorse the National Framework for Flood Warning Infrastructure and the Flood Warning Infrastructure Standard on 27 August 2019. As a consequence the Working Group was able to deliver the defined deliverables within the specified timeframe.

Collaboration the Key to Success

Collaboration was the key, to the success of the Working Group. In accordance with the Total Flood Warning System, flood warnings in Australia are provided via a partnership involving all levels of government: Commonwealth, State, Territory and local. While the Bureau of Meteorology has the responsibility for the provision of forecasting and warning services for riverine flooding in all states and territories (with limited exceptions), the prime responsibility for flash flood warnings lies with states and territories in partnership with local government. However, the Bureau provides forecasts and warnings for severe weather conditions and potential heavy rainfall conducive to flash flooding. Given the already inter-dependent nature of these relationships, the Working Group demonstrated the significance of a cooperative spirit to improve the preparedness and safety of the community.

For further information on the Flood Warning Infrastructure Standard:
http://www.bom.gov.au/water/standards/floodwarning.shtml

References

Bureau of Meteorology, 2019, *Flood Warning Infrastructure Standard*, Viewed November 2019, http://www.bom.gov.au/water/standards/floodwarning.shtml

Munro, C, 2011, *Review of the Bureau of Meteorology's extreme weather and seasonal forecasting capacity*, Viewed November 2019, http://www.environment.gov.au/resource/review-bureau-meteorologys-extreme-weather-and-seasonal-forecasting-capacity

Department of Water and Environmental Regulation of Western Australia, 2019 Hydrographic Technical Forum

Luke Donovan, Department of Water and Environmental Regulation, Kununurra, Western Australia

Introduction

Recently the AHA Journal has featured a number of articles featuring Acoustic Doppler Current Profilers (ADCP), Real Time Kinematic (RTK) surveying and Digital Elevation Models (DEM) created from Drone captured imagery.

These are some of the evolving measurement technologies that make up one of the three key foundations that define the Western Australian Government's Water Measurement Program.

In the preceding years there have been a number of National ADCP Regattas and other workshops to inform the creation of National Standards and consistent hydrographic operational techniques. Building on these great examples the Department of Water and Environmental Regulation's (DWER) Measurement Lead Team (MLT) have introduced an Annual Hydrographic Technical Forum (HTF) to ensure all DWER Regional Measurement Teams from around the State of WA have the opportunity to evolve with these new and emerging technologies and on the way improve data quality, operating procedures and consequentially find efficiencies in the way they work.

Inaugural Hydrographic Technical Forum

On the 22nd - 24th of October the inaugural 2019 HTF was hosted by DWER's North West Region Measurement Team in conjunction with key leads Simon Pinnington (chair of the ADCP Working Group) and Michael Whiting (Water Resource Assets Project Manager, Hydrologic Technology Centre). The Forum was attended by over twenty Hydrographers and Technicians from DWER's Regional Teams and the Hydrologic Technology Centre (HTC).

The HTC has recently deployed new and upgraded instruments and equipment as per a recent 'Gauging Capability Improvement Business Case'. A key recommendation of this business case, the use of consistent deployment and data collection methods combined with improved safe operating techniques.

Figure 1. The 2019 HTF participants below the Ord River Dam-Lake Argyle.

Hosting the forum within the confines of the Ord River Irrigation Area (ORIA) which includes the Ord River Dam (Lake Argyle) and the Kununurra Diversion Dam (Lake Kununurra) guaranteed an ideal environment and flows for the integration of these initiatives into a practical forum.

The Miriwoong people believe we have three seasons: Nyinggiyi-mageny (wet), Warnka-mageny (cold) and Barndenyirriny (hot). These three seasons are broken down into eight stages, October or the Dilboong stage is no surprise, in the hot season. Hosting this event in Dilboong, on the banks of the Ord provided an added opportunity for DWER's Southern Hydrographers to experience working and living in +40 ºC temperatures. They also endured bush fires and road closures ensuring a real 'Kimberley experience'. Some were fortunate enough to travel the 55 km by boat, from Lake Argyle back to Kununurra, otherwise locally known as the Dam to Dam, due to the road closures.

DAY ONE — Measuring flows from a river bank

Day one was located on ORIA's main irrigation channel, the M1. Here we compared and evaluated multiple bank deployment methods, multiple software programs and multiple flow gauging instruments, including water surface velocity (Velocimetry) data captured using an aerial drone.

The velocimetry data can be applied to a known cross sectional area to generate a flow result. In this case the result was 5.5 m^3/sec and a very good comparison to the data captured with the ADCPs.

In high flow events ADCPs can be problematic to use, due to overbank flows across heavily vegetated flood plains or simply the area being inaccessible by boat. Measuring flows from a drone using velocimetry will provide the ability to collect data that has not previously been accessible. The use of a drone also reduces the Occupational Safety and Health (OSH) risk and hence protecting our Hydrographers' safety, by reducing the time required to be spent on the water, during high flow events.

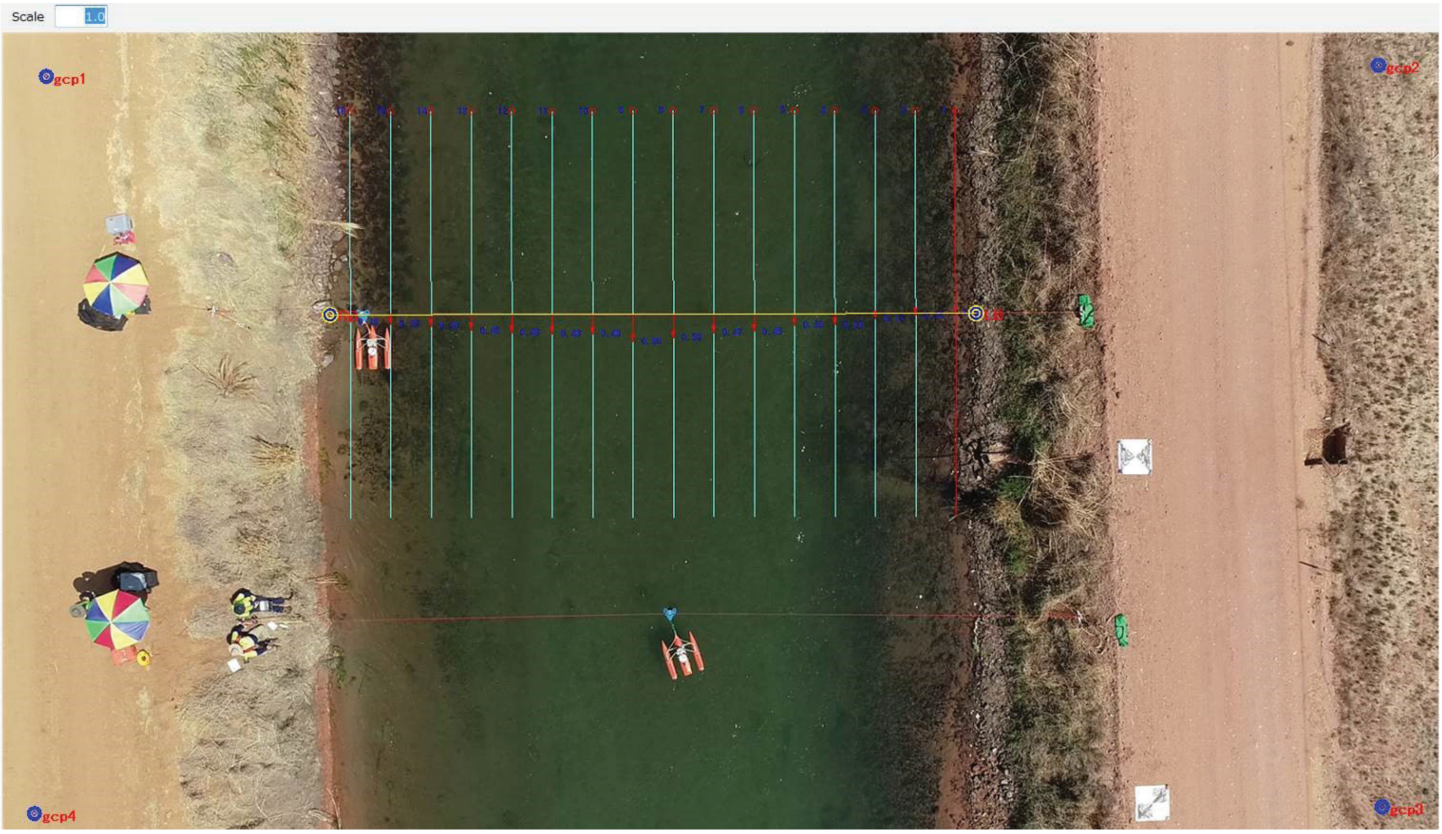


Figure 2. Drone captured velocimetry data (result 5.5 m^3/s). Ord Irrigation Scheme M1 Channel.

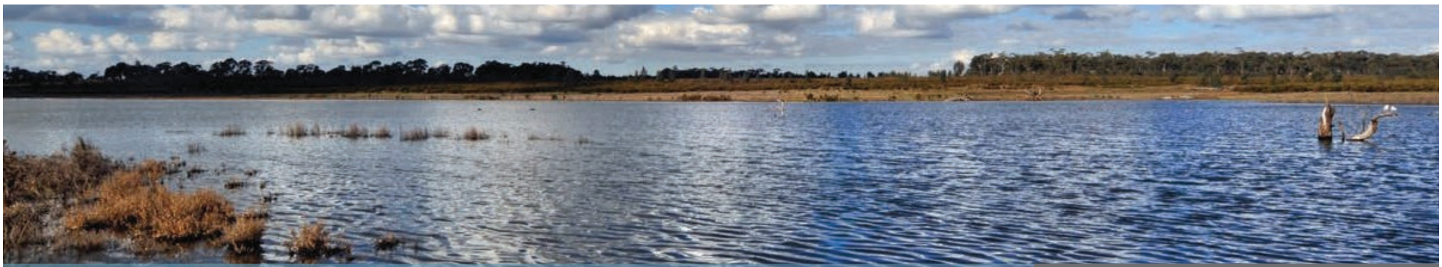
DAY TWO — Boat gauging

The Ord River Dam not only provided a unique and a spectacularly scenic location: the releases from Lake Argyle, used to supply water for irrigation, also generate hydro power for Wyndam, Kununurra and the Argyle Diamond Mine. These releases on day two varied between 80 and 85 m^3/s (or 6912 ML/day). This guaranteed an environment where our hydrographers could not only test the instruments and boat gauging techniques, but also provided an opportunity for to brush up on their swift water boat handling skills and safety procedures.

DAY THREE — Data verification and processing

Day three was a welcome relief, for some, to escape the Dilboong (hot season). At one stage there were up to 20 people in the little Kununurra Depot meeting room, but not one complaint, so everyone must have been happy in the air conditioning. Consistent deployment and data collection techniques are important; also critical is the use of consistent data verification processes. Comparing results, software programs, techniques, methodology and instruments generated the opportunity for some really positive and robust discussions around improving operating procedures and data verification methods.

Figure 3. Boat gauging downstream of the Ord River Dam.



Providing Australia with Water Information

Australian Government
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www.bom.gov.au/water

Have you checked out the Bureau of Meteorology’s water information web pages recently?

They provide a comprehensive and reliable picture of Australia's water resources for the benefit of all water users.

The published water information is based on data provided by almost 200 organisations across Australia. Working closely with data providers and stakeholders, a portfolio of water information products has been developed covering historic information and trends; current status; forecasts; and planning tools to provide users with both a local and national perspective on water resources in Australia. Key products include:

Water Data

- Water Data Online provides a single access point to data for more than 6000 monitoring stations across Australia.
- Water storages dashboard compares daily water levels and volumes for more than 300 storages.
- Design Rainfalls provide Intensity-Frequency-Duration rainfall estimates for designing hydraulic structures.
- Australian Water Market website tracks and reports water trading.

Water Status

- Our suite of national water assessment products, groundwater information products, National Water Account and Urban Performance Report provide information to support water policy and planning.
- The Landscape Water Balance Model assists in understanding how catchments have responded to rainfall and runoff both currently and in the past.

Water Forecasts

- The 7-day streamflow forecasting service and Seasonal Streamflow Forecasts provide streamflow forecasts to assist river operators with decision-making.

MORE INFORMATION

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Outcomes and future hydrographic technical forums

DWER's ADCP working group is in the process of collating results and developing a technical report which will guide new operating and verification processes. Particularly the introduction and use of 'QREV', which is an independent data verification software program developed by the USGS (United States Geological Survey). QREV allows the Hydrographer to view and determine the best data collection method while onsite before and during the flow measurement.

Measurement Technologies, specifically velocimetry and the Internet Protocol (IP) telemetry are evolving fast; this is especially pertinent in the emerging communication methods, such as micro satellites and the 5G Internet of Things (IOT). An annual Hydrographic Technical Forum will provide space for Hydrographers and Technicians to be on the front foot and improve safety, operating procedures, data collection, and verification and find continued efficiencies in the way they work. Ultimately hydrometric data sets form the cornerstone for DWER's business needs, making the continuous improvement of its quality and availability business critical.

Figure 4. Ord River Dam.

Manly Hydraulics Laboratory

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Call that an extreme event? Describing the extremeness of an event before, during and after it has occurred.

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

Abstract

Being able to define how extreme an event will be; is currently being experienced; or was, is vital information to assist in preparing for extreme events.

There have been some semi-recent changes in the probability terminology that is used to define how extreme an event is. This is being done to ensure that everyone is clear about what the terminology means and are consistently used in messaging/communications to a range of stakeholders.

This new terminology emphasises that there is an equal probability of an event of a specified magnitude occurring or being exceeded in any given year, and that the probability of an event is independent of what has happened in recent years. The use of Average Recurrence Interval (ARI) as in '1 in 100 year event' is now discouraged as it leads to confusion by suggesting an elapsed time between each event, whereas in reality a "100-year flood" can happen in successive years.

The paper demonstrates how the Bureau of Meteorology has used this information for recent large rainfall and flood events.

Glossary

AEP – Annual Exceedance Probability

ARI – Average Recurrence Interval

ARR – Australian Rainfall and Runoff

EY – Exceedances per Year

PMP – Probable Maximum Precipitation

Introduction

After large rainfall and flood events, news reports often make statement such as:

> *"Train commuters hit with cancellations as 'one-in-100-year' storm clean-up continues"*
>
> *"Tennant Creek deluged with 'one-in-50-year' flood"*
>
> *"Severe weather warnings issued as a once in 50-year storm barrels towards the nations southeast"*

But what does it mean? How extreme are these events and how often do they occur? The ability to accurately determine the extremeness of an event and then clearly communicate this to a range of users from technical people to members of the general public is a critical part of managing these events.

- Before an extreme event — to ensure that infrastructure such as stormwater drains, flood levees and emergency management plans are developed for the appropriate level of risk;
- During an extreme event — to assist in identifying the extremeness of forecast and observed rainfall and flood events to enable the issuing of severe weather and flood warnings; and
- After an extreme event — to determine the extremeness of the event in order to review the emergency management strategies for future events of different extremities.

Australian Rainfall and Runoff (ARR) (Ball *et al.*, 2016), the design guidelines used throughout Australia for estimating flood potential for drainage and infrastructure design has been revised.

As part of the revision of ARR there have been some changes in the probability terminology to ensure clarity of meaning, technical correctness, practicality and acceptability. The aim is to reduce the misunderstandings amongst practitioners and in the broader community about the probability of a particular event occurring. In the sections below, the new probability terminology is discussed including comparisons with the previous terminology; followed by examples of how the new probability terminology is used by the Bureau of Meteorology before, during and after extremes events provided.

Probability terminology

Assigning a probability to a rainfall or flood event is a common approach for determining the extremeness of an event. Previously, it has been common practice to describe the extremeness of an event using average recurrence interval (ARI) in years. For example, an event had a 1-in-50 year ARI or was the 50 year event. Although this terminology was intended to describe the probability or frequency of an event occurring in terms of the *average* time interval between events of the same magnitude, it was often misconstrued to be the elapsed time between each event. For example, it is often thought that because the 1-in-20 year flood has just happened it won't happen again for another 20 years.

However, the probability of a particular rainfall or flood occurring in a given year is not dependent on what has happened in recent years. As such, it is possible for an event to occur more than once within the given period of time and such events can be clustered. It does not matter if there was a 1-in-100 year event two years ago, there is still a 1% chance of the event being equalled or exceeded in the current year.

This new probability terminology emphasises that there is an equal probability of an event of a specified magnitude occurring or being exceeded in any given year, rather than implying an elapsed time between each exceedance. In a given climatic environment, the probability of an event is assumed to be unchanged throughout the life of the infrastructure asset. It is also possible for an event to occur more than once within the given period of time and such events may be to be clustered.

Table 1 shows the new probability terminology and how it relates to the old probability terminology for the full range of probabilities. The higher the percentage AEP, the more likely the event is to occur or be exceeded within a given year and the lower the percentage AEP the less likely the event. The terms in bold are those recommended to be adopted for each of the frequency descriptor classes and the standard probabilities available through the Bureau Intensity-Frequency-Duration (IFD) design rainfall system. While Table 1 shows the full range of probabilities, in practice the probabilities highlighted by the red bounding box are the ones most commonly used to describe most extreme weather situations.

Table 1. New and old probability terminology — detailed

	Frequency Descriptor	New Terminology			Old Terminology
		Likely number of exceedances per year	Percentage probability of event in any given year	Probability of event in any given year	Average Recurrence interval in years
More likely		EY	AEP (%)	AEP (1 in x)	ARI (years)
↓	Very Frequent	12			
		6	99.75	1.002	0.17
		4	98.17	1.02	0.25
		3	95.02	1.05	0.33
		2	86.47	1.16	0.50
	Frequent	1	63.2	1.58	1.00
		0.69	50.00	2.00	1.44
		0.5	39.35	2.54	2.00
		0.22	20.00	5.00	4.48
		0.2	18.13	5.52	5.0
	Infrequent	0.11	10.00	10	10.00
		0.05	5.00	20	20.0
		0.02	2.00	50	50.0
		0.01	1.00	100	100
	Rare	0.005	0.50	200	200
		0.002	0.20	500	500
		0.001	0.10	1000	1000
		0.0005	0.05	2000	2000
	Extremely Rare	0.0002	0.02	5000	5000
				↓	
Less Likely	Extreme			PMP	

Using the new probability terminology

The probability terminology shown in Tables 1 and 2 can be summarised as follows:

- The term Annual Exceedance Probability (AEP) will be used for design events (rainfall and flood) with a probability of 50% AEP and rarer (less frequent);
- AEPs are to be expressed as a percentage exceedance probability; for example a design rainfall might be described as having a 1% AEP instead of 1 in 100 year ARI;
- Events more frequent than those with a 50% AEP will be expressed as X Exceedances per Year (EY). For example, a design event (rainfall or flood) with a 6 month recurrence interval will be expressed as having 2 Exceedances per Year (2 EY);
- The use of Average Recurrence Interval (ARI) is discouraged, as it leads to confusion with the public by suggesting the elapsed time between each event.

One way to remember this is that a 1-in-100 year event has a 1% chance of being equalled or exceeded **in any given year**, while a 1-in-1 year event has a 63.2% chance of being equalled or exceeded **in any given year**. These values are derived from statistical relationships based on observed rainfall or flood flows and therefore related to the climate of the region.

The relationship between AEP and ARI for events less frequent than 10% AEP (1-in-10 year ARI) is quite similar — it's just the inverse. However, for 20% and 50% AEP the usual conversion does not apply and the values in Table 1 should be used.

Describing the Extremeness of an Event

The new probability terminology provides a consistent approach for describing the extremeness of events — before, during and after an event. The Intensity-Frequency-Duration (IFD) design rainfall suite, updated and expanded by the Bureau of Meteorology in 2016 (Bureau of Meteorology, 2016), has adopted the new probability terminology to assist users. These are a useful way of defining extreme rainfall events and can be used to identify possible events from forecast rainfall data before they happen.

Before events, the new IFDs are used by engineers in the design of water conveyance and storage infrastructure and by planning authorities to determine the acceptable level of risk of extreme events communities exposed to. After events, they are also being used to assign a probability to the event and to assist in reviewing the emergency management plans for events of different extremities. The new IFDs are now being used internally within the Bureau to estimate the probability of observed and forecast rainfall events and to identify the potential risk of flooding, particularly in urban areas, to guide emergency management preparedness and response. Each of these three scenarios is described in the following sections.

Before extreme events

Design rainfall estimates are used in the design of infrastructure including gutters, roofs, culverts, stormwater drains, flood mitigation levees, retarding basins and dams. They are used by engineers to determine things like potential water levels and flow velocities in areas subject to inundation as well as required flood capacity to meet necessary levels of safety.

In preparation for extreme events, planning decisions are made about the magnitude and the probability of extreme events occurring based on what is deemed to be an acceptable level of risk.

Although the design standards for structures vary from State to State, broadly they can be categorised as shown in Table 2. These design probabilities prepare communities for events up to and including extreme events.

During extreme events

During extreme events, the probability terminology used with the design rainfall grids allows forecasters to identify when severe weather is forecast and to provide warnings to emergency management services. Typically the 10% AEP is used by the Bureau's Severe Weather teams to:

- Determine thresholds used for issuing warnings for rainfalls that are may lead to flash flooding.
- Label area of the forecast rainfall grids as heavy.

Table 2. Typical Design Probabilities

Infrastructure	Typical Range of AEPs
Water sensitive urban design (WSUD)	4 EY
Road reserves	50% to 10%
Gutters and pipes	20% to 10%
Stormwater drains	2% to 1%
Minor culverts	20% to 2%
Major culverts	2% to 1%
Flood mitigation	5% to 1%
Floodplain management	2% to 0.05%
Bridge design	0.05%
Dam spillways	1 in 10 000 to 1 in 10 000 000

For the Flood Forecasting teams, the probability terminology used with the 2016 design rainfall grids:

- Provides forecasters with situational awareness and provides historical context to observed rainfall at individual sites;
- Enables forecasters to identify the extremeness of observed rainfall at individual sites, highlighting catchments that may be at risk of significant flooding; and
- Facilitates the issuing of flood warnings to emergency management services.

An example of how this has been used is shown from the flooding that occurred along the East Coast of NSW in March 2017.

Figure 1 shows the rainfall depths that were recorded in rainfall gauges across the Tweed River Catchment in NSW for the 24 hour period between 2am 30 March and 2am 31 March 2017. The incorporation of the design rainfall data into the Hydrological Forecasting System (HyFS) used for flood forecasting at the Bureau of Meteorology enables forecasters to view the AEP of observed rainfall in real time.

As shown in Figure 1, the observed rainfall depth at each of the rainfall gauges in the Tweed River catchment is shown together with the AEP of the observed rainfall. These AEPs range from 20%, in the north east of the catchment, to less than 1% (or rarer than 1 in 100 AEP) at ten locations in the catchment, as indicated by the stars in Figure 1.

This information enabled forecasters to become quickly aware that very heavy (or extreme) rainfall had been recorded at many rain gauges in the catchment and that significant flooding could potentially occur.

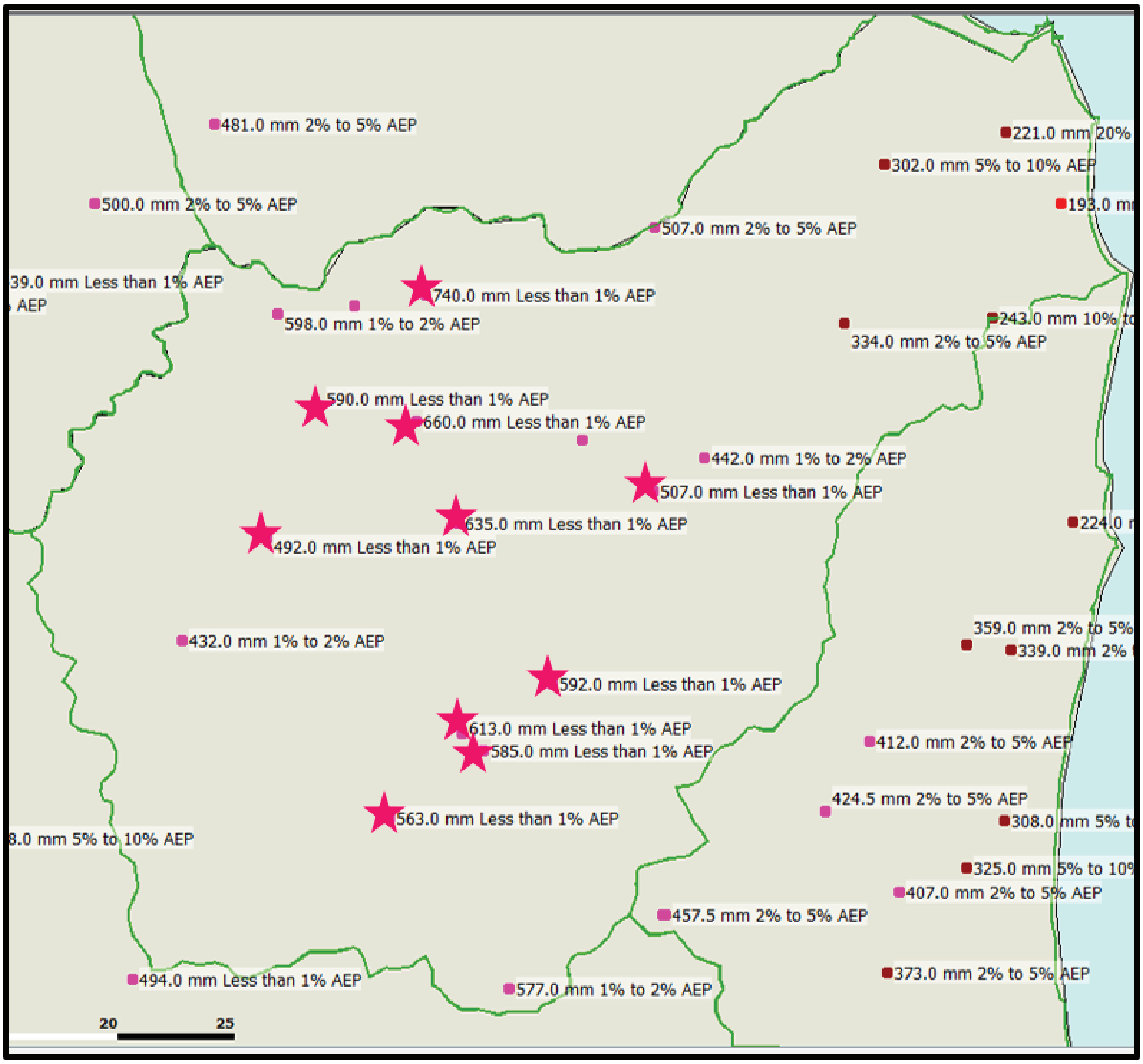

Figure 1. Tweed River catchment 24 hour rainfall depths and operational AEPs — March 2017.

After extreme events

Following the occurrence of extreme events, it is valuable to determine the extremeness of the event and assess how well existing warnings and emergency management responses worked to mitigate the impacts on the community. As discussed above, during the severe event that occurred in the Tweed River catchment in March 2017, it was sufficient for flood forecasters to know that the observed rainfall was rarer than the 1% AEP event at ten rain gauges. However, after the event it is beneficial to know how much rarer than 1% AEP the observed rainfall was.

By comparing the observed 24-hour rainfall at the ten rain gauges that reported the largest rainfall depths to the design rainfalls, as shown in Figure 2, it can be seen that the observed rainfall depths had the following AEPs:

- ~1 in 200 AEP at eight locations
- ~1 in 500 AEP for one location
- ~1 in 1000 AEP for one location

While there are caveats that need to be applied to the assigning of an AEP (or estimate of extremeness) to operational rainfall depths, the information provided is sufficient to confirm the extremeness of the events that occurred.

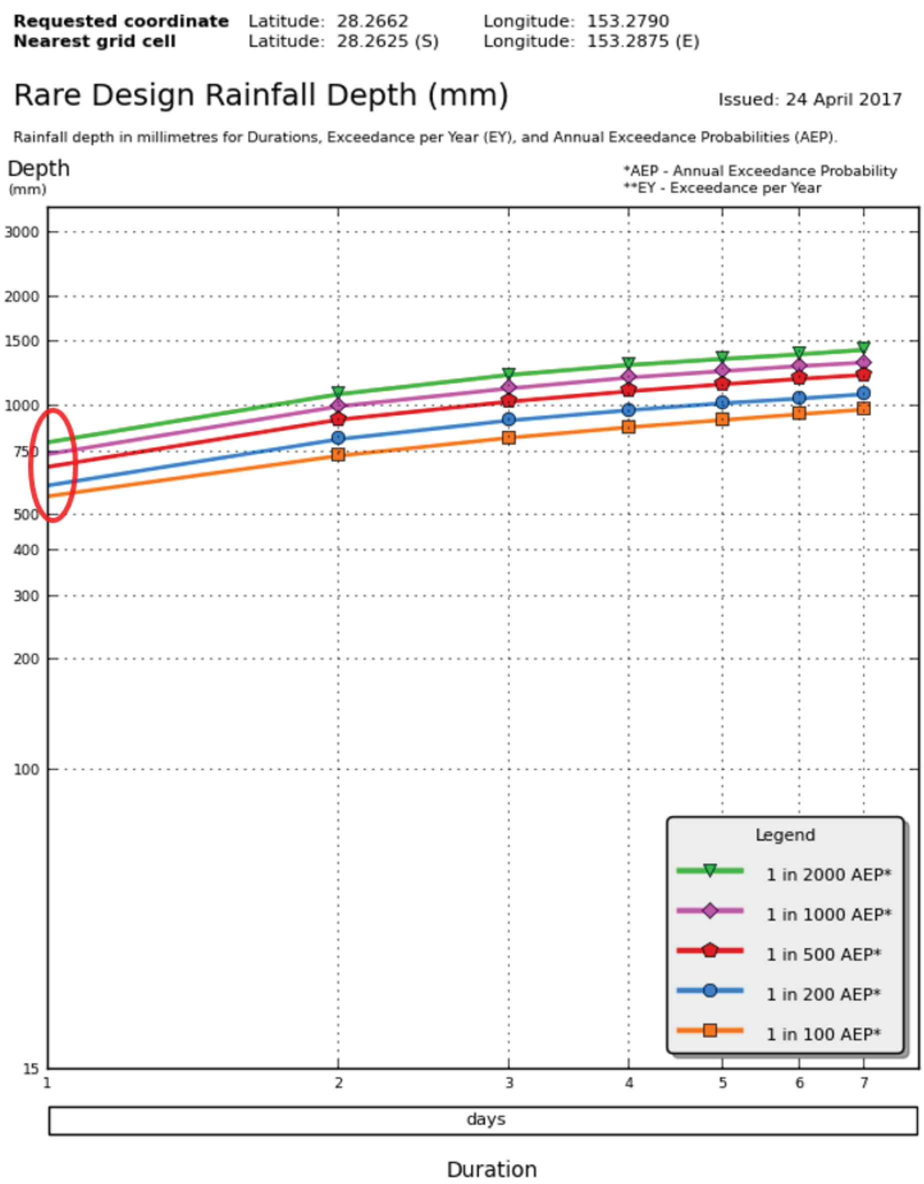

Figure 2. Tweed River catchment 24 hour rainfall depths March 2017 — assessment of AEPs.

Summary

Semi-recent changes to the terminology adopted for assigning probabilities to events has made it possible to better describe the extremeness of events before, during and after an event. The new probability terminology discourages the use of Average Recurrence Interval (ARI) as it leads to confusion by suggesting an elapsed time between each event. Instead the new probability terminology emphasises that there is an equal probability of an event of a specified magnitude occurring or being exceeded in any given year.

The new probability terminology has been adopted to:

- Ensure that infrastructure such as stormwater drains, flood levees and emergency management plans are developed for the appropriate level of risk before an extreme event;
- Assist in identifying the extremeness of forecast and observed rainfall and flood events to enable the issues of severe weather and flood warnings during an extreme event; and
- To determine the extremeness of the event in order to review the emergency management strategies for events of different extremities after an extreme event.

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