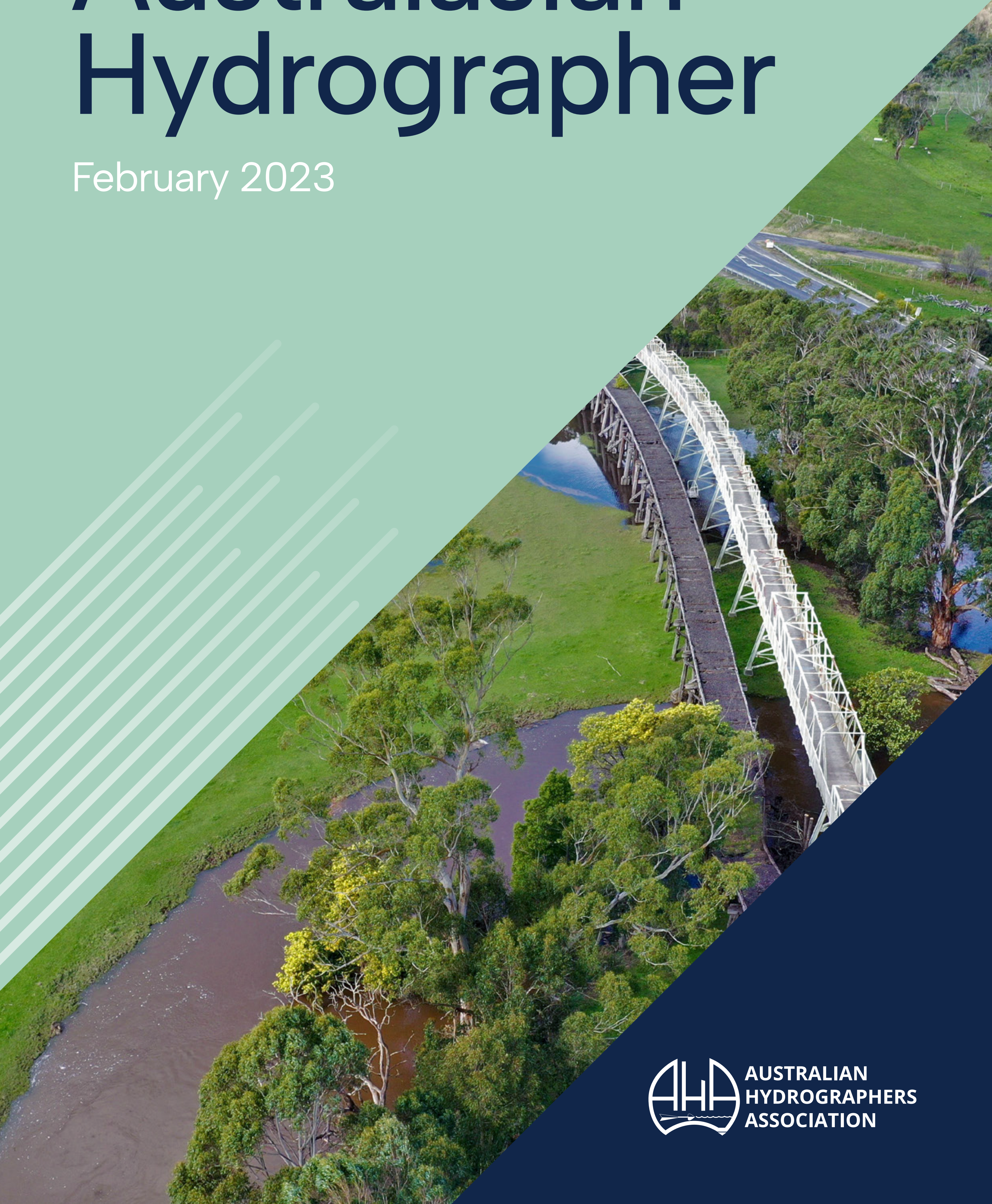
Australasian Hydrographer

February 2023



AUSTRALIAN HYDROGRAPHERS ASSOCIATION

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Material Submitted

Photo Credit: Cameron Turner – ALS
Photo Information: Tarwin River, Vic

Acknowledgement of Country

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

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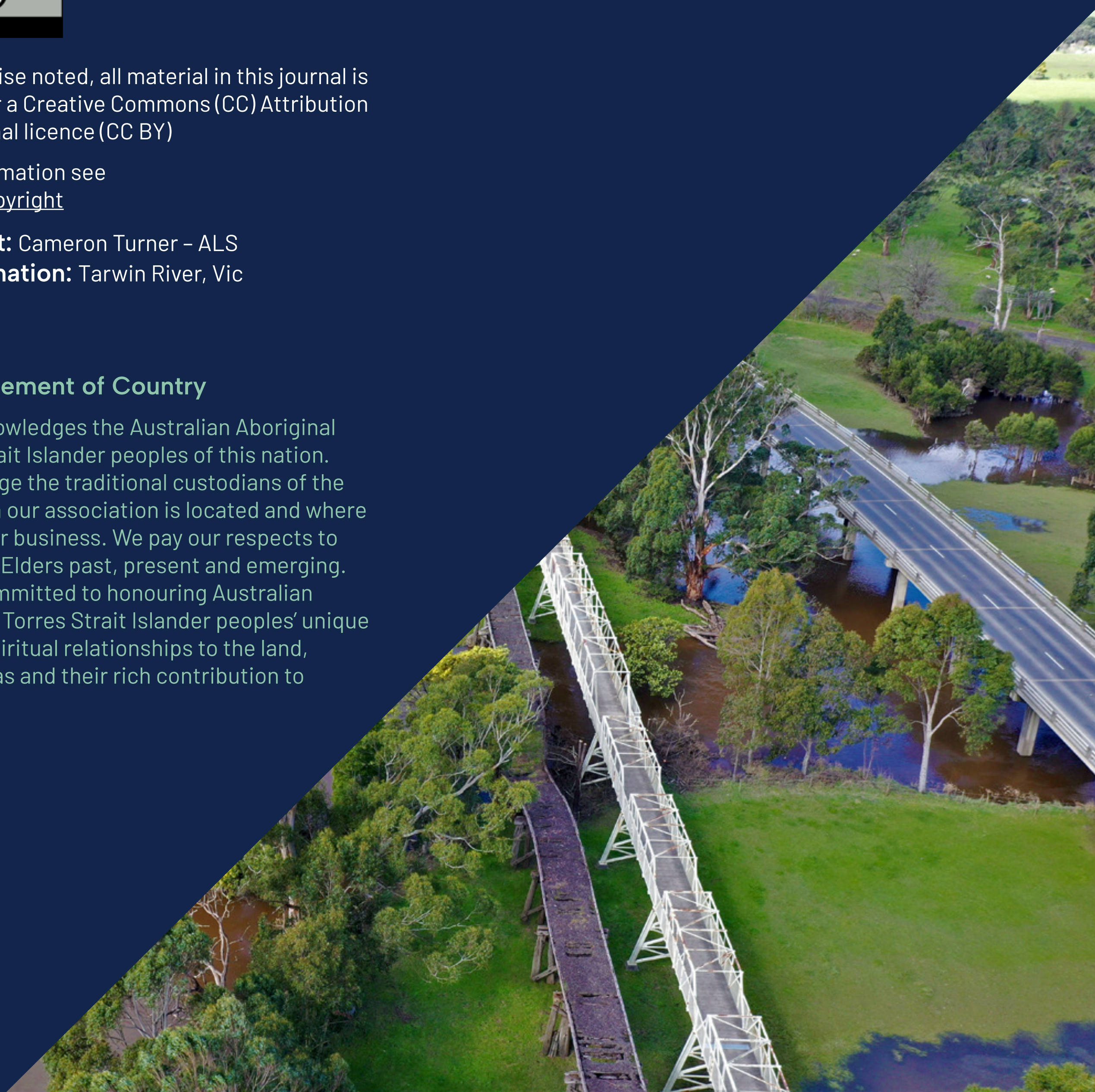

From the Editor-In-Chief

Zac Ward

Greetings everyone & welcome to another year!

With a new year, as always comes another set of challenges and there's none more relevant to all of us than flooding and extreme weather events. Whether you're on the East/Northwest Coast of Australia or across the ditch with our hydrographic *compadre's* in New Zealand & Auckland more specifically. As always please spare a thought for all the people doing it tough and battling/persevering through tumultuous times but nonetheless performing incredibly beneficial water measurement, monitoring and strategy. Stay safe, stay compassionate and look out for your fellow humans as always!

Closer to home for me on the West Coast the extreme scale of rainfall/flow events along the Fitzroy River and the town of Fitzroy Crossing has been nothing less than jaw-dropping. Having somewhat explored the amazing country around Fitzroy Crossing (Bunuba, Gooniyandi, Nyikina, Walmajarri and Wangkatjungka Country) + Broome (Yawuru Country) seeing various photo's shared of destroyed Department of Water & Environmental Regulation (DWER) gauging stations has been really eye-opening and a constant reminder about the devastation that 1 in 100 year climate events (and others) can bring with them. On this I do personally hope to hear more information (and potentially articles) from our hydrographer friends and colleagues at DWER about the rebuilding/reinstatement process for these super critical monitoring stations.

Anyway, enough personal reflection from me and back to this edition of the Australasian Hydrographer. Unfortunately, this month's read is somewhat shortened featuring only two submitted articles from amazing, regular contributors Jacquie Bellhouse and Daniel Wagenaar. Whilst these particular articles are both very in-depth, detailed and relevant (Climate Change & Complex Flows) there is still a large lacking in submitted articles and photos for the publication itself. Please reach out anytime to contribute, nothing is ever too small or perceived insignificant.

Moving on from this I'm hoping the upcoming AHA Conference in Penrith this May will bring with it a whole swag of articles, presentations, papers and also be a triumphant return to face-to-face, large scale events. I'm really looking forward to seeing a heap of old, new and familiar faces so please be sure to register your attendance, perhaps even sponsorship for those so inclined. Make sure to come say G'day and tell us how we're doing.

Cheers,

Zac Ward CPH

Figure 1: Destroyed DWER Gstn (802137)
Reference – ABC Kimberley Posts Facebook (16/02/2023)

From the President

Arran Corbett

Welcome to 2023, a year which has kicked off with some of the largest flooding ever seen in Northern WA and devastating flash flooding for our friends over the ditch in Auckland. And this wet season is far from over yet.

These recent extreme events serve to remind us of the importance of our work. There is a need for insight that can only be gained through outstanding data collection, a need for ongoing skills development, safety enhancements and substantial network investment.

Recent interest in our upcoming conference and training workshop (to be held in Penrith this May) from State and Federal agencies gives me hope that the authorities are listening. We need to take this opportunity as we come together in Penrith to call out the changes required to ensure that we are in the best shape possible to face the next challenge. Greater coordination between Local Govt and State responsibilities with regards to flooding is one area where I am sure we can all agree greater effort is required.

In other news, our past efforts at AHA training reform and development are now paying off. John Skinner and team are about to deliver the first of a series of Nationally Accredited hydrographic skills training packages for the Bureau of Meteorology (BoM). These training packages cover a wide range of skills including surveying, measurement basics and flood site maintenance. We owe our thanks to BoM of sponsoring the development of these packages that we will look to provide to a wide audience over the coming months and years. If you are interested in learning more reach out to our training manager John Skinner (training@aha.net.au).

We are currently reviewing and updating our certification process to make it more streamlined and transparent. Bill Steen is leading the charge on this initiative – an effort that is much appreciated from a man that has already given a great deal to the industry.

Two points to leave you with;

1) Early bird registration for our upcoming conference offers a 15% discount over the full registration... Registration - Australian Hydrographers Association (aha.net.au)

2) Mike Ede and the team from NZHS have kindly given us a couple of free registrations for their upcoming Technical Workshop (Napier late March). Send me an email (president@aha.net.au) if you interested in attending. First in, best dressed. (Note that travel and accommodation are not covered)

If feels like 2023 is going to be good/busy, enjoy and stay safe.

Arran

Why Hydrographers Should Understand the Climate Change Challenge

Jacquie Bellhouse CPH,
Water Corporation, Perth, Western Australia

Climate change is a global concern. Around the world, the effects of climate change are already being observed, warming temperatures influencing global cycles resulting in changing precipitation patterns, reduced snow and ice cover, and more extreme weather events including floods and droughts. These changes have significant impacts to humans and the environment and are expected to intensify as greenhouse gas (GHG) emissions continue to rise.

Australia's Hydrographers and the hydrometric data they collect has a major part in the nation's ability to proactively address the impacts of climate change. After all the work to date has relied on the data we have collected since the 1800's.

The Changing Climate

It is clear that the global climate has changed and the reasons for this are reasonably well understood. The global changes, however, affect different regions of the world in different ways.

Australia is no different, our climate is changing, with increasing frequency and intensity of extreme weather events and long-term changes to weather patterns in line with the rise in Australia's average temperatures. As has been seen around the world these changes are occurring in different ways and at different rates across our nation. It is also worth noting that the changes in climate extremes such as heatwaves and downpours are more pronounced than changes in the average climate (CSIRO, 2022).

Currently temperatures in Australia are about 1.4°C higher than they were in the 1950s (BoM 2020), with further warming expected. As a consequence, many communities across Australia have begun to experience the effects, including more intense extreme events such as cyclones, localized flooding, droughts, bush fires and as a consequence impact critical infrastructure and resources such as our water resources.

It is estimated that unchecked climate change will reduce the size of the Australian economy by 6.3 per cent by 2070, and lead to a net reduction of 880,000 jobs (Deloitte Access Economics 2020).

In addition, disadvantaged groups, and those who do not have the financial capacity, social resources, and necessary information to respond, will be particularly vulnerable as will individuals and businesses within regional areas regions where the physical impacts are expected to be particularly severe.

The Need for Adaptation

In order to adapt to these changes, collective action is needed. Understanding the potential future change, assessing the likely risks and the consequence of their impact, the first step to ensuring society is nimble enough to build climate resilience and protect the interest of our people.

In particular federal, state, and local governments have an important role to play in helping to manage the economic and social impacts of climate risks by, for example, taking action to avoid or reduce disruptions to public services, protect government assets, and support adaptation within the community. This is why enhancing our resilience to climate change is the focus of the National

Climate Resilience and Adaptation Strategy 2021-2025 [1] and state and government policies such as the NSW Climate Change Policy Framework [2] and Western Australian Climate Change Policy [3].

Within Western Australia the Department of Water and Environmental Regulation (DWER) and the Water Corporation, have been proactively working together to address the impacts of climate change through long-term source planning, risk assessment and stakeholder engagement & education. This work has relied on Hydrometric data collected since the early 1900s.

Moving forward the ability to articulate the risk climate change presents is reliant on the planners and policy makers having access to good quality historical climate and hydrometric data in conjunction with the projected climate trends in order to best to explore the possibility and likely outcome of a particular risk.

The Problem

As we have seen with the recent and wide-ranging droughts, floods, fires, and heatwaves the impacts of a changing climate are complex.

In many cases, predictive science and modelling are the only ways to gain early warning of potential catastrophic impacts, including to changes to rainfall and rainfall runoff, the nature and possible frequency of extreme weather events, changes to bushfire risk, sea level rise, species range shifts and changes to the ecology and interdependencies of species.

Whilst modelling and analytical tools are invaluable in improving our understanding of the impacts of climate change and the effectiveness of our adaptation and mitigation strategies, they are only as good as the data and information they were built from.

Enter the Hydrographer and their particular skill in collecting high quality data and information on all things hydrometric.

Extreme Events

Change in the frequency and/or intensity of extreme weather and climate events resulting from climate variability and change is one of the most important impacts of climate change.

In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCCC) highlights eight key risks for human well-being that will require adaptation measures. Most of these risks are driven by extreme events, including storm surges, coastal and inland flooding, extreme heat, drought, precipitation variability, extreme heat, and wind gusts.

This is echoed in the Global Risk Report 2022 delivered to the World Economic Forum, which identify Extreme weather and climate action failure are among the top five short term risks to the world, and the five most menacing long-term threats are all environmental. Climate action failure, extreme weather and biodiversity loss also rank as the three most potentially severe risks for the next decade (World Economic Forum, 2022).

Since what is perceived as an extreme event varies from place to place and is not always immediately evident in the future projections, the indicators for a particular event are often based on the frequency of deviations from a typical range, such as the number of times a specific percentile is exceeded within a particular local. It is worth noting that it is very hard to define a typical range without good quality historic baseline data.

1. https://www.dcceew.gov.au/climate-change/policy/adaptation/strategy
2. https://www.energy.nsw.gov.au/sites/default/files/2022-08/nsw-climate-change-policy-framework-160618.pdf
3. https://www.wa.gov.au/service/environment/environment-information-services/western-australian-climate-change-policy

Communicating the Potential Risks

Assessing and clearly communicating the possible risk and opportunities presented by climate change and the associated uncertainty is no easy task.

There is a wealth of trustworthy and useful existing avenues to acquire historic data and regional climate change information (such as BoM's Australian Water Outlook, climatechangeinaustralia.gov.au, interactive-atlas.ipcc.ch). If not approached appropriately these can pose several challenges with a high potential for information overload to impact the stakeholder's confidence in the results.

It is therefore important that resource planners and policy makers are equipped to choose and present the right level of fit for purpose information. The availability of high-quality data and information on all things hydrometric, pivotal in this process.

Knowing what has been, vital in our ability to project what might be

Before assessing the future potential climate change risk and its consequence, it is vitally important operators, resource planners and risk managers take the time to understand the system they are assessing:

1. What is known and what do you need to know about the system? What historic data is there that can help guide this?
2. What is the best case or worst-case outcome for your assessment?
3. What is/are the critical climate/hydrometric metric(s) and variable(s) required to gain full understanding of the potential risk of climate change?
    a. Do you need to use future climate data (sometimes using historic records may be appropriate)?
    b. How are the climate metrics represented in the future projections?
    c. What is the appropriate time horizon for the assessment?
4. Are there known thresholds or parameters that could inform the decision? Can these be determined form historic data?
5. How do the climate metrics relate to historic information on the exposure, vulnerability, and sensitivity of the system?

The vast quantity of climate projections data is non-trivial to analyse, involving multiple generations of climate models, multiple scenarios, and multiple ensemble members. In many cases the regional projections calculated from this vast source of information are highly uncertain due to model, scenario, and internal variability uncertainty. Additionally, the data from global climate models may not be relevant at the scale of every decision. Ultimately it may not always be appropriate or feasible to apply the full ensemble of projections requiring approaches to select the most appropriate.

It is also important planners and policy makers consider the best way to communicate the projected risk, associated uncertainty, and resultant consequence in such a way that does not adversely impact the stakeholder's overall confidence, risk perception and resulting risk tolerance.

Storylines Approach

One approach which is currently gaining favour within the Climate Change Adaptation industry is the storylines approach. The approach involves developing descriptive and coherent 'storylines', 'narratives' or 'tales' of the implications of climate change on a particular decision point (Shepherd et al, 2018; NESP, 2022).

A very important component of the storylines approach is its consideration of past events as an indicator of what might occur and their potential consequence. The objective is to help create an understanding about the possible future impacts by relating them to episodic memory. This ensures the projected risks are tangible, tailored and relevant for local decision-making even when these may be projected to occur in a distant future (NESP, 2021).

Typically, in approach requires the identification of the key climate change drivers, and the quantification of their influence. How well this can be done is wholly dependent on the availability and consistency of good quality historic data including Climatic and Hydrometric Data and observations. The most salient plausible outcomes are then investigated based on combinations of those drivers.

The storyline approach can also help to determine which variables are important and which projections to choose.

CASE STUDY

Harding Dam Future Yield Reliability

West Pilbara Water Supply Scheme (WPWSS)

The West Pilbara Water Supply Scheme (WPWSS), established in 1969, supplies the towns of Karratha, Wickham, Dampier, Roebourne, and Point Samson. Water is also provided to major iron ore exporting ports operated by Rio Tinto Iron Ore, at Cape Lambert and Dampier, as well as numerous smaller, but significant, industrial customers, mostly located on the Burrup Peninsular.

The scheme, located within the in the Pilbara Region of Western Australia, is supplied from three sources: Harding River Dam; Millstream Borefield; and the Bungaroo Borefield.

Harding Dam is considered the primary source, due to the stringent regulatory requirements designed to protect Millstream Borefield' s significant environmental, social, and cultural values. These conditions include a requirement that abstraction from the Millstream Borefield only be undertaken when water from Harding Dam is unavailable.

The Bungaroo Borefield supplies bulk water via the West Pilbara Water Supply Scheme, to support Rio Tinto operations, in accordance with a Deed of Agreement between Rio Tinto and the State of Western Australia (DoW, 2012). The borefield is owned and operated by Rio Tinto Iron Ore.

All three sources are highly dependent on recharge through rainfall and rainfall generated runoff whilst Harding Dam also experiences high losses due to evaporation from the lake.

Harding Dam

Harding Dam was commissioned in 1985 after it was recognised that the Millstream Borefield (established in 1969) could not sustain rates of abstraction above 6.0 GL/yr, particularly when rainfall recharge was low.

Harding Dam, which at full supply level can store up to 63 GL, is capable of providing up to 2-2.5 years of supply under current climate and demand conditions. Evaporative loss from the surface averages 16 GL per annum while the town demand, which is currently at around 9 GL, is projected to reach 10 GL by 2025.

The dam's future ability to reliably meet demand is highly influenced by the magnitude and frequency of recharge events, the rate of evaporative loss, and town demand.

Harding Dam, West Pilbara

CASE STUDY – Harding Dam Future Yield Reliability

Historic Climate

The Pilbara region has a predominantly arid climate with mean annual rainfalls of 200-350mm. Extended dry periods are an inherent part of the climatic cycle, with little or no rain for several consecutive months not uncommon.

Within the Harding Catchment the 1920s to the 1940s were particularly dry periods with 1924, 1936 1944 and 1949 having annual rainfall totals exceeded by 95% of years on record. Extended duration droughts, of two or more years of below mean annual rainfall, occur 14% of the time.

The WPWSS is located within the Pilbara ranges of the Rangelands North Natural Resource Management Sub-cluster, where historic rainfall observations show an increasing trend in summer (wet season) rainfall, although with intermittent periods of wetter and drier conditions. Temperatures have also increased over the past century, with the rate of warming higher since 1960.

Hydrology

The Harding River which supplies the Harding Dam is located within the Port Hedland Coast Basin (709).

The river is formed by the junction of three main tributaries, Western Creek, Harding River, and the Harding River East. The rivers flow parallel to each other their confluence about 12 km upstream of the Harding River Dam. A fourth stream formed by the junction of Fish Creek and the Springs Creek, drains the easternmost part of the catchment, and flows into the Harding River 3 km upstream of Harding River Dam. While the streams in the north and west tend to have well defined courses, streams in the lower reaches of the catchment are wide and braided, often with many parallel and interlinked branches (W&R, 2000).

The Harding River is ephemeral and flows only following significant rainfall events. It is generally dry most of the year, except for a few pools that may last for considerable periods. The pools are common in the riverbeds of the large rivers within the Pilbara and in some cases are due to the occurrence of springs along the river courses. After heavy rains the rivers flood and often overflow their banks and inundate the coastal plain.

Harding River *(Photographer: Rcss67)*

CASE STUDY – Harding Dam Future Yield Reliability

Site	Data	First Measurement	Last Measurement
Harding River	Modelled runoff	01/01/1908	30/11/1965
709001 - Harding River - Upstream Cooya Pooya	Continuous - Water level-flow	13/12/1965	29/01/1985
709002 - Harding River - Marmurrina Pool Down-stream	Continuous - Water level-flow	18/10/1967	21/10/1987
709007 - Harding River - Marmurrina Pool Upstream	Continuous - Water level-flow	06/09/1974	05/05/1999
709211 - Harding River - Downstream Cooya Pooya	Continuous - Water level-flow	08/10/1968	12/09/1980
Harding Dam	Storage Level Inflow (via Water Balance)	01/05/1985	Ongoing

Table 1: Harding Dam Historic Inflow Data Availability

Streamflow Monitoring

The first measurements of streamflow in the Pilbara commenced in December 1965 on the Harding and Fortescue Rivers as a consequence of the springboard provided by the Commonwealth Parliament of the States Grants (Water Resources Measurement) Act 1964. The sites were established following the 1964 Pilbara Aerial Survey, the basis for a comprehensive streamflow gauging network across the Pilbara region.

Following the construction and commissioning of the Harding Dam in 1985 Monitoring of Harding River Flow ceased at 709001 at Harding River at Upstream Cooya Pooya due to the drowning of the site by Lake. Inflow into the dam from this point on has been calculated utilising a simple dam water balance.

Earlier yield reliability models also included the generation of modelled runoff via a Sacramento Rainfall Runoff model calibrated using the Gauged and Calculated Inflows.

Future Climate

Historic trends indicate that the Harding Dam climate and hydrological system displays high year-to-year and interdecadal variability as influenced by the seasonal monsoon in the north (DWER, 2022). Changes in rainfall are also not consistent in space or in time, thanks to the influence of tropical cyclones and lows. This natural variability is projected to continue to predominate, over any projected trends due to greenhouse gas emissions by 2030 (CSIRO, 2015).

The longer-term potential precipitation changes are also not clear with projections between 2016 to 2045 spanning between a 19.5% decrease to a 69% increase in comparison to the 1976 to 2005 baseline period, a majority (21 of 32) indicating an increase out till the end of the century.

Due to the large spread of the projected precipitation, and the remaining uncertainty around the behaviour of the monsoon under a warming climate, significant rainfall decreases are still considered plausible and should not be discounted (BoM, 2022). There is a high level of confidence in the continued projected rise in average temperatures and potential evapotranspiration across all seasons.

CASE STUDY – Harding Dam Future Yield Reliability

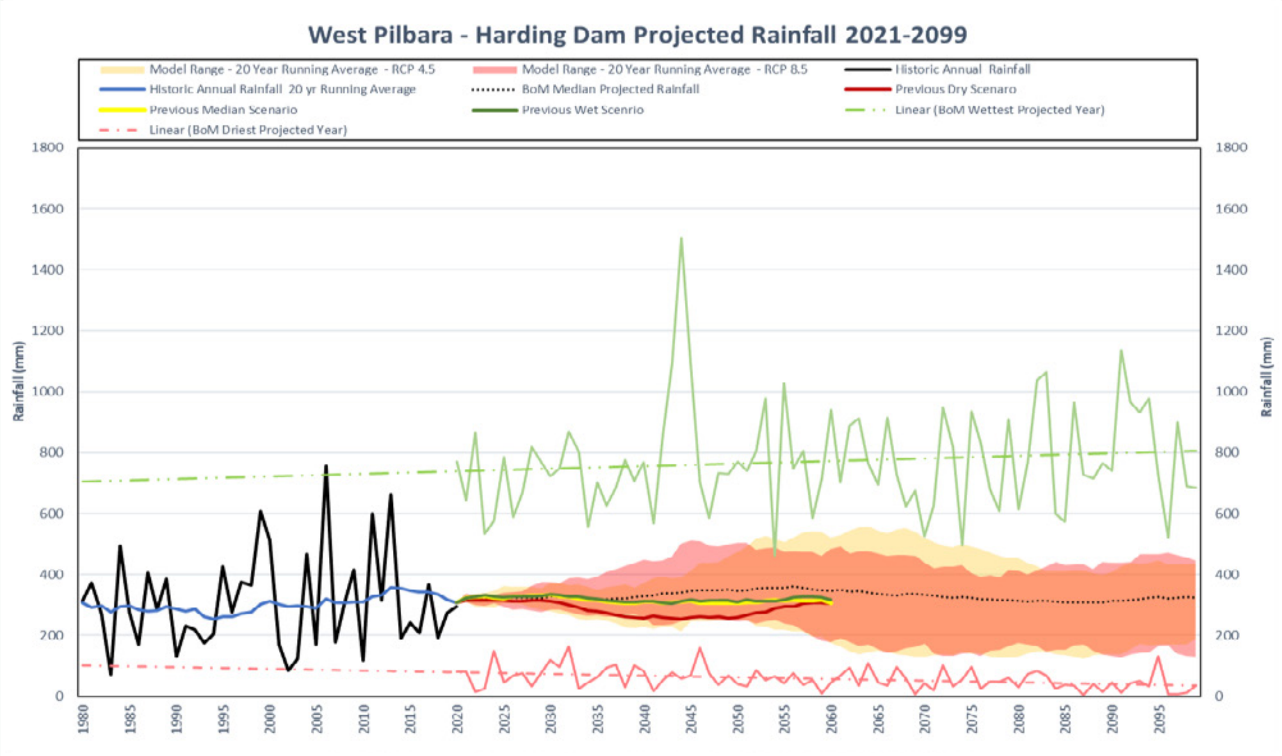

Figure 1: Harding Dam, Summary of Projected Rainfall

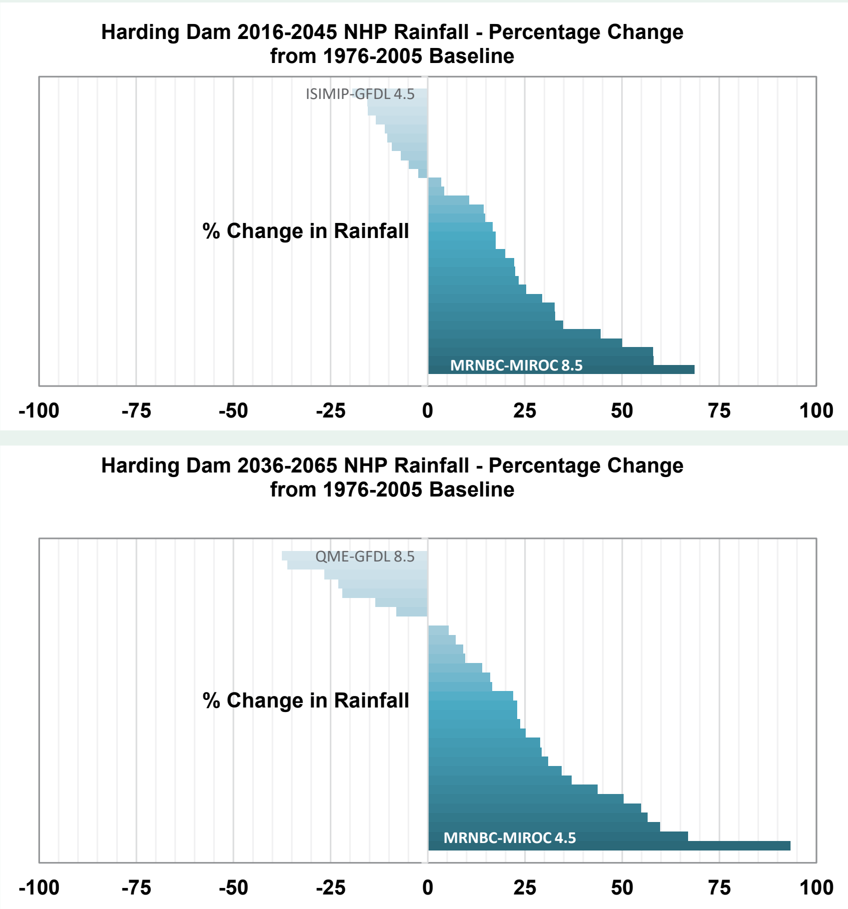

Figure 2: Harding Dam Average Annual Projected Rainfall Percentage Change from 1976-2005 Baseline

CASE STUDY – Harding Dam Future Yield Reliability

The Conundrum

Despite a majority of the projections indicating an increase in annual rainfall recent yield reliability modelling projected a noticeable decline in the proportion of time the Harding Dam will be able to reliably supply the West Pilbara Water Supply Scheme.

Due to high evaporative losses (averaging 16GL per annum) and water quality issues at lower storage volumes, wet season storage volume needs to peak above 43GL for the Harding dam to be able to fulfill the current town demand of 9 GL for a year.

Since its commissioning, monitoring indicates that the Harding Dam has reliably met this 43 GL target 60% of the time (Figure 4). In addition, previous modelling, utilising historic climate trends, indicated the dam would potentially continue to be a reliable source between 30 to 70 % of the time (Figure 5).

However recent supply system modelling utilising the NHP ensembles, indicate a potential further spread in the dam's projected reliability, with a majority indicating further declines in response to a changing climate. (Figure 4).

BoM's National Hydrological Projections show a wide range of potential declines and increases to the average total annual rainfall. At first glance these do not appear to explain the reason for the projected decline in the future reliability of Harding Dam. However, if you examine the projected behaviour in relation to what has been observed the cause becomes clear.

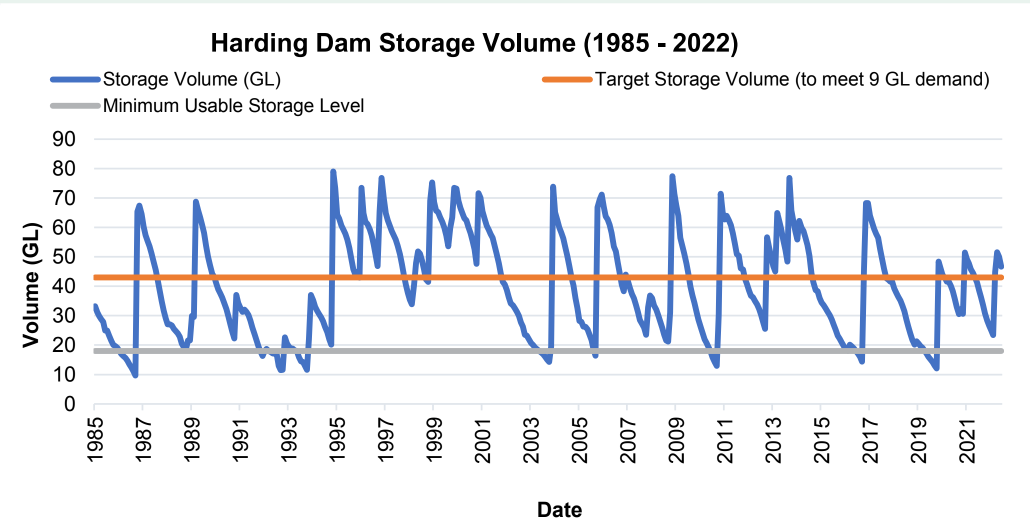

Figure 3: Harding Dam Recorded Storage Volume (1985 - 2022)

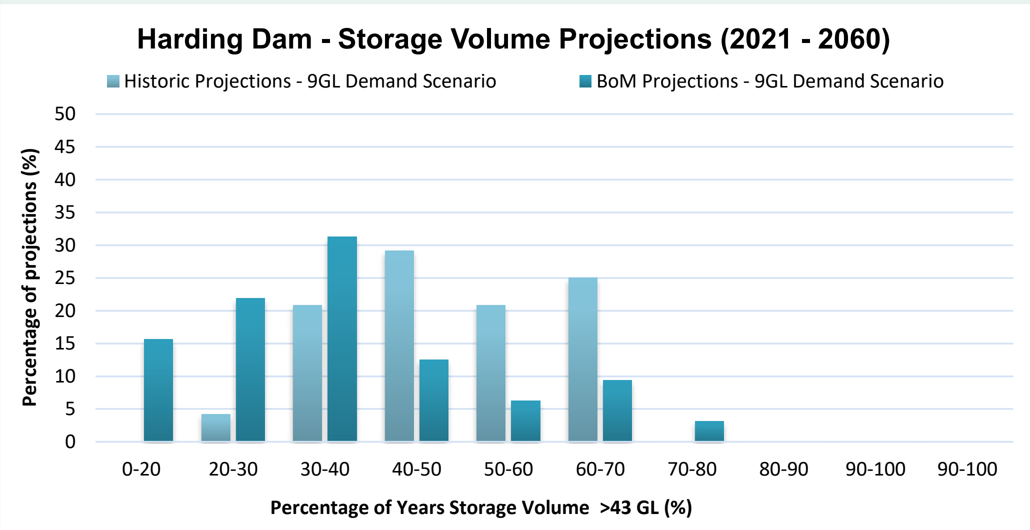

Figure 4: Harding Dam Storage Volume Projections (2021-2060)

CASE STUDY – Harding Dam Future Yield Reliability

Outcome

When compared to historic trends the projections highlight a potential increase in the duration of hydrological droughts, periods when there are insufficient water resources, within the Harding Dam, to meet the defined need (BoM, 2022).

As previously defined, storage within Harding Dam, needs to peak above 43GL for the source to reliably fulfill town demand for a year. For this to be realised, allowing for the unusable portion of storage (18 GL), the wet season inflow, observed from November-April, needs to be greater than or equal to 25 GL. The drought duration, for Harding Dam, is therefore defined as the period of time, in years, total wet season inflow was < 25 GL.

The range of projected hydrological droughts, for Harding Dam, with respect to the percentage of time they were observed, has been illustrated in Figure 6. The chart compares previous modelling, utilising historic climate trends to the latest modelling utilising rainfall and potential evapotranspiration from BoM's National Hydrological Projections.

The results indicate that historically, 90% of the drought durations ranged between 3-3.2 years or less. Comparatively the latest modelled runoff, across the full range of BoM's NHP ensembles, indicated potential drought durations ranging from 2.8 years to almost 14 years or less, 90% of the time.

Currently the Harding Dam is solely dependent on runoff generated from episodic cyclones and tropical lows. The dam lake is also susceptible to high evaporative loss.

Whilst a proportion of BoM's NHP projections indicate a potential increase in the average annual rainfall, a majority also indicate a potential, and significant, increase in the durations in between recharge events.

The conclusion it is not the potential long-term changes in average rainfall but rather the projected increase in durations between these events that poses a significant risk to the dam's ability to maintain continuity of supply.

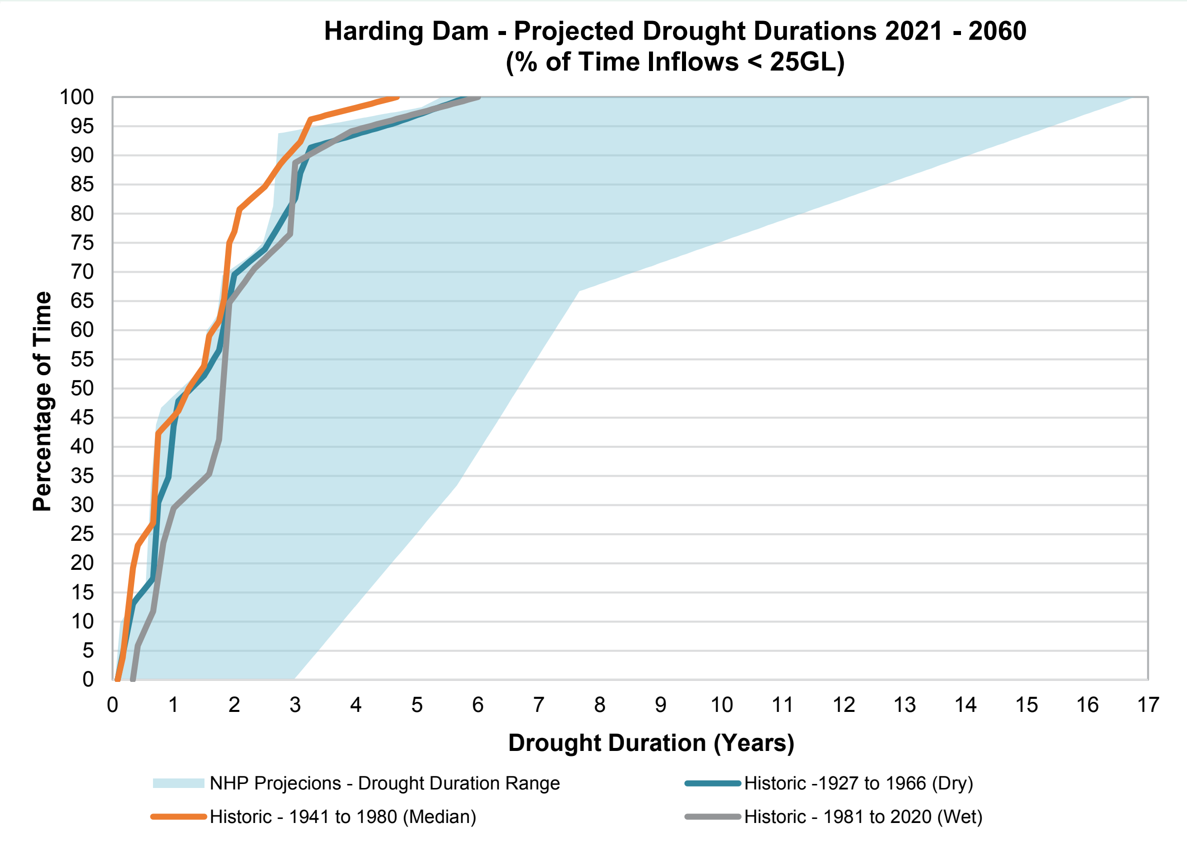

Figure 5: Harding Dam Projected Drought Durations

The Role of Monitoring and Evaluation

This need is quite strongly reflected in an increasing number of Australian Climate Change Risk Management Guides (for example DPIE's Climate Risk Ready NSW Guide, Practical guidance for the NSW Government sector to assess and manage climate change risks and DWER's Climate change risk management guide (interim), Practical guidance for the Western Australian public sector to assess and manage climate change).

Access to reliable monitoring data is essential in not only identifying and evaluating the risks Climate Change presents but is also integral in the ongoing Monitoring and Review of the effectiveness of adaptation and mitigation initiatives.

Monitoring and evaluation is in fact critical in ensuring the long-term success of climate adaptation initiatives, plans and actions. Including:

- Identifying and evaluating climate risk.
- Tracking the performance of activities undertaken during the development of a climate change adaptation plan.
- Tracking pre-identified risk thresholds/trigger levels which identify when new adaptation actions should be implemented.
- Determining whether planned outputs and outcomes from adaptation actions have been achieved.

Effective monitoring and evaluation can also demonstrate the accountability of local/state/federal government, industry, and other resource managers to their constituencies. This is important for leveraging continued support for adaptation initiatives, and for demonstrating that taxpayer and/or investor funding has been spent wisely. This can help to ensure ongoing support for actions and any further funding that may be required. It can also improve performance through evaluation of efficiency and effectiveness and supporting adaptive management.

Conclusion

Effective hydrometric monitoring by suitably qualified professionals is pivotal not only in our ability to understand the systems we are assessing and in identifying what changes have already occurred, but it is it is also essential in our ability to assess what the tangible future risks are.

The hydrographic profession, as the experts in effective hydrometric monitoring have a key part to play in our ongoing efforts and ability to adapt to the impacts of Climate Change.

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Application of Index Velocity Method in Complex Flow Conditions

Daniel Wagenaar, Thomas King, Tim Hawgood

Introduction

The collection of accurate and reliable flow records in open channel flow is dependent on several factors of which a stable Stage-Discharge relationship is crucial.

Flow monitoring site and hydraulic conditions that can impact a stable Stage-Discharge relationship comprises of unstable section control, sediment transport, debris, vegetation, off-channel storage, variable backwater effects and unsteady flow conditions.

Variable backwater, off-channel storage and unsteady flow conditions are all hydraulic conditions that can have a significant impact on Stage-Discharge relationship and accurate flow calculations. Flood-wave movement, operation of irrigation canals, tidal effects, stream junctions and flood control measures are some examples of both variable backwater and unsteady flow conditions. The effects of the conditions on Stage-Discharge Rating curves are illustrated in Figure 2.

There are a number of established methods in defining a Stage-Discharge Rating curve effected by variable backwater, off-channel storage, and unsteady flow conditions. The methods consist of direct measurements, analytical investigation using simplified approaches, modelling using physical-based approaches, index-velocity method and continuous slope are method. This technical note focuses on the application of the Index-Velocity technique using a bank mounted acoustic doppler velocity meter, SonTek SL1500-3G instrument.

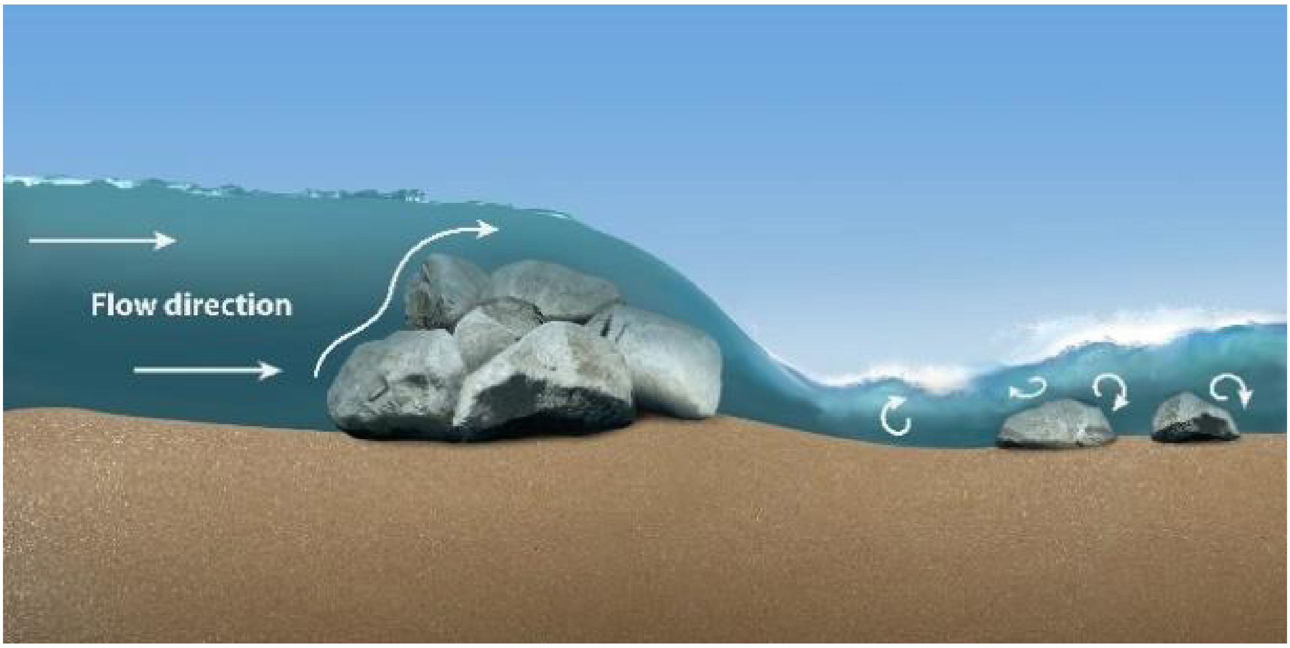


Figure 1: Section Control

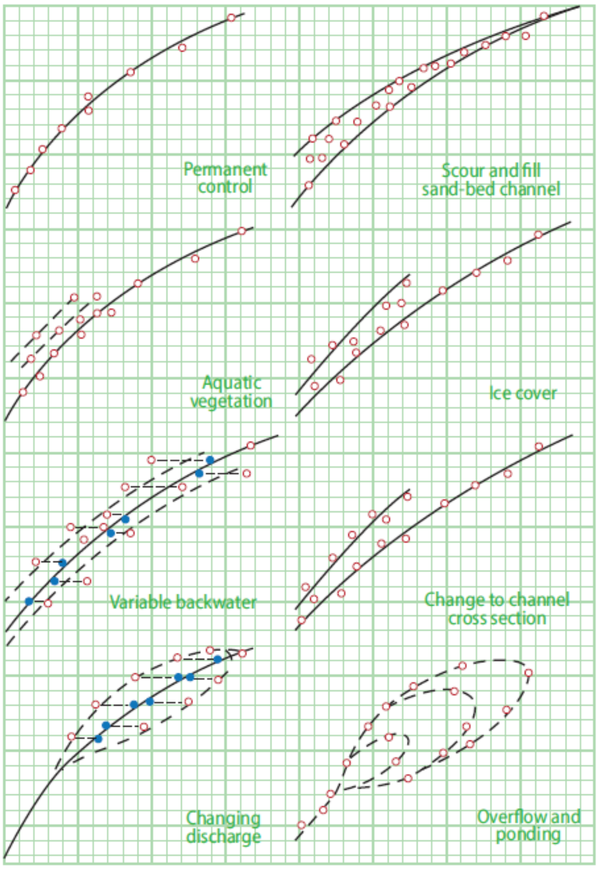


Figure 2: Rating Curves Different Hydraulic Conditions
(Adapted from Herschy (2009))

CASE STUDY

Application of Index Velocity Method in Complex Flow Conditions

The flow monitoring site is situated in a stormwater drain (tributary) shown in Figure 3 for the monitoring of total runoff in the upstream catchment. The tributary discharges into the mainstem of the catchment approximately 1.5km downstream of the flow monitoring site.

The site and hydraulic conditions that will affect the development of a traditional Stage-Discharge relationship at the flow monitoring site consists of variable backwater from the mainstem, off-channel storage on the left bank, backwater due to bridge deck and vegetation.

The conditions present at the flow monitoring site were not suitable for development of a traditional stage-discharge relationship and it was decided to develop an Index-Velocity Rating using a SonTek SL1500-3G instrument. The instrument was installed in 2021 on the right bank upstream of the bridge at an elevation of 1.2m above the channel bed.

Index Velocity Method

Calculating flow using the Index-Velocity method is different from the traditional Stage-Discharge Rating curve. Index-Velocity method consists of two ratings, the Index-Velocity Rating and Stage-Area Rating with the output from each rating multiplied to calculate a flow. The Index-Velocity Rating is a relationship between the mean-channel velocity and streamwise velocity measured by the SL1500-3G instrument. The Stage-Area Rating is calculated from the cross-section survey of the reference cross section used for the Index-Velocity. The Index-Velocity method is outlined in several published documents listed in the reference section of the tech note.

Figure 3: Flow Monitoring Site

CASE STUDY – Application of Index Velocity Method in Complex Flow Conditions

Data Collection

Reference Cross Section: A reference cross section in line with the SL1500-3G instrument was selected for the area calculation. The cross section was surveyed to top of bank, with the left bank starting at chainage 0.000m shown in Figure 4.

Stage-Area Rating was developed from the reference cross-section surveyed by calculating the area at 1cm intervals for the entire stage range shown in Figure 5.

Stage: Continuous time series of the stage measurements were recorded from the SonTek SL1500-3G acoustic Doppler velocity meter (ADVM) instrument shown in Figure 6.

The sampling interval of the stage measurements was set to every 15 minutes.

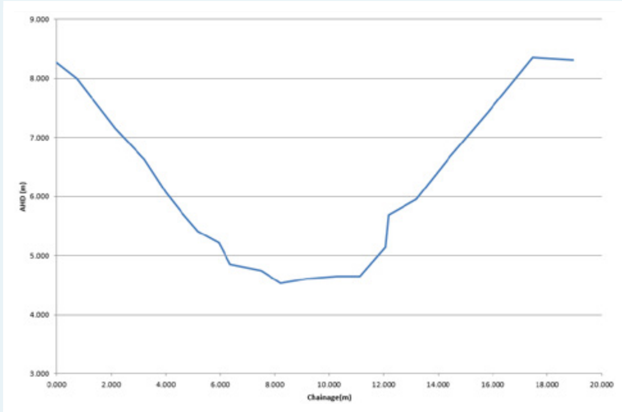


Figure 4 : Reference Cross Section

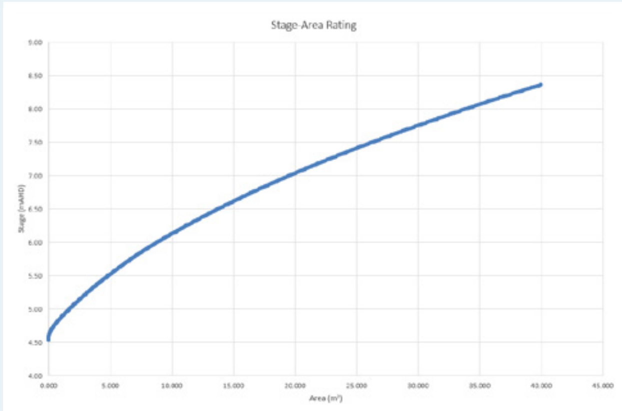
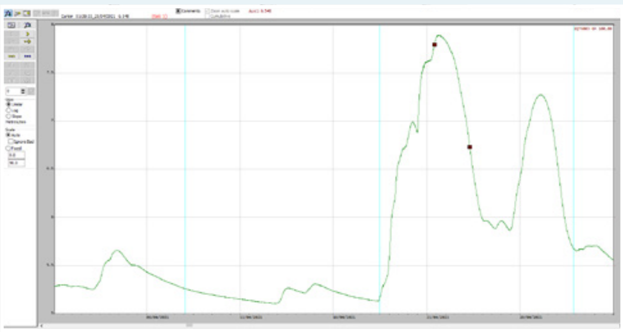


Figure 5 : Stage-Area Rating



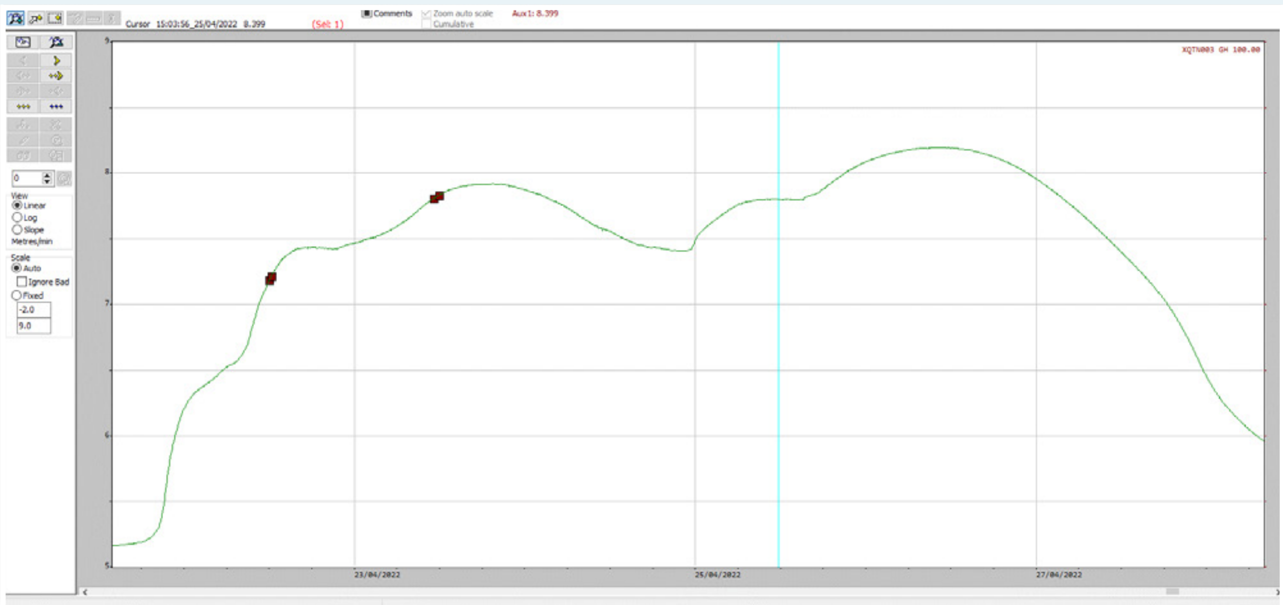


Figure 6: Stage Measurements

CASE STUDY – Application of Index Velocity Method in Complex Flow Conditions

Streamflow Gauging's: A series of streamflow gauging's were performed at the flow monitoring site over a period of 3 years as shown in Table 1.

The streamflow gauging's performed in 2021 was used to develop the initial Index-Velocity Rating. Measurements performed in subsequent years were used to analyse and further develop the Index-Velocity Rating at the flow monitoring site.

Streamflow gauging's were performed with RiverSurveyor M9, RiverRay and RS5 acoustic Doppler current profilers (ADCP) shown in Figure 8, during the development of Index-Velocity Rating. Moving boat technique was used to perform streamflow gauging's and comprised of a series of reciprocal transects (at least 2 transects) and minimum total exposure time of 800 seconds (AUS standard). A loop tagline was used across the channel as this provided increased control over the instrument during streamflow gauging's.

Figure 7: Moving Boat Measurement

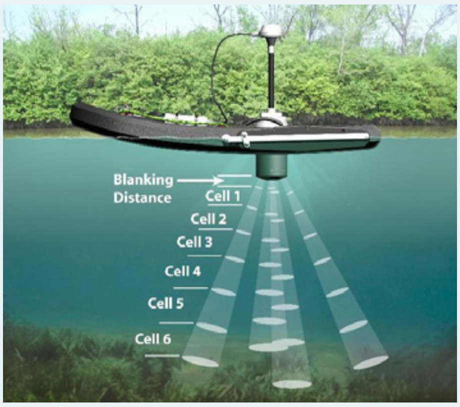


Figure 8: RiverSurveyor M9

Table 1: Flow Measurements

Date	Time	Flow Measurement (m3/s)	Water Level (mAHD)	Water Level - CTF
29/01/2020	10:12	0.291	5.279	0.649
12/03/2020	09:14	12.349	7.322	2.692
12/03/2020	17:31	5.989	6.791	2.161
13/03/2020	07:23	2.138	6.094	1.464
13/03/2020	12:30	3.932	6.286	1.656
14/03/2020	16:27	1.03	5.595	0.965
17/02/2021	13:20	10.835	7.024	2.394
17/02/2021	13:59	10.963	7.034	2.404
17/02/2021	14:39	10.613	7.035	2.405
18/02/2021	08:42	27.782	8.089	3.459
21/04/2021	09:58	18.685	7.799	3.169
23/04/2021	07:33	5.507	6.732	2.102
22/04/2022	12:01	13.369	7.187	2.557
22/04/2022	12:18	13.613	7.215	2.585
23/04/2022	11:11	8.135	7.81	3.18
23/04/2022	11:57	7.506	7.834	3.204

CASE STUDY – Application of Index Velocity Method in Complex Flow Conditions

Index-Velocity: Continuous time series of the Index-Velocity measurements were recorded from the SonTek SL1500-3G acoustic Doppler velocity meter (ADVM) instrument shown in Figure 9. The configuration used for the flow monitoring site comprised of the following,

- Sampling duration: 600 seconds
- Sampling interval: 900 seconds
- Number of multi cells: 6
- Multi-cell begin distance: 0.900m
- Multi-cell size: 0.700m

The velocity and stage measurements from the SonTek SL1500-3G instrument were performed concurrently with the streamflow gauging's.

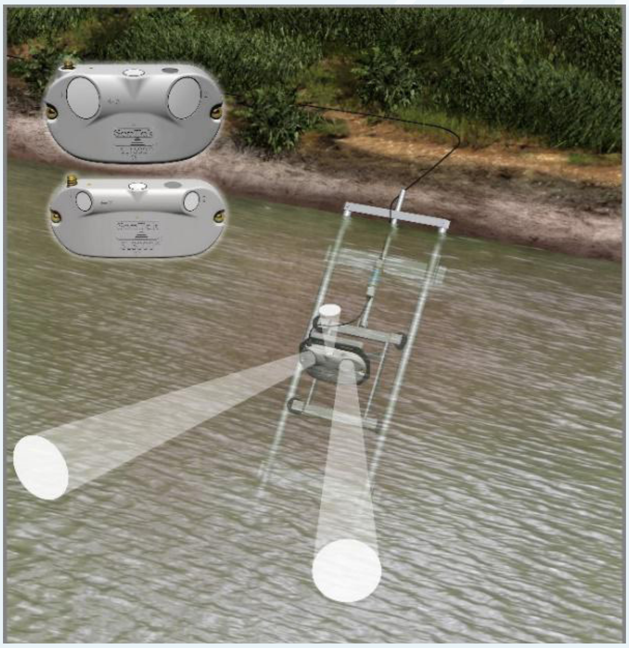
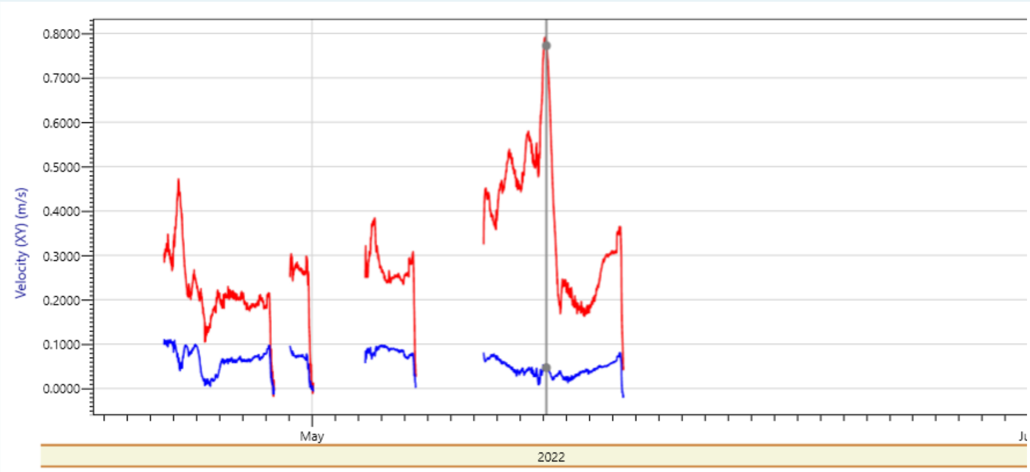


Figure 9: SonTek SL1500-3G

The Index-Velocity types measured by the SonTek SL1500-3G instrument comprised of the following key data sets,

- Velocity (XY).X-MC
- Velocity (XY).Y-MC
- Velocity (XY).X-IVC
- Velocity (XY).Y-IVC
- Velocity Magnitude-MC
- Velocity Magnitude-IVC



Sample time	Index Velocity (m/s)	Depth (m)	Velocity (XY).X-MC (m/s)	Velocity (XY).Y-MC (m/s)	Velocity (XY).X-IVC (m/s)	Velocity (XY).Y-IVC (m/s)
2022-05-10 23:59:34	0.7630	1.8498	0.7630	0.0500	0.7630	0.0500
2022-05-11 00:14:34	0.7680	1.8614	0.7680	0.0520	0.7680	0.0520
2022-05-11 00:29:34	0.7810	1.8724	0.7810	0.0500	0.7810	0.0500
2022-05-11 00:44:34	0.7830	1.8806	0.7830	0.0520	0.7830	0.0520
2022-05-11 00:59:34	0.7900	1.8875	0.7900	0.0490	0.7900	0.0490
2022-05-11 01:14:34	0.7920	1.8936	0.7920	0.0510	0.7920	0.0510
2022-05-11 01:29:34	0.7920	1.8987	0.7920	0.0490	0.7920	0.0490
2022-05-11 01:44:34	0.7930	1.9034	0.7930	0.0470	0.7930	0.0470
2022-05-11 01:59:34	0.7910	1.9070	0.7910	0.0500	0.7910	0.0500
2022-05-11 02:14:34	0.7870	1.9100	0.7870	0.0450	0.7870	0.0450
2022-05-11 02:29:34	0.7910	1.9122	0.7910	0.0490	0.7910	0.0490
2022-05-11 02:44:34	0.7780	1.9147	0.7780	0.0470	0.7780	0.0470
2022-05-11 02:59:34	0.7740	1.9177	0.7740	0.0470	0.7740	0.0470
2022-05-11 03:14:34	0.7810	1.9192	0.7810	0.0480	0.7810	0.0480

Samples

Figure 10: Velocity Measurements

CASE STUDY – Application of Index Velocity Method in Complex Flow Conditions

Index-Velocity Rating

Data Compilation: The velocity and stage time series data recorded during the SonTek SL1500-3G measurements, and the calibration data collected at each field visit were compiled into an Index-Velocity spreadsheet shown in Figure 11. The data collected from both the SonTek SL1500-3G instrument and field visits comprise of the following key variables,

- Streamflow gauging's
- Velocity measurements
- Stage measurements
- Stage-Area Rating

The streamflow gauging's, velocity measurements and stage measurements were synchronized based on individual time stamps of each measurement. The synchronized timing improves the overall accuracy of the Index-Velocity Rating.

Site Name: Flow Monitoring Sites
Site Number: Flow Monitoring Sites
List of all measurements ma (Ctrl) e
Averaging/Sampling Interval of Velocity Data During Qms (sec): 600
Averaging/Sampling Interval of Stage Data During Qms (sec): 600
Note: measurements to be used for rating must be marked "Yes" in column BF before clicking on macro
Click to copy measurements to be used for rating to the Rating Development tab.
Enter Data in Yellow Fields
Do Not Enter or Change Data in Maroon Fields

Measurement No.	Date	Time Zone	Start Time (hh:mm:ss)	End Time (hh:mm:ss)	Start Date/Time (mm/dd/yy hh:mm:ss)	End Date/Time (mm/dd/yy hh:mm:ss)	Mid Date/Time (mm/dd/yy hh:mm:ss)	Rated	Measured Discharge	Mean Measured Velocity (from ADCP)	Measured Area (from ADCP)	AREA from Stage/Area Rating (Uses stage from Qm)	Vm Measured: Mean Channel Velocity (Q/Rated A)	Synchronized Average Stage	Average of User-Selected Cells	Range-Averaged Cell	Vx*Stage	Average of User-Selected Cells	Range-Averaged Cell	Vi: Selected Velocity for Index	Vm Compu Rate Vme
2021-02-17_1	2-17-21		13:15:37	13:25:19	2-17-21 13:15:37	2-17-21 13:25:19	2-17-21 13:20:28	E	10.8350	0.5327	20.3400	20.9549	0.5171	7.10	0.52	0.56	3.98	0.10	0.10	0.56	0.5
2021-02-17_2	2-17-21		13:54:50	14:03:06	2-17-21 13:54:50	2-17-21 14:03:06	2-17-21 13:58:58	E	10.9630	0.4663	23.5100	21.0848	0.5199	7.11	0.51	0.55	3.91	0.10	0.11	0.55	0.5
2021-02-17_3	2-17-21		14:34:36	14:43:03	2-17-21 14:34:36	2-17-21 14:43:03	2-17-21 14:38:49	E	10.6130	0.4774	22.2300	21.0848	0.5033	7.11	0.51	0.55	3.92	0.10	0.11	0.55	0.5
2021-02-18_4	2-18-21		8:36:16	8:48:28	2-18-21 8:36:16	2-18-21 8:48:28	2-18-21 8:42:22	E	27.7820	0.8090	34.3400	37.5430	0.7400	8.21	0.71	0.82	6.71	0.04	0.04	0.82	0.7
2021-04-21_1	4-21-21		9:50:24	10:05:34	4-21-21 9:50:24	4-21-21 10:05:34	4-21-21 9:57:59	E	18.6850	0.6454	28.9500	32.1495	0.5812	7.88	0.59	0.61	4.82	0.03	0.04	0.61	0.5
2021-04-23_1	4-23-21		7:21:48	7:43:16	4-23-21 7:21:48	4-23-21 7:43:16	4-23-21 7:32:32	E	5.5070	0.3551	15.5100	17.3600	0.3172	6.81	0.33	0.35	2.36	0.04	0.05	0.35	0.3
2022-04-22_1	4-22-22		11:58:32	12:03:24	4-22-22 11:58:32	4-22-22 12:03:24	4-22-22 12:00:58	E	13.3690	0.7200	18.6300	23.3495	0.5726	7.28	0.63	0.63	4.56	0.05	0.06	0.63	0.5
2022-04-22_2	4-22-22		12:12:56	12:22:23	4-22-22 12:12:56	4-22-22 12:22:23	4-22-22 12:17:40	E	13.6130	0.7300	18.7200	23.7598	0.5729	7.31	0.66	0.65	4.78	0.05	0.06	0.65	0.5
2022-04-23_1	4-23-22		11:04:11	11:18:27	4-23-22 11:04:11	4-23-22 11:18:27	4-23-22 11:11:19	E	8.1350	0.3200	26.6300	32.3067	0.2518	7.89	0.20	0.20	1.55	0.04	0.04	0.20	0.2
2022-04-23_2	4-23-22		11:44:30	12:08:57	4-23-22 11:44:30	4-23-22 12:08:57	4-23-22 11:56:43	E	7.5060	0.2900	25.7600	32.6221	0.2301	7.91	0.19	0.18	1.46	0.03	0.03	0.18	0.2
					1-0-00 0:00:00	1-0-00 0:00:00	1-0-00 0:00:00					#N/A	#N/A	#N/A		#N/A	#N/A		#N/A	#N/A	#N/
					1-0-00 0:00:00	1-0-00 0:00:00	1-0-00 0:00:00					#N/A	#N/A	#N/A		#N/A	#N/A		#N/A	#N/A	#N/
					1-0-00 0:00:00	1-0-00 0:00:00	1-0-00 0:00:00					#N/A	#N/A	#N/A		#N/A	#N/A		#N/A	#N/A	#N/
					1-0-00 0:00:00	1-0-00 0:00:00	1-0-00 0:00:00					#N/A	#N/A	#N/A		#N/A	#N/A		#N/A	#N/A	#N/
					1-0-00 0:00:00	1-0-00 0:00:00	1-0-00 0:00:00					#N/A	#N/A	#N/A		#N/A	#N/A		#N/A	#N/A	#N/
					1-0-00 0:00:00	1-0-00 0:00:00	1-0-00 0:00:00					#N/A	#N/A	#N/A		#N/A	#N/A		#N/A	#N/A	#N/
					1-0-00 0:00:00	1-0-00 0:00:00	1-0-00 0:00:00					#N/A	#N/A	#N/A		#N/A	#N/A		#N/A	#N/A	#N/
					1-0-00 0:00:00	1-0-00 0:00:00	1-0-00 0:00:00					#N/A	#N/A	#N/A		#N/A	#N/A		#N/A	#N/A	#N/

20220525 Simple Linear RA1 | 20210525 Multi Linear RA1 | ADVM QM Summary | Rating Development | Plot 1 - RA Vx vs Vmea

Figure 11: Index-Velocity Spreadsheet (provided by USGS)

Rating Development: The Index-Velocity types and stage measured by the SonTek SL1500-3G instrument were analysed (graphical plots) against the mean channel velocity that was calculated from the streamflow gauging's and reference cross-sectional area (*V = Q/A*) shown in Figure 12. If patterns are evident in the graphical plot analysis it indicates the Index-Velocity type that provides the best relationship with the mean channel velocity.

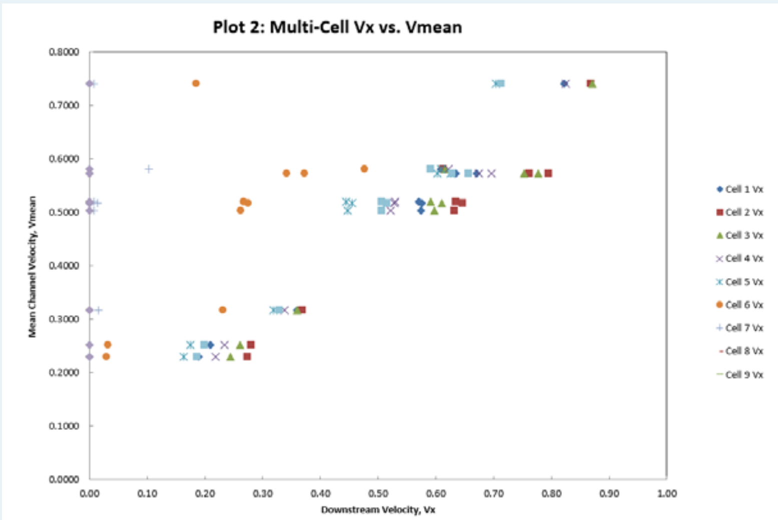


Figure 12: Multi-Cell vs V_{Mean}

CASE STUDY – Application of Index Velocity Method in Complex Flow Conditions

A simple linear regression and multi linear regression analyses were performed using the Index-Velocity type with the best relationship with mean channel velocity. In case of the multi linear regression, stage was also included in the analysis because graphical analysis between mean channel velocity and stage also indicated a pattern. The multi linear regression and associated plots are provided in Figure 13.

	A	B	C	D	E	F	G	H	I
1	SUMMARY OUTPUT								
3	*Regression Statistics*								
4	Multiple R	0.99672103							
5	R Square	0.993452811							
6	Adjusted R Square	0.991582185							
7	Standard Error	0.014969485							
8	Observations	10							
10	ANOVA								
11		*df*	*SS*	*MS*	*F*	*Significance F*			
12	Regression	2	0.238014884	0.119007442	531.0805468	2.27087E-08			
13	Residual	7	0.001568598	0.000224085					
14	Total	9	0.239583482						
16		*Coefficients*	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
17	Intercept	0.085240387	0.013853443	6.153011106	0.000466162	0.0524822	0.117998574	0.0524822	0.117998574
18	Range-Averaged Cell	0.415444732	0.155051611	2.679396422	0.031566855	0.048805932	0.782083532	0.048805932	0.782083532
19	Vx*Stage	0.048260098	0.019520934	2.472222775	0.042693722	0.002100424	0.094419772	0.002100424	0.094419772
23	RESIDUAL OUTPUT					PROBABILITY OUTPUT			
25	*Observation*	*Measured: Mean Channel Velocit*	*Residuals*	*Standard Residuals*		*Percentile*	*sured: Mean Channel Velocity (Q/Rated A)*		
26	1	0.509771585	0.007291496	0.552308888		5	0.23008963		
27	2	0.502734245	0.01721476	1.303966255		15	0.251805431		
28	3	0.503565305	-0.000215967	-0.016358842		25	0.317223868		
29	4	0.748132237	-0.008126851	-0.615584495		35	0.503349339		
30	5	0.571548985	0.009641833	0.730339791		45	0.517063082		
31	6	0.343441698	-0.02621783	-1.985921696		55	0.519949006		
32	7	0.565482121	0.007079301	0.536235703		65	0.572561421		
33	8	0.587685829	-0.014742331	-1.116687177		75	0.572943498		
34	9	0.241743012	0.010062419	0.762197931		85	0.581190818		
35	10	0.232076459	-0.00198683	-0.150496357		95	0.740005386		

20220525 RA1 - Vx vs Vmeana | 20220525 Simple Linear RA1 | **20210525 Multi Linear RA1** | ADVM QM Summary | Rating Develo ...

Figure 13: Multi Linear Regression

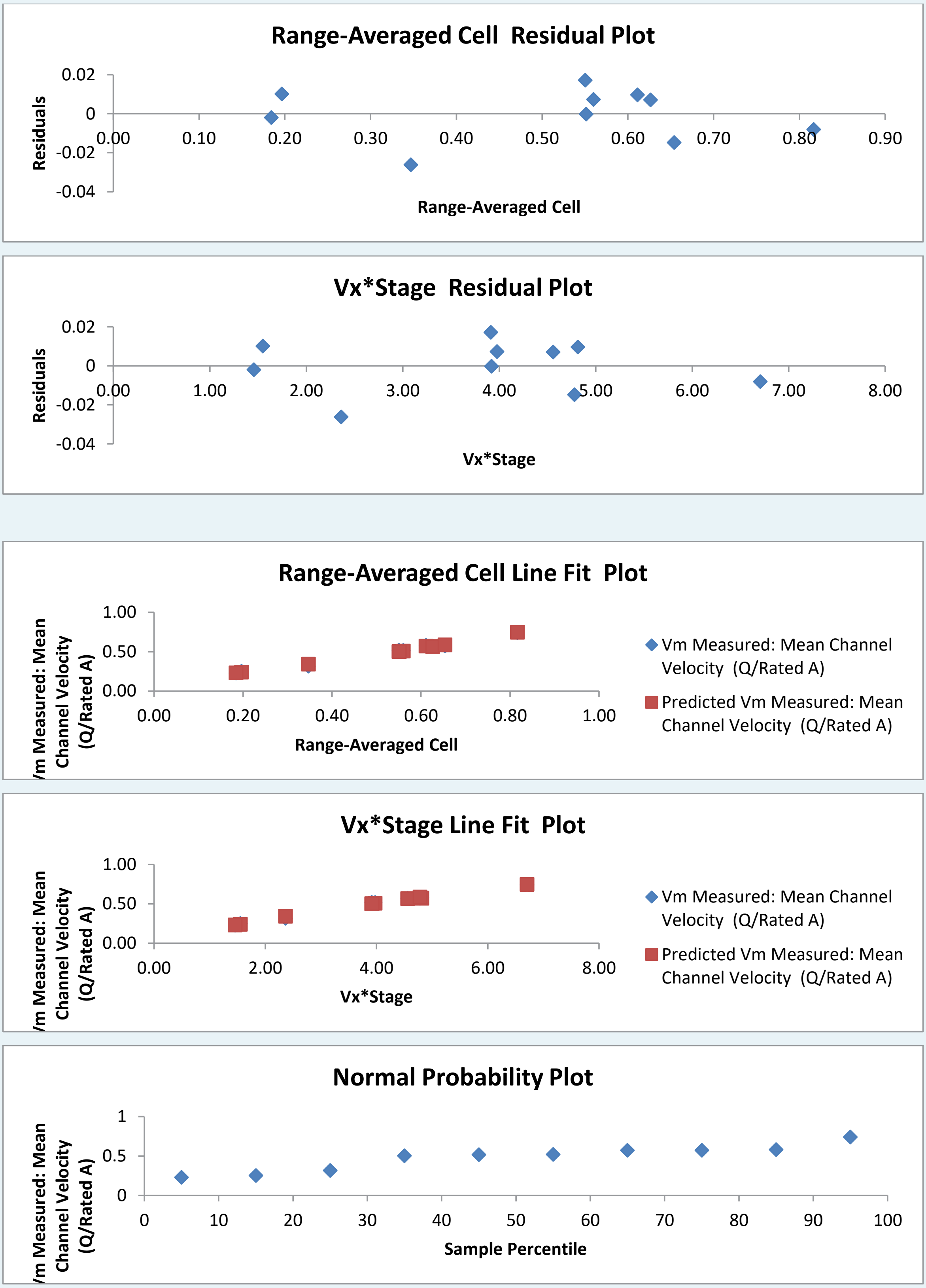


Figure 13: Multi Linear Regression

CASE STUDY – Application of Index Velocity Method in Complex Flow Conditions

Traditional Stage-Discharge Rating

The Stage-Discharge Rating was developed based on all the streamflow gauging's performed at the flow monitoring site to compare the flow calculations against the Index-Velocity Rating. The Stage-Discharge Rating was developed in Hydstra Rating Workbench, Hydrological Information Management System shown in Figure 14.

The results of the tests performed on the Stage-Discharge Rating developed in Hydstra Rating Workbench is provided in Table 2. The tests and formula used is published in Annexure A, ISO 1100/2, Liquid flow in open channels - Part 2: Determination of the Stage-Discharge relation.

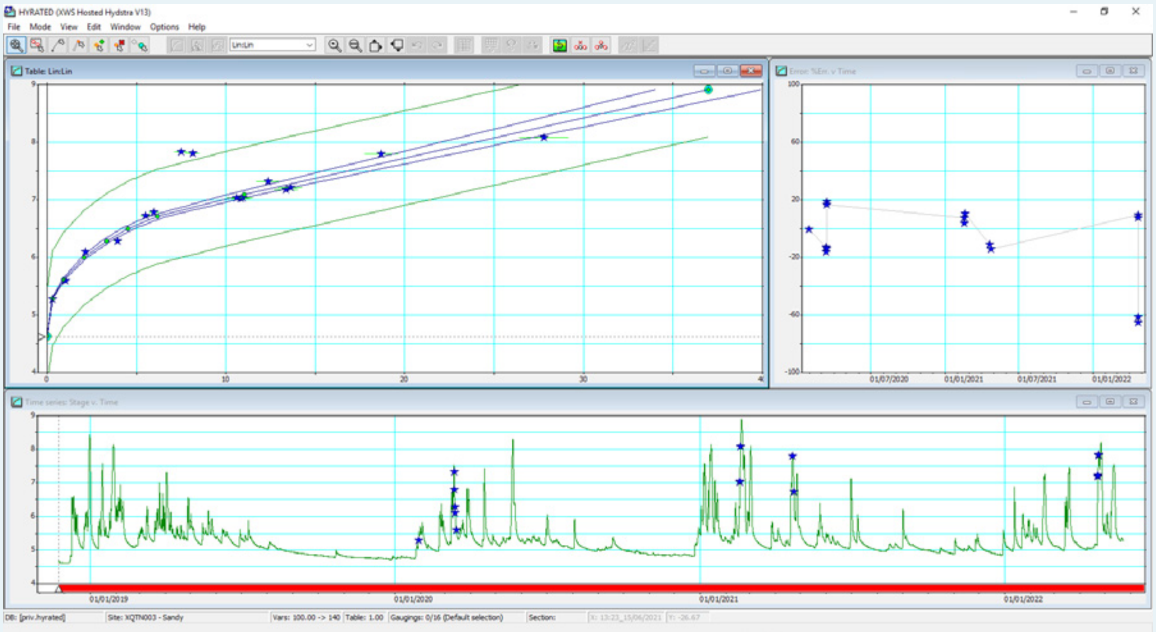


Figure 14: Stage-Discharge Rating

Table 2: Stage-Discharge Rating Test Results

Test	Result	Statistics	Description
Value Bias	Pass	Mean % errs: -7.116 Confidence -20.312..6.080	Value bias test will fail if the mean of all percentage errors is too far from zero
Sign Bias	Pass	Tot +ve errs: 8 Should be within 3..12	Sign bias test fails if the number of negative errors is too different from half of the total
Time Runs	Pass	Runs: 4 Should be at least 3	Runs tests (sorted by both time and stage) fail if the number of runs of
Stage Runs	Pass	Runs: 7 Should be at least 3	Runs tests (sorted by both time and stage) fail if the number of runs of negative or positive errors cannot be explained as random variation
% Within	Fail	31.25% (5 of 16) were within Must be at least 80%	Percentage of gauging's within a percentage of rated discharge" test

The deviation of streamflow gauging's from the Stage-Discharge Rating curve is evident from the % Within test performed.

This is a direct result of variable backwater conditions present at the flow monitoring site.

Flow Calculation

Stage–Discharge vs Index–Velocity

A comparison between the Stage-Discharge Rating and Index-Velocity Rating flow hydrographs is provided in Figure 15. The first peak of the Index-Velocity flow hydrograph developed shows a much steeper rising and falling limb than the Stage-Discharge flow hydrograph. The flow directly after the peak of the hydrograph reduces to zero due to backwater influences from the mainstem in the catchment during flood events. The bridge deck at flow monitoring site also effects the flow hydrograph of Index-Velocity compared to Stage-Discharge.

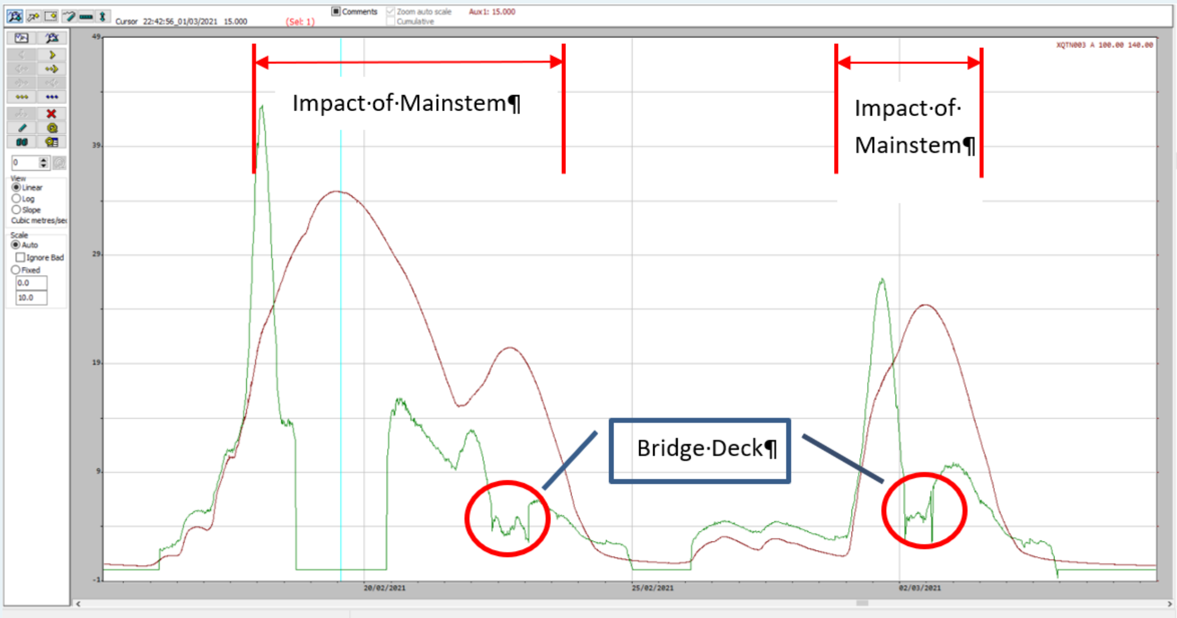


Figure 15: Comparison Stage-Discharge vs Index-Velocity Flow

Influences

Bridge Deck: The bottom of the bridge deck is at 7.8mAHD elevation shown in Figure 19. Flows exceeding 7.8mAHD water elevation will be impacted by the bridge deck shown in Figure 16, resulting in decrease in velocity because of backwater effects caused by orifice / full flow conditions. This flow condition is clearly visible in Figure 15 where a reduction in flow is reported from the SonTek SL1500 instrument.

Figure 16: Bridge Deck

CASE STUDY – Application of Index Velocity Method in Complex Flow Conditions

Off-Channel Storage: Off-Channel storage is occurring on the left bank just upstream of the monitoring site shown in Figure 17. This can result in unsteady flow conditions resulting in a loop rating.

The approach velocity to the monitoring site is also reduced, impacting the stage-discharge relationship.

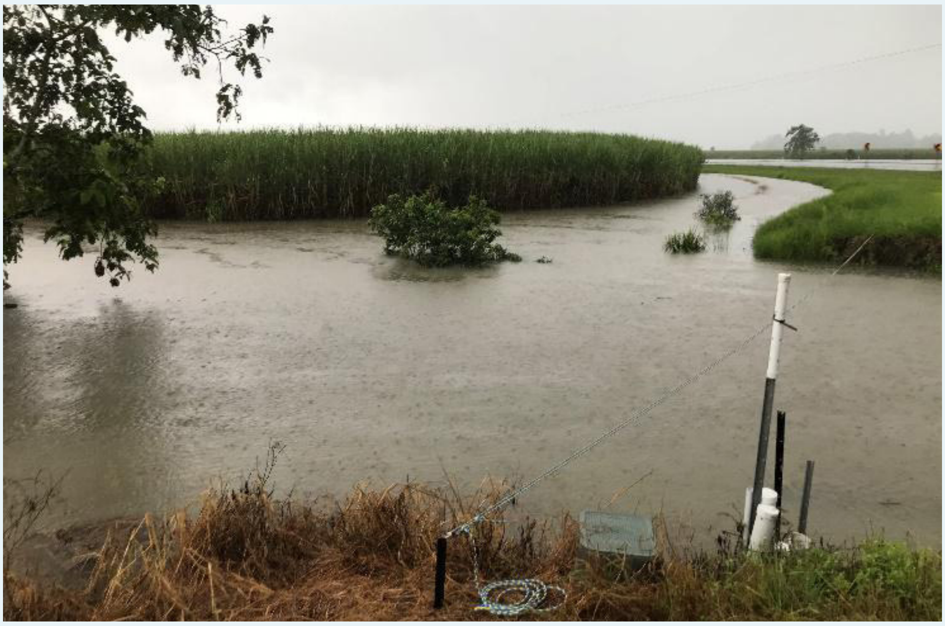


Figure 17: Off-Channel Storage

Mainstem: The mainstem was in flood during the same time the stream flow gauging's were performed at the flow monitoring site.

The confluence of the tributary and mainstem is located close to the flow monitoring site shown in Figure 18. Any runoff occurring in the mainstem will flow upstream into tributary.

Figure 18: Mainstem Confluence

CASE STUDY – Application of Index Velocity Method in Complex Flow Conditions

The extent of the backwater influence is dependent on the magnitude of the flow hydrograph in both the mainstem and tributary systems. The flood event in February 2021 clearly shows the impact of the mainstem on the flow monitoring site flows in Figure 19.

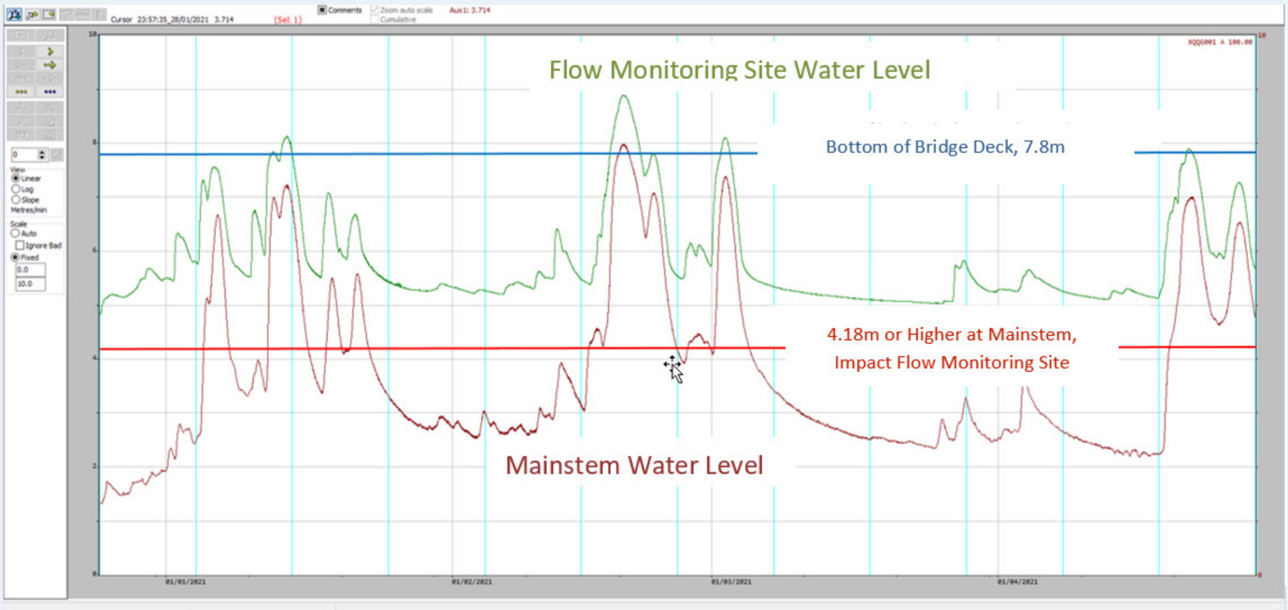


Figure 15: Comparison Stage-Discharge vs Index-Velocity Flow

Conclusion

The proximity of flow monitoring site in relation to the mainstem of the catchment makes it very sensitive to any flow events that may occur in the mainstem. This sensitivity impacts the accuracy of Stage-Discharge relationship significantly over the entire stage range especially for traditional Stage-Discharge Rating. The flow hydrograph comparison in Figure 15 shows that the traditional Stage-Discharge Rating overestimates the total flow significantly especially during periods of zero velocity when the backwater effects from the mainstem is most significant.

The Index-Velocity method is designed for these type of flow conditions, however the final flow calculations are extremely complex as several factors need to be considered to determine the quality and validity of the flow data.

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