# Australasian Hydrographer

**April 2020**

AUSTRALIAN HYDROGRAPHERS ASSOCIATION

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**Cover Image:**
Wellington Flume in the south west of Western Australia

**Photo Credit:**
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JACQUIE BELLHOUSE

# Editor's Introduction

I hope this (slightly delayed) edition of the Australasian Hydrographer finds our members in good health and spirits given these challenging times. I am not going to delve into the recent bushfires and current COVID-19 situation as I am sure you are all full bottle given the level of news coverage. Instead I hope I have provided a bit of light reading for those who (might) be experiencing some down time.

This month's Journal is therefore quite a diverse coverage of what was, what is and maybe what could be.

Now for a little history. In 1978 the first Hydrographic Conference was convened by the Australian Water Resources Council (AWRC). The conference, which was held in Perth WA, was the birth place of today's Australian Hydrographers Association (AHA).

The forbearer of the Australasian Hydrographer, the Australian Hydrographic Newsletter, was subsequently born in 1979 as a medium for technical communication between Hydrographers across Australia. In 1995 (coincidentally the year I "formally" entered the profession) the Australian Hydrographic Newsletter was renamed to the Australasian Hydrographer to reflect the wider audience.

But why is this relevant? Well as such the Australasian Hydrographer (rather quietly) celebrated its $40^{th}$ Birthday last year! And the up and coming Technical Workshop (formerly the AHA Conference) will be our $20^{th}$.

How better to celebrate these two milestones than to look back at some of the brilliant articles from the 2018 Conference and introduce our new "From the Vault" Series.

From our collection of 2018 Conference papers please find a brilliant paper by John Hayes and Ray Boyton "What is an Extreme Event", "The Importance of Hydrological Data during an Extreme Event" by EMALTE's Mark Wolf and from across the ditch Ethan Coulston's paper "Korokoro flood warning project".

Finally for the first, of what I hope will be many, "From the Vault Articles" I have included a reprint of the Introductory and Inaugural Australian Hydrographic Newsletters (published in January and April 1979). This is the first of what I hope to be many "From the Vault Articles".

Keep safe, stay well,

**Jacquie Bellhouse**
Journal Editor


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ARRAN CORBETT

# From the President

And in the blink of an eye our world has changed... Of the many challenges we have faced in recent times this current crisis, COVID-19, is truly unique. The consequences of shutting down our way of life and tipping our economy on its head will be felt for many years.

Early indications are coming through that we will see massive cuts to state and federal spending in our industry, capital budgets are evaporating and projects are being cut. Please don't get me wrong, I support the actions being taken by our government and place human life ahead of data. Our defining challenge is now and the resilience of the hydrographic community will shine through – we will find ways to keep our networks running and as soon as it is safe to do so we will be back in the thick of it.

As a team your AHA committee is now working to identify ways in which we can provide support and value to its members through these tough times.

We recently recorded sessions at the NZHS workshop and will share these via our website. We are close to presenting you with our long term strategy for training and we are strengthening our relationships with related organisations. I have challenged our operations team to develop a value improvement and growth strategy through direct feedback from you – please speak up your involvement in this process is critical!

I sincerely hope that you continue to find value in the AHA and thank you for your ongoing support.

Best regards,

**Arran Corbett CPH**
AHA President

# What is an Extreme event?

**John Hayes and Ray Boyton**

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

## Abstract

*Is rare extreme or is extreme rare?*

*What is extreme? How is it defined for the hydrographic events we deal with most, i.e. droughts and floods?*

*What happens if the projections for climate change are true? As the number of extreme events increase and they stop being rare, do they stop being extreme? Are the old extremes the new norm?*

*Maybe not something to worry about now but for the latest generation of hydrographers it will probably be something they will have to consider in both their work and lifestyle.*

*We look at extreme events their definitions, and a 100-year or greater return period seems to be the winner, as well as the practical issues in trying to calculate a specific value for some of the more common definitions with the data that we collect.*

*We also look at some of the ways that hydrographers might plan to mitigate and deal with extreme events).*

## Background

So, what makes an extreme event for a hydrographer? Is it in the existential plain, i.e. is it to do with its frequency of occurrence or its rarity. Is it related to physical plain i.e. things like duration, peak, frequency, volume and intensity? Or has the role of a hydrographer extended so that the social, financial, political, safety or damage aspects need to be considered as well?

Common elements to all these are typically time, location, and size. But what may be an extreme event in one location may not be in another. So how do we define an extreme event?

The three most common data sets associated with the Australian hydrographic profession are surface water level and flow, groundwater levels and to some lesser extent rainfall data. We apologise in advance to those who may also be involved with monitoring activities such as oceanographic/estuarine/coastal data, those involved with the more extended range of weather data and those involved in other various environmentally related activities.

Certainly, as a profession, we consider things related to extreme weather events as impacting us and the two most common things that impact our profession, as opposed to us personally (or our family and friends), are floods and droughts. But in our professional roles we also can't ignore a range of other extreme environmental, weather and natural or man-made phenomena.

Figure 1. La Jument Lighthouse 2016.

Extreme floods are thought to be relatively easy to categorise and we'll examine this for a sample location but what is a drought let alone an extreme drought?

- To a livestock farmer who has feed and groundwater 6 months without rainfall is not a big issue;
- To an irrigator with a licence and water in the dams 6 months without rainfall is not a big deal;
- To a dryland farmer who planted and crop and then went 6 months without rain — it's a big deal.

So, for droughts as well as floods there are the common elements of time, location, and size, but there are now extra ingredients including duration, extent and available assets/resources. Analysing droughts may be a journey too far for us but we'll try.

## What are Extreme Events?

In examining extreme events we may not necessarily be able to give you a clear definition of an extreme event but hopefully we can get you thinking about these events and what your responses as hydrographers need to be.

Figure 2. A very extreme event? (sourceable.net, 2018).

The Oxford Dictionary[1] doesn't define an "extreme event" but offers separate definitions for each word which doesn't really help us a great deal.

### Extreme

- Reaching a high or the highest degree, very great
- Not usual; exceptional
- Very severe or serious

### Event

- A thing that happens or takes place, especially one of importance

[1] https://en.oxforddictionaries.com/definition/extreme

Wikipedia[2] on the other hand does a slightly better job with definitions for rare events and extreme weather. But again, it doesn't help us a great deal with extreme events.

> **Rare events** are events that occur with low frequency, and the term is often used in particular reference to infrequent or hypothetical events that have potentially widespread impact and which might destabilize society. Rare events encompass natural phenomena (major earthquakes, tsunamis, hurricanes, floods, asteroid impacts, solar flares, etc.), anthropogenic hazards (warfare and related forms of violent conflict, acts of terrorism, industrial accidents, financial and commodity market crashes, etc.), as well as phenomena for which natural and anthropogenic factors interact in complex ways (epidemic disease spread, global warming-related changes in climate and weather, etc.).

> **Extreme weather** includes unexpected, unusual, unpredictable, severe or unseasonal weather; weather at the extremes of the historical distribution-the range that has been seen in the past. Often, extreme events are based on a location's recorded weather history and defined as lying in the most unusual ten percent. In recent years some extreme weather events have been attributed to human-induced global warming, with studies indicating an increasing threat from extreme weather in the future.

So, what makes an extreme event, or is it, what makes an event extreme?

Either way, as Stephenson (2008) describes, extreme events are generally easy to recognize but difficult to define. This is due to several reasons. First, there is no unique definition for what is meant by the word "extreme" especially as it applies to hydrometric events, several definitions are in common use. Second, the concept of "extremeness" is relative and as we've seen with the drought example above so strongly depends on context and location. Third, according to Brian Williams in his blog on "Definition of extreme Events" the words "severe," "rare," "extreme," and "high-impact" are often used interchangeably.[3]

Williams goes on to give a useful series of definitions:

- **Severe events** are events that create large losses in measures such as number of lives, financial capital, or environmental quality (e.g. loss of species). The severity can be measured by the expected long-term loss, which is known as the risk. Risk depends on the product of the probability of the event (the hazard), the exposure to the hazards (e.g. how many people are exposed), and the vulnerability (i.e. how much damage ensues when someone is hit by the event). In other words, severity is a function of not only the meteorological hazard but also the human state of affairs.
- **Rare events** are events that have a low probability of occurrence. Because of the rarity of these events, human societies (and other ecosystems) are often not well adapted to them and so suffer large amounts of damage when they do occur. Hence, despite their rarity, the large vulnerability associated with such events can often lead to large mean losses (and hence they are a type of severe event).
- **Extreme events** are events that have extreme values of certain important meteorological variables. Damage is often caused by extreme values of certain meteorological variables, such as large amounts of precipitation (e.g. floods), high wind speeds (e.g. cyclones), high temperatures (e.g. heat waves), etc. Extreme is generally defined as either taking maximum values or exceedance above pre-existing high thresholds. Such events are generally rare; for example, extreme wind speeds exceeding the 100-year return value, which have a probability of only 0.01 of occurring in any particular year.

Stephenson extends the discussion on extreme events further by introducing the medical illness concepts of chronic and acute and suggesting that these can be usefully applied to weather and climate events:

- **Acute extremes:** events that have a rapid onset and follow a short but severe course. Examples are short-lived weather systems such as tropical and extratropical cyclones, polar lows, and convective storms with extreme values of meteorological variables such as wind speed and precipitation that can lead to devastating wind. In addition to these obvious examples of high-impact extreme events, there are less obvious acute extreme events, such as fog that causes major transport disruption (e.g. at airports).
- **Chronic extremes:** events that last for a long period of time (e.g. longer than 3 months) or are marked by frequent recurrence. Examples are heat waves and droughts that can lead to such impacts as critical water shortages, crop failure, heat-related illness and mortality, and agricultural failure. Because of their extended duration and generally lower intensity, chronic extreme events can often be harder to define than acute extreme events, but they have the advantage that there is more time to issue warnings and take protective actions. Note that not all high-impact weather events are acute; for example, blocking weather events that last several days are chronic events.

[2] https://en.wikipedia.org/wiki/Extreme_weather
[3] https://www.briangwilliams.us/climate-variability-extremes/

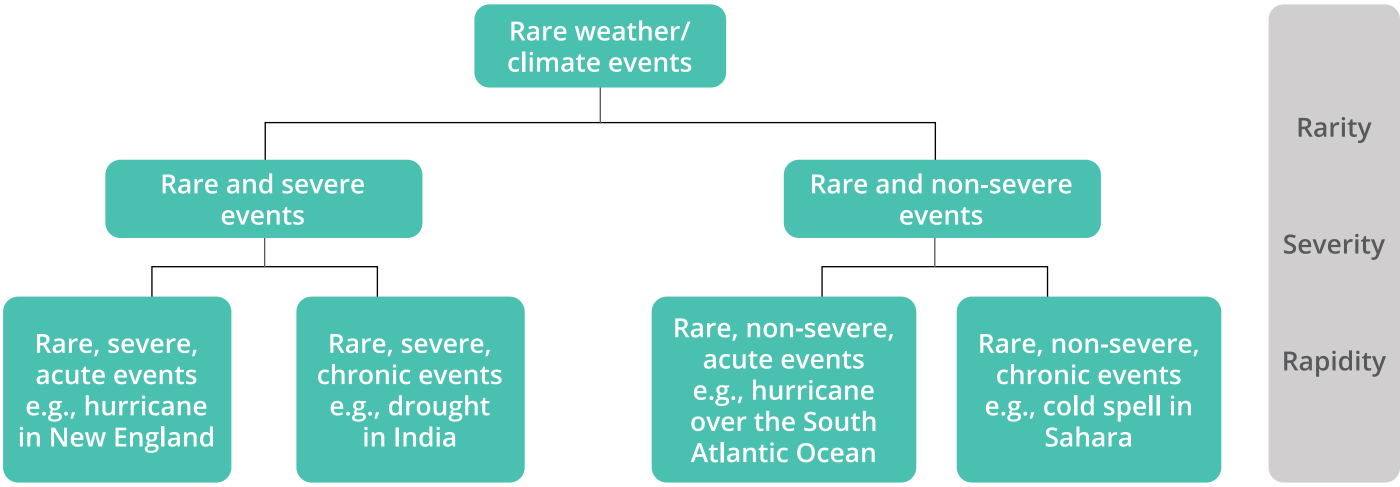


Figure 3. Taxonomy of Extreme Events.

McPhillips *et al.* 2018, examined some 244 papers. Among those that specified a threshold of "extremeness," various numeric and statistical thresholds were used, with 99th percentile or 100-year return period being the most commonly identified.

This definition ties in with NOAA[4], the US National Oceanic and Atmospheric Administration who are more succinct but less specific, they define extreme events as typically "lying in the outermost ("most unusual") 10 percent of a place's history".

The WMO and the IPCC define an extreme event as:

> *"The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. In many cases, a weather or climate event with high impact is also deemed as extreme event. In this guideline, frequently occurring high impact weather and climate extremes such as heat wave, cold wave, extreme precipitation and drought are the main focus"* (WMO, 2016).

So, not that helpful but there are some common themes running through these definitions but we also know that labelling an event as 'extreme' requires some context to the timescales and the type of event being considered. We also know that what is considered 'extreme' varies from place to place. For example, a rainfall event that delivers 50 mm of rain is quite rare in a desert area but is nearly a daily occurrence in some areas of the tropics.

Stephenson suggested extreme events have attributes such as:

- rate (probability per unit time) of occurrence
- magnitude (intensity)
- temporal duration and timing
- spatial scale (footprint)
- multivariate dependencies
- and we have added location

But in any case, terms like 'extreme' while useful for news headlines and for catchy titles for presentations at conferences, don't necessarily match with hydrological events. Nature doesn't easily fit into boxes like 'extreme' and 'normal'[5] and constantly keeps surprising us. Instead, hydrographers need to use better defined terminology to characterize hydrologic events according to their frequency, duration, and magnitude as well as the spatial extent. As we know, events that occur infrequently (i.e. events of low probability) are the ones to watch out for.

[4] https://www.ncdc.noaa.gov/climate-information/extreme-events
[5] https://www.e-education.psu.edu/earth111/node/595

But in trying to come up with a definition for hydrographic related extreme events the concept of probability of occurrence seems to offer the best possibility as it is something that we know about and which our software can produce for us from our data. However, our definition for an extreme event is still hampered by the lack of any definitive numbers with the estimates ranging from:

- Stephenson's 1 in 100 year event or a probability of only 0.01 of occurring in any particular year, to
- WMO/IPPS's - above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable, to
- NOAA's - lying in the outermost 10 percent of a place's history, to
- McPhillip *et al.*'s - various numeric and statistical thresholds were used, with 99$^{th}$ percentile or 100-year return period being the most commonly identified.

So, for our definition of an extreme event, it appears we are looking at something between the 90$^{th}$ to the 99$^{th}$ percentile or something around the 100 year return period. (Note: it is not now deemed good practice to use the term a "1 in 100 year flood" any more, a 100 year return period is better but the literatures is encouraging us to talk in probabilities, i.e. a probability of occurrence of 0.01 in a year).

While there is no formal, universal definition for what a hydrographer might consider to be 'extreme' events, there is a workable definition of the a 100 year or greater return period or probability of occurrence of 0.01 or less in a year.

There are also numerous ways that rainfall and streamflow events can be assessed within the appropriate context (timescale and location) to determine how they compare with 'normal' conditions. Hydrographers are fortunate that they typically have both the data and the software to be able to undertake the analysis and quantify an event. But as the next section shows there are still some tricks to the trade.

## Extreme Events in Hydrographic Context

### Floods

Wikipedia calls floods "an overflow of water that submerges land that is usually dry".[6] Predominantly the overflow of water is caused by rainfall. Floods are a natural process, and Australian ecosystems, river systems and estuaries have adapted over long periods of time to depend on low flows and an irregular pattern of large floods. Many species, such as River Red Gums, rely on this pattern of dry periods separated by periods of intense rain and overbank flooding.

For Australia and South Africa, for any given precipitation variability, the runoff variability is much higher than for the rest of the world (McMahon *et al.*, 1987). This immense variability observed in Australia's naturally occurring precipitation and streamflow makes it difficult to determine what actually constitutes an 'extreme' event. Indeed, most rivers flood (i.e. water completely fills the channel and spills out onto adjacent floodplain) every one to five years. River discharge during such events is often on the order of 10 times the mean annual flow and often 100 to 1000 times greater than the lowest flows. In that context, perhaps they could be considered extreme. However, considering them within the context of all the floods that occur over a century, floods that occur every one to five years would be referred to as 'common floods.

The most common way that hydrologists determine the rarity of an event is by calculating the frequency with which the event has occurred in the past, and using that as an estimate of the probability that it will occur in the future.

This is a rational and useful way to make predictions, but note that climate change throws a bit of a spanner in the works for the notion of using the past to predict the future. If the entire distribution of events shifts, so the probabilities associated with all of the events will shift as well. But the traditional assumptions on the statistical distribution of hydrologic events used to analyse hydrologic extremes depend on "stationarity".

A stationary time series is one whose statistical properties such as mean, variance, etc. are all constant over time (Logan & Helsabeck, 2009). The assumption of stationarity underlies most traditional flood forecasting methods, including those codified by laws and regulations. Estimation of the "100-year flood," for example, uses historical stream gaging data from rivers that are assumed to behave similarly over the period of record to precipitation events that are also assumed to be generated from the same random population of possible events.

[6] https://en.wikipedia.org/wiki/Flood

Yet the recent record shows that this assumption is not accurate. Changing climate, land use changes, urbanization, and the operation of water management facilities such as dams, irrigation works, wells, and diversions challenges this assumption (National Research Council, 2011) and this is particularly true in most developed countries where it is difficult to find a site that is not impacted to some extent by land use changes upstream.

As a result, a coherent picture of the nature of likely future changes in hydrologic extremes has yet to evolve. A "grand challenge" thus faces the climate and hydrologic sciences communities—to understand the nature of ongoing changes in climate and hydrology and the apparent anomalies that exist in reconciling their extreme manifestations.

The USGS[7] describe the term "100-year flood" as an attempt to simplify the definition of a flood that statistically has a 1-percent chance of occurring in any given year. Likewise, the term "100-year storm" is used to define a rainfall event that statistically has this same 1-percent chance of occurring. In other words, over the course of 1 million years, these events would be expected to occur 10,000 times. But, just because it rained 250 mm in one day last year doesn't mean it can't rain 250 mm in one day again this year.

## Droughts

What is a drought?

- To a livestock farmer who has feed and groundwater 6 months without rainfall is not a big issue.
- To an irrigator with a license and water in the dams 6 months without rainfall is not a big deal.
- To a dryland farmer who planted and crop and then went 6 months without rain- it's a big deal.

Indeed, farmers talk about water droughts and feed droughts as meaning completely different things to them. So, drought can be difficult to define.

According to the Australian Bureau of Meteorology[8] drought in general means acute water shortage:

Figure 4. A grass drought.

http://www.abc.net.au/news/2015-12-17/queensland-drought-photos-before-after/7035610 accessed 29 March 2020.

- **Serious** rainfall deficiency: rainfall lies above the lowest five per cent of recorded rainfall but below the lowest ten per cent (decile range 1) for the period in question,
- **Severe** rainfall deficiency: rainfall is among the lowest five per cent for the period in question.

But as shown in the opening section, this still doesn't capture the true nuances of droughts. Indeed, Wilhite and Glantz (1985), after studying some 150 definitions of drought, came up with 4 different ways of defining drought:

1. Meteorological drought: Usually expressions of precipitation's departure from normal over some period of time. Reflects one of the primary causes of a drought.
2. Hydrological drought: Usually expressions of deficiencies in surface and subsurface water supplies. Reflects effects and impacts of droughts.
   a. Hisdal and Tallaksen (2000) also suggested breaking hydrological drought into a further 2 categories; one for surface water and one for groundwater.
3. Agricultural drought: Usually expressed in terms of needed soil moisture of a particular crop at a particular time.

[7] https://water.usgs.gov/edu/100yearflood.html
[8] http://www.bom.gov.au/climate/glossary/ accessed 29 March 2020.

4. Socio-economic drought: Definitions associating droughts with supply of and demand for an economic good.

And a fifth one has been added recently:

5. Ecological drought[9] – a deficit in natural water supplies that affects multiple ecosystems.

According to the Guinness Book of Records[10], the worst drought happened in China between 1876-79. Estimates are that between 9 and 13 million people died in Northern China when the rains failed to come for 3 whole years. Around the same time in India (1876-78), around 5 million died when the monsoon rains didn't come for 2 years.

Currently, a scarcity of comprehensive datasets limits scientific understanding of the causes, onset, and effects of droughts. Unlike floods, droughts evolve slowly and may not be recognized until they are almost over and the opportunity for data collection is lost. Measurement of soil moisture may also become an additional responsibility of hydrographers.

## Floods and Droughts Case Study - Gundagai

But as Knox and Kundzewicz (1997) explained, because the memories of experiences of the living human population are short term and because historical instrumental records at most locations are often also short, there is a tendency to perceive incorrectly that even moderate magnitude and relatively high recurrence frequency natural events are rarer and more extreme than they are. They used an example of the 1993 flood in the Mississippi where peoples and the media's perception of the event differed from the historical record.

Gundagai in southern NSW was chosen to examine some of the issues with the perception and definition of extreme events and then the issues of trying to use the most common definitions of extreme events involving recurrence intervals and probabilities to examine droughts and floods at Gundagai.

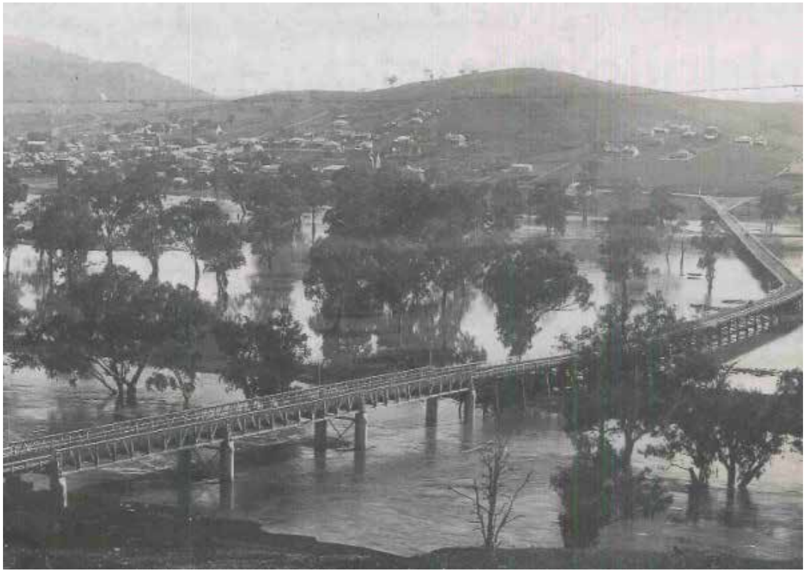

Figure 5: A Gundagai Flooding 1896; B Historic d Flood levels at Gundagai.

Source: A http://floodlist.com/australia/gundagai-floods-1852 B http://floodlist.com/australia/gundagai-floods-1852

[9] https://waterfilteranswers.com/drought-facts/ accessed 29 March 2020.
[10] http://www.guinnessworldrecords.com/world-records/worst-drought-famine accessed 29 March 2020.

### Gundagai bracing for major flood today

*Posted 5 Mar 2012, 12:32am*

*Towns and villages across the Riverina are waking up to see the effects of the weekend's flash flooding, as the Murrumbidgee River rises towards a major flood peak of 10.9 metres in Gundagai, sparking more evacuation warnings.*

http://www.abc.net.au/news/2012-03-05/gundagai-flood/3868670

### Dry as dust, and set to hurt city pockets

*By Wendy Frew, Environment Reporter 16 October 2006 — 10:00am*

*The pastures should be green, the lambs fat and the wheat a golden stubble. But the creeks have stopped running, the dams are drying up and the crops are failing.*

*This is Gundagai, where farmers like Nick Keatinge move through a cloud of dust left behind by years of gruelling drought.*

*In good times, Gundagai has more rainfall than many other farming regions in the state, but this year it is one of the worst hit, receiving less than 20 per cent of its average annual rainfall.*

https://www.smh.com.au/national/dry-as-dust-and-set-to-hurt-city-pockets-20061016-gdoltz.html

This location was chosen because

- The impacts on the flood plain at Gundagai have been minimal compared to many other sites with long periods of record. While bridges have been built to cross the flood plain there are no major structures or levees on the flood plain to severely impact the comparison of flood levels at Gundagai;
- There have been land use changes, e.g. the construction of Canberra as well as the construction of several storages upstream of Gundagai, forestation and deforestation, but our assumption at least is they are less likely to have major impacts during extreme flood events and minimal impact over multiyear droughts;
- There is a long period of continuous record at this site extending back to the 1880s as well as a good record of a number of historic flood events extending back to 1852.

### *Floods at Gundagai*

We have examined the flood frequency at Gundagai and look at a couple of ways that extreme events are defined. The results are summarised below.

We have seen that extreme events have been defined in terms of percentiles or recurrence interval but, as examination of the data at Gundagai shows, getting a definitive answer at least for recurrence interval is somewhat problematic. So, let's start with looking at the data for Gundagai and three of the extreme event definitions which give us measurable definitions:

- Stephenson's 1 in 100 year event;
- NOAA's - lying in the outermost 10 percent of a place's history; to
- McPhillips *et al*.'s - 99$^{th}$ percentile or 100-year return period.

The time weight flow duration curve for Gundagai of instantaneous recorded water levels at Gundagai from 3/08/1886 to 19/10/2017 is a good place to start looking at the percentiles. Examination of this data produces the percentiles show in Table 1.

**Table 1. Top 10% Percentile recorded stream Heights at Gundagai 1886- 2018**

| Percentage of Time the Value was Exceeded | Percentile | Gauge Height at Gundagai m |
|---|---|---|
| 10 | 90 | 3.454 |
| 5 | 95 | 4.258 |
| 4 | 96 | 4.525 |
| 3 | 97 | 4.841 |
| 2 | 98 | 5.279 |
| 1 | 99 | 6.221 |
| 0 | 100 | 11.009 |

The variation between the 90th and the 100th percentile stream heights of some 7.56 m is extensive. Even the difference between the 99th and 100th percentiles of 4.79 m is large. So possibly the NOAA definition of lying in the outermost 10% or even McPhillips' 99th percentile may not provide the best definition of extreme events as well, the 99th percentile height of 6.221 is considerable below the Bureau of Meteorology's definition of a major flood at Gundagai of 8.5 m.

Then in examining Stephenson's and McPhillips *et al*.'s definition of the 100 year return period as defining an extreme event this also runs into some problems.

The choice of which statistical distribution, to fit to historical discharge data, is critical when attempting to predict the most extreme flows. It has been shown that depending upon the distribution selected the calculated return periods can vary dramatically (Eadie & Favis-Mortlock, 2010).

This is borne out by Tables 2 and 3. In these tables the water levels for specified annual exceedances for both annual series and partial series (including historical flood events back to 1852) floods for Gundagai are shown. The best visual fit of the distributions is shown by the grey shading.

**Table 2. Flood Frequency Distributions for Annual Series at Gundagai 1887-2016 (123 values)**

| Annual Exceedance Probability | Return Period 1/year | Log Normal Distribution | Pearson 3 Distribution | Gumbel Distribution | Log Pearson 3 Distribution | Gumbel Extreme Value |
|---|---|---|---|---|---|---|
| 0.500 | 2 | 3.79 | 5.80 | 5.53 | 5.57 | 5.73 |
| 0.429 | 2.33 | 4.05 | 6.23 | 5.95 | 6.01 | 6.16 |
| 0.200 | 5 | 5.04 | 7.90 | 7.74 | 7.86 | 7.90 |
| 0.100 | 10 | 6.81 | 9.09 | 9.20 | 9.31 | 9.17 |
| 0.040 | 25 | 9.12 | 10.43 | 11.05 | 11.06 | 10.59 |
| 0.020 | 50 | 11.31 | 11.34 | 12.42 | 12.31 | 11.53 |
| 0.010 | 100 | 13.99 | 12.17 | 13.78 | 13.50 | 12.39 |
| 0.005 | 200 | 17.28 | 12.93 | 15.13 | 14.63 | 13.16 |
| 0.002 | 500 | 22.83 | 13.86 | 16.92 | 16.03 | 14.07 |
| 0.001 | 1000 | 28.16 | 14.51 | 18.27 | 17.03 | 14.69 |

**Table 3. Flood Frequency Distributions for Partial Series at Gundagai 1852-2016 (466 values)**

| Annual Exceedance Probability | Return Period 1/year | Log Normal Distribution | Pearson 3 Distribution | Gumbel Distribution | Log Pearson 3 Distribution | Gumbel Extreme Value |
|---|---|---|---|---|---|---|
| 0.500 | 2 | 4.05 | 3.93 | 4.11 | 3.82 | 3.79 |
| 0.429 | 2.33 | 4.35 | 4.28 | 4.44 | 4.10 | 4.05 |
| 0.200 | 5 | 5.69 | 5.87 | 5.86 | 5.52 | 5.40 |
| 0.100 | 10 | 6.81 | 7.24 | 7.02 | 6.96 | 6.81 |
| 0.040 | 25 | 8.25 | 9.01 | 8.49 | 9.18 | 9.12 |
| 0.020 | 50 | 9.35 | 10.33 | 9.58 | 11.18 | 11.31 |
| 0.010 | 100 | 10.44 | 11.63 | 10.65 | 13.48 | 13.99 |
| 0.005 | 200 | 11.54 | 12.91 | 11.73 | 16.11 | 17.28 |
| 0.002 | 500 | 12.98 | 14.56 | 13.15 | 20.14 | 22.83 |
| 0.001 | 1000 | 14.05 | 15.75 | 14.22 | 23.60 | 28.16 |

You will notice that there is no one distribution that produces the best fit for the data sets and demonstrates that you cannot assume that any particular distribution can be applied across all sites or even the datasets at a specific site.

You will also notice the spread in the water levels of between 10.77 m and 14.32 m, produced for the 0.10 exceedance probability water level. This is both between 5 different flood frequency distributions and between analysis of a partial series including historical flood and the annual series from recorded floods.

So even if you use the 100 year return period flood, as your definition of what specifies an extreme flood (or rather flood event with an exceedance probability of .010), your analysis cannot provide you with any certainty to what that flood level may be.

### *Droughts at Gundagai*

The "calculation" (as opposed to the interpretation of the result) of recurrence intervals of extreme events of duration up to one year is relatively straightforward in the sense that the methods for selecting the data and calculating the various distributions is well established, even if selection of the appropriate distribution for the annual series can be more problematic.

However, the calculation of the recurrence interval of hydrological events of duration longer than one year could be a bit more complex (Srikanthan & McMahon, 1985).

We decided to adopt a methodology outlined in a book by Nagarajan (2010) where the negative departure of cumulative monthly stream flows from the long term monthly average stream flows were used to define a drought period.

**Table 4. To 10 Drought Ranking at Gundagai/Wagga 1868 - 2018 (for full table and cumulative sum graph See Appendix A)**

| Start Date | End Data | Duration (Months) | Rank | Recurrence Interval | Probability |
|---|---|---|---|---|---|
| 01/01/1895 | 01/04/1990 | 64 | 5 | 30.2 | 0.033 |
| 01/10/1900 | 01/04/1906 | 66 | 4 | 37.8 | 0.027 |
| 01/10/1909 | 01/07/1916 | 57 | 6 | 25.2 | 0.039 |
| 01/01/1926 | 01/04/1930 | 52 | 7 | 21.6 | 0.046 |
| 01/10/1939 | 01/07/1949 | 117 | 2 | 75.5 | 0.013 |
| 01/01/1965 | 01/07/1970 | 67 | 3 | 50.3 | 0.020 |
| 01/04/1971 | 01/07/1973 | 27 | 9 | 16.8 | 0.059 |
| 01/04/1980 | 01/07/1982 | 27 | 9 | 16.8 | 0.059 |
| 01/04/1999 | 01/07/2010 | 123 | 1 | 151 | 0.007 |
| 01/01/2013 | 01/07/2016 | 42 | 8 | 18.9 | 0.053 |

However, there are some questions on the definition of the drought period depending on how strictly you interpret the data. For example:

- Should you consider the four consecutive droughts from 1885 to 1916 as 3 separate events or as one effectively continuous drought for 30 years?
    - This would make this drought the #1 ranking drought.
- Should the slight positive flow events in 1943 indicate that the 1939-1949 droughts were two separate droughts or what about the 3 months between the 1937-1939 drought and the 1939-1949 drought?
    - We didn't think that the 1943 flow event would have been enough to break the previous 4-5 years of drought;
    - If we ignore the slight blip in late 1939 the 1937-1949 becomes by far the worst drought.
- Should the start of the millennium drought be 1997 or 1999 or 2001?
    - This was tough, there had been 15 months of drought from 1999 prior to an increase and effective return to average flows until 2002;
    - The decision impacts whether the rank of the millennium drought drops from 1 to 2.

When this paper was presented in November 2018; the ongoing drought in parts of Eastern Australia, that at the time was attracting significant media coverage, was not yet ranked in the top 10.

So, nothing is simple. Depending on how you define the drought period, the millennium drought in the Murrumbidgee River basin in terms of duration, is either the number 1 (150 year event – so definitely extreme), number 2 (75 year event - so not extreme) or number 3 (50 year event – again not extreme).

There are also other factors also impact the severity of droughts. Certainly, from a demand perspective the level of development and population in the millennium drought make it by far the worst drought especially when compared to the development and population during the 1890s or even the 1940s. Another measure of drought severity could be the total volume deficit from the average flow during the drought period.

## Extreme Events and Disasters

A disaster occurs when an extreme event exceeds a community's ability to cope with that event (FEMA, 2004). While we have been concentrating on the technical aspects of extreme events, it is important for hydrographers not to distance themselves from the reality of the impact of extreme events. The impacts of extreme events in terms of financial, lives and social costs are outlined in Appendix B.

As outlined by Knox and Kundzewicz (1997) extreme floods and droughts have caused and continue to cause high tolls in deaths and economic losses. Floods are more spectacular as they are short lasting and violent. The highly visible direct destructive effect of floods may be followed by a chain of secondary, indirect calamities including famine, epidemics, and fire that cause concerned populations additional suffering. There have been floods during historical times that have resulted in death tolls of several hundred thousand human beings (for example, 900,000 and about 500,000 deaths in the catastrophic floods in China in 1887 and 1939, respectively). Present-day floods do not take such high tolls in the number of lives because of modern systems of advanced warning, but present-day floods continue to cause very high economic losses. Losses associated with the record-breaking Mississippi River flood in 1993 are estimated to be in exceedance of US$10 billion.

Disasters are upsetting experiences for everyone involved. The emotional toll that disaster brings can sometimes be even more devastating than the financial strains of damage and loss of home, business or personal property and this can also true for hydrographer's and their families and friends if they are caught up in a disaster.

As well, hydrographers by the very nature of their work in having to monitor extreme events can be exposed to incidents not normally experienced by the general public. These may be critical incidents in the sense that exposure to scenes, situations and events might potentially lead to critical incident stress. It is crucial that it is recognised that it is these incidents that are abnormal, and not the individuals' reactions to the incidents. Nevertheless, the reactions need to be recognised and dealt with appropriately ignoring the impacts can adversely impact the individual or their team's safety in an extreme event as the judgements and reaction times can be impaired.

Everyone reacts differently to situations that could be found disturbing at the time or even later in after the event. Common reactions to such situations can include nausea, fatigue, stress, anxiety and depression to name a few which may lead to excessive alcohol consumption and other antisocial activities. Hydrographers need to be aware of these symptoms in themselves and their colleagues and seek professional help when required. While, unlike some of the emergency services, there is no assistance programs of measures within the industry there are a number of confidential and free services that hydrographers can afford themselves of in most states and territories.

## Impact of Climate Change on Extreme Events

With its iconic reference to 'droughts and flooding rains', Dorothea Mackellar's 1904 poem, My Country, highlighted the large natural variations that occur in Australia's climate, leading to extremes that can frequently cause substantial economic, environmental and social disruption[11].

As outlined by the Committee on Extreme Weather Events and Climate of the US National Academy of Sciences, extreme weather has affected human society since the beginning of recorded history and certainly long before then. Although this extreme weather can cause loss of life and significant damage to property, people and virtually every other creature have, at least to some degree, adapted to the infrequent extremes they experience within their normal climatic zone (National Academy of Sciences, 1996).

However, there is increasing concern that extreme events may be changing in frequency and intensity as a result of human influences on climate. Climate change may be perceived most through the impacts of extremes, although these are to a large degree dependent on the system under consideration, including its vulnerability, resiliency and capacity for adaptation and mitigation (IPCC, 2007);

[11] https://www.science.org.au/learning/general-audience/science-booklets-0/science-climate-change/5-how-are-extreme-events accessed 29 March 2020.

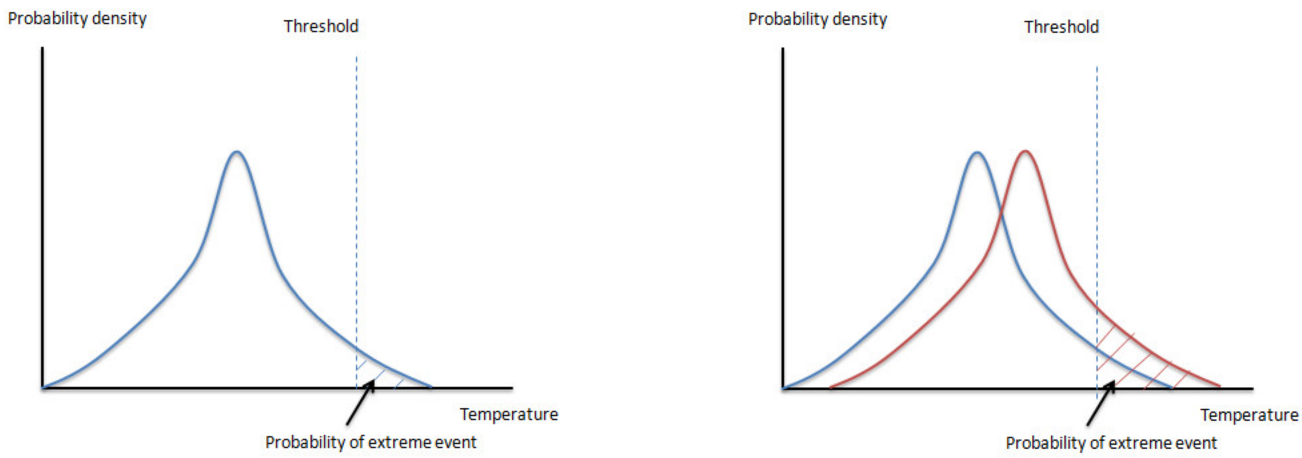


Figure 6. Projected Impacts of Climate Change on Temperature Extremes.

However, if, as projected, there is the predicted change in climate conditions so that average temperatures increase, then as shown in Figure 6 above from Paul Krugman's blog entitled Gradual Trends and Extreme Events[12], above, this will have the impact of increasing the number of some extreme temperature events while decreasing others.

US National Academy of Science Committee on Extreme Weather Events and Climate went on to say that while it may be possible to make confident statements about how some class of extreme events are expected to change because of human induced climate change, attribution studies of an individual event may be unable to make a confident statement about the human influence on that one specific event. Thus, for all of these reasons, counts of available attribution studies with any positive, negative, or neutral results are not expected to give a reliable indication of the overall importance of human influence on extreme events.

## Impact of Climate Change on Extreme Events in Australia

### Climate change making drought worse, farmers' federation chief says

*Gabrielle Chan Wed 29 Aug 2018 07.28 BST*

*Fiona Simson says people have been tiptoeing around the subject for too long and it is time for a national strategy.*

https://www.theguardian.com/environment/2018/aug/29/climate-change-making-drought-worse-says-farmers-federation-chief

So as with everything else we've seen with extremes, nothing is as simple as the graph in Figure 6 suggests. When looking at the impact of climate change you are looking to address a number of key questions:

- Frequency: Are events occurring more often than they did in the past?
- Intensity: Are events getting more severe, with the potential for more damaging effects?
- Duration: Are events lasting longer than "the norm"?
- Timing: Are events occurring earlier or later in the season or the year than they used to?

The Committee on Hydrologic Science of the US National Research Council (2011) stated that climate theory dictates that core elements of the climate system, including precipitation, evapotranspiration, and reservoirs of atmospheric and soil moisture, should change as the climate warms, both in their means and extremes. The assumption is that a warmer atmosphere can hold more water vapour, which in turn will support more vigorous precipitation and surface wetting, and more intense evaporation and evapotranspiration. Although the current generation of climate models effectively simulates this phenomenon's atmospheric components, there is mixed observational evidence on the hydrologic response to these postulated changes, namely, floods and droughts.

[12] Krugman, P, 2011, https://krugman.blogs.nytimes.com/2011/02/08/gradual-trends-and-extreme-events/ accessed 29 March 2020.

In Australia, as in all countries, these natural variations have existed for many thousands of years, and indeed past floods and droughts in many regions have likely been larger than those recorded since the early 20th century. This high variability poses great challenges for recording and analysing changes in climate extremes and attributing man's influence not just in Australia, but the world over. Nevertheless, some changes in Australia's climate extremes stand out from that background variability[13].

In recent decades, anomalously warm months in Australia have occurred more often than anomalously cold months confirming to some extent the effects outlined in Figure 6. Many heat-related records were broken in the summer of 2012-13 and in the year of 2013[14], including Australia's hottest day, week, month and year averaged across Australia. Extreme summer temperatures during 2012–13 were unlikely to have been caused by natural variability alone, and according to a scientific analysis, the record heat that summer was made at least five times more likely—a 500% increase in the odds of it occurring—by human-caused warming. This conclusion, using the observed temperature record and climate models, was made with more than 90% confidence (Hassol *et al*., 2016). Since 2001, the number of extreme heat records in Australia has outnumbered extreme cool records by almost 3 to 1 for daytime maximum temperatures and almost 5 to 1 for night-time minimum temperatures.

Consistent with global studies, an increase in the proportion of heavy rainfall has been detected over Australia. The fraction of Australia receiving a high proportion (greater than the 90th percentile) of annual rainfall from extreme rain days (greater than the 90th percentile for 24 hour rainfall) has been increasing since the 1970s. Significant regional variability exists, with the east coast region experiencing a significant decrease in extreme rain events since 1950. There is also an increase in the fraction of Australia receiving summer (December to February, accumulated) rainfall that is above the 90th percentile.

But, not every type of event discussed is a pure meteorological event. Droughts, floods, and wildfires, for instance, all have human, as well as natural, components. Land management, controlled burning, and dams and levees impact the magnitude and frequency of these extreme events. But there is increasing concern that extreme events may be changing in frequency and intensity as a result of human influences on climate.

Still as outlined by the Australian Academy of Science[15], climate model projections also suggest (though with considerable uncertainty) that in the next several decades, warm days and heavy rainfall events in Australia will tend to increase under a high emissions pathway (see Figure 7).

The Academy also noted that across the globe, projections also point broadly to an intensification of the wettest days and a reduction in the return time of the most extreme events (Figure 8), although there is much regional variation in these trends. For Australia, a warmer future will likely mean that extreme precipitation is more intense and more frequent, interspersed with longer dry spells, likewise with substantial regional variability.

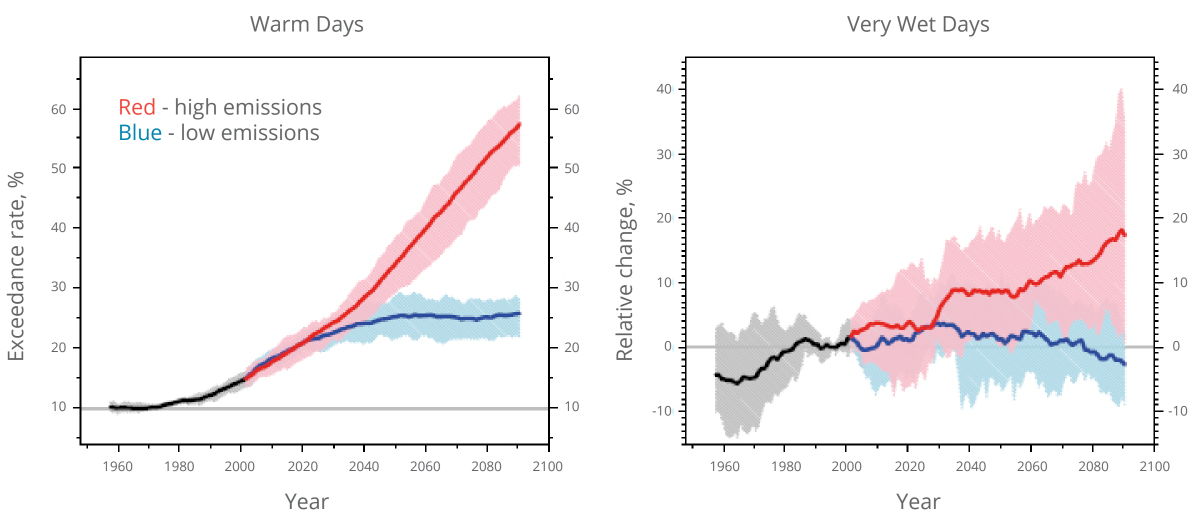


Figure 7. Projected Impacts of Emissions on Warm Days and Very Wet days.

[13] Australian Academy of Science, *5. How are extreme events changing?*, https://www.science.org.au/learning/general-audience/science-climate-change/5-how-are-extreme-events-changing accessed 29 March 2020
[14] CSIRO, *Climate change in Australia*, https://www.climatechangeinaustralia.gov.au/en/ accessed 29 March 2020
[15] ibid

In many continents, including Australia, a high temperature event expected once in 20 years at the end of the 21st century is likely to be over 4°C hotter than it is today (Figure 9). Furthermore, what we experience as a one-in-20-year temperature today would become an annual or one-in-two-year event by the end of the 21st century in many regions.

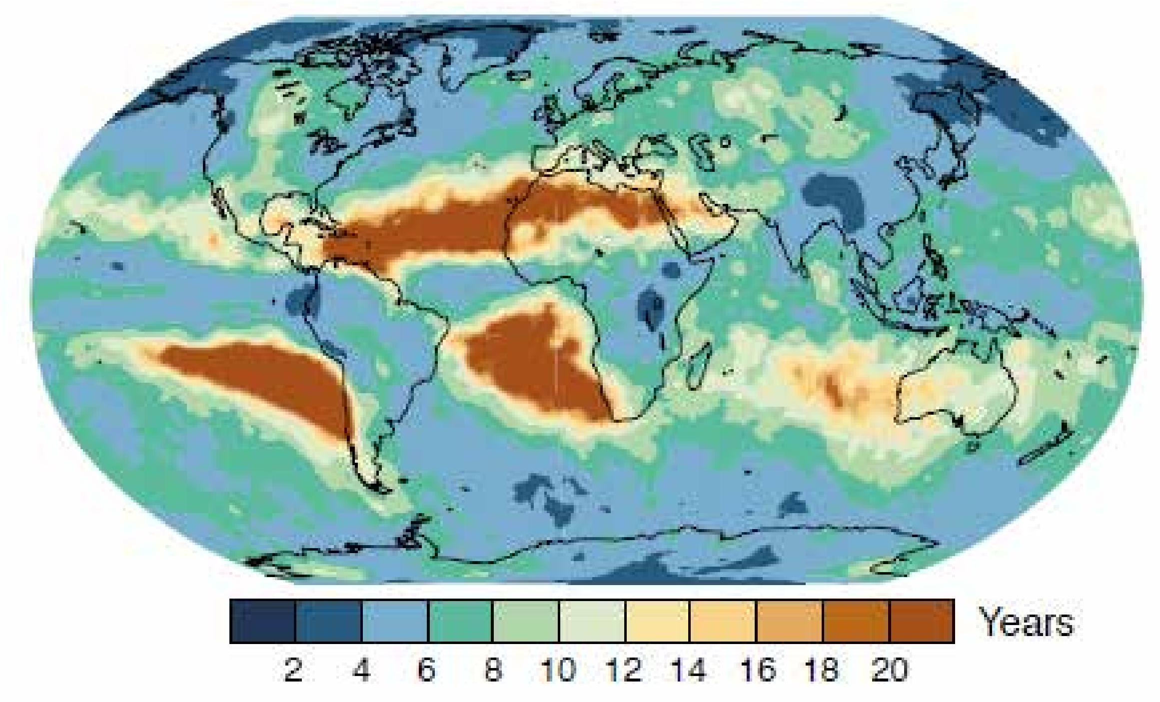


Figure 8. Projected changes to recurrence interval for a 20 year rainfall events due to Climate Change.

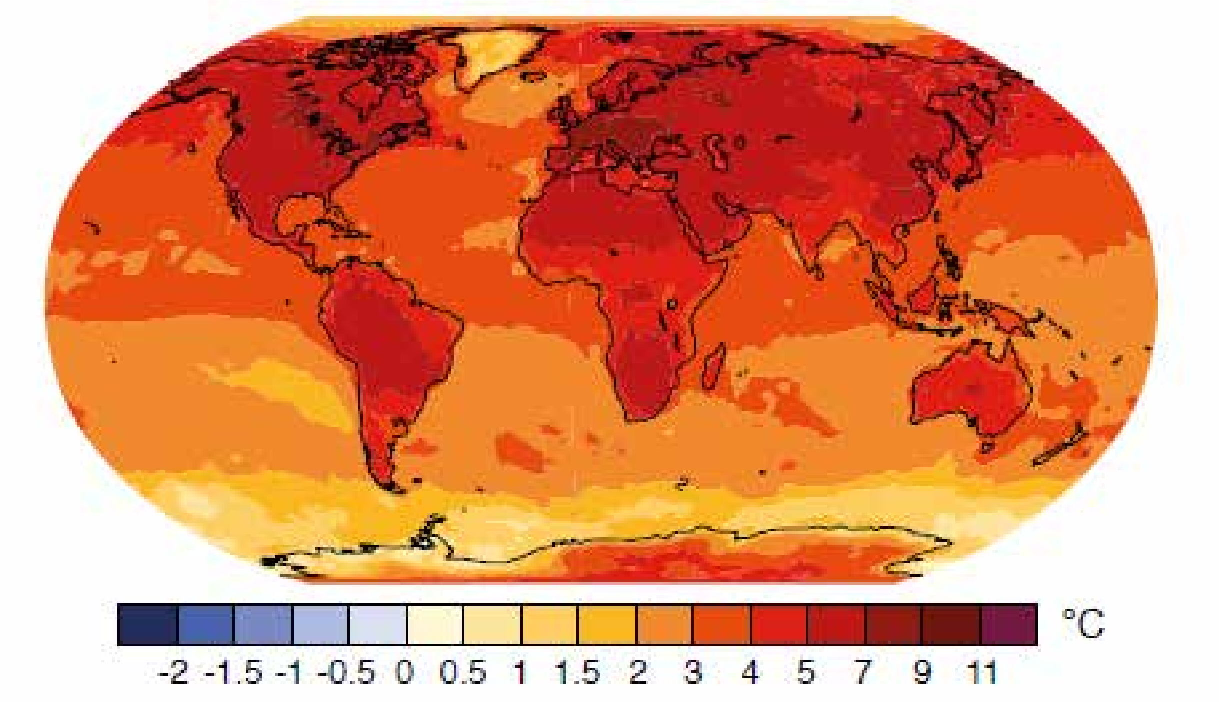


Figure 9. Projected temperature increases due to Climate Change.

Future changes in other extreme weather events are less certain. The Australian Academy of Science, however, did suggest that from the evidence available there will be fewer tropical cyclones, but that the strongest cyclones will produce heavier rainfall than they do currently.

The US National Academy of Sciences Committee on Extreme Weather Events and Climate Change (National Academy of Sciences, 2016) believed that the effective, rigorous, and scientifically defensible analysis of the attribution of extreme weather events to changes in the climate system not only helped satisfy the public's desire to know but also provided valuable information about the future risks of such events. They believed that a solid understanding of extreme weather event attribution in the context of a changing climate could also help provide insight into and confidence in the many risk calculations that underpin much of society's building codes; land, water, health, and food management; insurance; transportation networks; and many additional aspects of daily life.

This Committee also summarized the state of attribution science for different event types as shown below in Figure 10. The horizontal position of each event type reflects an assessment of the level of understanding of the effect of climate change on the event type and an understanding of the impacts of these events due to human activities.

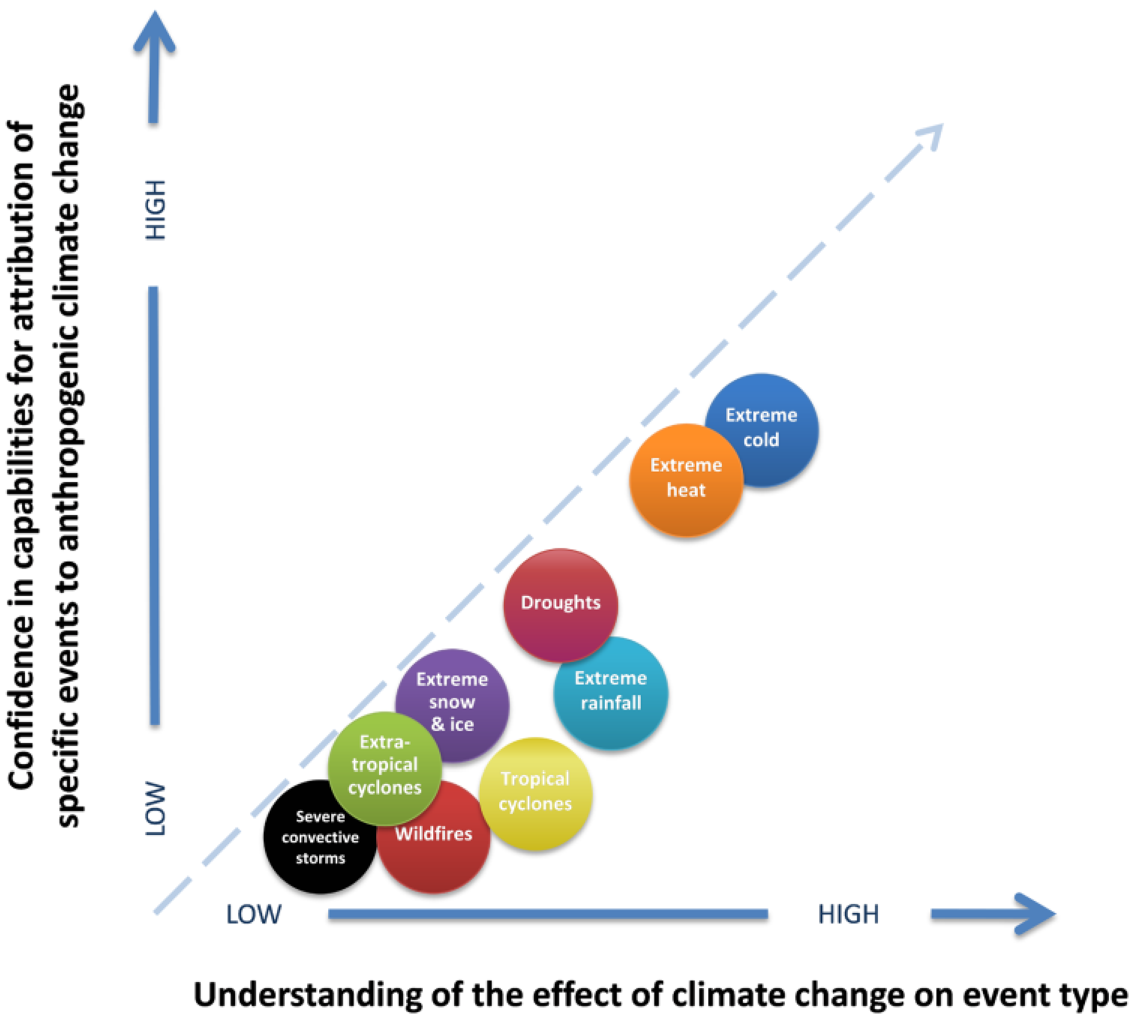


Figure 10. Impacts of human activities on extreme events.

As the US National Research Council (2002) Committee on Abrupt Climate Change said: “We do not yet understand abrupt climate changes well enough to predict them. The models used to project future climate changes and their impacts are not especially good at simulating the size, speed, and extent of the past changes, casting uncertainties on assessments of potential future changes. Thus, it is likely that climate surprises await us.”

However, as the US National Research Council (2013) report showed, studies of Earth’s climate history also suggest the inevitability of “tipping points”—thresholds beyond which major and rapid changes occur when crossed—that lead to abrupt changes in the climate system. The history of climate on the planet—as read in archives such as tree rings, ocean sediments, and ice cores—is punctuated with large changes that occurred rapidly, over the course of decades to as little as a few years.

The Committee goes on to warn of multiple other factors including resource depletion and increasing human consumption and expanding population are pushing natural and human systems toward their limits, and thus become more sensitive to small perturbations that can trigger large responses and are exerting enormous pressure on nature’s and society’s resilience to sudden changes.

Groundwater aquifers which are critical for many farmers to be able to lessen the impact of droughts, are for example, being depleted in many parts of the world. The previous safety net may not be there so the impact of droughts on the food supply has the potential to be even larger.

Understanding the potential risks posed by both abrupt climate changes and the abrupt impacts resulting from gradual climate change is a crucial piece in advancing the ability of society to cope with changes in the Earth system. This will increasingly require more data to be able to understand, study, model and predict climate change as well as monitoring the impacts on the natural and man-made environments.

Hydrographers today are already encountering a wider range of extreme climatic conditions and the extreme events associated with them. Demands for a wider range of more timely data is therefore likely to and continue and may even increase.

## Impact of Extreme Events on Hydrographers

While we have concentrated on floods and droughts it is important for the hydrographic professions to remember that these are not the only extremes that they will face when undertaking their work especially now with a range of more frequent extreme weather events attributed to climate change.

### Impacts on what work has priority

Most monitoring networks are not specifically designed to measure extreme events, nor should they be. In some cases, it is not until several decades have passed since the installation of a gauging station that it is used as an indicator of an extreme event.

Most hydrometric agencies have what they deem as an acceptable amount of lost record both in consecutive days and total days lost over a calendar year. Extreme events such as floods and fires can destroy gauging stations. These occurrences will result in a site not meeting its ‘acceptable lost record’ Key Performance Indicator. These ‘acts of god’ are generally recognised and accepted if documented in advance between the client and the hydrographer.

For most gauging stations with a considerable length of record, any flood event that is the largest on record is an extreme event for the hydrographer. Any flood event for the site where the discharge is above the maximum gauged is likely to be an extreme event. Based on these “hydrographic” definitions many older gauging stations are unlikely to have an extreme event in a working lifetime (“gauged to death” is an expression that comes to mind*).

To be in a position to undertake a stream gauging it may be necessary to have a trigger other than the river level. A common example is the use of weather rainfall predictions to mobilize for a river flood event. Typically, the smaller the catchment the less time there is to get to the site. So, it may be necessary to have a surrogate as a trigger for an extreme event. Using predicted rainfall as a surrogate has a number of shortcomings such as the predicted rainfall may not eventuate or may not eventuate in the specific catchment or it may not create the response from the catchment to reach the extreme event classification, or there may be significantly more rainfall than forecast. In some instances, it may be necessary to mobilise for an extreme event before the rain begins to fall.

In some cases, being seen at the location of an extreme event is in itself a good result. While being seen (on the 6 o'clock news) is not as good as actually doing something it may need to be factored into any extreme event planning exercise.

An example of being seen is when the Prime Minister visits the location of an extreme event such as a fire, flood or drought affected farm. The PM rarely does anything; however, it demonstrates the event is important. For hydrographers however, there is a fine line between being seen and being seen as a sightseer.

## Data Needs related to Floods

The Hydrologic Hazard Science committee of the USGS (National Research Council, 1999) made a series of recommendations about the data needs related to floods that still resonate today and are relevant for hydrographers and their managers.

- Proper design of data collection and communication networks, with an emphasis on real-time data collection, are key issues in understanding, predicting, and documenting floods.
- Availability of reliable field data so that predictions and models are appropriate and grounded in reality. Emphasis should be given to the collection of data that capture the variability of high-flow hydrologic events in space and time.
- Adequate stream-gaging network providing data for hydrologic warning in real time, for analysis of historic events, and for documentation of rare extreme events.
- Adequate database systems process and archive relevant hydrometric data. But data needs will transcend many traditional guaging (and agency) activities and the greatest value will result from the synthesis of land use, hydraulic modification, river regulation, meteorology and climate conditions, with gauge data and flow measurements."

## Data Needs Related to Drought

The same USGS Hydrologic Hazard Science committee back in 1999 also made a series of recommendations about the data needs related to droughts. The committee also acknowledged that a scarcity of comprehensive datasets limited the scientific understanding of the causes, onset, and effects of droughts.

Unlike floods, droughts evolve slowly and may not be recognized until they are almost over and the opportunity for data collection is lost. The committee recommended that the USGS should develop coordinated plans for data collection related to droughts in order to provide a comprehensive picture of how a drought develops and evolves. Their recommendations included:

- Coordination of such data collection programs with climate data collection programs and large-scale remote sensing activities would offer more timely opportunities to add to integrated databases supporting research, analysis and management of drought.
- Collection of key data that are relevant to drought including low-flow measurements and flow duration measurements in surface water and long-term ground water-level fluctuations.
- Ongoing long-term water-level measurements in lakes and wetlands which are essential to document the effects of drought and to provide data to construct hydrologic models.
- Ongoing monitoring of ground water levels and soil moisture with long-term fluctuations in ground water levels often an excellent indicator of overall climatic patterns. These measurements need to be combined with other climatological measurements such as precipitation, temperature, wind, soil moisture, and other parameters in order to create a complete picture of droughts as extreme hydrologic events.

## Impacts on your ability to do the work

The extreme conditions that could impact on hydrographers' safety and their ability to carry out their hydrometric tasks go beyond the standard flood and drought to include things like drought, fire, weather conditions and pestilence.

These types of events have a range of direct and indirect impacts on hydrographers going about their business.

**Table 5. Impacts on hydrographers of other extreme events**

| Events | Direct | Indirect |
|---|---|---|
| Fires | **Immediate**<br>• Damage to equipment and infrastructure,<br>• Personal safety.<br><br>**Longer Term**<br>• Damage to equipment and infrastructure (increased flows - washing of sediment and debris in "first rains"),<br>• Changes/instability of station ratings,<br>• Impact of modified water quality on sensors (e.g. values out of range). | • Restricted access to sites,<br>• Dangerous driving conditions,<br>• Loss of communications. |

Many hydrographic agencies have, as part of their Work Health and Safety processes, protocols to deal with a number of these occurrences.

But in planning for an extreme event, the human factor also needs to be considered. In theory having staff work outside 'normal' working hours is straightforward and can be planned well in advance. In practice this is not the case. It is not unusual for modern hydrographers to have commitments other than work which stops them from being able to respond to an extreme event at short notice.

In other cases, it is the extreme event that precludes the hydrographer from responding. Most hydrographers would choose to evacuate their family and worldly possessions out of a flood's reach well before getting into their vehicle to undertake flood measurements. It is also not unheard of for hydrographic offices and depots to be inundated during flood events making it impossible to mobilise for that event.

While the authors were not aware of any actual or anecdotal evidence in amongst their contacts, there could be instances where hydrometric vehicles have been incapacitated attempting to cross flooded streams. We are certainly aware of hydrographers taking a more considered approach and not crossing flooded streams to get to sites and or vehicles being bogged for extended periods.

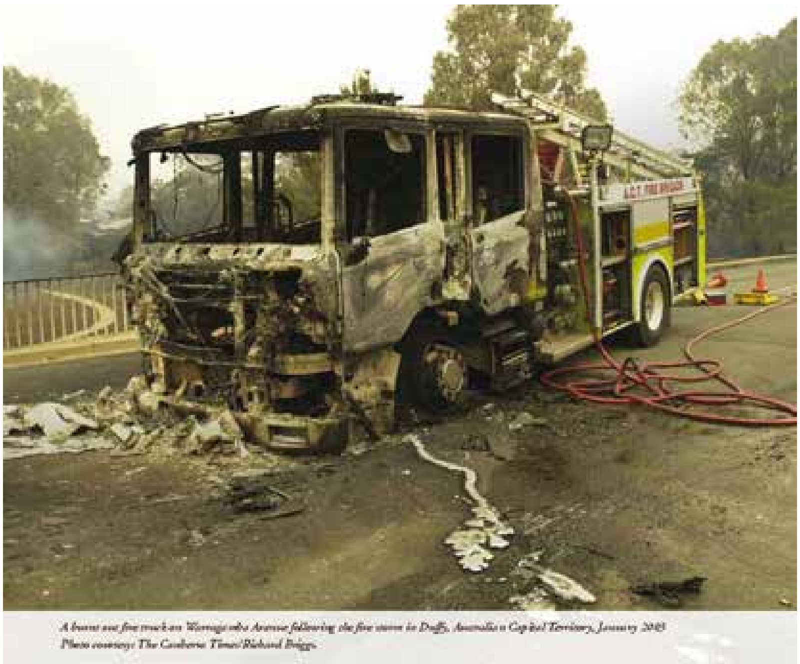

Figure 11. Possible impacts of poor planning.

Source: www.ga.gov.au

Risk analysis is a generic term for methods that support decision making by quantifying consequences and their probabilities of occurrence. The various methods in different settings are called probabilistic risk assessment, risk assessment and management, or, simply, risk analysis. Whether one is talking about nuclear power plants or environmental regulation or extreme events, the underlying problems are the same: identification of consequences, estimation of probabilities, and the combination and consideration of results prior to decision-making.

A graphic example of not being able to work effectively is shown in Figure 11. These sorts of situations while hopefully rare are not unknown in the hydrographic world and need to be considered as part of the planned response in an extreme event.

## Extreme Event – Planned Reponses

An Extreme event is happening or has a high probability of occurring - how will you respond?

- 1st Option – do nothing (not the Aussie–Kiwi way?)
- 2nd Option – do what you're told (doesn't sit well with hydrographers, and at the whim of somebody in H.O.)
- 3rd Option – have an agreed plan (be in the driving seat)

There are always a large number of activities that you can and should do before you get in your hydrographic vehicle and this is where your procedures become critical as well as your training.

The impacts of lack of thought and preparation can be catastrophic to you and members of your team. Risks increase dramatically during an extreme event and their rarity means that it is difficult to get and maintain experience in operating in these conditions.

The sort of things that you need to consider may include:

### *Event information:*
What is the extreme event you are responding to?

- How extreme is it?
- How widespread is it?
- How long is the event likely to last?
- What you plan to return with?

### *Hydrographic Activity*
What are you going to collect?

- What information needs to be sent where?
- What information needs to be kept?
- How quickly does it need to be notified?
- Who needs to be notified?

### *Personal Safety*
- What are the potential hazards?
- What safeguards and controls need to be put in place?
- Is the Vehicle fully equipped and checked?
- Who needs to be notified?

### *Management*

- Planning – cross border/jurisdiction assistance
- What action will be taken on the information provided?

But what is the chance of extreme event occurring during work hours and of securing pre-approved overtime, etc.

Let us assume you work in the order of 36-40 hours per week. You have a 25% chance of being at work if a short duration Extreme Event was to occur.

In some agencies with a high staff turnover the chances of the person who can approve overtime understanding the extreme event can be low. Even if they understand the event they will need supporting documentation for the overtime.

All these things need to be agreed on before an event if you are going to be able to respond as meet the professional and safety demands of an extreme event.

## Client Defined Response to Extreme Events

However, there can be other drivers for hydrographers' responses to extreme events.

In some cases, a client will go to tender or approach a hydrographic group seeking solutions to extreme events. In these cases, the extreme event is well known or at least well defined by the client, albeit the technical solution is generally complex.  An example of this is the flood system in Kuala Lumpur previously described in hydrographic papers by Mark Wolf[16].

Many hydrometric agencies provide services to paying clients where extreme events may not be the primary reason for the site's existence. Getting a timely OK to undertake additional work can be an issue at short notice. Again, agreement on what constitutes an extreme event with the client in advance is better.

In the hydrographic world a number of extreme events usually happen at the same time making it impossible to get to all the listed sites in one event even with Doppler technology and better road infrastructure. Therefore, prioritising what extreme to respond to is very important so that expectations can be managed.

## Forecaster Defined Extreme event

Another driver for responses to extreme events may come courtesy of the Bureau of Meteorology (BOM) in its legislative role of flood forecaster.

The Bureau is responsible for issuing flood warnings for Australia and it has an escalation process by which it normally issues a flood watch prior to a flood event warning of developing weather conditions that may trigger a flood event. A flood warning is issued when flooding is occurring or expected to occur in a geographical area based on defined criteria. these warnings are in three categories Minor, Moderate and Major.

### *Minor flooding*

Causes inconvenience. Low-lying areas next to water courses are inundated. Minor roads may be closed and low-level bridges submerged. In urban areas inundation may affect some backyards and buildings below the floor level as well as bicycle and pedestrian paths. In rural areas removal of stock and equipment may be required.

### *Moderate flooding*

In addition to the above, the area of inundation is more substantial. Main traffic routes may be affected. Some buildings may be affected above the floor level. Evacuation of flood affected areas may be required. In rural areas removal of stock is required.

[16] Wolf, M, 2008, *Australian Hydrographers Working Together to Protect Kuala Lumpur City from Natural Disasters and the effects of Climate Change*, AHA 2008 Conference, https://aha.net.au/aust-hydrographers-kl/ accessed 29 Mar 2020
Also Wolf, M. 2020, The Importance of Hydrological Data during an Extreme Event, *Australasian Hydrographer* (this issue).

### *Major flooding*

In addition to the above, extensive rural areas and/or urban areas are inundated. Many buildings may be affected above the floor level. Properties and towns are likely to be isolated and major rail and traffic routes closed. Evacuation of flood affected areas may be required. Utility services may be impacted.

The Bureau does not have a category for Extreme flooding (yet?) but for each level which varies at every location, the Bureau has expectations of actions and activities that will be undertaken by various agencies. There are generally no specific requirements for hydrographers from the Bureau's classification. The Bureau does encourage hydrographers to prioritise the repair of Flood Warning Sites as quickly as possible during and after an event to ensure that most stream level data is available for flood predictions.

## Conclusion

As the US National Research Council (1988) Committee on Techniques for Estimating Probabilities of Extreme Flood stated that other than the familiar death and taxes, few events, if any, can be predicted with certainty. Virtually all of our decisions and actions are taken in the face of uncertainty, from the daily choice of a commuting route to the design of a spillway on a dam or regulatory approval of new drugs. In each of these cases, making a decision requires weighing the consequences of alternative actions and the likelihood of each consequence occurring.

A critical part of any extreme event is data dissemination. Hydrographers need to maintain the current emphasis on rapid data acquisition and retrieval during extreme events and assist engineers and planners with the integration of their datasets with other scientific disciplines.

Any work with extreme events needs to consider how changes in land use, climate, and streamflow regulation influence these events. Continued data collection is the still the basis for the understanding and quantification of extreme hydrometric events.

Hydrographers also need to be cognizant of risk management during the events as well as the planning before these events which allows the application of risk mitigation measures.

But as a profession, we also need to be aware that extreme events are not just numbers, they are also often associated with disasters, with their resultant social, financial and human impacts.

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# The Importance of Hydrological Data during an Extreme Event

**Mark Wolf, Principal Consultant, EMALTE, Coffs Harbour, NSW**

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

## Abstract

*The purpose of this article is to consider the importance of Hydrological Data during an extreme event. In this paper we will consider the subject matter with regard to real time systems used to:*

- *Protect people and property (mitigate flooding).*
- *Provide public warning.*

*Referenced will be the "Kuala Lumpur SMART Tunnel Flood Detection and Stormwater Management System". Designed and installed by an Australian led team in 2007, this world leading system is fully dependent on "accurate" and "reliable" hydrological data pre, during and post extreme events. We will focus on "during".*

## Real-time data

Real-time hydrological data is essential for the operation of systems designed to protect people and property from extreme flood events and where mitigation is unlikely to inhibit an extreme event, to provide public warning.

Such systems:

- Store and/or divert stormwater (dams/tunnels).
- Provide Public Warning.

## The importance

Without accurate and reliable real time hydrological data flood forecast models cannot provide the information required to make intelligent decisions whether logic based or based on interpretation.

### About the Kuala Lumpur SMART Tunnel Flood Detection and Stormwater Management System

The Kuala Lumpur **S**tormwater **M**anagement **A**nd **R**oad **T**unnel (SMART) system is a real time fully operational logic based flood detection and stormwater management system comprising:

- 30 hydrological monitoring stations (rainfall and water level), within the catchment 16 water level monitoring stations equipped with Acoustic Doppler Current Meters
- 1 Supervisory Control Centre
- 1 Disaster Recovery Centre

- Multiple means of communications including
  - VHF radio
  - GSM (Global System for Mobiles)
  - Optical Fibre
  - Leased Line
  - Cable (RS485)
- An Automated Peer-to-Peer Monitoring Control System incorporating Remote Telemetry Units at:
  - 7 sets of gates
  - 6 pumps including 4 x 1 $m^3/s$
  - Multiple sets of triple redundant water level sensors for pond level and tunnel water pressure monitoring
  - 3 electronic warning stations
- Triple redundant Supervisory Control And Data Acquisition system
- Aquarius Time Series and Forecast modelling software
- Mike 11 Hydraulic modelling software

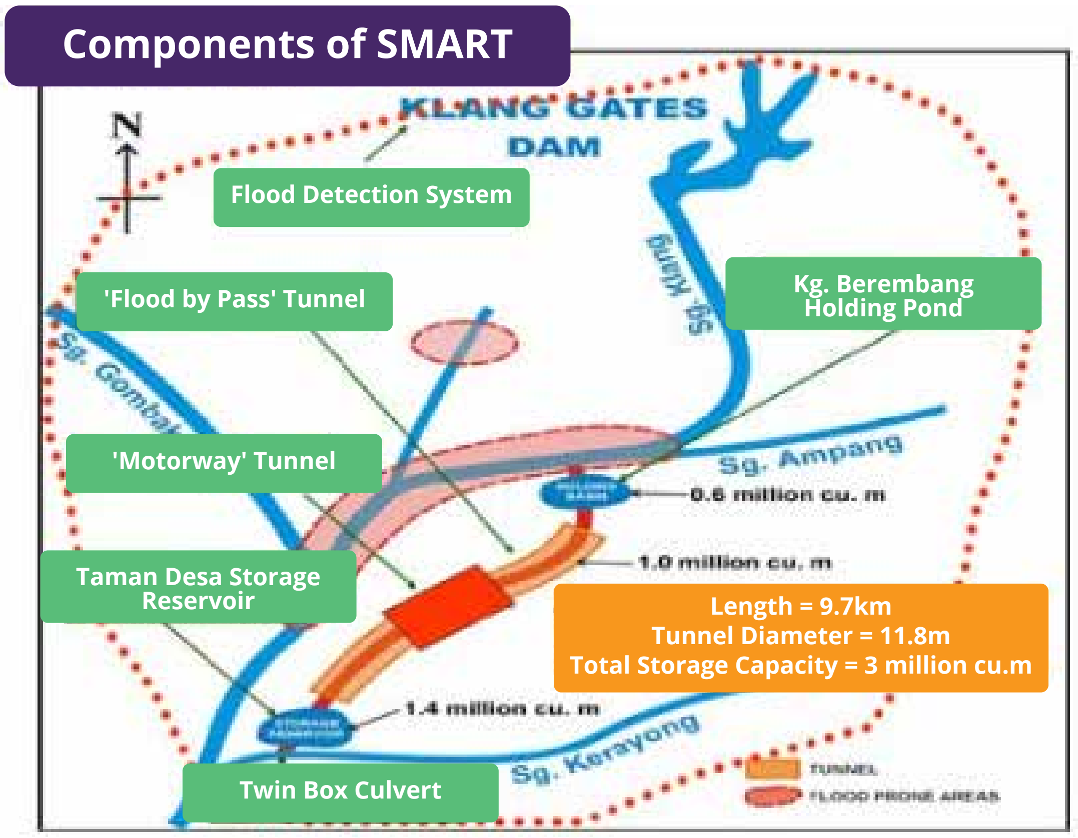


Figure 1. Components of SMART.

The purpose of the SMART system is to protect life and property from moderate and major (extreme) flood events plus provide a bypass for traffic.

It does this by automatically regulating water flow through the City Centre (via 4 large radial undershot gates – Figure 2) and diverting and storing water in the SMART Tunnel and associated ponds. After the event is over the water is discharged and made ready.

Figure 2. Radial Undershot Gates, controlled by the Flood Detection System, regulate flow to the City and into the tunnel.

The automatic gate operation during flood events event is based on the forecast and real-time flow upstream of the gates with water level sensors upstream and downstream of the gates and an upstream ADCP providing real-time data. This allows flow to the City to be regulated and stormwater to be diverted into the SMART Tunnel.

The hydrological data collected in the catchment and throughout the system (recorded every 60 seconds) is used as the input to six 1D hydrological models. The results of the hydrological models are then input to the Mike 11 2D model.

The hydrological data of such critical importance to enable:

- Average catchment rainfall to be calculated and displayed
- The flow at the regulating gates to be measured and forecast
- Automatic control of gates, warning systems and management of the SMART Tunnel proper to take place based on the measured and forecast data
- Emptying of traffic from the SMART Tunnel Traffic decks in the event that an extreme event has occurred and the forecast flow requires the full use of the SMART Tunnel for storing the stormwater

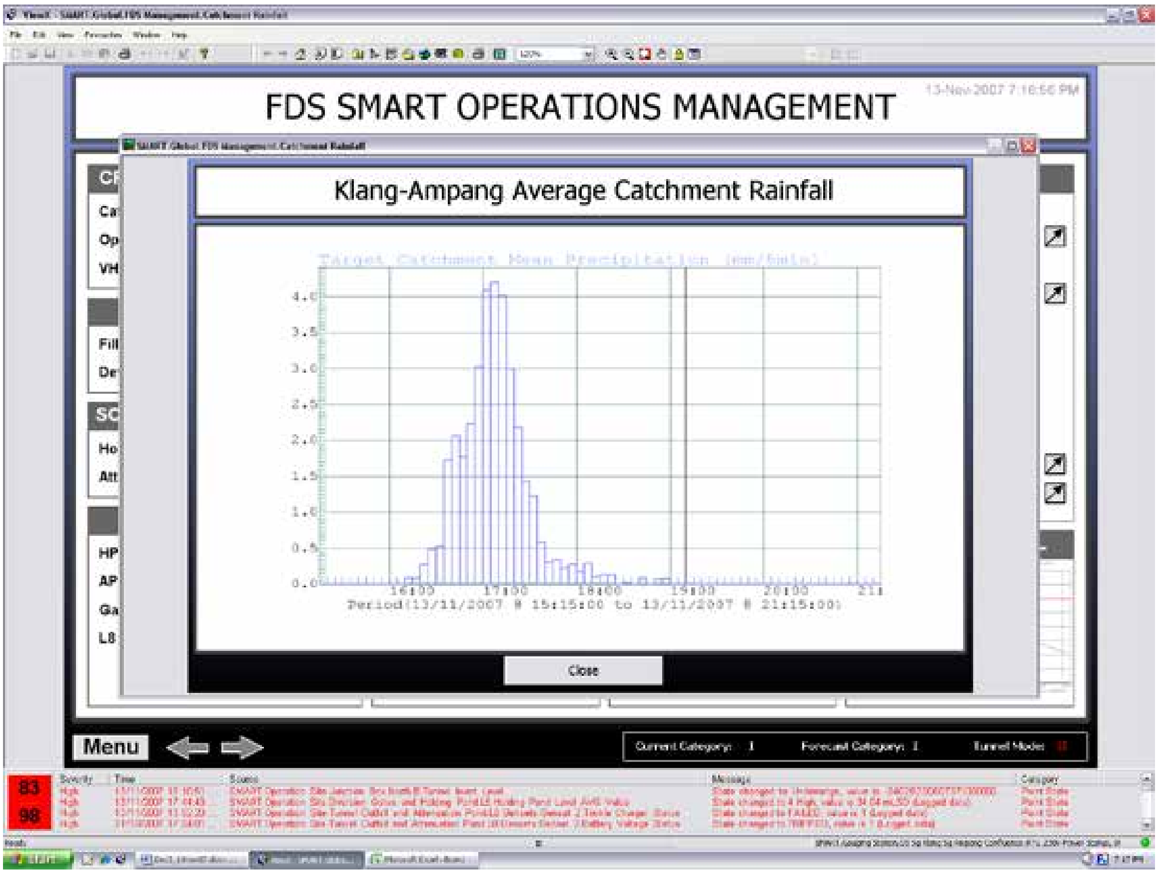


Figure 3. Average Catchment Rainfall complete with now line and forecast.

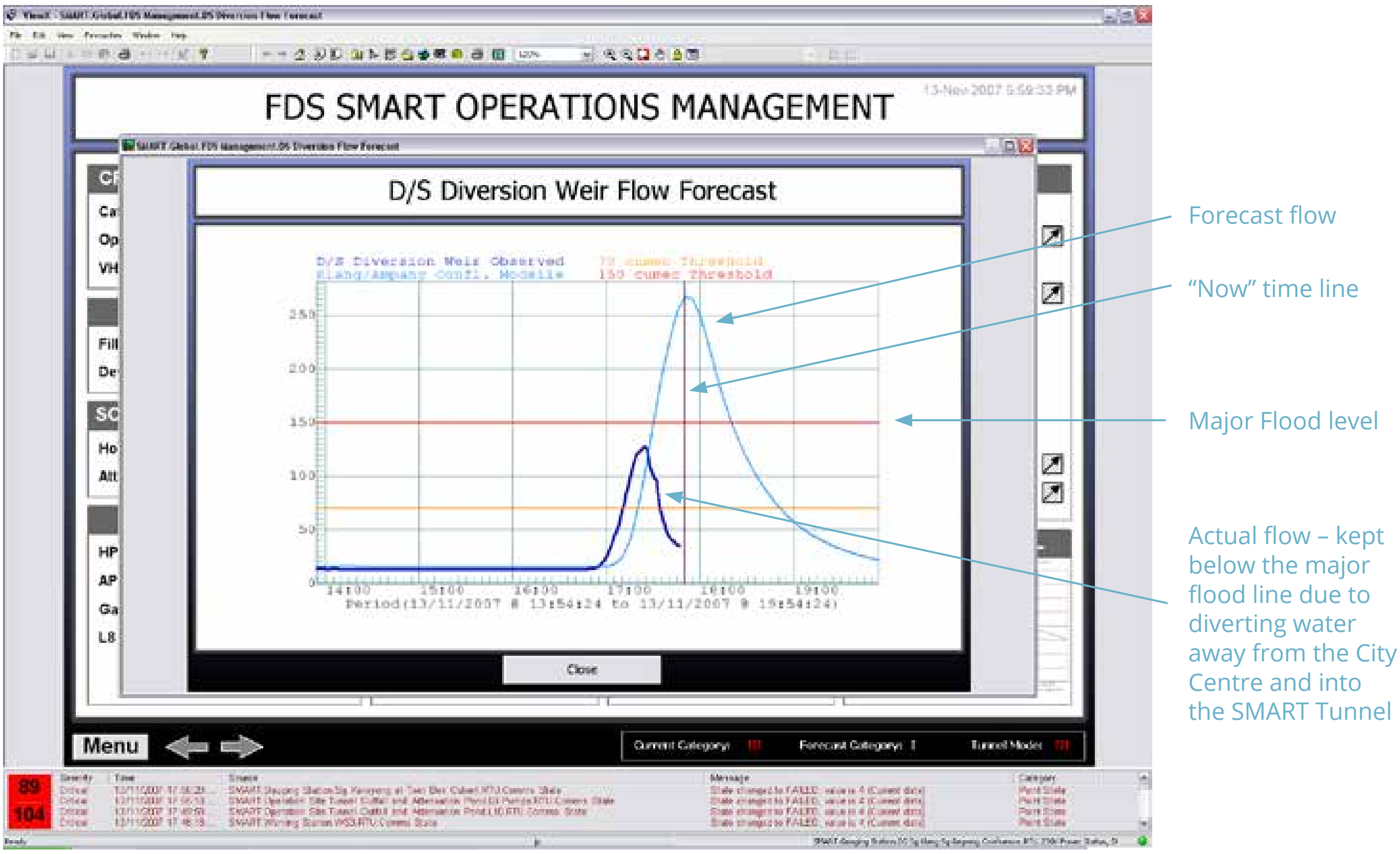


Figure 4. Model and actual flow curves – note the forecast and now time line, the moderate and major flood levels and the flow curve showing the effectiveness of diverting the water away from the City into the Tunnel.

## Hydrological Data Acquisition System

To ensure that the accuracy of the modelled flow at the Regulating-Diversion Gates (the system was designed based on the client's requirements that relate to: forecast lead time and the accuracy of the forecast):

- All data logger's clocks are synchronised to the SCADA system clock to ensure that the systematic error resulting from inconsistent time stamps are eliminated.
- Data is recorded every 60 seconds (measurements, system data).
- Triple redundant sensors are used with "two out of three" voting employed to ensure the most accurate water level or pressure measurement is used (a failed or out of acceptable range reading is ignored).
- Stations are polled every 5 minutes, data backfilling implemented as required.
- All instruments have their calibration checked at regular intervals.
- Doppler current meters provide real-time mean velocities which are indexed using specially developed modelling software to generate real time flow.
- In the event that Doppler current meter sensing heads are blocked by debris or damaged, the SCADA system detects the fault and automatically switches over to using a HEC-RAS developed rating curve to determine real time flow.

Flow through gates and the tunnel are calculated using hydraulic formulas with the inputs to the formulae-efficient being the data from the water level/pressure sensors and gate position sensors.

### Pre-Event

- The system is always in a state of readiness.
- Hydrological data and system status is continually updated.
- Sensors are triplicated at key locations.
- The Supervisory Control Centre is manned 24/7.

### During the Event

The system has been designed to operate automatically; Operators can however switch sections of the system to manual operation.

The operation of the main regulating gates and offtake gates which divert water into the SMART Tunnel and the activation of warning systems (sirens) are always set to automatic mode.

The models run continuously, updating the MODE of the event. MODE 0: normal operations MODE 1 requires the Tunnel to be used for storage of stormwater, MODE 2 requires the use of the Traffic Decks also.

The system continues to record data every minute and update the forecasts every 5 minutes.

### Post Event

The system continues as normal.

The traffic decks and tunnel are emptied and cleaned and the road decks are re-opened for traffic.


Figure 5. Entrance to the SMART Tunnel upper traffic deck.

## The Legacy

The results of the attention to detail regarding the design, establishment and operation of the SMART hydrological monitoring system (the heart of the SMART Flood Detection System) have included:

- Protecting the City Centre from flooding during major and extreme events over 30 times with not one life lost (that alone makes the collection of quality hydrological data worthwhile).
- Multiple awards received including:
    - World's Best International Project (2008 British Construction Industry).
    - United Nations Habitat Medallion (2011).
    - Many others.
- Applying the knowledge gained to assist with the design of dam safety systems.
- Securing business for Australian Consultants and Companies.
- Providing Australian Hydrographers, Hydrologists, Modellers, IT Professionals, Engineers and Project Managers with a greater appreciation and understanding of applied hydrology.
- Transferring knowledge to Department of Irrigation and Drainage staff in Malaysia.
- Continued work for EMALTE, Entura, Aquatic Informatics (we are all still working on the SMART Flood Detection System – refining, improving, auditing as of today).
- Demonstrating the importance of hydrological monitoring for the management of extreme events.


Figure 6. SMART Tunnel –combined Stormwater Storage and Traffic Tunnel.

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# Providing Australia with Water Information

Australian Government
Bureau of Meteorology

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**

For more information come and talk to us at Booth 13; visit www.bom.gov.au/water or send an email to waterinfor@bom.gov.au

# Korokoro flood warning project

**Ethan Coulston, Greater Wellington Regional Council, Wellington, New Zealand**

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

## Abstract

*In December of 2016, Greater Wellington Regional Council (GWRC) was requested by the New Zealand Transport Agency (NZTA) to provide flood warning services in the Korokoro Stream catchment which is located at the north-west end of Petone, Wellington.*

*Flood warning services were required due to the state highway 2 (SH2) downstream being susceptible to inundation by the Korokoro stream, causing road closures (for example two major floods occurred in 1976 and 2015.*

*Flooding occurs because the Korokoro stream is confined by a culvert running under a local factory. Provided it is clear of gravel build-up and debris; the culvert has a capacity of 37.5 $m^3/s$. During large floods the carrying capacity of this culvert is exceeded and flooding occurs.*

*It was intended for flood warning to be provided through the installation of a flood warning network and the subsequent analysis of flood peak timing, to provide a predictive timeframe for when highway downstream should be closed.*

*The Korokoro flood warning network consists of two sites; a raingauge in the upper Korokoro stream catchment and a water level site in the lower catchment main-stem, on a historic dam.*

*The network is designed to provide as much warning as practicable for the SH2/Cornish street hotspot. The upper catchment raingauge was intended to provide early warning of heavy rain actually falling in either of the main sub-catchments and provide confirmation of Metservice (New Zealand's Bureau of meteorology) issued warnings. The river level site is intended to provide confirmation of a physical rise in water level in the stream and the magnitude of the rise. A temporary water level sensor was also installed, for the first year, in the vicinity of Cornish Street to provide data for analysis of travel times of flood peaks within the catchment.*

*As a newly employed Environmental Monitoring Officer with roughly 6 months of experience, this project was assigned to me so I could learn a number of core aspects of field hydrology (raingauges, bubble water level sensors, pressure transducers, site installs etc.) in a single project. I was thrown in the deep end if you will!*

*This article will contain all of the aspects of this project (planning, execution, analysis, reflection etc.) and encompasses all of the fundamentals of surface water hydrology.*

## Installation overview

The Korokoro Flood Warning System is consisted of two sites; a raingauge in the upper Korokoro stream catchment and a water level site in the lower catchment main-stem. Both sites are located on GWRC owned land that forms part of Belmont Regional Park. Site locations are indicated on the map in Figure 1.

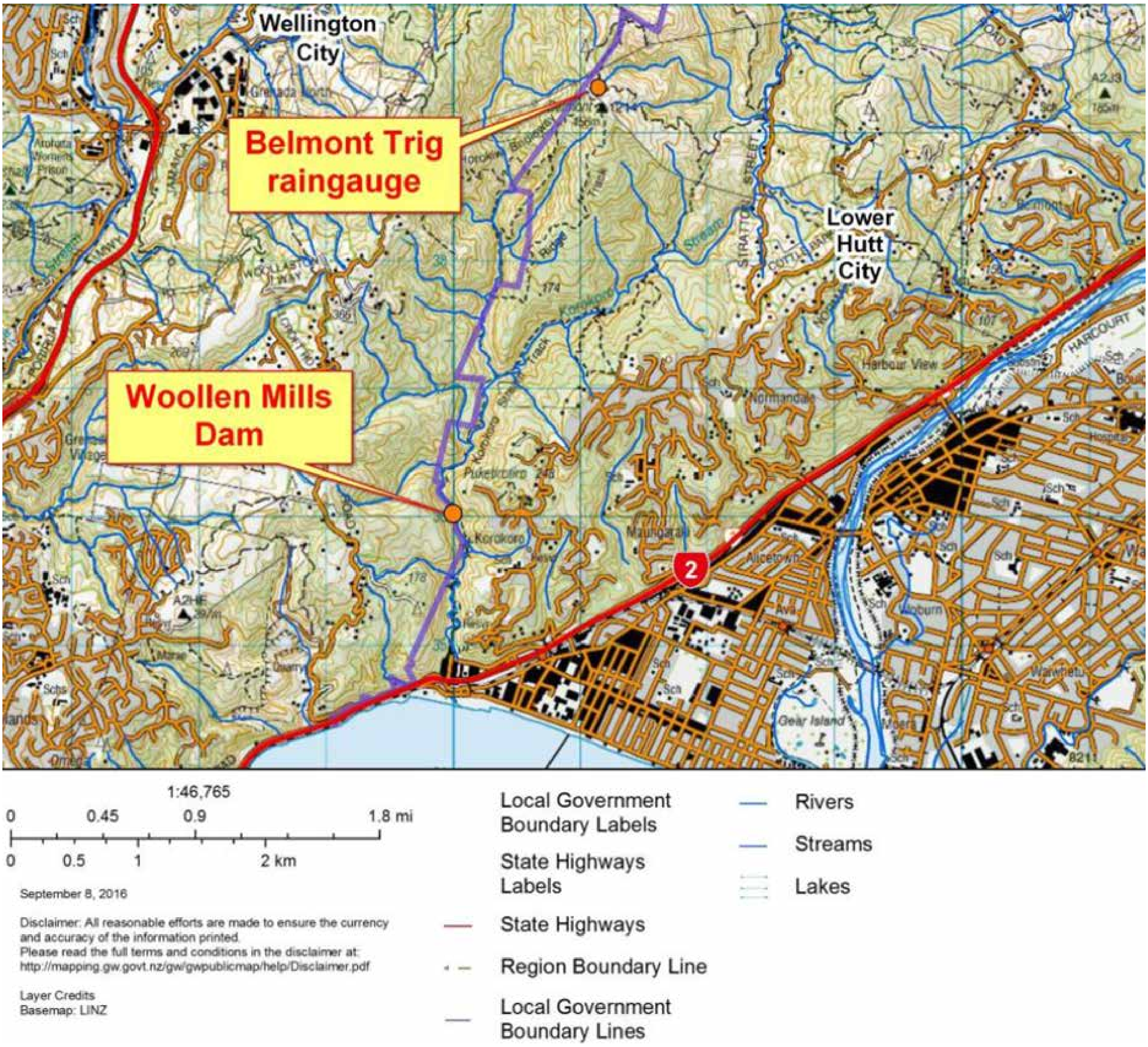


Figure 1. Map of site locations.

The network is designed to provide as much warning as practicable for the Cornish Street/SH2 hotspot. The upper catchment raingauge was intended to provide early warning of heavy rain actually falling in either of the main sub-catchments and provide confirmation of Metservice (New Zealand's Bureau of meteorology) issued warnings. The river level site is intended to provide confirmation of a physical rise in water level in the stream and the magnitude of the rise. A temporary water level sensor was also installed for the first year in the vicinity of Cornish St to provide data for analysis of travel times of the flood peaks within the catchment. Figure 2 shows the relative position of the two sites in the catchment.


Figure 2. Relative position of the two sites within the Korokoro catchment.

## Raingauge: Korokoro Stream at Belmont Trig

This site is a standard GWRC raingauge installation, designed and installed to meet the National Environmental Monitoring Standard (NEMS) QC600.

Access is by 4WD vehicle via Stratton Street in Belmont and then the 4WD track to Belmont Trig. The land is owned by GWRC and is operated as a Regional Park. GWRC Parks Department granted permission for the gauge to be installed. Due to the public nature of this type of site installation, consideration needs to be made for ensuring that the gauges are both secure and that the gauge compounds are built to a suitable aesthetic standard. As can be seen in Figure 3, the rainfall sensor onsite is a tipping bucket raingauge. The data is sent to the office by a 3G cellular modem.

Based on GWRC standard procedure, a rainfall alarm threshold was set at 20 mm over a two-hour period. This is because it is a good threshold to provide an early warning to be on the watch for rising stream levels. This can be reviewed after a set time or if numerous rainfall alarms are received with little flow response.

Figure 3. Rainfall monitoring site at Belmont Trig?

## Water level: Korokoro Stream at Woollen Mills Dam

This site is a basic water level monitoring station using a water level bubbler sensor which communicates to the office server through a 3G cellular modem. The installation was designed and installed to meet a minimum standard equivalent to the NEMS QC500 quality standard. Access is by 4WD vehicle up the Korokoro valley from the Cornish Street entrance to Belmont Regional Park. The water level control for this site is the historic Woollen Mills dam that has been modified to act as a weir. The land is owned by GWRC and is operated as a Regional Park. Figure 4 shows the water level site installed on the Woollen Mills dam.

Based on a channel capacity analysis, completed by local engineering firm BECA, following the 2015 flood, the channel bottleneck was found to be a triple-barrel culvert running underneath a local business. Capacity at this reach is reduced to 29 $m^3/s$ if a build up of gravel and debris existed within the channel. Therefore, alarms were recommended to be conservatively set at 10 $m^3/s$ and 20 $m^3/s$.

Damwatch (as a part of a safety review of historic dams in the Greater Wellington Region) built a HEC-RAS (a Hydraulic modelling program) model for the site which we subsequently adapted and used to estimate high flow vs level (Astwood and Baines, 2014).

Figure 4: Korokoro Water level monitoring site as indicated in figure 2.

## Water Level: Temporary site at Cornish Street

Following the installation of the two permanent sites, a temporary monitoring site was installed at the lower end of the catchment, in order to determine the travel time of flood waters from the water level site 1.3 km upstream, to the industrial buildings and the state highway downstream. The sensor utilised at this site is an unvented pressure transducer. The sensor was left at this site for several months in order to measure the flood peaks that came through over this timeframe.

After several flood peaks had come down the stream, the data collected was downloaded and then compared and analysed alongside the data gathered at the upstream site. This comparison allowed travel time to be derived. As the pressure transducer was 'unvented' it records the combined effect of barometric pressure and water level pressure; therefore it was necessary to offset the data utilising barometric pressure from a nearby meteorological station. Figure 5 is an example of the downstream water level data overlayed onto the upstream water level site.

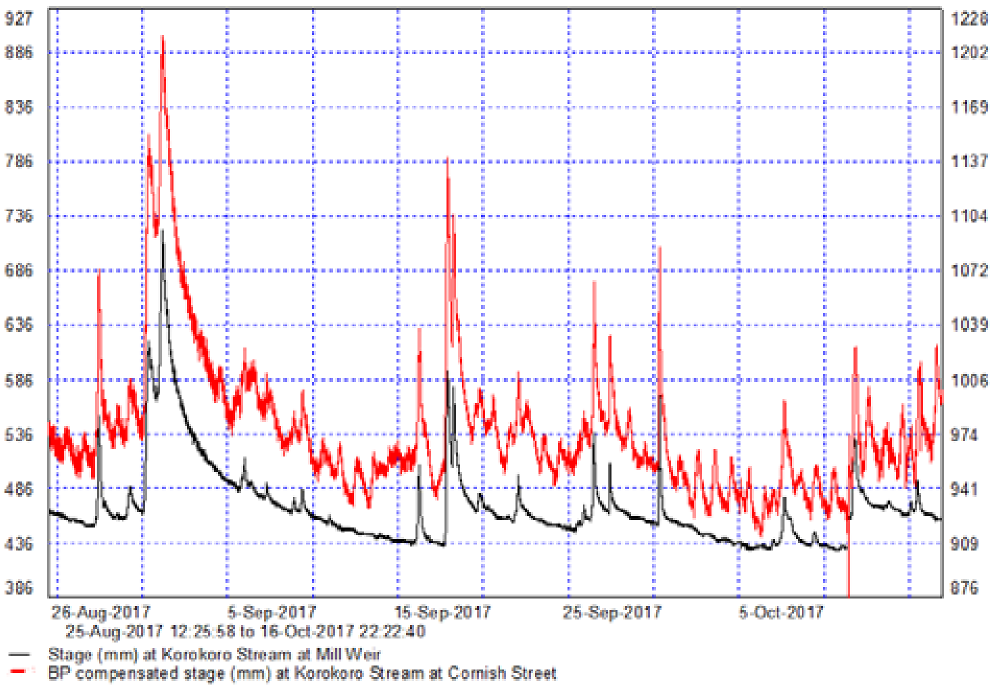


Figure 5. Water level from downstream site (red) overlayed with water level site upstream (black).

## Analysis

Data from the two level sites was compared in order to determine the travel time. A comparison can be seen in Table 1. Seven moderate events were analysed to find the average travel time however, as can be seen in Table 1, individual travel times can vary significantly. This is most likely due to the variations in the spatial distribution and magnitude of the rainfall events.

**Table 1. Analysis of flood peak travel time**

| Event | Belmont Trig Rainfall | Mill Weir | | Cornish St | | Travel Time b/w peak (min) |
|---|---|---|---|---|---|---|
| | Cumulative Event Rainfall (mm) | Time | Water Level Peak (mm) | Time | Water Level Peak (mm) | |
| 31-Aug-17 | 35.2 | 31/08/2017 08:46 | 620 | 31/08/2017 09:00 | 1152 | 14 |
| 7-Sep-17 | 1.1 | 07/09/2017 06:50 | 491 | 07/09/2017 07:05 | 1009 | 15 |
| 17-Sep-17 | 21.8 | 17/09/2017 21:30 | 594 | 17/09/2017 21:45 | 1139 | 15 |
| 18-Sep-17 | 6 | 18/09/2017 06:30 | 579 | 18/09/2017 06:35 | 1105 | 5 |
| 30-Sep-17 | 8 | 30/09/2017 08:10 | 571 | 30/09/2017 08:20 | 1085 | 10 |
| 26-Sep-17 | 9.8 | 26/09/2017 11:30 | 538 | 26/09/2017 11:40 | 1065 | 10 |
| 27-Sep-17 | 2.4 | 27/09/2017 10:35 | 509 | 27/09/2017 10:50 | 1033 | 15 |

## Reflection

Since this project has been finished and all monitoring sites have been installed, the ongoing issue has been communications with the river level site. Despite having tested the relative received signal strength indication (RSSI) of the site prior to the install commencing, the modem sporadically fail to communicate with the office server. This is a critical issue as the site's purpose is flood warning, making timely communications an essential feature. Solutions to this are currently being researched and tested. One of the more promising solutions is a 900 MHz wireless bridge which sends data from the water level site to a nearby reservoir which will then relay data to the office server via a 3G modem. A cell tower is located nearby and reception is reliable[17].

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[17] Editor: I understand that in 2018 investigations were ongoing hopefully an effective resolution has been found and implemented.

# From The Vault - The Birth of the Australasian Hydrographer

**Reproductions of Newsletters published in January and April 1979**

## Pre-face

*In January 1979 the Introductory and Inaugural editions of the **Australian Hydrographic Newsletter** were published. This Newsletter was the pre-cursor to today's Australasian Hydrographer (the newsletter was renamed to **Australasian Hydrographer** in 1995 to reflect the wider audience).*

*The Newsletter was born from a recognised "need to continue the momentum of communication" started at the 1978 "Hydrographic Workshop" convened by the Australian Water Resources Council, held in Perth, Western Australia. The Workshop represented the first gathering of hydrographers from all states. The Introductory Newsletter was quickly followed by the first issue in April 1979 at a cost to our members' of $3.00 an issue.*

*For your reading pleasure the contents of both the original newsletters (and the few illustrations) have been reproduced (the originals were typed, and copied).*

*The AHA archives have a gap after these issues through to 1987, if anyone has saved the odd copy please feel free to scan them and send to Journal@aha.net.au.*

## Australian Hydrographic Newsletter – Introductory Issue

*Published in January 1979*

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*Hydrographers working for other authorities within these States and Tasmania should correspond directly with the EDITOR in S.A.

**Introduction**

This preliminary copy of the Australian Hydrographic Newsletter is designed to give you, Australia's Hydrographers[1] the concept idea of a Newsletter which we hope will be your medium for technical communication.

It is hoped that you will react positively and indicate your interest to the Sub-Editor in your State or directly to me.

A negative response will mean sudden death and we can all crawl back into our little empires and wonder what the other blokes are doing[2].

Please give the Newsletter idea a chance, its success or failure will depend on YOU!

**Why a newsletter?**

Probably, if you asked the participants at the recent Perth Hydrographic Workshop[3], what they thought was the best thing they got out of it, they would reply:

> *"The value in talking to other hydrographers; seeing who they are; what they do; discussing mutual problems; discussing technical developments, was unlimited."*

As this was the first time they had had a chance to get together there was a general realisation that they were only just scratching the surface. The need to continue the momentum of communication was obvious. Hence the Newsletter.

**What will it cost?**

As this is to be OUR Newsletter, not an official departmental publication, it will be up to us to pay for it. Paper, printing, postage etc. for four (4) quarterly issues will require a subscription of $3.00.

We should be able to raise advertising revenue which would reduce this amount for subsequent issues. However, this will depend on whether this is the general desire of hydrographers. It would be appreciated, therefore, if you would indicate your willingness to receive and participate in the Newsletter, by forwarding your name, address etc. PLUS $3.00 to the Sub Editor in your State or directly to the Editor[4].

Please pay your subscription by the end of February, so that we can get the first issue off the ground by the end of April, 1979.

**Contributions**

As blank sheets of paper don't make interesting reading, your contributions are essential for the success of the newsletter.

Believe me, every one of us would have something to contribute and thus share with our fellow hydrographers.

Contributions would fit into the following groupings:-

1. Technical Reports - Special investigations carried out, dealing **with** various aspects of hydrography/hydrology.
2. Equipment - This could be a full report on new items of equipment developed or tested. It may also be just a few lines on minor modifications made to existing equipment to make life easier. This section would also include vehicles, and their fitting out, camping gear etc.
3. Humorous Essays - Everyone in hydrography by nature of their work has at least one humerous incident to relate. The obvious scope here would be wide and varied.

[1] in 1979.
[2] Mmmm a little drastic maybe?
[3] The 1st Hydrographic Workshop convened by the Australian Water Resources Council, in 1978.
[4] later communicated that cheques were to be made payable to the "Australian Hydrographic Society".

4. Problem Solving - Do you have a problem? (real or imaginary) – perhaps some of us have already solved it or are capable of solving it. You won't know until you put it down on paper. Let us solve your problems.

5. Letters to the Editor - Feel free to use this as a means of communication with your fellow hydrographers.

If your article doesn't fit in with any of the above but would still be of interest, send it in and we will fit it in somewhere.

Contributions to the first issue should be placed with the Sub Editors or Editor by 24th March, 1979.

**SUCCESS DEPENDS ON YOU**

**Letter to The Editor**

Sir,

THE NEED TO SUPPORT THIS NEWSLETTER

To me, the most significant outcome of the recent meeting of hydrographers from all states was the conclusion that an attempt be made to set up this Hydrographer's Newsletter.

I believe that this newsletter should be supported by every hydrographer and every would-be hydrographer in Australia. It will then become the only unifying instrument of an otherwise vastly dispersed group of like-minded people *(JB: today we have a few more options open to us yet the Journal still remains).*

If no support is given, any impetus generated at the recent gathering will be quickly dissipated marking the end of this attempt or it will degenerate into a vehicle for the aspirations of anyone who deigns to contribute.

I therefore exhort every hydrographic person in Australia to contribute in whatever way he sees fit to make this a viable and influential dialectic instrument

R.J.Marks[5], W.A.

[5] Russell Marks, who has always had a way with words, is now the semi-retired Chairman of Greenbase Pty Ltd. Refer to the Australasian Hydrographer, June 2019 for his member profile.

# AUSTRALIAN HYDROGRAPHIC NEWSLETTER

CORRESPONDENCE TO:
V Aeuckens Water Resources Branch E.& W.S. Department
Box 1751 GPO Adelaide 5001 or Subeditor in your state

Registered for posting as a publication - Category B

## FROM THE EDITOR'S DESK

Well here we go with our first issue of the Newsletter. Frankly I'm overwhelmed by the response. One hundred and seventy three initial subscribers, with possibilities of more to come. I'm sure most of you too, will be surprised at the response. It certainly proves one thing, hydrographers ARE interested in knowing what is going on and communicating with their interstate counterparts.

Unfortunately I was disappointed in the selection of material to print. It seems that most of us prefer to read rather than write. One notable exception was Andy Keep of the S.R. & W.S.C. at Kerang. Andy has been in the game so long that he's got enough material to write a novel. He has sent me enough for ten newsletters and in gratitude I have started a section which I've called KEEP'S CORNER. I'm sure many of you could equal or better Andy's tales, how about trying?

The Queensland Water Resources Commission has also contributed towards the Newsletter, as have two hydrographers from Western Australia. It's a good start but in order to balance the material printed I will need a much wider selection preferably from all States.

I thank all those who sent their best wishes and hope that the momentum continues.

A list of initial subscribers is published in this issue. All subscribers can consider this to be an acknowledgement of receipt of their subscriptions. Any new subscribers may send their $3.00 subscription direct to me or the sub-editors in their State. Please make cheques payable to the Australian Hydrographic Society.

The next issue is due for printing in July, please forward your literary contributions no later than June 30.

Wally Aeuckens

## Technical Report
## Syphon Method for Constant Pump Rate Test of a Borefield

This report was submitted by Ken McIntosh. Ken is an Hydrographer with Alcoa of Australia, Box 172 Pinjarra, W.A.

Ed.

2.

Several years ago a series of boreholes were drilled on a steep hillside. These boreholes were primarily for monitoring of water table fluctuations and also monitoring the underground water quality. The bores were cased with 2" PVC pipe.

As a result of some unusual water table fluctuations the Hydrologist in charge of the project needed information on the transmittivity of the unconfined aquifer, to help him understand the hydrology of the area. Thus a constant discharge pump test of a bore was required. This test couldn't be carried out by normal means because the size of the casing was too small to allow the use of a submersible pump, the water level was too far below ground level to allow the use of a surface pump and the flow rate of the bore was known to be very low.

However since the borehole was on a very steep slope it was possible to use a regulated syphon to carry out the test. At a distance downslope from the bore of about 150 metres the ground level was below the level of the water in the bore.

The syphon was started by firstly back pumping along the 1" poly pipe which lay from the pumping point up the hill, down to the base of the borehole. Once the pipe was full and all air was removed the pump was disconnected and syphon began operating. A top was fitted to the end of the poly pipe to regulate the flow so that the bore was not syphoned dry i.e. the syphon rate equalled the amount of water entering the bore.

After a bit of trial and error this method was successfully used to determine the Transmittivity and Storage Coefficient of the aquifer.

If anyone requires a more detailed report on the method and its results please do not hesitate to contact me. One extra advantage of the method is its cheapness as it doesn't involve the purchase of an expensive pump.

Ken McIntosh

## Wet Season Bulletin - Queensland Water Resources Commission

While our southern associates are suffering the effects of heat waves and bush fires the northern hydrographic outposts of Queensland were battling with the floods produced by cyclones "Peter", "Greta" and the wandering cyclone "Kerry" which did circuits and bumps around the Central and North Queensland Coast.

As a result of the influences depositing huge quantities of rainfall on the catchments, e.g. January Rainfalls - Babinda 2 000 mm
February Rainfalls - Babinda 971 mm
some quite impressive floods were experienced.

One hydrographic team from Mareeba operated a manned cableway on the Barron River at Kamerunga. This cableway has 10.9 m and 12.4 m towers and a span of 300 m.

During the height of the cyclone the hydrographic team carried out measurements and obtained sediment samples under extremely difficult conditions to collect data for the Barron River Delta Study. Maximum discharge measured was 4 100 cumecs with maximum velocity of 4.055 metres per second. The medium high flows were measured using an Ott Mark V meter suspended with a 50 kg Columbus weight.

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3.

Higher flows were measured using a nose mounted Ott C31 on a 100 kg weight with a bottom sensing device. All equipment was manually operated.

Continual wet conditions caused failures in cableway traversing counters, depth indicator, Ott Z100 counter and the Ott F4 counters. Submerged debris broke the Ellsworth cable holding an Ott Mark V meter and a 50 kg Columbus weight. Fortunately they were recovered several days later.

Further south the Mackay hydrographic team were having their share of the wet conditions.

| | | |
|---|---|---|
| January Rainfalls | Dalrymple Heights | 1 023 mm |
| February Rainfalls | Dalrymple Heights | 1 051 mm |

Here point sediment sampling measurements were carried out for a major pump station design together with measurements for a weir design. Sediment sampling was carried out using the modified Gulp sampler from a boat.

Stream measurements were obtained using an Ott Mark V meter suspended with a 150 kg weight using a power winch from a cableway. Maximum discharge measured was 3 150 cumecs with maximum velocity of 4.65 metres per second.

Numerous logs and tree trunks damaged the heavy duty hanger bar and made conditions very difficult. Some problems were experienced with moisture affecting the control box and later with the operation of the power winch.

Further south again a Rockhampton hydrographic party were flood bound at a gauging station on the Connors River which crosses the highway between Rockhampton and Mackay, known locally as the "horror stretch" because of traffic disruptions which occur during the wet season.

Measurements were obtained at this station using a 12 foot Topper John aluminium boat. Results from this trip have not yet been recieved but the stream was measured to bankful which is about 14 metres gauge height.

No major flooding has occurred in the southern parts of the State.

The Burdekin River, one of the largest rivers in the State has medium flooding and is currently flowing at a rate of approximately 11 000 cumecs.

<u>Editor's Comment</u>

This article contains the familiar lament of equipment failure just when you need it the most. Has anyone had any success in waterproofing counters etc? If so, I'm sure we'd all like to hear from you.

Has anyone got any comments on use of boats and associated equipment based on personal experience? e.g. I don't think I'd be keen on using a Topper John in a fast flowing stream.

I'm sure we could generate some good discussion on flood gauging.

Ed.

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## Gas Mechanical Water Level Recorder

The Queensland Water Resources Commission has designed and built a revolutionary gas mechanical water level recorder, which was discussed at the Perth Hydrographic Workshop.

At present six gas mechanical recorders have been installed throughout the State. Two of these have been installed in conjunction with D.P. transducers and one has been installed in a float well to compare the record from a float with the gas mechanical record.

Copies of the traces were enclosed. Unfortunately, space does not allow them to be reproduced here, but I can say, it is extremely difficult to detect the difference between the float and gas mechnical traces.

Further details on the gas mechanical recorder are available from Keith Smythe, Supervising Hydrographer, Q.W.R.C.

## Automatic Pumping Samplers

Ken McIntosh (and a lot of others) would like to hear from anybody who has information on the "field operation" of commercially available automatic pumping samplers. I believe the A.C.T. boys have had some experience with Manning Samplers, perhaps they would be prepared to report.

My own Department (E. & W.S.) has recently purchased an ISCO automatic sampler, but we have not had the unit installed long enough to come to any conclusions.

Any other comments?

## Queensland Water Resources Commission Sediment Gulp Sampler

The Surface Water Resources Branch was requested to obtain point sediment samples from a site on the Pioneer River at Mirani, which is near Mackay, for a major pump station design.

In view of the difficulty in obtaining sediment samples from a boat it was decided to modify an existing gulp type sampler similar to the "Van Dorn" type to enable samples to be obtained in fast flowing streams.

A sampler was designed so that it could be attached to the hanger bar of a 25 kg or 50 kg weight. Further modifications have now been made to enable the sampler to be easily detached from the hanger bar so that the sample can be decanted into a sample bottle. The sampler capacity is approximately 2 litres.

Modifications are being carried out to the hanger bar to enable velocities to be obtained with a current meter while sampling.

Plans and further details can be obtained from the Q.W.R.C.

5.

## To Make Life Easier

Andy Keep
S.R. & W.S.C., Kerang, Vic.

Most of us make use of pulleys of one kind or another for various purposes, e.g. in tackles, as travellers, up front on the boat rig etc., and we at Kerang are no exception. As supplied, these invariably employed a metal sheave which is rotated with some difficulty on a plain mild steel shaft, a principle which promoted excessive wear in the absence of frequent lubrication, and required much unnecessary exertion in operation. Many years ago, we fitted ball races to the centres of a few experimental sheaves, and found ease of operation to be so vastly improved that the modification at once became standard practice. Not only is physical effort considerably reduced, but accuracy in suspension and sounding applications is greatly assisted as the operator is better able to "feel" the bed of the section - in fact I have heard it alleged that blades of grass can be felt striking the weight on the way day - presumably on the way up they can be missed.

As regards fitting, we have found that a crimp of 0.002" minimum is required to hold the bearing firmly in position, but this amount of constriction is sufficient to jam a new ball race. We therefore have promoted an arrangement with a local automotive electrician who provides us with abundant quantities of worn double-sealed bearings from generators and alternators for a couple of cents each. These, when pressed into the pulley with the necessary crimp, assume as new tolerances, and rotate freely. Bearing centre diameter is also reduced to 5/16" (or 8 mm if you are metric-minded) by means of a brass sleeve which also requires some crimp, and the length of this sleeve is machined to project a little on either side of the bearing, perhaps 0.040" (or 1 mm) to provide positive clearance for the sheave.

Pulley sheaves modified as above provide the ultimate in ease of operation, never need further lubrication or attention, and require replacement only if dropped in the stream, or otherwise lost, <u>or if stolen by other gauging parties</u>.

## Synthetic Membranes and Water Quality Analysis

R.J. Marks
P.W.D. Manjimup, W.A.

Can we reduce the large number of filter papers being used in the hydrographic laboratory?

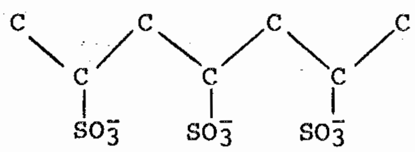
It seems possible after reading an article on Synthetic Membrance Technology by Harry P. Gregor of Columbia University and Charles D. Gregor of the State University of New York.

In part the article describes the process of ultrafiltration using very thin membranes of non-fouling polymers which incorporate the sulphonate group ($SO_3^-$) in the chemical structure.

6.

It is apparent that clays etc. (which are of interest to the hydrographers) are hydrophobic, or in other words repel water. When a hydrophobic substance is in an aqueous environment it can reduce its total energy by reducing the surface area exposed to the water: two hydrophobic particles for example tend to clump together expelling the water from the space between them. In the same way such a particle can be held to the surface of a membrance by the elimination of repulsive interactions with the surrounding water. Most of the fouling materials also bear a negative electric charge, and hydrogen bonding involving these charges could also contributed to fouling.

One obvious way to avoid hydrophobic interactions is to create a membrance that is extremely hydrophillic, one that has a very strong affinity for water. Such a material remains wetted even in the presence of hydrophobic particles, so that particles cannot adhere to the surface by excluding water. The most hydrophilic of known polymers are those bearing on their surface the sulphonate group ($SO_3^-$).




Polyvinyl Sulphonic Acid

One of the Non-Fouling Polymers

Like the sulphuric acid from which they are derived, sulphonate polymers have an enourmous affinity from water. Each sulphonate group is ordinarily surrounded by many water molecules which cannot be displaced by hydrophobic particles. Also the negative charge repels the negatively charged couling particles.

When the sulphonate polymer membranes were tested with solutions that usually caused severe fouling the results proved remarkable. One membrane for example was tested for nine months with a sequence of liquids that included salt solutions, dyes, wastes from pulp and paper mills, molasses, whey from cheese manufacture and sewage. At the end of the test sequence the membrance was still clean and glistening.

The authors foresee applications in the field of desalination sewage treatment etc. where membrances fabricated with pore diameters averaging between one and ten nanometers extract large molecules such as most proteins, virus particles and micro organisms. Of course the hydrographer may not necessarily be interested in such sophisticated filters (unless he required biological information) for the normal applications such as sediment analysis, but a filter fabricated of such a substance as sulphonate ploymer would allow it to be used again and again after backwashing.

It would then be possible to eliminate the large number of filter papers currently used in the laboratory.

For further information one is directed to the full article in Scientific American July 1978 vol 239 no. 1.

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## For Sale

Geoff Smith, Senior Hydrographer with the State Rivers and Water Supply Commission of Victoria, suggests that various Authorities may have superceded, but serviceable hydrographic equipment, which they may no longer have any use for. He suggests that the Water Commission may be interested in Stevens 'F' type recorders and Gurley current meters. Anyone interested?

## Keep's Corner

Snake Tails

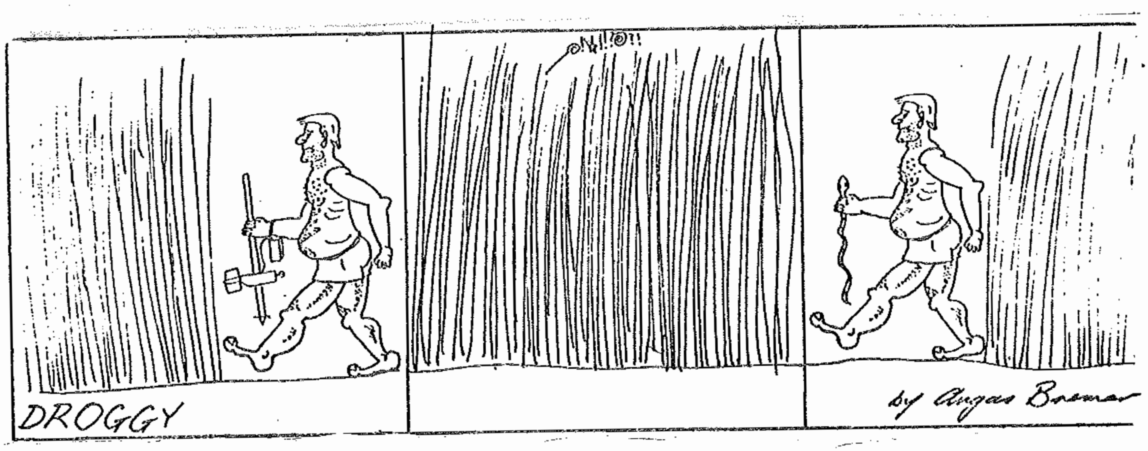
In 1975, the River Murray was in high flood in the vicinity of Piangil, Victoria, the recorder at that station being installed on a well located close to the normal flow channel and extending some 20 feet above the natural surface, supported by a long horizontal access ramp from near the top of the bank.

Visiting the station, we noted that the approach ramp was invisible beneath at least two feet of flowing water, so I put the waders on and found a stick with which to feel my way along the ramp to the recorder. Reaching it, I unlocked and opened the door which was hinged at the top and opened outwards and upwards, to be confronted by a very active and obviously quite angry tiger snake.

Those who crave a little excitement may sometime try standing on a slippery submerged catwalk in waders about 20 feet of moving water, holding up a recorder shelter door with one hand whilst belting away at an infuriated tiger with a dead gum twig which breaks off from time to time throughout the encounter, at the same time trying to avoid damage to an expensive instrument in the immediate vicinity.

Ultimately the snake, almost finished, squeezed it's way between the planks of the recorder platform and into the river, where we quickly administered the coup de grace with clods of dirt. How it found it's way into the recorder I will never know, but I hope that the route does not become too well known.

A. Keep

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The Explosives Expert

Bill was middle-aged when he transferred to Hydrographic in the early 1950's, having earlier achieved a fair degree of seniority in another Branch of the Commission. On his own unimpeachable authority, Bill was an acknowledged expert on virtually everything, and when arrangements were made made for instruction of hydrographic staff in the safe use of explosives, nobody was very surprised to learn that Bill, who professed vast knowledge and experience in this field also, was generously prepared to attend and assist, or perhaps to instruct the instructor.

The instructor, however, was extremely well versed in his subject, and Bill wisely kept silent in his presence whilst continuing at other times to vaunt his wealth of knowledge to the rest of us.

The course took place at a current Commission construction site, and after a brief run-down on the do's and don'ts of blasting and some more thorough instruction on procedure and safety precautions, we were taken to an area where the trees had been cleared and a greater number of large stumps were awaiting removal. Here the instructor amazed us by time and again placing precisely the correct charge in exactly the right place to blow each stump a couple of eet into the air and allow it to fall back into it's own hole.

Each of us were then required to select a stump and blow it out, deciding both on the amount of charge and it's placement, and the instructor stated that he would not interfere unless a dangerous situation was likely to occur. The first few attempts were ineffectual, due mainly to the selection of too small a charge, but the instructor said nothing.

Then came Bill, who declared that he may as well have a go to keep his hand in and to show everybody how it was done. He took a handful of gelignite plus a few extra sticks, about three times as much as the previous man had used, set up his fuse and lit it. The instructor spoke at last, but only to say that we had better get well back for this one.

The stump flew from the ground at an angle of about 45 degrees, headed almost directly at Bill and spinning viciously. Bill, trying to display poise, moved at walking pace away from the line, but the spin took hold like a fierce off-break when the stump landed, and it cartwheeled along the ground at a remarkable speed straight towards his new position. Bill took off like a bullet with the stump in hot pursuit. Fortunately for him it ran out of steam before he did.

The instructor put the finishing touch to the episode, and to Bill, by remarking at once, "Some of you don't seem to have been listening to me at all. Let's have no more spectacular displays like that one."

A. Keep

<u>Fried Fish Anyone?</u>

We have all heard strange and tall tales about hydrographers and stream gauging. This one comes from the "wet season" camp way up North Queensland.

The cook-of-the-day fried fish for tea. The others in the party remarked on the amount of black smoke, but as he wasn't a very good cook anyway, didn't take much notice.

The cook (allegedly) wasn't hungry, and the helicopter pilot ate most of the fish. He remarked that it tasted a bit funny, but as it was fresh out of the river decided it should be okay and ate it anyway. During the night he was very ill.

The next morning, preparing for gauging, and somebody remarked that there wasn't much oil left for the Ott Major - horrors - then the pilot was sick.

That is what comes of storing all sorts of liquids in the plastic water sample bottles without labelling them.

Anon. Q.W.R.C.

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## AUSTRALIAN HYDROGRAPHIC SOCIETY

## List of Members as at April 1979

### SOUTH AUSTRALIA

Engineering and Water Supply Department . . . . . . . . 15

#### Adelaide

| | | |
|---|---|---|
| V. Aeuckens | B. Bajka | G. Pike |
| M. Harvey | P. Hutton | R. Leaney |
| R. Fleetwood | P. Stace | J. Vandenberg |
| B. Nicholson | L. Marshall | S. Cramer |
| J. Whitbread | K. Bilsborough | K. Good |

### WESTERN AUSTRALIA

1. Public Works Department . . . . . . . . . . . . 40

#### Perth

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| R. Pickett | F. Davies | P. Collins |
| J. Garbutt | F. DiCamillo | P. Hulbert |
| S. Whitfield | P. Rosair | P. Roberts |
| R. Sheridan | B. Chester | P.K. Roberts |
| N. Chapman | G. Parsons | |

#### Albany

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| W. Fowlie | C. Gilbert | |

#### Manjimup

| | | |
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| D. Barrett | R. Marks | P. Helsby |
| R. Murton | | |

#### Harvey

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| A. Deane | P. Buckley | R. Bickers |
| K. Baldock | B. Hawkins | G. Terlick |

#### Welshpool

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| G. Colback | P. Earp | P. Boreham |
| G. May | A. Cramp | |

#### Karratha

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| T. Metzke | | |

#### Geraldton

J. Waddington

Kununnurra

K. Griffin
R. Doherty

W. Tingey

J. Hartley

2. Alcoa of Australia . . . . . . . . . . . . . . 1

K. McIntosh

VICTORIA

1. State Rivers and Water Supply Commission . . . . . . 32

Armadale

E. Geredy
R. Melville
B. Bell
S. McKenzie

G. Smith
B. Kelly
J. Cameron
E. Jenkins

C Peynenborg
G. Leslie
J. Anson

Kerang

A. Keep

P. Runciman

Hamilton

F. Ryan

N. Carracher

Orbost

P. Young,

G. Ryan

Camperdown

W. Mitchell

B. Smith

Werribee

B. Fenton

Maffra

H. Reynolds

P. Powney

Myrtleford

S. Zyga

R. Andison

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W. Barham
R. Hansen

A. Bruton
B. Shaughnessy

I. Balfour

Tatura

I. Osborne

L. Tepper

G. Prowd

2. Dandenong Valley Authority . . . . . . . . . . 3

I. Orr

M. Briggs

S. Noble

12.

3. Bureau of Meteorology . . . . . . . . . . . . 1

M. Mann

4. State Electricity Commission . . . . . . . . . . 1

R. Lilywhite

5. Melbourne Metropolitan Board of Works . . . . . . . . 1

K. Dowling

QUEENSLAND

Water Resources Commission . . . . . . . . . . . . 34

Brisbane

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|---|---|---|
| K. Smythe | G. Gilles | A. Downing |
| P. Martin | D. Alexander | J. Mobbs |
| A. Seabrook | D. O'Reilly | |

Mareeba

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| M. Hopper | S. Parker | B. Reurich |
| V. Manley | J. Pitts | N. Kelly |
| J. Walker | | |

Rockhampton

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| R. Findlay | M. Searle | G. Long |

Townsville

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|---|---|---|
| R. Mincher | V. Walsh | G. Pocock |
| R. Alford | | |

Bundaberg

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|---|---|---|
| P. Kelly | T. Wolfe | J. Stephenson |
| G. Amos | D. Amos | R. Maynard |

NEW SOUTH WALES

Water Resources Commission . . . . . . . . . . . . 11

Sydney

| | | |
|---|---|---|
| P. Coveny | J. Pfitzner | D. Lough |
| B. Wing Quay | | |

Armidale

| | | |
|---|---|---|
| R. Peters | E. White | W. Moloney |
| L. Jones | | |

Bega

P. Corbett

Tumut

D. Thatcher G. Quinn

AUSTRALIAN CAPITAL TERRITORY

1. Dept. of Housing & Construction - Water Supply & Sewerage Div. 6

| | | |
|---|---|---|
| I. Tite | R. Conway | E. Speering |
| M. Lahiff | J. Vahalia | L. Spendler |

2. C.S.I.R.O. Forestry Research . . . . . . . . . . 1

J. Burns

3. C.S.I.R.O. Land Use . . . . . . . . . . . . . . 1

H. Alksnis

4. A.W.R.C. . . . . . . . . . . . . . . . . . 1

P. Janowski

NORTHERN TERRITORY

Dept. of Transport and Works . . . . . . . . . . . . 20

Darwin

| | | |
|---|---|---|
| J. Lawrie | M. Nicholas | M. Noaks |
| T. Copping | J. Fraser | G. Hargrave |
| C. Brooks | R. Roos | N. Haskew |
| P. Spikings | D. Kinter | M. Chin |
| M. Errity | B. Burr | |

Katherine

| | | |
|---|---|---|
| R. Bishop | R. Grenfell | L. Bilton |
| I. Harvey | R. Boyd | G. Arnold |

TASMANIA

Hydro Electric Commission . . . . . . . . . . . . 5

Hobart

| | | |
|---|---|---|
| W. Robinson | B. Cane | G. Wells |
| C. Cully | G. Farrington | |

AUSTRALIAN
HYDROGRAPHERS
ASSOCIATION