Australasian Hydrographer

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AUSTRALIAN HYDROGRAPHERS ASSOCIATION

AHA

Australian Hydrographers Association
National Office
02 6296 3635
services@aha.net.au
PO Box 1006
Mawson ACT 2607
Australia

Editorial Team

Jacquie Bellhouse BSc CPH
(Editor-In-Chief)
Harrison Schofield BSc
Zac Ward CPH

publication.thinktank@aha.net.au

Design

ByFriday
1300 BYFRIDAY (1300 293 793)
design@byfriday.com.au
www.byfriday.com.au

Material Submitted

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Photo Credit: Carnarvon Growers Association

Photo Information: Gascoyne River Catchment during 2021 February Floods.

Contents

Acknowledgement of Country

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

JACQUIE BELLHOUSE

Editor-In-Chief's Introduction

Since I last wrote life has settled back into some form of normalcy intermittently broken by the odd snap lockdown. I am madly juggling multiple initiatives (running the odd Hydrological model interspaced by trying to source Automatic Pump samplers, coordinate/aid the formulation and review of not one but two new Hydrometric Guidelines (keep up the hard work guys!) and in my off time drum up contributions to this fine publication).

Off course I might have dropped a few of those "balls" by now if it were not for the recently formed Publication Think Tank. To be honest I am quite impressed by how well the team is working well together consequently new ideas are well and truly flowing (no pun intended). We are hope that you will get the chance to see some of these in our future editions.

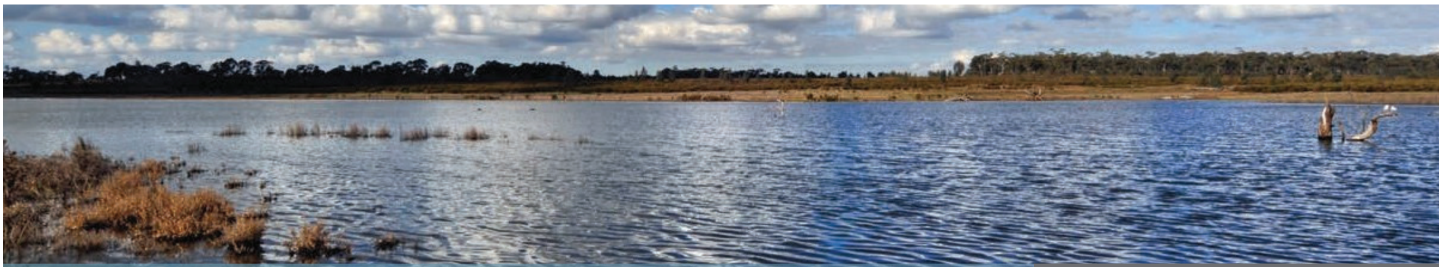
Members of the think-tank take turns in selecting and assembling our members' submissions to the *Australasian Hydrographer*. You will remember that our last edition kindly edited by the Zac Ward CPH while this edition is the product of a lot of hard work by Harrison Schofield (in between undertaking several field trips for his employer).

However, there would not be an *Australasian Hydrographer* at all if it were not for our AHA members' efforts who take the time to submit papers and articles for inclusion.

Interestingly our members seem to have ADCP on the brain this quarter. With papers from Hydro Tasmania's James Newett *(Investigating variations between old and new school flow measurement techniques, and the potential to combine the two)*, the Water Corporation's Zac Ward *(Ord Irrigation Flow Trial & Investigation)* and Xylem's Dr Xue Fan *(SonTek RS5: Performance Evaluation Through Field Data)* all having a ADCP flavor.

However, because the Think Tank thinks celebration of our members' milestones are important, we have taken the opportunity to acknowledge those have recently graduated the NWP50715 - Diploma of Water Industry Operations (Hydrography). In doing so we have also attempted to provide a little insight into where our training and professional terminology is heading. I hope you enjoy.

Jacquie Bellhouse CPH
Editor-In-Chief



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ARRAN CORBETT

From the President

The road back to normality or learning to live with the new normal in the COVID19 era may take some time. While it is great to see state borders opening and activity increasing, we are reminded, on a daily basis, that the next "hot spot" is always waiting to pop up. I do believe that our state leaders are doing a great job of managing these hot spots whilst doing all they can to keep the rest of the state moving.

These challenges are front of mind right now as your AHA committee search for signs that we can once again come together as an Association to share our learnings. Steps towards achieving the goal of an actual (as opposed to virtual) conference were taken in February. Your AHA committee came together in person and remotely to workshop ideas and strategies for our next big event. Other topics discussed included training and of course increasing engagement/value building with our membership. I wish to thank the committee for making the personal commitment of time to travel in challenging circumstances.

In my very first *From the President* message, I called out several challenges I wish to tackle during my term. A quick recap:

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

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

By way of update, I thought I may share some actions against the above factors:

- Technical – we have seen our corporate partnerships increase in number over the last year. This has led to several industry/hydrographer collaborations for testing and evaluation. A great example of this being the Zepiro D2O product.
- Training – we have seen a new MOU with a training provider and the launch of our new training package. Enrolments are now open, and I encourage you and/or your team to sign up.
- Communication – our recent virtual conference was very well received and attended. Our email notifications to members have increased and click through rates remain high.

Please don't get me wrong, while I don't think we have achieved our goals yet, we are on the right path and are making progress!

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

Arran Corbett CPH
AHA President

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AHA Acknowledgements

The AHA would like to congratulate the following graduates of the NWP50715 - Diploma of Water Industry Operations (Hydrography) and those who also subsequently applied for and received Certification from the AHA:

Name	Employer	Date Completed	State / Country
Andrew Blair CPH	Water Corporation	15-July-2020	WA
Andrew Campbell	WaterNSW	15-July-2020	NSW
Clare Hogan	WaterNSW	24-July-2020	NSW
Duncan Macpherson CPH	NIWA	3-July-2020	NZ
Jayde Simmons	DNRME Qld	11-Sept-2020	QLD
Mark Bretnall	DWER	11-Sept-2020	WA
Markian Kawun	Water NSW	3-Sept-2019	NSW
Pamela Fulton-Brown	DNRME	24-Sept-2019	QLD

A Change is Afoot

The above graduates have completed what was formerly called the Hydrography specialty.

Previously enrolled candidates who have not yet finished must complete all work by the end of April in order to receive the NWP50715 - Diploma of Water Industry Operations (Hydrography).

However, as alluded to in this editions “From the President”, those who have not completed by April and all new starters enrolled in 2021, must enrol in the replacement NWP50118 - Diploma of Water Industry Operations (Hydrometric Monitoring).

This is significant as whilst AS 3778 and the Bureau of Meteorology (BoM) previously recognised our activities as “Hydrometric Monitoring” now so does the Australian Government’s Department of Education Skills and Employment (training.gov.au).

So:

- ABS recognise our practitioners as Hydrographers;
- BoM, AS 3778 and training.gov.au describe the activity or “what we do” as Hydrometric Monitoring.

These amendments are consistent with the Wikipedia definition of hydrography and the Australian Hydrographic Office in the Department of Defence (www.hydro.gov.au).

As a consequence, you will notice the Australasian Hydrographer will also apply this revised terminology into the future.

References

Bureau of Meteorology, 2019, *National Industry Guidelines for Hydrometric Monitoring*, https://aha.net.au/published-in/nig/ accessed 18 March 2021

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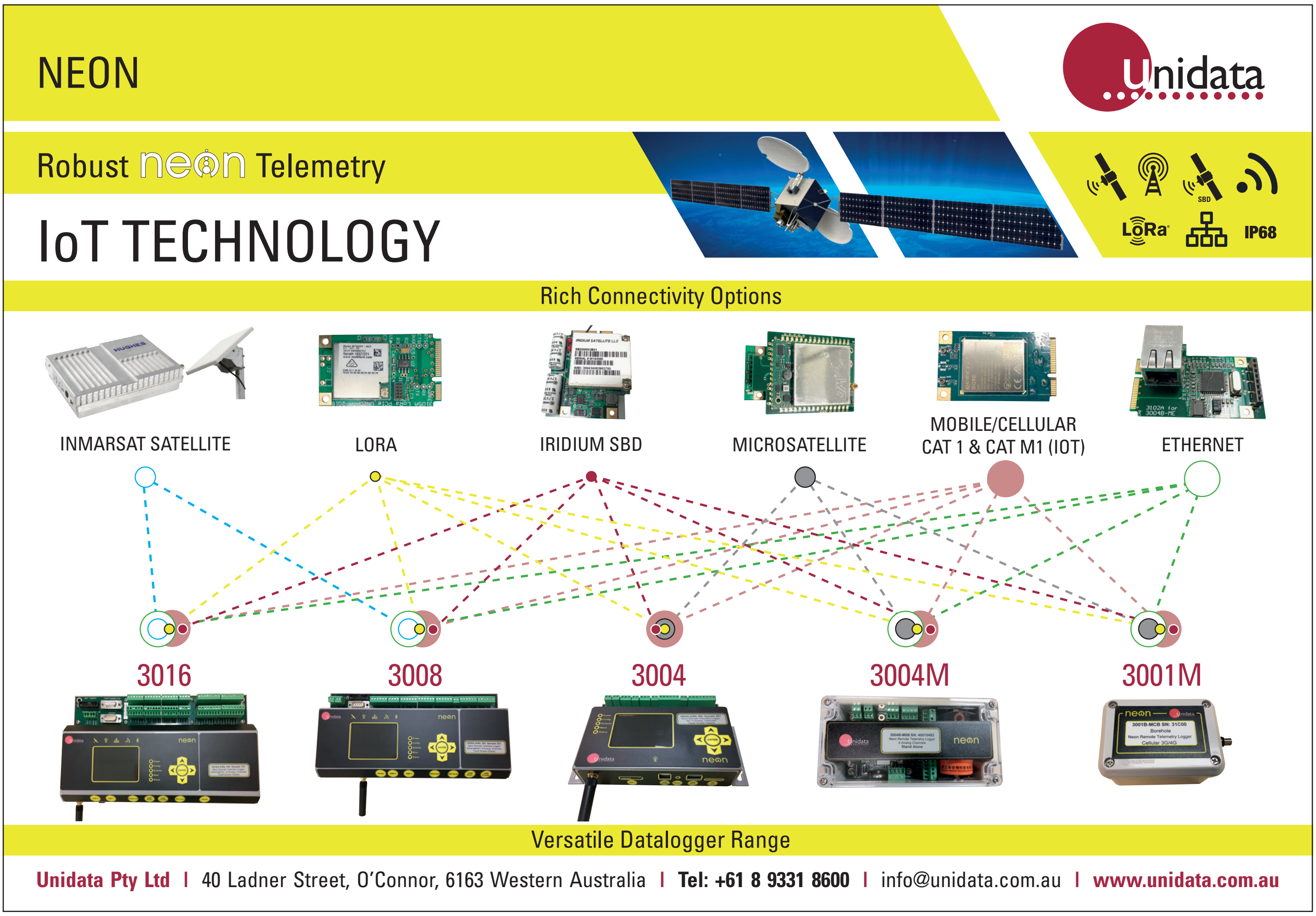

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Investigating variations between old and new school flow measurement techniques, and the potential to combine the two

James Newett, Hydro Tasmania, Hobart, Tasmania

Abstract

Hydro Tasmania has frequently found using Acoustic Doppler Current Profiling (ADCP) technology for flow gauging to be inconsistent and inaccurate within concrete rectangular canals when compared to traditional Current Meter (CM) measurements.

By directly comparing ADCP and CM gaugings using the same discharge calculation techniques at two monitoring stations, it was found that ADCP and CM measurement techniques produced results more consistent than previously observed. Both techniques were then combined to form a hybrid gauging where CM velocity measurements were supplemented into those measurements captured by the ADCP.

Although this process requires further investigation, initial observations suggest ADCP velocity cells, measured using the stationary method within canals, closely resemble those of the CM. Information also suggests historical discrepancies may have been due to compass errors and the incorrect operation of the ADCP. Tests highlighted the potential to blend measurement styles, however simply adjusting the ADCP's coordinate system where compass errors occur appeared the more time effective strategy for the accurate measurement of flow at the study locations.

Introduction

Hydro Tasmania has used manual CMs for almost 100 years while ADCP technology is a more recent inclusion to its flow monitoring tool kit. Despite the changes and an increased availability of information and standards on their use, hydrographers at Hydro Tasmania often refer to old school methods which are perceived as trustworthy (and perhaps are more accustomed to being interpreted).

Recognising the importance of selecting the correct instrument for the conditions, as well as the desire to understand the limitations of the methods employed, this research investigated the potential benefits of combining both old and new school techniques and instruments to achieve a more detailed and representative measurement.

Two monitoring stations, located at Bronte and Monpeelyata, on separate concrete above ground rectangular canals were selected as test locations. Both sites are configured so that they facilitate measurement using both CM and ADCP techniques.

Once collected, information was then processed, and the results, obtained by different techniques and calculation methods were compared.

The more traditional CM measurements were calculated using either the 3 or 5 point mean section method, and ADCP data was calculated in the same manner, using River Surveyors MATLAB™ export to access the raw velocity data, and utilising CM velocities where required.

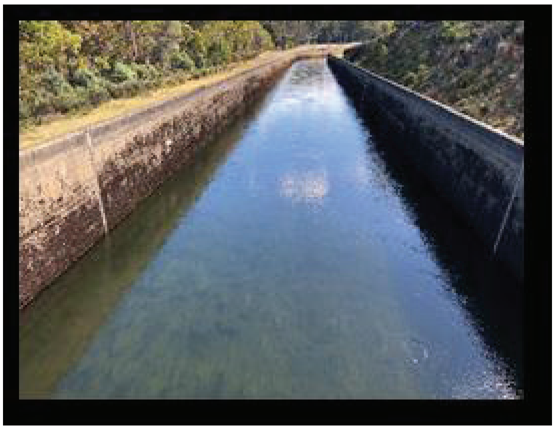
The ADCP measurements were also calculated within the River Surveyor software, testing both coordinate systems (ENU and XYZ). Where section depth resulted in the ADCP blanking the velocity, in order to calculate the 3 point and 5-point method, velocity values were taken from CM observations, resulting in a hybrid of the two methods.

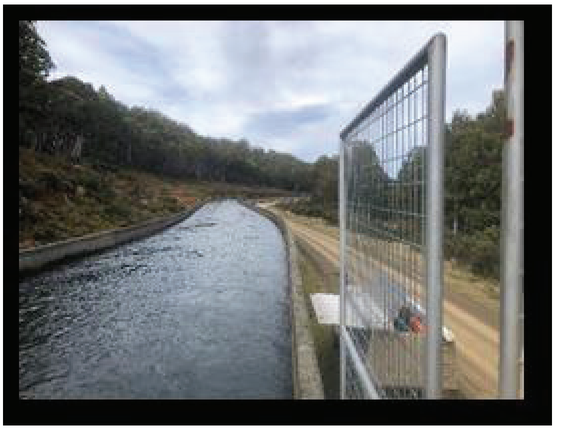
Methods

Site selection

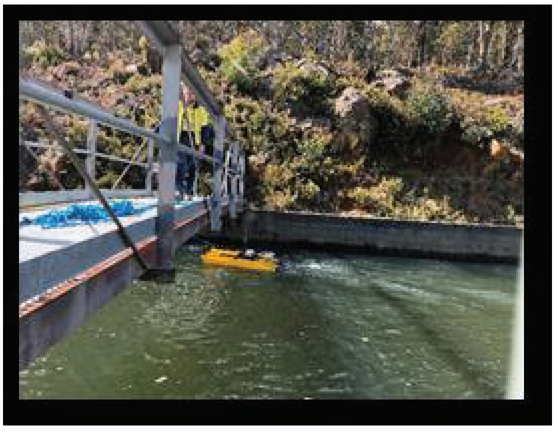
The measurement locations were selected considering a combination of factors:

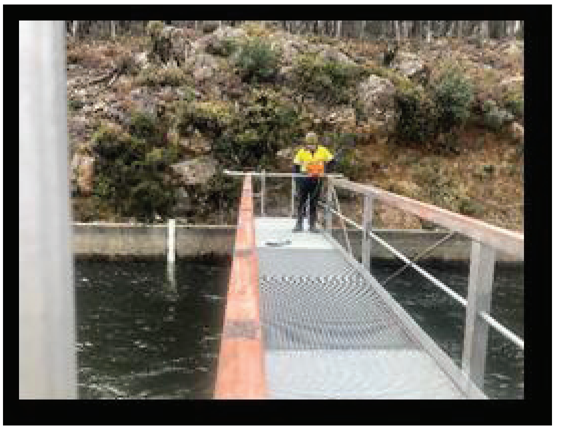
- Both locations are rectangular canals, which have previously proved to be difficult and inconsistent when applying ADCP technology to measure discharge;
- Both locations have upstream gates allowing the release of water to be regulated;
- Both locations have a significantly large number of historical flow measurements;
- Both locations possess bridge structures enabling the easy deployment of both measurement techniques.





Images 1 & 2. Bronte Canal upstream approach and downstream departure. Note shallower conditions within image 1 demonstrating the presence of algae lining the bottom of the canal.





Images 3 & 4. Bronte Canal gauging bridge. Image 3 shows the winch/board arrangement for deploying the CM and columbus weight upstream of the bridge, and image 4 captures the ADCP secured slightly DS of the bridge.

Images 5 & 6. Monpeelyata Canal upstream approach and downstream departure. Note the presence of the hydraulic jump downstream of the gauging station in image 6.

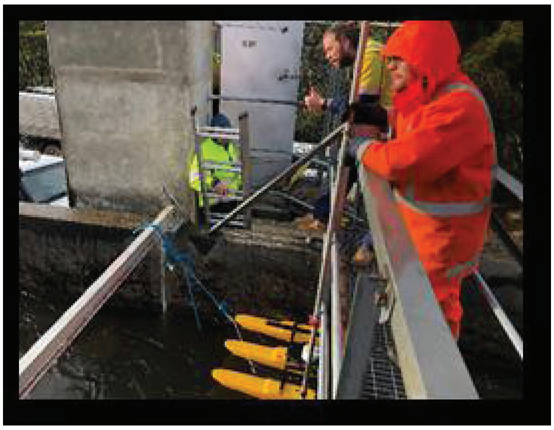


Image 7. Monpeelyata Canal gauging bridge. This image shows ADCP and CM being deployed simultaneously. CM measurements are made using a canal rod, and ADCP measurements by sliding its securing line along the canal's structural pier to the appropriate chainage.

Discharge calculation

Flow measurements were computed using the Hydstra/TS and River Surveyor software to calculate section area, velocity and total discharge.

Mean Velocity (*Vmean*) was calculated using either the 3 or 5 point method as described within the National Industry Guidelines for Hydrometric Monitoring (BoM 2019) using Hydstra/TS, and raw section/cell measurements when using river surveyor.

The ADCP measurements were also calculated in the same manner as CM measurements within Hydstra TS, allowing results to be directly compared. Where the ADCP had 'blanked' and not recorded velocity, velocities recorded at the required position by the CM were supplemented, resulting in a hybrid measurement. Additionally, where the required depth of a velocity point fell between two velocity cells, the mean of both was utilised.

For flow calculations at Monpeelyata Canal the 5-point Vmean calculation was utilised. This technique requires the standard velocity shots to be taken at 0.2, 0.6 and 0.8 of the section depth and with the addition of a surface and bed velocity. For flow calculations at Bronte Canal the 3 point Vmean calculation was utilised. This technique requires the standard velocity shots to be taken at 0.2, 0.6 and 0.8 of the section depth.

Measuring, calculating and combining measurements made with the ADCP and CM

ADCP measurements were recorded using the section by section method, with a single measurement taken with the M9 being compared to that taken by the CM at each location.

Hydrographers placed the ADCP in a traversing position as close to that measured during the CM measurements. Measurements were recorded using the river surveyor software, taking samples for 40 seconds at each measured location. The specific depth of individual measurement cells taken by the ADCP throughout the section was identified through using the raw data provided by the MATLAB™ export function and considering the screening depth and the number of cells/individual cell size. Once identified, the velocity of the appropriate cells was utilised to replicate the method used to calculate the CM gauging at the relevant location (using the 3 or 5 point method). All results other than that output from the River Surveyor software were calculated within Hydstra/TS, Excel and MATLAB™.

Analysing results

Comparisons between differing measurement methods and calculations were made using CM measurements as a baseline. This specifically involved looking for any inconsistencies between measurements and analysing whether results from other techniques varied from the CM measurements.

Results

Monpeelyata Canal DS of Spillway	Discharge (m^3/s)	Area (m^2)	Mean Velocity (m/s)
Current meter (5-point method).	6.823	4.110	1.660
ADCP (River Surveyor, ENU Coordinate system).	6.323	3.880	1.630
ADCP Hybrid (5-point Calculation).	7.042	4.181	1.685
ADCP (River Surveyor, XYZ Coordinate System).	6.319	3.880	1.629

Table 1. Discharge, Area and Mean Velocity values of a single ADCP and CM measurement at Monpeelyata Canal, calculated using the 5 point/ mean section method and River Surveyor software.

Bronte Canal BL Intake	Discharge (m^3/s)	Area (m^2)	Mean Velocity (m/s)
Current meter (5-point method).	34.521	20.360	1.695
ADCP (River Surveyor, ENU Coordinate system).	31.664	19.899	1.591
ADCP Hybrid (5-point Calculation).	34.586	19.872	1.740
ADCP (River Surveyor, XYZ Coordinate System).	35.795	19.899	1.799

Table 2. Discharge, Area and Mean Velocity values of a single ADCP and CM measurement observed at Bronte Canal, calculated using the 3 point/mean section method and River Surveyor software.

Discussion

As expected, and observed historically, discharge calculated using the River Surveyor software within these canals resulted in a discrepancy between ADCP and CM measurements. However, when the velocity and depth data from the ADCP are computed in the same fashion as the CM, we observe very similar outputs, with both hybrid ADCP measurements varying by <5% compared to CM measurements at both test locations.

Despite the added confidence that the raw ADCP velocity values closely resemble those from the CM, further exploration is required to pinpoint the source of historical variation. Prior to manually calculating how the river surveyor software extrapolates its blanked cells, during post processing of ADCP data, significant flow angle and unit heading variation raised concerns regarding the direction the water was moving in relation to the section, and the direction the ADCP was facing. This was a significant concern, as the flow measured at both locations was visually moving perpendicular to the cross section with minimal movement of the ADCP. Closer inspection highlighted a trend where the unit's compass became significantly affected when close to the canal walls. This was the most obvious at Bronte Canal.

On inspection the presence of nearby ferrous metals may explain why the compass data appeared to be unreliable. Interestingly, Monpeelyata did not experience the compass variation to the same degree as that observed at Bronte, and consequently referencing the ENU system did not appear to significantly alter the ADCP's computed discharge.

Concerns regarding compass errors had been raised previously by hydrographers in Tasmania, however on advice from supplier Xylem Analytics, changing the coordinate system to avoid referencing the unit's compass resulted in the ADCP calculating discharge more closely to that observed by the CM, with measurements falling within 8% at Monpeelyata and 5% at Bronte of CM measurements when using River Surveyor software.

Conclusions

Despite the close resemblance observed between the hybrid and CM flow calculations, this research has not been able to quantify any time saving and/or added accuracy when performing hybrid flow measurements compared to traditional CM techniques. The number of tests directly comparing the two methods within the studied environment is the limiting factor within this research. Initial observations suggest that hybrid measurement techniques may be unnecessary within rectangular canals if ADCP technology is deployed appropriately.

Whilst data collected supports that velocity and area measurements from both the ADCP and CM closely resemble one another, the small variation observed should be investigated further. Initial observations suggesting it is most likely linked to operator/human error as opposed to equipment error.

Other factors potentially contributing to inaccuracies, as determined within this research, includes the assumption that CM measurements are in fact precise and an appropriate baseline for making comparisons against, the lack of a section control at Bronte Canal as opposed to Monpeelyata, the small sample size and any differences in water quality across the test sites, which may influence the ADCP.

Regardless of these limitations, ongoing comparisons of ADCP and CM measurements remain a must within Hydro Tasmania to further understand the technology we use daily.

Acknowledgements

Special thanks to the following for reviewing this document:

- Mark DeHoog, Technical Officer, Data management;
- Mark Johnston, Technical Specialist (retired);
- Ray Clark, Remote Monitoring Supervisor.

References

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SonTek RS5: Performance Evaluation Through Field Data

Dr Xue Fan, Senior Application Engineer, Xylem Water Solutions

Introduction

The SonTek RS5, released in August 2020, is the newest member of the RiverSurveyor family of acoustic Doppler current profilers (ADCPs). The RS5 builds upon the acoustic technology developed for the RiverSurveyor M9/S5 while adding expanded capability through its Broadband transducers, self-resolving Pulse-coherent pinging, and creative design to achieve the best data possible for discharge measurements.

Figure 1. SonTek RS5

This Technical Note introduces certain technical aspects of the RS5 and highlights its capabilities in the field by showing data comparisons using other ADCP systems at a wide variety of different sites.

SmartPulse+

At the core of the RS5 acoustics engine is a combination Broadband/Pulse-coherent pinging algorithm using new Broadband transducers. Compared to the M9/S5-style narrow-band transducers capable of Pulse-coherent and Incoherent pinging, the RS5 acoustic capability is expanded to allow complex combinations of Broadband and hybrid Pulse-coherent acoustic signals resulting in 4 different specialized ping types per sample. The SmartPulse+ algorithm uses the detected depth for each sample and automatically configures the appropriate settings for all 4 ping types. The algorithm then combines the best dataset from the different ping types based on complex algorithms to achieve the highest quality velocity profile for each sample and changes those settings automatically throughout the measurement.

Figure 2. Application Engineer RS5 testing, Yuma AZ USASonTek RS5 versus SonTek RiverSurveyor M9/S5 and TRDI StreamPro.

During the development of the RS5, discharge measurements were performed at controlled sites with different systems commonly used for those sites and conditions. For instance, discharge measurements were performed at a concrete-lined canal at USGS gauging station 09522500 at Yuma Arizona (AZ) using the SonTek RS5, SonTek RiverSurveyor M9, S5, and the TRDI StreamPro.

This site has been surveyed extensively due to the trapezoidal broad-crested weir built downstream of the measuring location. Because of the remnants of a cofferdam at this location, velocities are consistently higher on the right side of the transect, which can be seen from the higher volume of red in the RS5 and M9 contour plots. It is clear that the velocity profiles from the RS5 and M9 provide the most detail in terms of resolution and flow structure changes across the transect compared to the S5 and the StreamPro. While the RS5's profile shows comparable definition to the M9 transect, the M9 data quality is only comparable to the RS5's thanks to its dual-frequency SmartPulseHD® capabilities. Due to its single-frequency limitations, the S5 SmartPulse algorithm was forced into Incoherent mode given the velocities at this site, resulting in a very coarse dataset when compared to the RS5 (which is capable of staying in Pulse-coherent mode). Finally, the StreamPro requires the user to set a fixed cell size configuration and ping type, resulting in velocity contours that do not resolve the complex velocity structure that is observed at this site, despite the seemingly simplistic type of site.

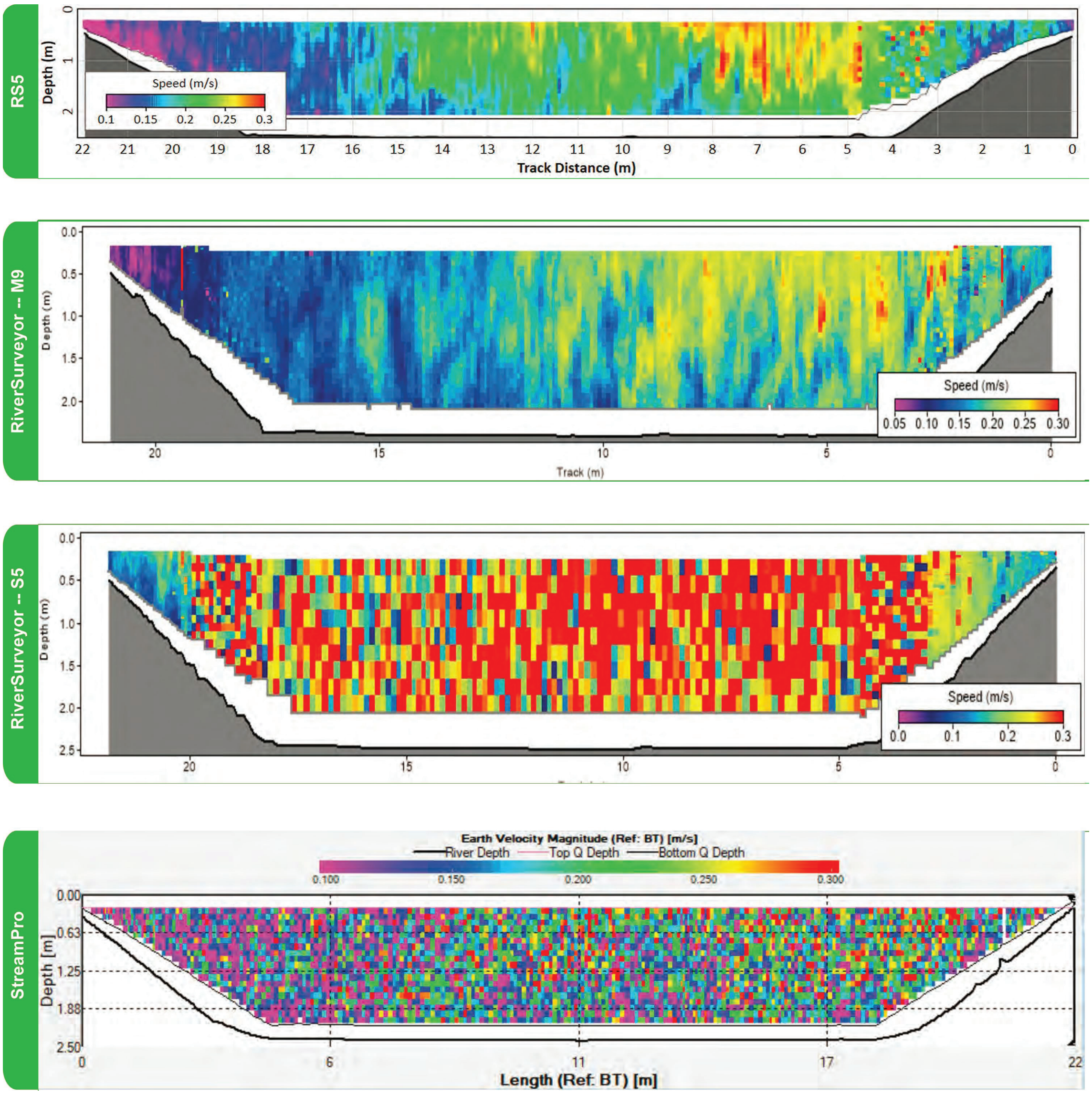

Figure 3. From the top RS5, RiverSurveyor-M9, River Surveyor S5, Stream Pro Profiles.

RS5 (Broadband/Pulse-coherent) versus M9 (Incoherent) Performance

Sites with certain velocity and depth features allow the RS5 SmartPulse+ algorithm to stand out even when compared to the RiverSurveyor-M9, like the following Environment Agency River Gauging Station called Skelton on the River Ouse near York in the United Kingdom (UK). In the middle of the transect, velocities were high enough and the channel was deep enough to force the M9 SmartPulseHD algorithm to use the 1 MHz Incoherent ping type, resulting in much larger cells and noisier data compared to its Pulse-coherent (called "HD") pings near the edges.

While the final discharge values are comparable, it is clear from this example that the RS5 SmartPulse+ algorithm better handles such variation in flow, ranging from very slow-moving water near the edges, to deep and faster flow in the central part of the transect. In this case, the RS5 is able to resolve the detailed surface-intensified flow in the centre of the channel, whereas this ability is not as apparent in the M9 dataset.

Figure 4. Skelton on the River Ouse near York, United Kingdom. Data and photo credits: Lee Pimble, SonTek Hydrometric Technical Applications Manager, Europe.

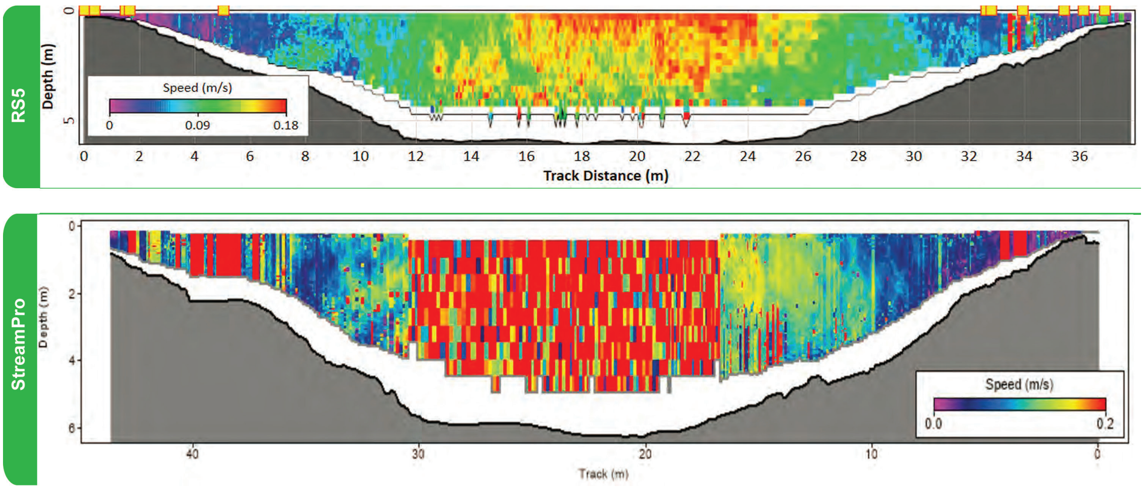

Figure 5. From the top RS5 & RiverSurveyor-M9 Profiles.

High Resolution Profiling

The RS5 is designed to produce optimal data quality in shallow, often noisy stream environments. Because shallow environments are much more susceptible to unusual flow conditions due to obstructions and variability in the flow, development focused on producing the highest resolution dataset while at the same time measuring velocities with the least uncertainty and noise.

Noise in acoustic profiling instruments often results in a “patchwork” or “harlequin” looking image with no apparent flow pattern, as can be seen at the following site using the StreamPro. This shallow stream, located at USGS Gauging Station 03302000 at Pond Creek near Louisville, KY (USA), highlights the high-resolution shallow capabilities of the RS5.

Figure 6. USGS Gauging Station 03302000 at Pond Creek near Louisville, KY (USA). Photo and data courtesy of Tim (Shawn) LeMaster, USGS.

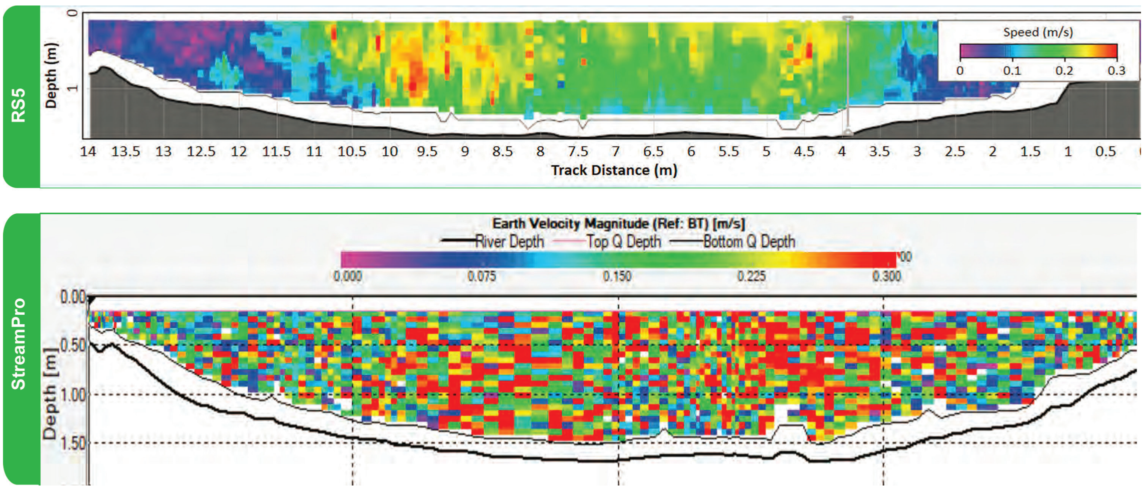

Figure 7. From the top RS5 and RiverSurveyor-M9 Profiles Louisville, KY (USA).

At another site near Asheville, NC (USA) at USGS gauging station 034557730 (Figure 87), shows the same effect.

It is evident from the photo that complex flows might be expected due to the cobbles and large boulders on the bottom. The transect from the RS5 clearly highlights the complex flow structure caused by the varying bottom shape and shows some unexpected areas of highest flow off-centre from the middle of the channel. Also evident is the more detailed channel bathymetry provided by RS5’s vertical acoustic beam, whereas the StreamPro can only provide a mean depth averaged from its four slanted beams.

Figure 8. Asheville, NC (USA) at USGS gauging station 034557730. Photo and data courtesy of John Mazurek, USGS.

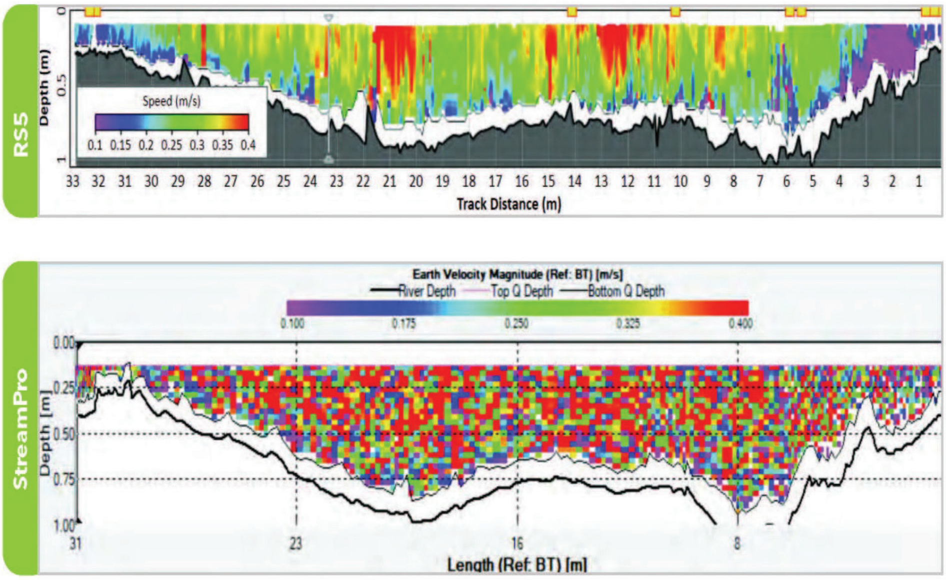

Figure 9. From the top RS5 and RiverSurveyor-M9 Profiles, Asheville, NC (USA) at USGS gauging station 034557730.

Velocity Profiles with Less Random Noise

The RS5 SmartPulse+ uses many different criteria to decide on the best velocity profile for a given sample. One of the most important factors used in the decision is the velocity standard deviation. The standard deviation is a statistical value representing how noisy a certain velocity sample is; the higher the standard deviation, the higher the noise, and the "patchier" the data will look.

Because great care has been taken to reduce measured velocity noise, data from the RS5 at many sites will have a higher resolution, whereas other instruments may produce a lower resolution image of the flow.

An example of such a site is shown here, at the USGS gauging station 07378000 on the Comite River near Comite, LA (USA).

While the general structure of the flow can be observed in the StreamPro data, with more red colours near the centre of the channel where highest velocities exist, the RS5 dataset produces a smooth contour plot with minimal grainy noise throughout the velocity contour plot. Noise reduction provides the most precise velocity measurements to calculate discharge and allows various fine-scale features to be visible in the transect that would otherwise be hidden in the data scatter, like the small near-bottom peak in velocity near the left bank.

Figure 10. USGS gauging station 07378000 on the Comite River near Comite, LA (USA). Photo and data courtesy of James Fountain, USGS.

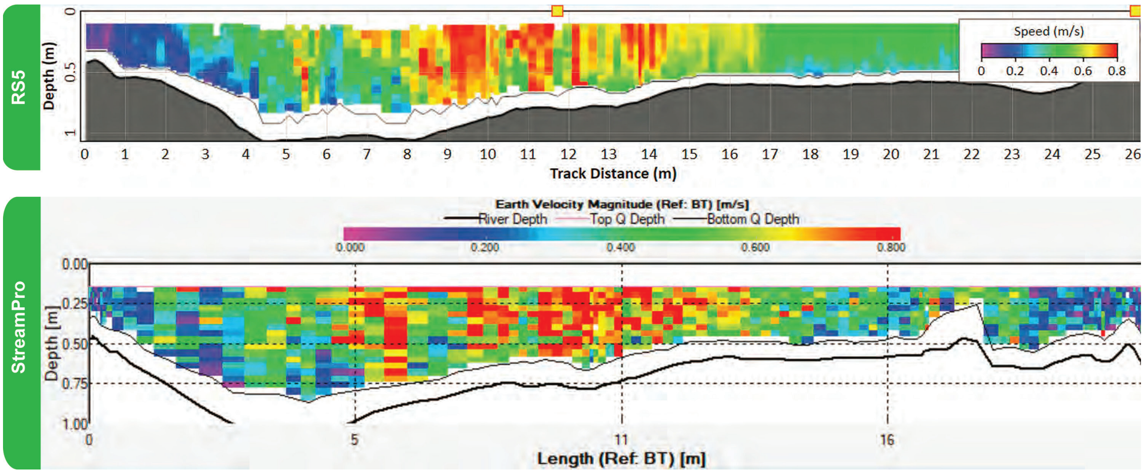

Figure 11. From the top RS5 and RiverSurveyor-M9 profiles, USGS gauging station 07378000 on the Comite River near Comite, LA (USA).

Ultra-Shallow Capabilities

The RS5's compact shape and small footprint make it ideal for shallow water discharge measurements where the user prefers not to wade (with a FlowTracker, for example) or requires a profile as opposed to a point measurement, where possible. The SmartPulse+ algorithm is optimized for fine-scale near-surface measurements, ensuring that the shallowest data possible can be collected.

The RS5 is able to achieve velocity cells at depths that are too shallow for other instruments. An example is illustrated here, again from Asheville, NC (USA) at USGS gauging station 03298150.

Figure 12. USGS gauging station 03298150 at Asheville, NC (USA). Photo and data courtesy of Tim (Shawn) LeMaster, USGS.

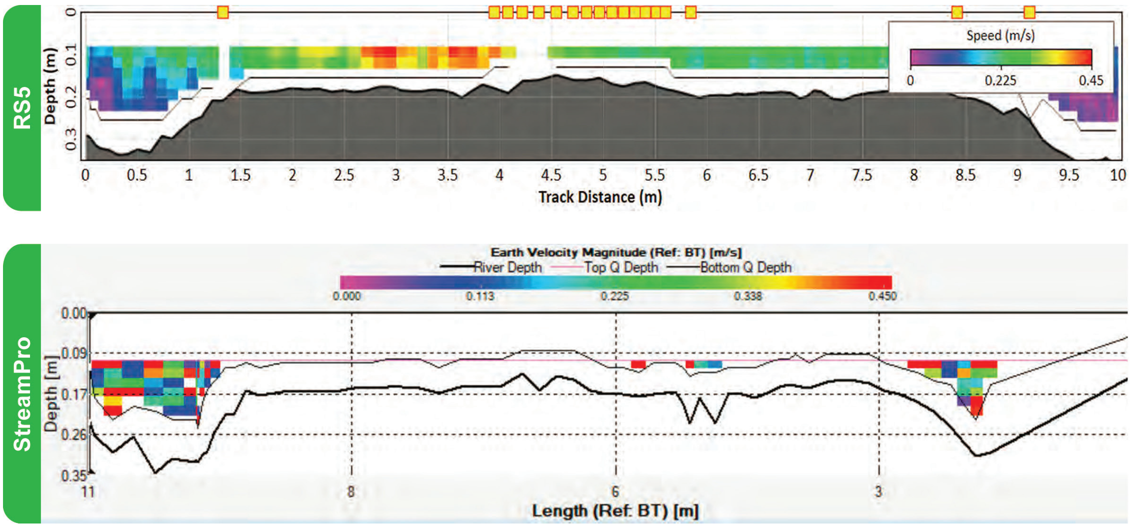

Figure 13. From the top RS5 & RiverSurveyor-M9 profiles, Asheville, NC (USA) at USGS gauging station 03298150.

At this site, water depths get as shallow as about 13 cm. While the StreamPro is unable to achieve any cells or profiles in most of the shallowest region of the cross-section, the RS5 is able to return at least one cell (and often many cells) throughout most of the transect. Sites originally too shallow to measure with an ADCP are now accessible with the RS5.

Figure 14. RS5 Application Engineer testing site, Yuma, AZ (USA).

A combination of the RS5's shallow capabilities and high-definition data resolution is shown in the example here, collected near Yuma, AZ (USA).

This shallow site reaches no more than 30cm at its deepest. While the StreamPro is able to achieve velocity cells at these depths, the RS5's high resolution algorithm is able to highlight in smooth gradients the areas of highest and lowest flow which are lost in the noisier StreamPro data.

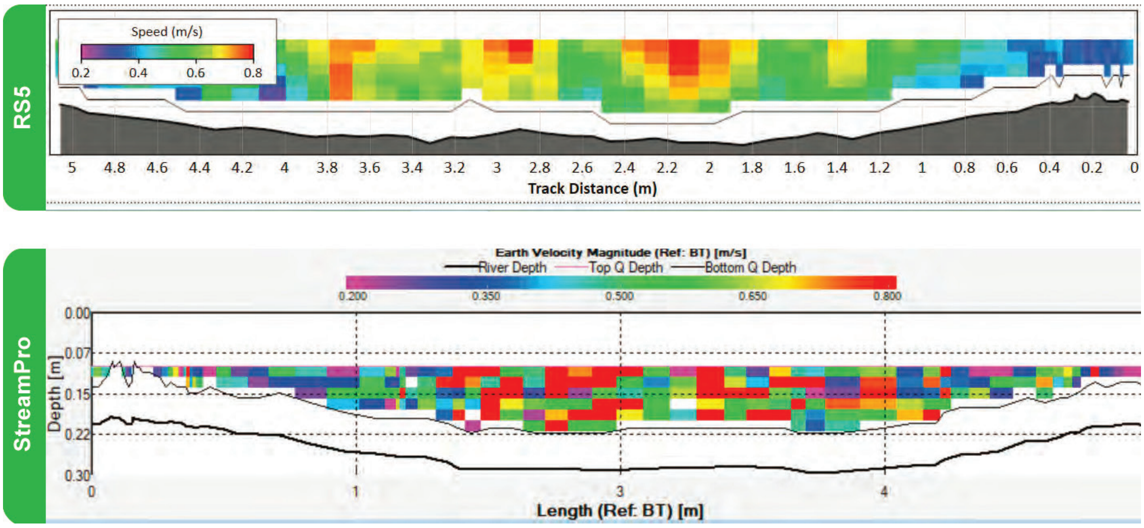

Figure 15. From the top RS5 and RiverSurveyor-M9 profiles, Application Engineer testing site, Yuma, AZ (USA).

Bottom-Tracking and Bottom Detection in Difficult Substrates

The RS5 SmartPulse+ algorithms apply to all velocity calculations, which include both velocity of the water and the boat movement, called Bottom-Tracking. The Bottom-Tracking algorithm calculates with great accuracy the movement of the boat over ground, which is then used to correct the raw velocity measurements to separate out the water velocity itself. Because of the use of the combined Broadband and self-resolving Pulse-coherent techniques, the RS5 is able to achieve more stable, better quality Bottom-Tracking than comparable instruments. It provides more reliable Bottom-Track data in difficult conditions for acoustics (including highly variable rocky bottoms and some types of vegetation).

The following measurements (Figure 17) were collected at the USGS gauging station 07048600 on the White River near Fayetteville, AR (USA). The site photo (Figure 16) shows a semi-turbid flow with a transect containing large cobbles and vegetation near the edges. The main streambed is mainly gravel. The combination of high sediment load and variations in bottom substrate (cobbles to gravel) make this site a challenge for both bottom detection and Bottom-Tracking. With the benefit of having a vertical beam, the RS5 is able to maintain a depth measurement throughout the transect and reliably reports Bottom-Tracking velocity compared to the StreamPro.

Figure 16. USGS gauging station 07048600 on the White River near Fayetteville, AR (USA). Photo and data courtesy of Neil Holaway, USGS.

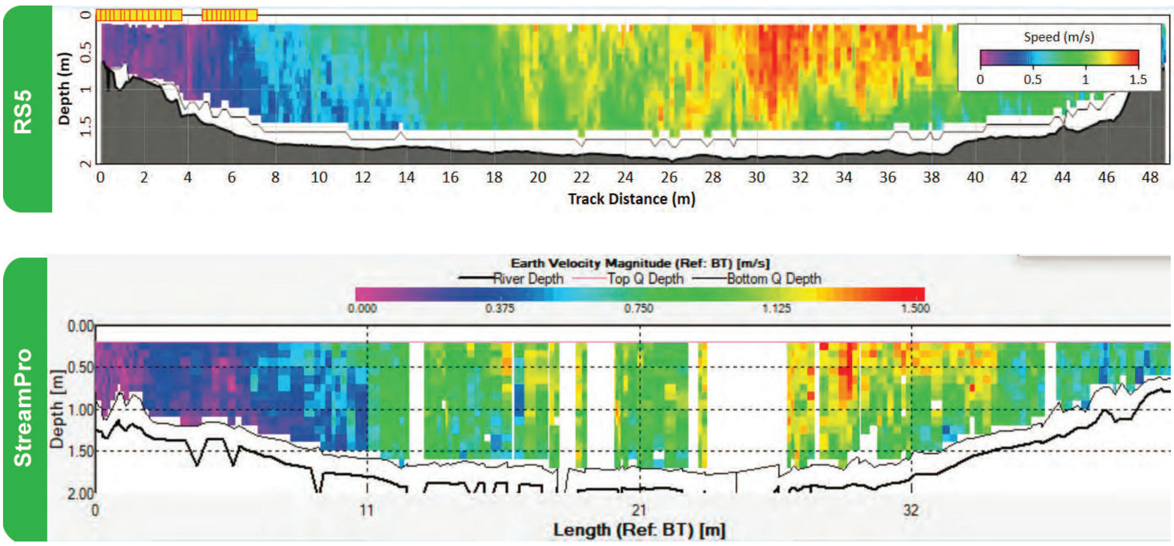

Figure 17. From the top RS5 and RiverSurveyor-M9 profiles, USGS gauging station 07048600 on the White River near Fayetteville, AR (USA).

During the RS5 development, sites that have historically caused Bottom-Tracking issues for ADCPs were targeted. The example below shows a site, operated by Canals and River Trust, with a highly variable stone bed under fast-flowing up to 1 m/s), silty water. It is located on the Bywash channel at the Toddbrook Reservoir at Whaley Bridge near Manchester, UK.

The combination of these conditions proves to be very difficult for the RiverSurveyor M9 to maintain bottom-track lock during the transect, as shown below. Because the bottom-tracking algorithm has the help of the self-resolving Pulse-coherent pinging and tuning specifically for these difficult shallow sites, the RS5 successfully collects a full dataset across the cross section.

Figure 18. Site, operated by Canals and River Trust, Toddbrook Reservoir at Whaley Bridge near Manchester, UK. Photo and data courtesy of Nick Martin, Xylem UK, and the Canals and Rivers Trust.

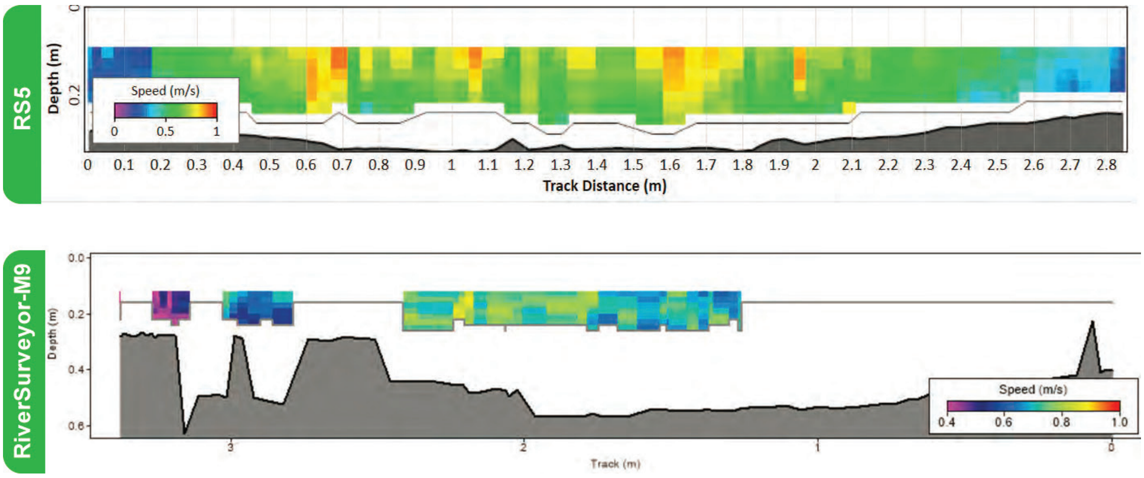

Figure 19. From the top RS5 and RiverSurveyor-M9 profiles at Canals and River Trust site.

RS5's Other Unique Features

Unlike the StreamPro, the RS5 comes standard with a magnetic compass, whether it be the Standard (no GPS/GNSS) or Max (GPS/GNSS-enabled) model. This enables the user to collect Loop Moving Bed Tests and stationary discharge measurements (coming soon). The RS5 magnetic compass is the same high-quality SonTek-built compass used in the M9/ S5 systems (often referred to as the "G3" compass) and provides real-time magnetic error feedback. In the example below, the RS5 performed a transect upstream of the bridge pictured.

Figure 20. Bridge and transect path upstream of bridge.

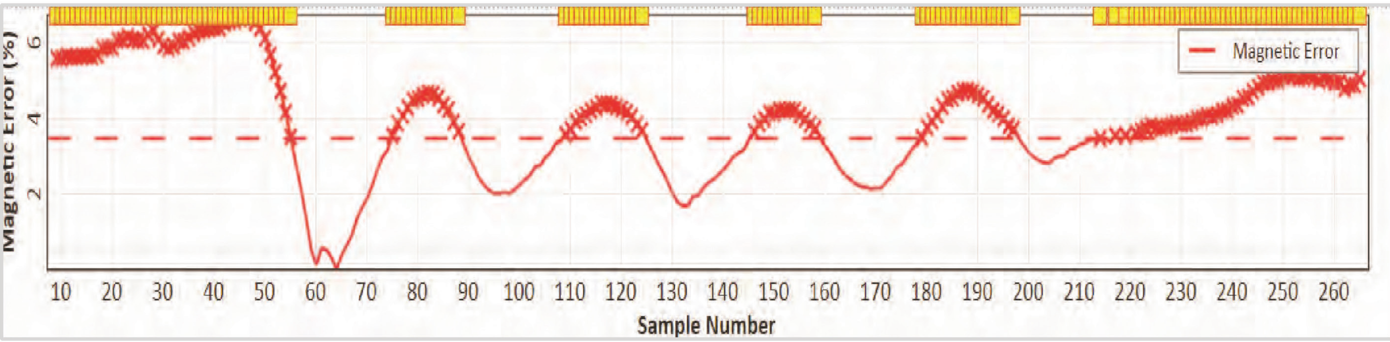

Figure 21. The magnetic error is reported along with warnings (red hashes) when the system goes near each bridge piling, indicating that the magnetic error exceeds the calibration limit for accurate discharge.

Automatic Reconnection and Data Buffering for 5 Minutes

The RS5 comes with a robust automatic reconnection feature that will re-establish Bluetooth connection if lost. Unexpected things always happen in the field, including losing direct line of site, mishaps with the radio antenna or USB radio, losing power, or as in the following case, accidentally flipping the boat entirely, resulting in lost communications. The RS5 and boat were underwater for about 10 seconds (during the period outlined in the figure) before they were righted, and the connection through the RSQ software was picked up immediately without any user interventions.

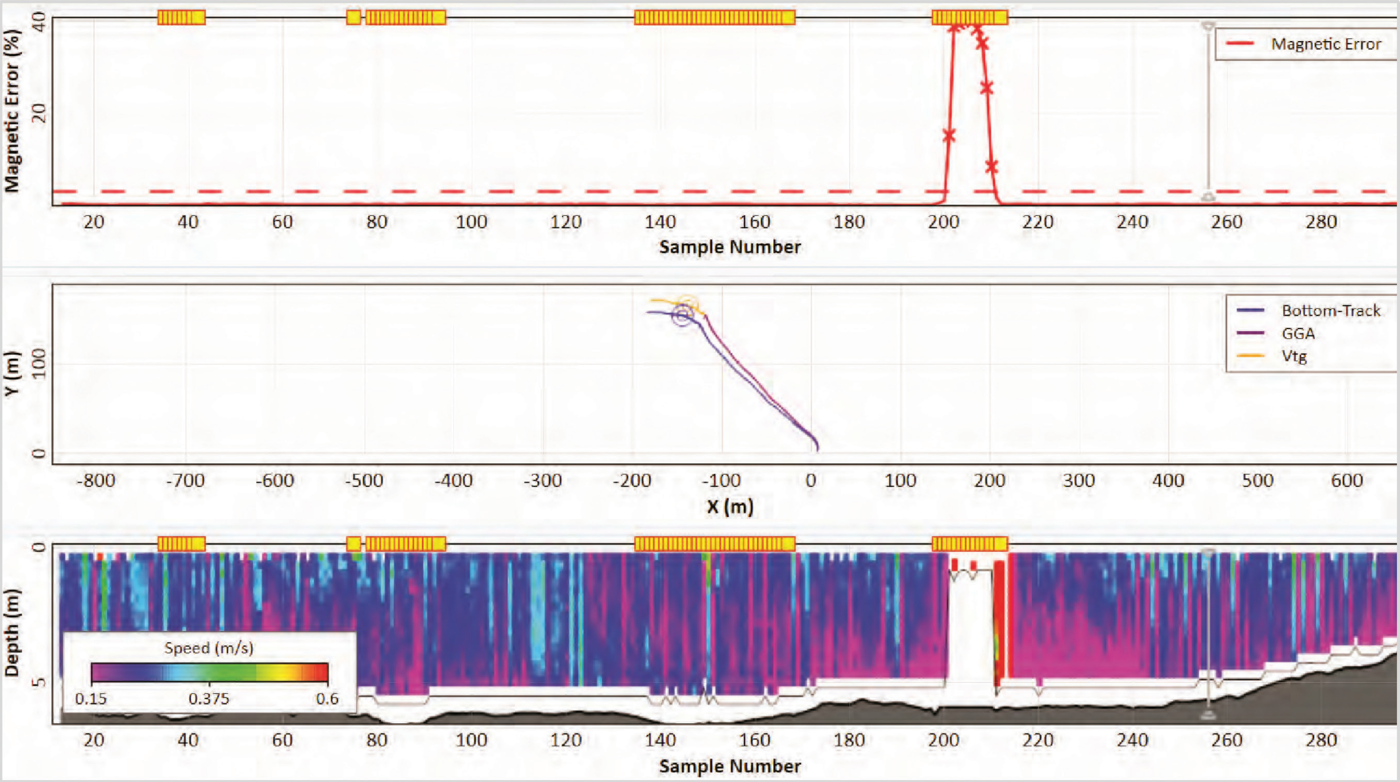

Figure 22. Boat Flip Incident (the RS5 and boat were underwater for about 10 seconds).

When data connection is lost, the RS5 stores backup data internally for up to 5 minutes. When communications are restored, the data are transferred back to the computer and sorted accordingly so no data are lost within the 5-minute communications gap. This data buffer offers a way to preserve samples if communications are lost so the transect does not need to be repeated.

Final Notes

The SonTek RS5 incorporates both innovations in acoustic technology as well as years of customer feedback on acoustics and software interfacing to provide the highest quality data and smoothest user experience available. The SmartPulse+ algorithm and new acoustic developments allow the RS5 to meet and exceed data quality and resolution capabilities compared to other discharge measurement systems. The data examples shown in this Technical Note span a wide range of site conditions and applications and display the power of a complex acoustics engine in a small physical form.

Note:

This article was originally published by SonTek, a Xylem brand, in 2020 as Technical Paper XA00135, https://www.xylem.com/siteassets/brand/sontek/resources/technical/sontek-rs5-performance-evaluation-through-field-data.pdf accessed 18 March 2021

Ord Irrigation Flow Trial & Investigation

Zac Ward CPH, Asset Monitoring and System Investigations, Water Corporation, Perth, Western Australia

Abstract

The M1 Irrigation Channel is the primary water supply channel for the Ivanhoe Plain Irrigation Area within Kununurra which, along with the Packsaddle Irrigation Area, forms Stage 1 of the Ord River Irrigation Area (ORIA). Both Water Corporation and the Ord Irrigation Cooperative (OIC) monitor flow rates and levels throughout the irrigation area. This article aims to summarise and detail the historical complexities and challenges with regards to measurement within the channel.

Acknowledgement

All flow measurements and investigation were carried out on Miriwoong Country, Kununurra, the lands of the Miriwoong and Gajirrawoong people.

Background

The Water within the M1 Irrigation Channel is supplied from Lake Kununurra which is located ~55 km downstream of Lake Argyle and the Ord River Dam, within Kununurra, Western Australia (WA). Lake Argyle which was formed in the 1970s following the construction of the Ord River Dam contains sufficient reserves to maintain the water level in the lower Lake Kununurra and gravity feed the M1 Irrigation Channel all year round through a series of radial gates (see Figures 4 & 5).

Prior to commissioning of the abovementioned gate structure, a Pump Station and associated pipes (see Figure 1 & 2) fed the M1 Channel. This Pump Station was eventually disconnected but saved in the interim as an emergency backup supply structure until 2004, after which it was formally disconnected and decommissioned by the Water Corporation. In 2007 it was included on the register of the Heritage Council of Western Australia (WA), preserved and opened as a fully functional public dining restaurant in 2008.

Figure 1. Lake Kununurra to M1 Irrigation Channel (decommissioned Pump Station in the Centre) left to right. (Right Bank viewing DS).

The first 100–120 m of channel downstream of the current M1 offtake structure is 35–40 m wide and is sufficiently deep such that it dissipates the velocity of water exiting the radial gates.

The following images show the Pump House and previously operated gauging station.

Figure 2. Heritage Listed Pump House.

Figure 3. Left Bank Facing US (Old M1 Gauging Station).

Figure 4. M1 Intake Radial Gates (left) and Pump Station (Right) as taken at the old M1 Gauging Station Hut (Looking US).

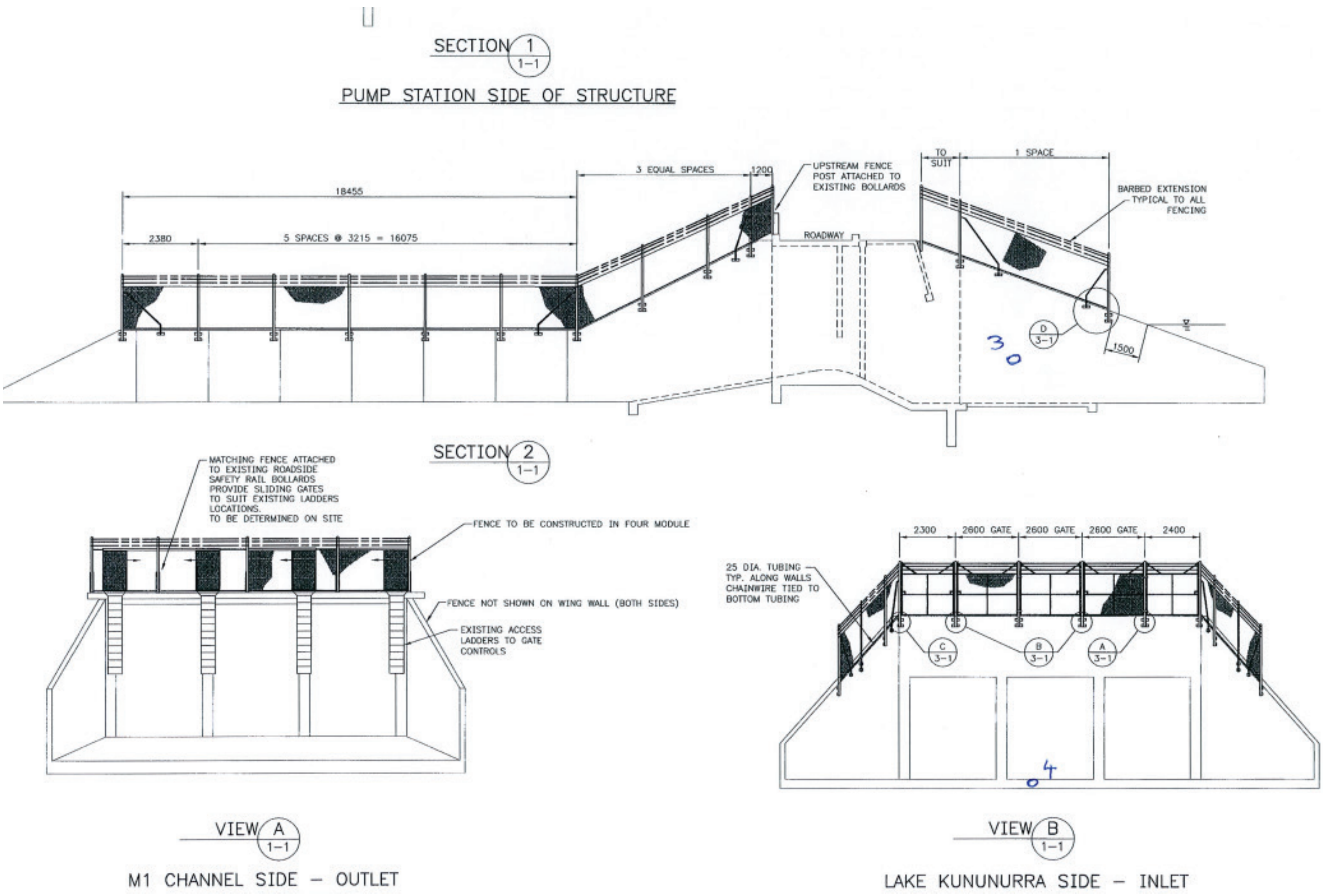

Figure 5. M1 Intake Radial Gates as constructed.

M1 Monitoring History

The original M1 Gauging Station (809338) consisted of a Parshall flume linked to a stilling well and a float operated transducer located approximately 100 m downstream of the intake structures (see Figure 3). The Parshall flume was later removed leaving the wing walls.

The accuracy of the derived flows at this point determined to be in the order of ±15 to 25% as verified by regular boat discharge measurements. The data collected from the station was eventually assessed as increasingly unreliable due to the impacts of weed growth, silt accretion, bed erosion and control degradation. Additionally, modifications to the channel to meet supply demand, further impacted the quality of the flow measurement resulting in the eventual closure of the gauging station and relocation of OIC monitoring station downstream (1996 onwards).

A number of papers authored by A.J. Deane (1996, 2001) outlined the Water Corporation's perspective on channel measurement moving forward with alternative technologies, varying capital expenditures and operating costs a point of contention and questioning. The following points of note are relevant in the ensuing sections of ongoing channel monitoring:

*"**Option 2** involves the construction and operation of a conventional gauging station to Australian Standard AS3778, Measurement of Flow in Open Channels. It applies standard Water Corporation equipment and procedures and 'proven' technology used worldwide to measure flows to better than ±5%. This option provides the greatest flexibility (including ad-hoc readings) and minimises the requirements for highly skilled hydrographers on site. The most appropriate site would be at the old flow measuring flume (120 m downstream of the offtake). The capital cost is highest for this option ($173,000-$223,000) however operation costs are the lowest ($5,000-$10,000 per annum)"*

*"**Option 3** is based on the installation of electronic velocity and head sensing equipment... This approach uses 'emerging' technology which is not yet considered to be sufficiently well developed for this application. No Australian Standards are known to exist for this technique. ad-hoc observations are difficult, and operation requires consistent input from highly skilled personnel. Access to the system for installation and regular maintenance is likely to be difficult and involve shutting down the offtake. Capital costs could be expected to be $50,000-$75,000 while annual operating costs are conservatively estimated to be in the order of $40,000-$60,000" (Deane, 1996).*

In 2003, the OIC contracted "Rubicon Pty Ltd" to commission a separate replacement streamflow monitoring station downstream of the existing Water Corporation offtake structure and stage-discharge monitoring station (809338).

"The OIC was formed in 1996 to operate and manage the business of providing water and drainage services to the farms within Stage 1 of the Ord River Irrigation Area (ORIA) as part of the transfer of the irrigation assets and business from the state to the growers."(OIC 2021)

Rubicon installed (on behalf of OIC) a comprehensive instrumentation system known as an Accusonic 7510+ Series Flow Meter within the channel at a site located immediately downstream of Victoria Highway. This system is comprised of several mounted velocity sensors to profile and derive mean channel velocity (multi-path transit-time flow measurements) and an ultrasonic water level sensor to provide channel depth. Following this installation in 2009 a channel upgrade was also undertaken, whereby a concrete trapezoidal channel section (~50 m long) was consolidated in order to provide optimal, laminar flow conditions for monitoring by reducing eddy currents and overall turbulence. Acrolein injections also commenced in the channel to limit aquatic weed growth.

Various comments and reports were produced in response to Rubicon's recommended site configuration prior to installation as described above. Particularly relevant once again is an extract from the Water Corporation's review of the proposal:

"A stable depth versus cross sectional area relation is needed for discharge computation and therefore the guidelines suggest those sections subject to variability in bed level or bed profile should be avoided.

It is recognised in the Rubicon proposal that the M1 channel is subject to both siltation and weed growth, both of which will result in variations to the effective cross-sectional area of the channel. This means that, firstly, regular cross-sectional area surveys will be required to monitor changes in siltation and secondly, regular maintenance of the measuring reach will be required to control weed growth within acceptable parameters. These requirements necessarily result in additional operating costs over the life of the station, however, without a thorough analysis, it is difficult at this juncture to estimate those costs or alternatively, estimate the effects on data quality should those requirements not be met. Weed growth will also seriously attenuate or disperse the acoustic signal resulting in errors in the measured mean velocity. Again, it is difficult to estimate the net effect of these errors on the data quality without a thorough analysis" (Deane 2001).

Eventually the Water Corporation relocated its measurement point to the same location with the installation of an Argonaut SL-1500, a side-facing Acoustic Doppler Velocity Meter (ADVM) which profiles and measures the theoretical mean channel velocity in a two-dimensional plane. Defined by two acoustic beams which run at 250 to the channel cross-section it uses multi-cell velocity profiling (ten separate cells) to compute and record a mean velocity and a vertical beam (with applied height offset) and a pressure sensor to calculate and record area (see Figures 6 & 7).

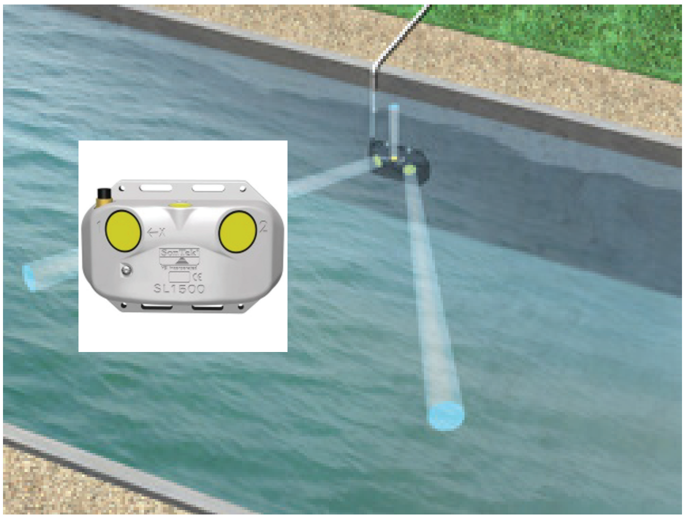

Figure 6. Pictorial representation of SL-1500 installation.

Figure 7. M1 Channel looking upstream concrete section.

Current Flow Measurements & Data Validation

Both staff from the Water Corporation's Asset Monitoring and System Investigations (AMSI) team and the Department of Water and Environmental Regulation (DWER) undertook a number of ADCP flow measurements along the M1 and S2 (downstream offtake) Irrigation Channel between 2019 to 2020 to add to observations obtained in previous years. While measurements over time have been undertaken for a myriad of reasons, most recently the aim has been to assess overall flow capacities and installed instrumentation accuracies (using OIC's Accusonic 7510+ and Water Corporation's Argonaut SL-1500).

The following equipment was utilised with relevant locations displayed in the below aerial image(s) Table 1, Figures 8 and 9:

- RDI StreamPro ADCP (DWER);
- SonTek RS5 ADCP (AMSI);
- SonTek RiverSurveyor M9 ADCP with RTK (AMSI);
- ADCP Traveller – NIWA (DWER).

All measurements recorded in WinRiver, RiverSurveyor Live and RSQ software systems, processed through QREV and stored on respective AMSI and DWER Hydstra databases.

Table 1. Key locations

Point	Description	Easting (MGA94)	Northing (MGA94)
A	Kununurra Diversion Dam	467398.846	8254102.808
B	M1 Channel Offtake	469775.258	8254037.601
C	Lake Kununurra	471726.305	8254120.069
D	Concrete Measurement Section (DS Victoria Hwy)	470183.134	8254944.880
E	Ivanhoe Bridge Crossing	470973.758	8256716.089
F	S2 Channel Offtake	470633.008	8260703.050
G	S2 Measurement Section	469621.250	8260898.190

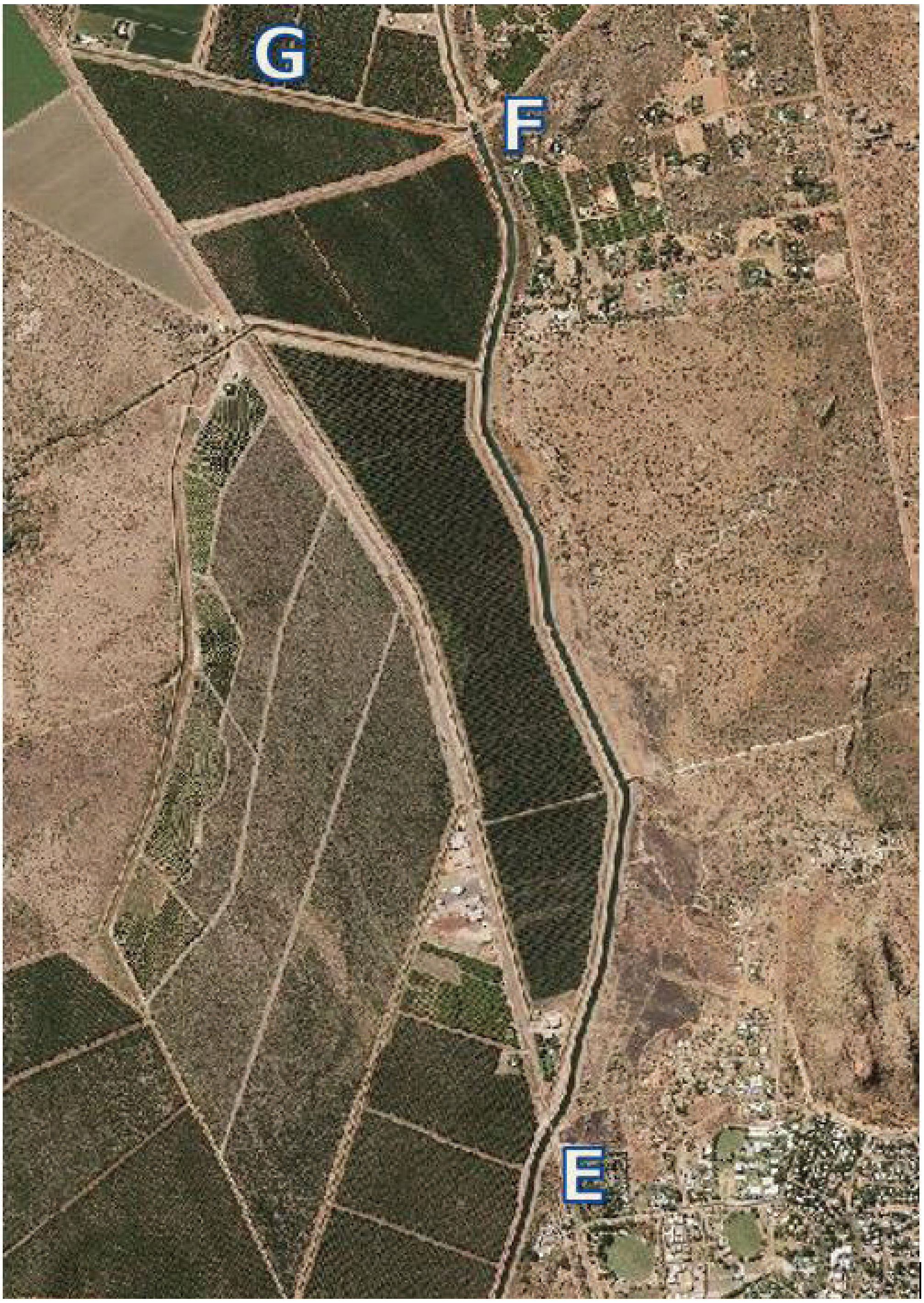

Figure 8. myWorld Aerial Imagery of Points G, F, E.

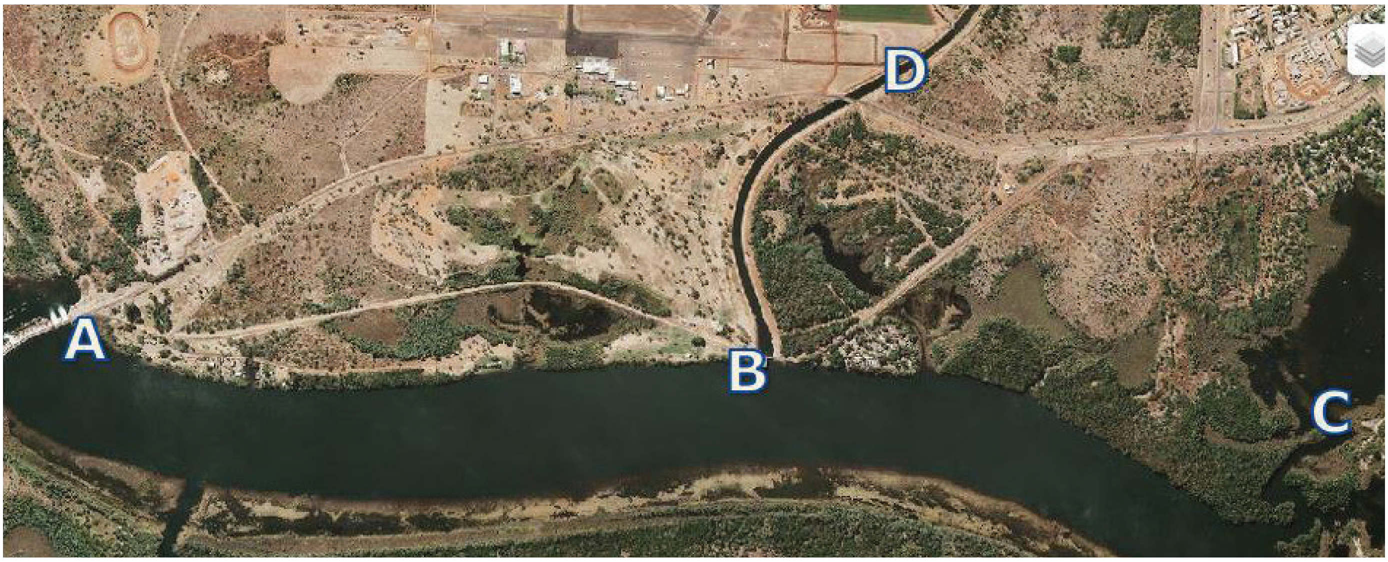

Figure 9. Close up myWorld Aerial Imagery of points A, B, C and D.

Figure 10. StreamPro ADCP Measurement.

Figure 11. StreamPro and M9 ADCP Measurement.

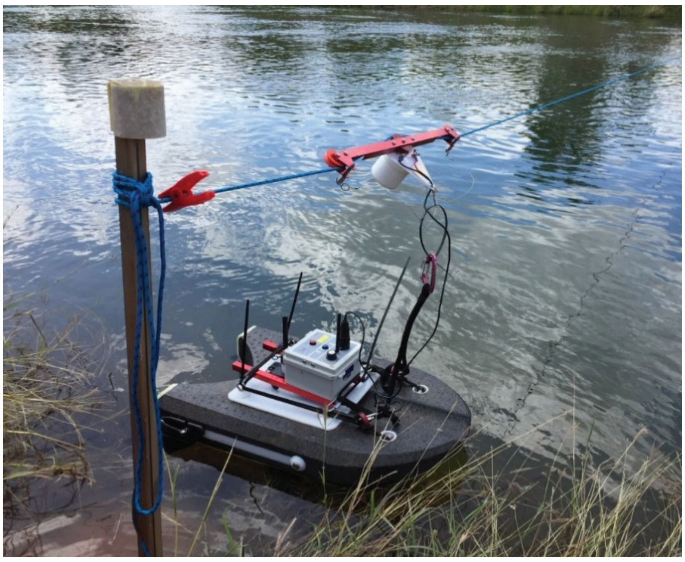

Figure 12. SonTek RS5 on ADCP Traveller – NIWA, M1 Channel.

AMSI and DWER were also requested to undertake some simplified channel bathymetry observations in order to ascertain the siltation and/or vegetation impact at Ivanhoe Bridge Crossing – a particular location of interest (see Figure 8, Point E). Heightened water levels and basic visual observations showed that, upstream of the bridge, there could be a possible impact on overall channel operation.

Two simplified cross-section surveys were carried out, upstream and downstream of the bridge, in attempt to show the channel profile and bathymetry. It should be noted that, as time was restricted, a full comprehensive channel review was not undertaken. The survey is therefore considered to be simply an indicator of apparent issues. Whilst RDI StreamPro operated by DWER struggled with profiling the centre of the channel (large amounts of silt and vegetation and low range Doppler frequencies meant bottom track was non-ideal) the SonTek RiverSurveyor M9 operated by AMSI clearly shows build-up of silt and vegetation on both the centre and right of the channel. Where previous channel measurements have shown a general depth of 2.5 m the most affected portions of the silted channel were 0.5-1 m deep indicating 0.5-1 m of silt and vegetation build-up *(see Figures 13 & 14).*

Note that a full-length longitudinal survey of the M1 Channel has since been carried out; initial profiles results indicate an average ~600 mm of silt throughout the channel reach.

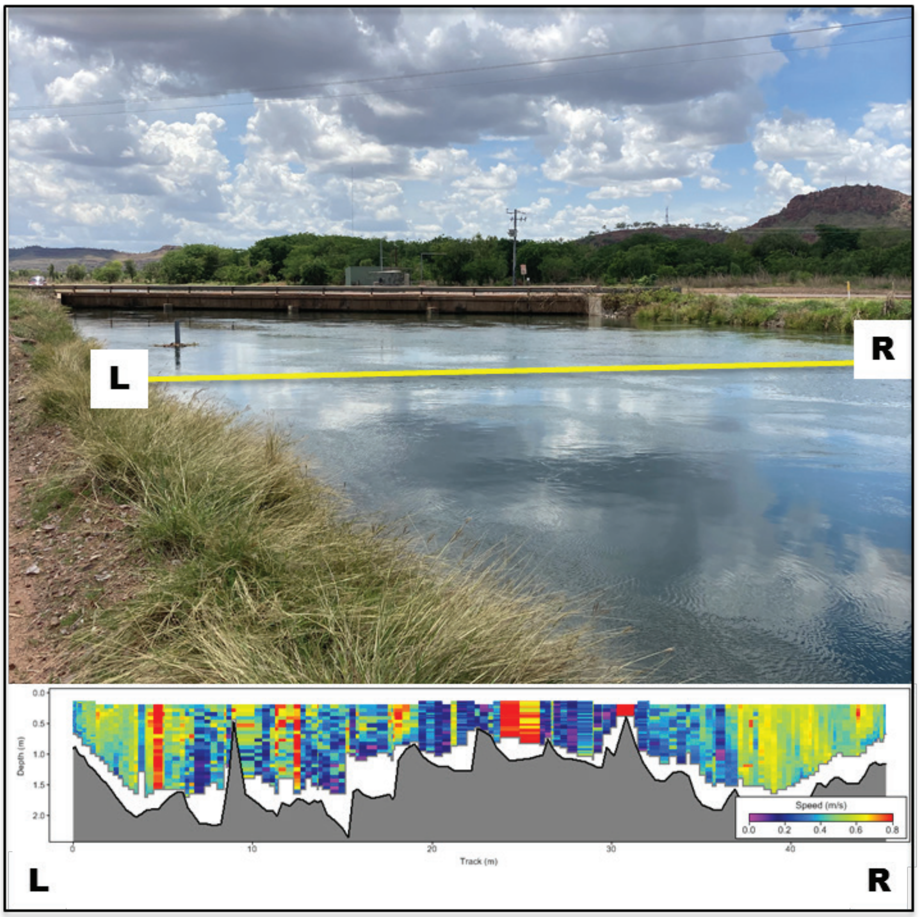

Figure 13. Upstream Cross-Section at Ivanhoe Bridge Crossing.

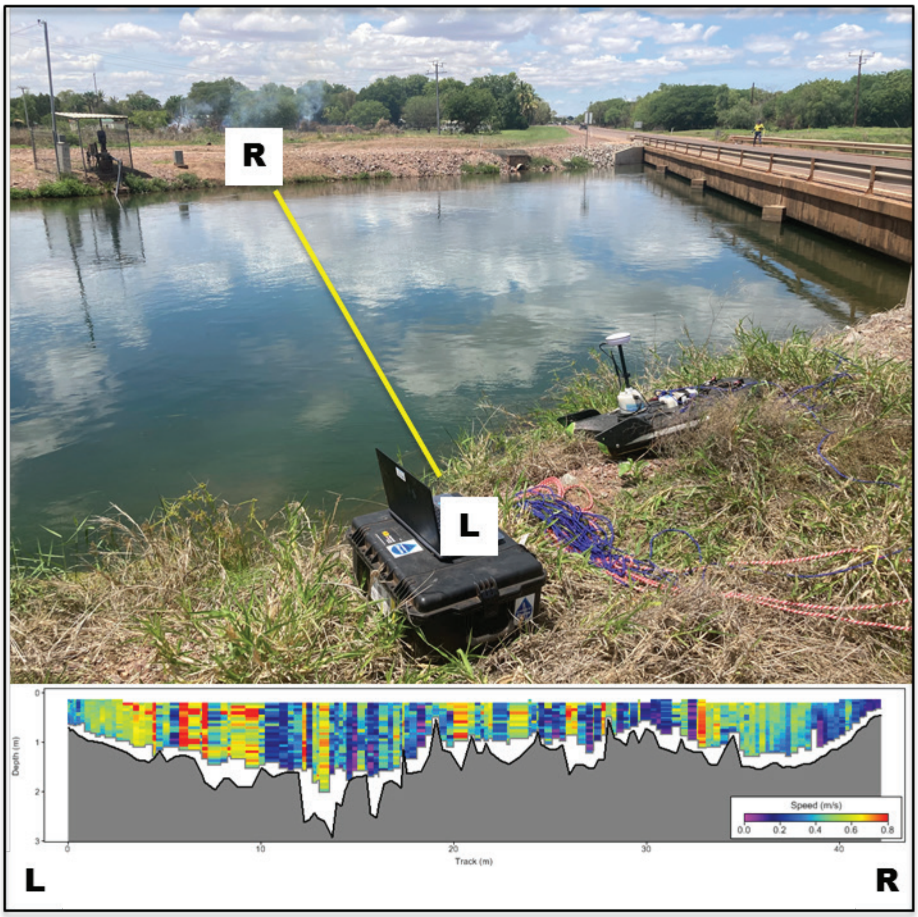

Figure 14. Downstream Cross-Section at Ivanhoe Bridge Crossing, E.

Discussion

Over the course of the operation of the M1 channel, measurement locations, observation methodologies and maintenance programs have been ever-changing.

From the recent conjunctive studies by AMSI and DWER to date it has become apparent that ongoing routine in situ flow observations are critical in order for relevant parties to understand the resultant quality of the flow records derived from their respective gauging stations.

Major points of note include:

- Instrumentation installed by both Water Corporation and OIC appears to be regularly affected by adverse channel conditions. ADCP flow measurements indicate the percentage of errors in both Accusonic 7510+ and Argonaut SL-1500 which are further exacerbated by ongoing vegetation build-up;
- Cross-section resurvey, routine sensor cleaning (including anti-fouling protection) and re-establishment and ongoing verification of Velocity-Index Ratings are recommended;
- Ongoing review of SL-1500 Beam outputs is recommended following review of ViewArgonaut stored metadata. See examples in Figure 15:

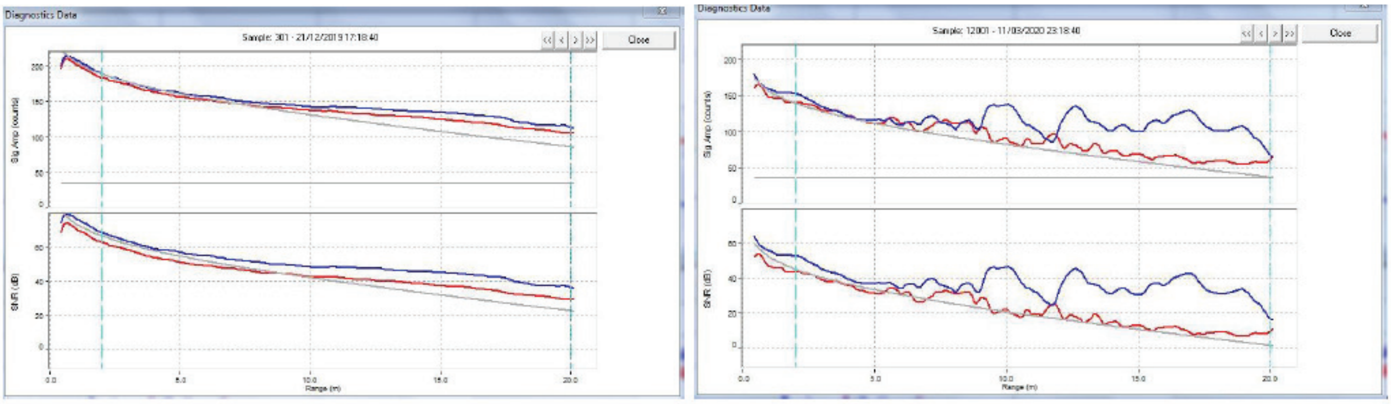

Figure 15. Ideal beam check scenario (left) and problematic beam check scenario (right).

- Siltation issues (such as the one displayed at Ivanhoe Bridge Crossing, E) are having an impact on the channel's ability to deliver the desired flows. The M1 Irrigation Channel has an allowed design specification Manning's n coefficient of n=0.03 however with assessed siltation levels across the channel the current configuration is more accurately n≈0.06 or higher. See below Manning's description Figure 16;

MANNINGS N CALCULATIONS

Values for computing Mannings Roughness Coefficient
(Adapted from Ven Te Chow)
$n = (n_0+n_1+n_2+n_3+n_4).n_5$

Parameter	Condition	Notes		Min	Max
Material	Earth		n_0		0.020
	Rock				0.025
	Fine gravel				0.024
	Coarse gravel				0.028
Degree of	Smooth	best obtainable for material	n_1		0.000
irregularity	Minor				0.005
	Moderate				0.010
	Severe	badly eroded banks of channel			0.020
Variation in	Gradual	*Change in cross section or*	n_2		0.000
channel cross	Moderate	*slope causing main flow to*			0.005
section	Severe	*shift from side to side.*		0.010	0.015
Relative effect	Neglible	*The degree of reduction of*	n_3		0.000
of	Minor	*effective area of cross section*		0.010	0.015
obstructions	Appreciable	*caused by stumps, boulders,*		0.020	0.030
	Severe	*debris etc.*		0.040	0.060
Effect of	Low	close cropped grass etc.	n_4	0.005	0.010
vegetation	Medium	tall grass, tree seedlings etc.		0.010	0.025
	High	scrub		0.025	0.050
	Very High	dense scrub, trees etc.		0.050	0.100
Degree of	1.0-1.2	*Ratio of meander length*	n_5	1.00	
meandering	1.2-1.5	*divided by direct length*		1.15	
	>1.5			1.30	

Manning's Equation

$$V = \frac{R^{2/3} S^{1/2}}{n}$$

V is average velocity (m/s)
R = hydraulic radius (m)
S = energy slope (m/m)
n = Manning's roughness coefficient

Discharge Equation

$$Q = \frac{A R^{2/3} S^{1/2}}{n}$$

Q is discharge (cms)
A = channel cross-sectional area (m2)

Figure 16. Typical Manning's n coefficients and equation configurations (Chow, 1959).

- SonTek RiverSurveyor M9 (with RTK) outperformed the RDI StreamPro with regards to the heavy vegetation/ siltation issues experienced at Ivanhoe Bridge Crossing;
- Water Corporation (AMSI) and DWER ADCP measurements were all within 5% of one another with the SonTek RS5 excelling in smaller offtake channels (S2) measuring between 75-85%;
- ADCP Traveller system (NIWA) was beneficial for measurement accuracies and processing through QREV (e.g. 300 s transects) however this can also be replaced easily by use of RTK systems such as the one utilised won the SonTek RiverSurveyor M9 in this case.

In an ever-changing and developing technical industry such as hydrometry, stakeholders need to be aware of the ongoing operational, maintenance and verification costs of monitoring installs.

The longstanding legacy of the M1 Irrigation Channel is one that sheds light on the need to provide routine control maintenance, regular instrumentation upkeep and a reasonable level of verification and calibration. These items need to be considered when calculating long-term asset costs and selection of instrumentation and methodology.

For example, the re-establishment of a Parshall (or similar engineering) flume control in place of an ADVM (laser, radar, pressure, etc.) is typically overlooked due to the more significant capital investment. However, in the long run it may prove to be the more cost-effective option due to the lower operational and maintenance costs. To the average asset operator these benefits can prove to be unclear if not clearly articulated by the hydrometric monitoring professional.

Conclusion

In an ever-changing and developing technical industry such as hydrometry, hydrographers need to be able to communicate to their stakeholders the need for ongoing routine maintenance and verification of monitoring installs (they are quite simply not a set and forget item).

The longstanding legacy of the M1 Irrigation Channel is one that illustrates the pitfalls if this is not done well. Initial capital expenditure of monitoring assets and instrumentation should not be an isolated point of reference in site and methodology selection. An ongoing relevant place exists for hydrographers in the advisement and verification dataspace, accurately quantifying and reporting on monitoring installation status and outputs to inform stakeholder confidence and influence decision making better.

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