# Australasian Hydrographer

## December 2016

AUSTRALIAN HYDROGRAPHERS ASSOCIATION

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# Contents

JACQUIE BELLHOUSE

# Editor's Introduction

Welcome to the December 2016 Issue of the AHA Journal and thank you to the Hydrographic community your prolific contributions. I hope that our readers continue to find some inspiration within these pages.

As you may have noted in the latest eNews releases, the AHA Strategies for 2016-2017 were have been introduced. These strategies, around AHA services to its members, include the production of publications such as the journal, E-bulletins, web articles, topic specific booklets, event proceedings and social media posts.

In alignment with this strategy, in 2017, the Australasian Hydrographer will be published on a quarterly basis, aided by your continued prolific contributions. If you do by chance feel motivated to contribute, please don't feel you need to wait for the next call for articles, put some notes together now and send them through.

In addition to the publications the AHA will continue to coordinate various events such as the biennial conference. Conferences such as this year's 18th Australian Hydrographers Association Conference, held in Canberra, are a great opportunity for members to meet and network. Other events the AHA will continue to provide include Professional development sessions and local events sponsored by our Corporate Partners, providing opportunities for members across Australia to meet and network in their home regions. After I finish writing this forward I will be attending the Perth AHA Hydrographers Christmas catch-up, the first event of its kind in over eight years.

This year I was fortunate enough able to escape work for a short while so that I could attend the our 18th AHA Conference. Entitled "Better Management of Water Resources, Technology, and Techniques & Applications", the conference was a great place to catch up with some long term friends and update myself on some of the newer advances in our profession.

I was so inspired by our presenters that I have decided to provide a selection of the papers, for the benefit of our members who were not so fortunate as to be able to attend. Each, for me, represents how far the field of Hydrography has come.

The first paper is by Elizabeth Fox from Opus in Wellington, New Zealand. This article is a great example of the quality of presentations we are seeing from our New Zealand counterparts as a result of the AHA's reciprocal agreement with NZHS. As a part of this agreement the winner of the best paper at the annual NZHS conference is invited to speak at the AHA conference, while the best paper at the AHA biennial conference is invited to speak in NZ.

The next two papers by Marcus Onken, Ventia Pty Ltd and Daniel Sinnott, WaterNSW, are for me great examples of how our counterparts are continuing to explore how the newer technology can help us.

During the conference and AHA AGM we were also fortunate enough to welcome some new Committee Members. Keep an eye out for their profiles in the coming journals.

Finally Season's Greetings and a prosperous (and hopefully wet!) New Year to all of our members.

Regards
**Jacquie Bellhouse**
Journal Editor

BILL BARRATT

# From the President

## Taking AHA to the next level

Over the last 16 years, AHA was resurrected by Alex Miller, and then capably developed under the leadership of Bill Steen. From a small club, it has grown to more than 250 members. It has

- advocated and helped deliver a nationally recognised Diploma;
- recognised professionals who are continuing to develop through a certification program;
- produced a biennial conference; and
- continued to produce a journal of technical articles.

In 2016 AHA has restructured the way it works:

## Governance

AHA is now following international standards in managing its affairs through a recognised Not For Profit governance structure.

It has recently completed strategic planning for the next 12 months (Ends Policies) and further forward.

It is working in a transparent way for the benefit of hydrography industry sector, the hydrographic profession and individuals.

## International

Internationally we are working with like-minded organisations and starting the process of writing MOUs.

We have started offering training and recognition of individuals in the region, particularly in countries that don't have their own national systems.

## National

Nationally we are focussing on training and recognition.

A new *Introduction to Hydrography* and training towards the new *Diploma of Water Industry Operations* will be offered in 2017.

We are working on the certification system, making it more credible and visible to employers and tenderers.

We aim to build a number of NATIONAL teams, drawing on members with appropriate expertise to assist:

1. The **Conference ThinkTank** to prepare the program for 2018.

2. **Industry (Training) ThinkTank** made up of representatives from water authorities and commercial industry providers who employ hydrographers to focus on Training outcomes.

3. **Consultant Register** starting with a repository of qualified (Cert IV) trainers that the organisation can draw on to prepare, implement and deliver training in 2017.

## Linkages

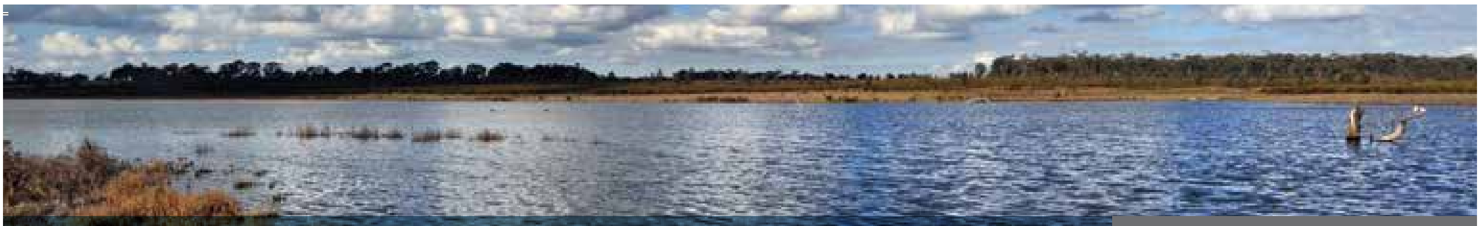
AHA aims to link members through workshops, field days, social events (like the Perth Christmas meetup) and social media (including LinkedIn, Facebook and Twitter).

- Link Partners with members through product knowledge sessions and sponsorship of AHA activities;
- Link AHA with other associations, government bodies and the private sector to make AHA more visible;
- Link WITH members through events, e-bulletins, journals, the website and social media.

The new EVENTS section in the website is the go to place for information about events run by (or in association with) AHA, its corporate partners and international partners.

So as we look to a busy 2017, I also wish you a Merry Christmas and hope you all have time to recharge over this holiday period.

Regards
**Bill Barratt**
President AHA



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# Implementation of National Environmental Monitoring Standards in New Zealand: benefits, challenges, and implications

***Elizabeth Fox***
***Opus, Wellington, New Zealand***

## Abstract

*There has been a significant change in the number and type of end-users utilising environmental data, shifting from primarily scientists and analysts to a wider demographic. With an increase in available environmental data on the web has resulted in the need for a clear, easily understood format describing what the data means, and if it is fit for intended purpose. In contrast to Australia, New Zealand's environmental monitoring industry had disparate standards on how to collect, process, and archive data. Environmental data from different agencies became difficult to collate and analyse, nor gave an indication to the end-user on its accuracy or reliability for analysis. This led to the creation of the National Environmental Monitoring Standards (NEMS) in 2009. With compounding problems for the end-user New Zealand has opted to move away from a national, centralised archive in favour of federating individual collection agencies' archives; forcing the need for quality control and standardisation across all environmental data collection agencies, enabling simplified product development for end-users.*

*NEMS provides nationally consistent procedures on how to collect, process, archive and assign Quality Codes to environmental data. Implementation of Quality Codes enables end users to utilise and review data that is comparable across multiple organisations. The Quality Code schema within NEMS gives important information regarding the reliability and accuracy of the collected environmental data, helping to determine what data is fit for specific purposes. At present, regional and unitary councils across New Zealand are implementing NEMS. Challenges have arisen adopting the new ways of collecting, processing, quality assuring and archiving environmental data, which are apparent when changing from individual organisation's standards to NEMS; making sure the end-user understands how this transition impacts the data for their intended purposes is vital. Overall, the implications of adopting NEMS will bring large benefits to managing, sharing and utilizing environmental data within New Zealand, particularly in servicing the growing number, and increasing variety, of end-users nationally and globally.*

## New Zealand history of environmental monitoring

The collection, processing and delivery of standardised environmental data has changed significantly since its commencement in New Zealand; Figure 1 illustrates a simplified timeline of events that have led the New Zealand environmental data monitoring industry to its present state. Understanding the history of New Zealand's environmental industry highlights how and why change occurred, and why moving forward into the future it needs to adapt to changing demands.

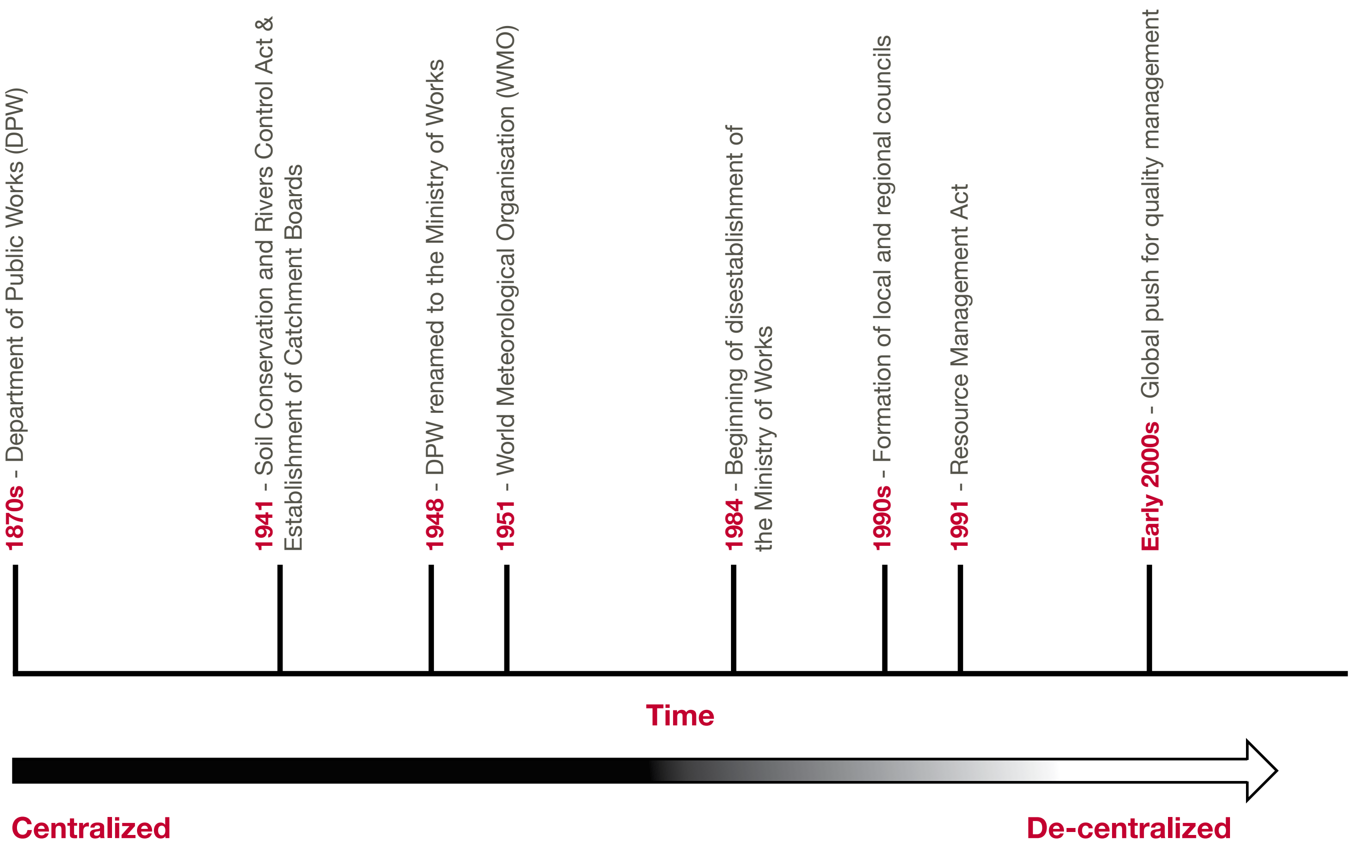


Figure 1: Simplified timeline of changes in the New Zealand environmental monitoring industry with key events that caused changes in the way data was collected, processed and managed.

The first government organisation that formed the foundation for the later environmental monitoring industry in New Zealand was the Department of Public Works (DPW). This was established in the 1870s to plan and construct railways across the country, combined with the construction of hydro dams to generate electricity. The main focus of the government organisation was the construction of infrastructure, which was a common theme for the next several decades.

A key turning point for the management of environmental resources occurred in 1941 with the implementation of the Soil Conservation and Rivers Control Act. This piece of legislation established the Soil Conservation and Rivers Control Council, where the powers of the Act made it mandatory for the promotion of soil conservation, mitigation of soil erosion, the control of flooding, and the use of land to achieve these objectives. This also led to the creation of catchment boards across the country, which were responsible for the organising and operating of soil conservation, river control, and requisite drainage works for communities within the catchments. Catchment Boards replaced the archaic River boards which were first introduced in 1884 as the first measure to control river ways in urban and rural areas. The establishment of Catchment Boards preceded the reformation of the DPW into the Ministry of Works in the mid-1940s. This is where standards began to be introduced in the collection and use of environmental data in order to meet the requirements of the Soil Conservation and Rivers Control Act 1941 (McLintock, 1966).

It wasn't until the 1950s to 1960s that environmental data standards, particularly in the realm of hydrology, really 'kicked off'. Known fondly as the 'Hydrological Decade' internationally, with the establishment of the World Meteorological Organisation (WMO) in 1951, the Ministry of Works adopted common international standards throughout its operating offices and with the individual catchment boards across the country. Therefore, all entities that practiced environmental monitoring were following the same standard of operating procedures. This provided national consistency, as there was only one set of methodologies to practice, creating constant and long term environmental monitoring records. The above methodology followed a centralised governance model for the data; after collection, the environmental data was sent to Wellington to be processed by the IBM 'supercomputer', forming one centralised archive. However, this did not last.

The disestablishment of the Ministry of Works began in 1984. From the late 1980s to the early 1990s was also the amalgamation of the catchment boards into the present day regional and unitary councils. One of the triggers of this was to tidy up local and central government; there were hundreds of catchments, and therefore catchment boards, across New Zealand, when many of these could be merged together, saving costs and allowing better allocation of funding. This led to a large, decentralising stage for New Zealand environmental monitoring; by the 1990s the old catchment boards were fully amalgamated into regional and local councils who became responsible for environmental data collection, no longer sending their data to one central archive. The decentralisation coincided with the Resource Management Act 1991 (RMA); this legislation greatly built on from the Soil Conservation and Rivers Control Act 1941 to further regulate and monitor our natural resources through environmental monitoring. With regional and unitary councils now responsible for the collection, processing, archiving and delivery of environmental data to their end-users led to changes to the original Ministry of Works standards of operating procedures. Due to funding restraints, end-user needs for specific regions and changes in organisations' mindsets led to changes in methodologies; the end product from environmental monitoring was no longer consistent across the country.

From the mid-1990s to the early 2000s there was a global push for quality management (not just for environmentally collected data). Quality management refers to the act of overseeing all activities and processes needed to maintain a set level of excellence for a product, with the aim to improve the product, reduce costs and increase efficiency. This includes the determination of a quality policy, creating and implementing quality planning and assurance, and quality control and quality improvement. A common quality management system that was implemented by environmental organisations in New Zealand were the ISO standards. This was a quality management system that provided a framework instructing agencies what they needed to do in order for their product (environmental data) to meet the ISO standards management and therefore be third party certified. This gave assurance to their end-users that the environmental data that they were using was collected and processed under a quality management system requiring standards and therefore gave further verification and reliability to the environmental data. The ISO quality management system was one example implemented by agencies, with other organisations creating their own general business and quality management processes, leading to a variety of environmental data management styles across the country.

This resulted in a decentralised governance model where the data collected and processed was no longer truly comparable, with large variations on data quality, methodologies and end products. This was not an immediate issue; what triggered the need for a change moving forward into the future was the changing requirements of the end-users.

## The changing end-user

The advancement of technology has revolutionised the way environmental data can be shared between individuals, organisations and countries since the early 1990s. No longer are the end-users just scientists or analysts, but range from school aged children to retirees. However, with changes in standards and improvements in technology, not all environmental data is the same; changes in instrumentation, methodologies and processing techniques all impact the reliability and quality of the end product (the environmental data). This message is important to get across to the end-user so that they can better understand if the data is fit for their own purposes.

Herein lies the problem; with increasing end users there is a clear decrease in understanding of the data and its associated metadata (see Figure 2). This is very important as a lack of understanding can lead to misinterpretation of the data, falsifying claims and leading to disastrous impacts to the environment if incorrect analysis results in execution of infrastructure. Due to the decentralising of the environmental sector in New Zealand adds further complexity to the issue; data from different agencies cannot necessarily be comparable. Moving forward, the status quo no longer met the requirements for the end-users, who needed an easily understood, consistent approach to the collection, processing, archiving and delivering of standardised environmental data. This was a major driver for the creation of the National Environmental Monitoring Standards (NEMS).

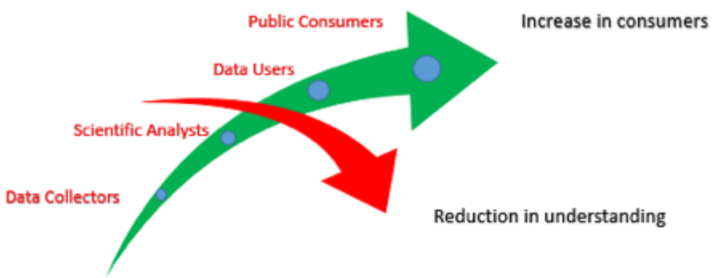


Figure 2:
Schematic of the increase of consumers of the data leads to a decrease in understanding of the data.

## Creation of National Environmental Monitoring Standards (NEMS)

The environmental monitoring industry in New Zealand needed consistent, code of practice operating standards to address meeting the end-users' demands as previously outlined. From 2009 this began to be developed, with the first proposal presented in 2011 by the Local Authority Environmental Monitoring Group (LAEMG) to the Resource Managers Group (RMG) and the Regional Chief Executives Group (RCEG). This was endorsed and environmental monitoring experts from multiple groups were appointed to form a Steering Group to develop the set standards (Watson, 2015). Initial funding from the Ministry for the Environment (MfE), with the rest derived from a collaboration of regional and unitary councils across New Zealand, set the groundwork to focus on coming up with universal measurement standards with an underlying, universal Quality Code Schema. Participation from the councils and other Crown Research Institutes (CRIs) led to the first draft proposals of the standards in 2012, which were coined the term 'National Environmental Monitoring Standards' or known as 'NEMS' in its abbreviated form (NEMS, 2013).

The whole process was extremely collaborative, with people from a variety of organisations pulling together to combine their knowledge and expertise for specific measurement standards. By 2013, the first version for nine standards was released in June. All of the documents are publicly available, and can be viewed by visiting the Land, Air, Water Aotearoa website at **www.lawa.org.nz**. This website is a collaboration of organisations telling the story of New Zealand's environment, helping local communities understand the state of their environment by providing information regarding the quality and availability of their natural resources (NEMS, 2013). The NEMS documents available on the LAWA website will be continually reviewed by their collaborators, ensuring it is still a team approach, with feedback received from the first versions being taken into considerations for the next version releases.

The core difference when creating these sets of measurement standards was the move away from recreating something similar to what was done by the Ministry of Works in the 1960s, of a centralised governance model. Instead, the creation of NEMS was developed implementing a federated system of data management mindset, whereby the local data recording agencies became the authoritative data holders of what they collected, processed and delivered to the public. As illustrated in Figure 3, this allowed the authoritative data holders more control on what they provided to the public, as they had the best understanding of the data that they collect and process. The authoritative data holders would also have the sole responsibility of the data they managed. However, since all agencies would be collecting, processing and archiving the environmental data to the same standards (NEMS) the end product would be a cohesive, standardised dataset. This meets the needs of the end-users that require environmental data that can be compared, contrasted and relied upon to meet the same standards.

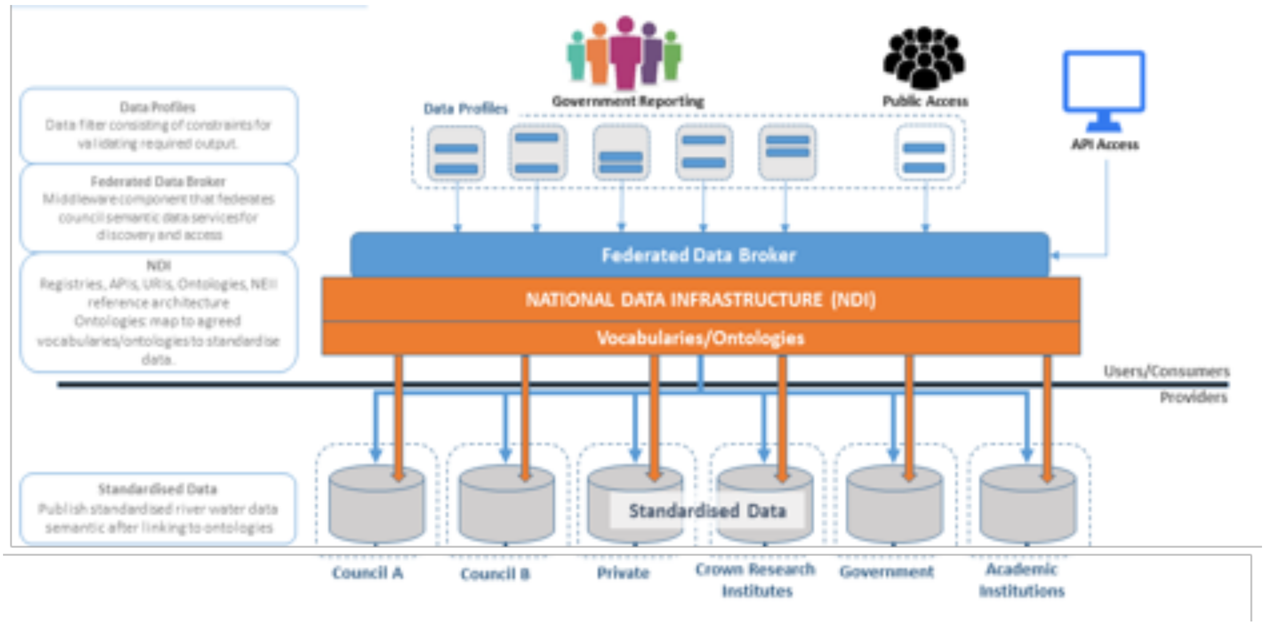


Figure 3: Federated data system model that NEMS was influenced, whereby each authoritative data holder is responsible for their own environmental data, collected to the same measurement standards as outlined in NEMS. At present, individual data can be retrieved from individual data authorities, though moving forward the idea of one 'Federated Data Broker' where the end-user can access all the required information is an option.

## National Environmental Monitoring Standards (NEMS) & National Quality Code Schema (NQCS)

The National Environmental Monitoring Standards (NEMS) are standards, or Codes of Practice, that describe how to collect, process, retain and archive environmental data. These measurement standards were devised using 'best practice' methodology across national and international standards, using ideas from what is currently done in New Zealand as well as from the WMO. Across all measurement standards NEMS utilises a common National Quality Code Schema (NQCS) where a common quality code can be assigned to any data source that allows it to be easily compared and contrasted by the end-users. The NQCS further provides internal linkages between the organisations' quality management systems with the nationally developed monitoring standards (NEMS) (see Figure 4). The importance of the NQCS as part of NEMS is very relevant when considering the end-users' needs; the schema provides insight and detail of potential issues associated with the provided datasets and highlights the need to review supplementary metadata. It engages with the end-user, stimulating them to question whether the data is suitable for their purposes. Furthermore, as the schema has the same foundation across all data sources, and can be implemented by any organisation, it provides a nationally consistent quality code schema that enables the end-users to consistently utilise and review environmental data sourced from multiple organisations.

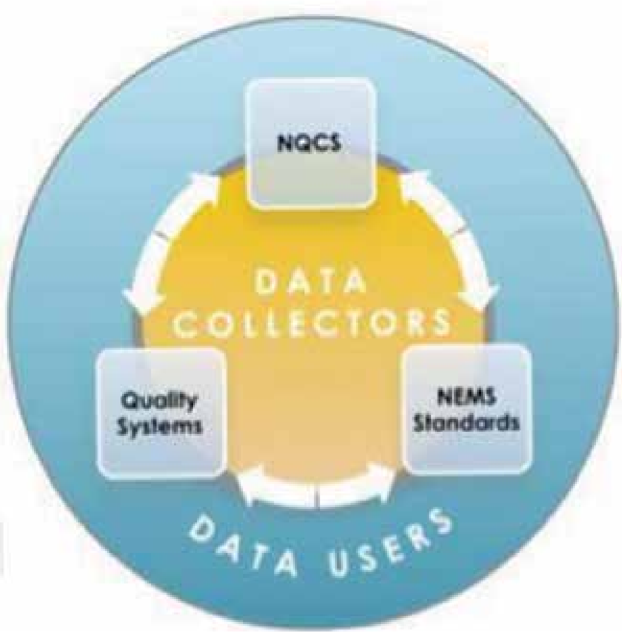


Figure 4:
The linkages between the NEMS, NQCS and Quality Systems (QS); the QS requires standards, which require codes of quality (NQCS) to assist with the quality management of the system to continue to improve on the product. All three are key components to produce good environmental data.

The NQCS is divided into six 'zones of quality' that apply to all data sources. These six zones have a parent code ranging from 100 to 600 (the number '0' is given to data that is not assigned a code). As described in Figure 5, the highest numbers (400, 500 and 600) refer to data that is considered 'poor', 'fair' or 'good' respectively in regards to the measured parameter. The codes 300 refer to 'synthetic', 200 to 'unverified or cautionary' and 100 as 'missing'. However, within these zones the data can be further quality coded with the use of Child codes to further differentiate the quality of the data.

One of the unique aspects of NEMS and the NQCS is the use of colour. Each of the 6 zones of quality has an associated colour to the quality code of the data. This is to aid the end-user in identifying how good the data is under the standard, whether or not the data is suitable for their needs and further engaging those to investigate the metadata associated. When one sees a colour change it should prompt the question as to why the data quality has changed; has something happened on site at the collection stage, has the data been edited to make it more representative, is the data faulty for my needs? These are the questions the colour change of the quality should be prompting. The quality of the data therefore becomes more transparent and easier to understand for the end-user visually rather than relying solely on numbers that could potentially be ignored.


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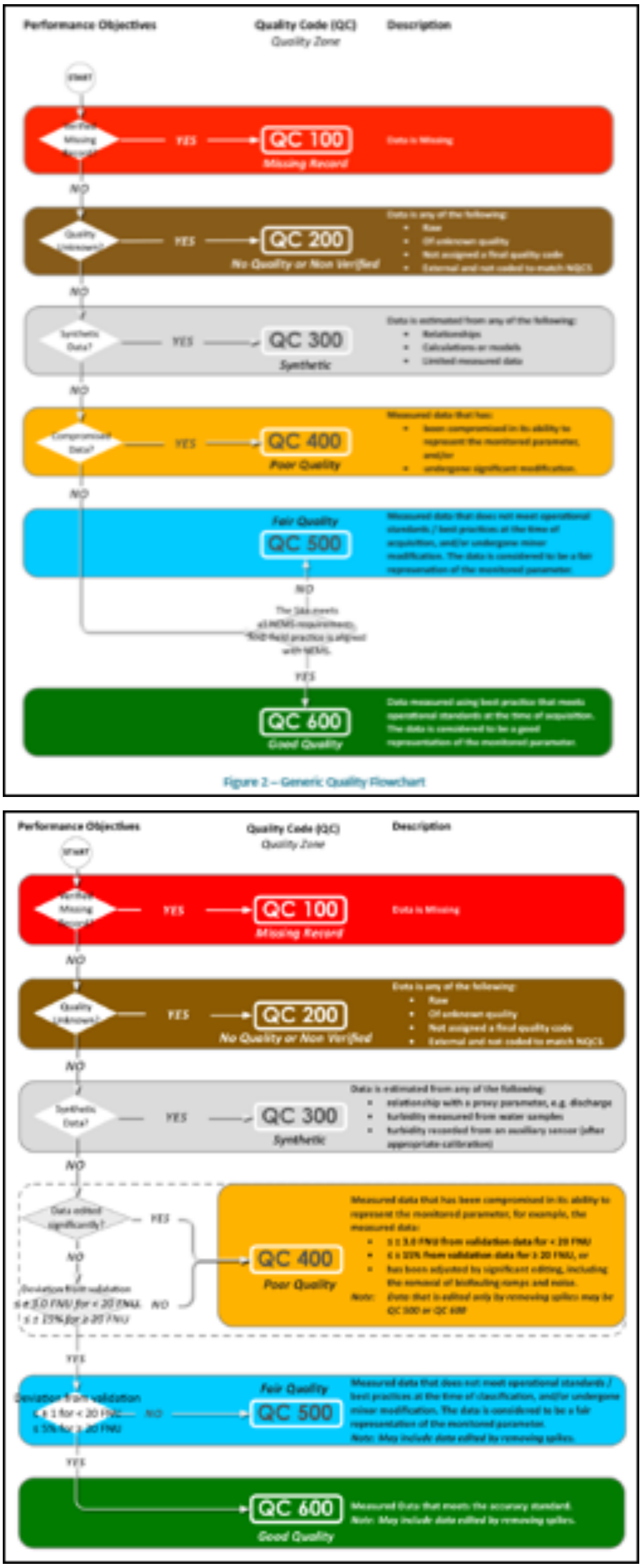


Figure 5: The National Quality Code Schema (NQCS) that is applicable to all data sources (top), with an example of a specific data source (Turbidity) (bottom), displaying how it utilises the same six core bands to differentiate the data based on it meeting the NEMS requirement.

## Implementation of National Environmental Monitoring Standards: case study using Horizons Regional Council data

Moving forward, NEMS is slowly being implemented across the country, with regional and unitary councils leading the way. Below are some examples of the benefits and challenges that Horizons Regional Council (HRC) has encountered when implementing NEMS for their environmental data. This region is based in the central to lower section of the North Island, from the east to west coast (see Figure 6). At present, due to current resources, Horizons Regional Council has adopted the first version of NEMS (2013) for Water Level, Water Temperature, and Rainfall data collection, processing and archiving of the data. Prior to this, like many New Zealand organisations, they had their own in-house Standard Operating Procedures (SOPs) detailing the above processes, with an overarching quality management system.

Figure 6: North Island of New Zealand, with the area in dark pink the Horizons Regional Council area.

One of the main benefits that immediately enhance the environmental data is evident for Water Level in informing the end-user through the NEMS quality codes (see Figure 7). The changes in colours pinpoint changes in the data meeting the measurement standard. Over a 16-year period for this site the quality, and therefore reliability, of the data has changed over time in reference to the standard, with the majority classified as 'good' but also with some areas coded as 'cautionary/unverified'. Without the NQCS of the NEMS it would not be evident to the end-user how the reliability, accuracy and applicability of this data set has changed over time; the assumption would be that if data is there, it is suitable for analysis. It prompts the end-user to further investigate the data in a clear, visually informative way.

This also allows data that may be hard to verify to still be included, allowing the end-user to make the decision whether or not to include it. For example, in the data set illustrated in Figure 7 the highest peak in record occurred in February 2004. This was a large-scale flooding event across the entire Horizons region, causing hundreds of millions of dollars' worth of damage. Interestingly, the recession of the peak has been quality coded as QC 300, defined as synthetic data. This is a clear flag for the end-user; why has synthetic data been generated for this period? Upon further investigation it would appear instrumentation failure resulted in missing data during this period, which has been filled by generating synthetic data. Therefore, depending on the analysis or use the end-user may have intended for the data, the use of this synthetic data may skew their results. NEMS provides this extra detail for the end-users adding further value to the environmental data by providing more information in a simple, easily understood manner.

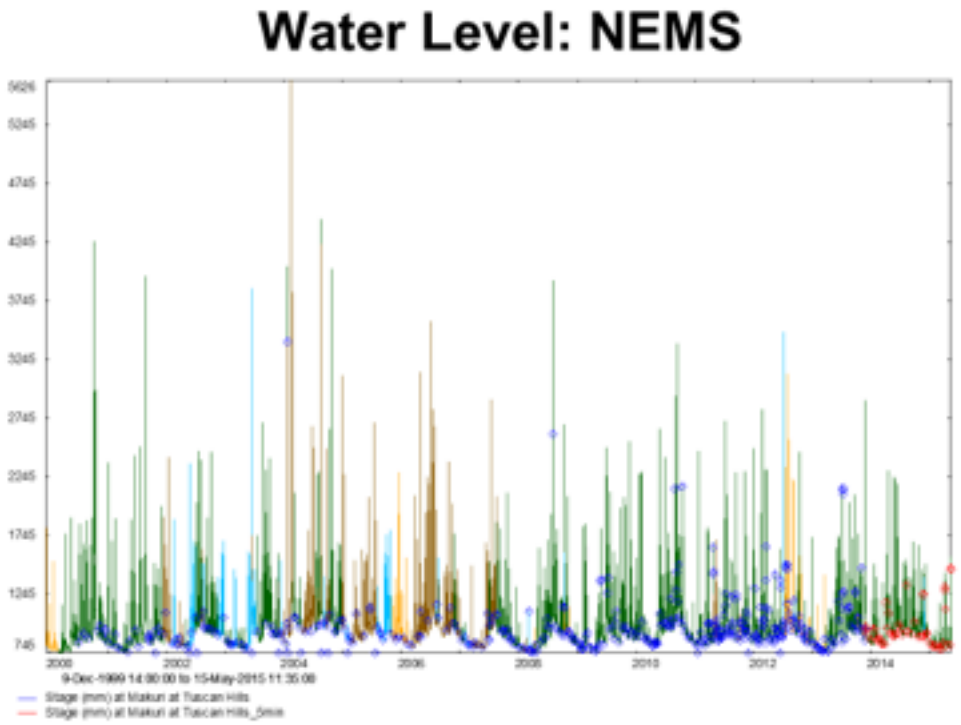


Figure 7: Water Level data from a Horizons Regional Council site (Makuri at Tuscan Hills) quality coded to the NEMS Water Level measurement standard. Blue diamonds represent on site verification of the data that is one of the components used to quality code the data.

One of the largest challenges Horizons Regional Councils, and other environmental data recording agencies face, is transitioning from one set of individualised measurement standards to a cohesive, federated data system model. Of particular concern is around getting the message across to the end-user what it means for the data if its quality changes under the new standards. It raises the question of what will happen to the data collected, processed and archived prior to the adoption of NEMS; will it get re-quality coded to match NEMS, assigned a '0', null or 'QC 200' for unverified/cautionary data, or will a 'draw a line in the sand' approach be taken where the standard will be implemented at a specific date & time with all previous data left as is (regardless if assigned a quality code or not under a previous standard). The end-users need to be considered in whatever final decision is made, as ultimately they are the ones utilising the data, so it needs to be as easy and as clear as possible for their benefit.

The difficulties HRC faces are that their previous standards used a similar quality code schema, with the same colours, numerical system and basic definitions, as that of NEMS. Figure 8 gives an example of Rainfall data under the HRC Standard and the NEMS for the same period of data. The two standards have different tolerances of acceptable deviation of rainfall measured at a site; the NEMS defines QC 600 'good' data as deviation < 10% whereas HRC requires <5%. The changes in the standards can lead to the assumption that the data has 'magically' gotten better or worse over time, which is not a true reflection of the end product of the process.

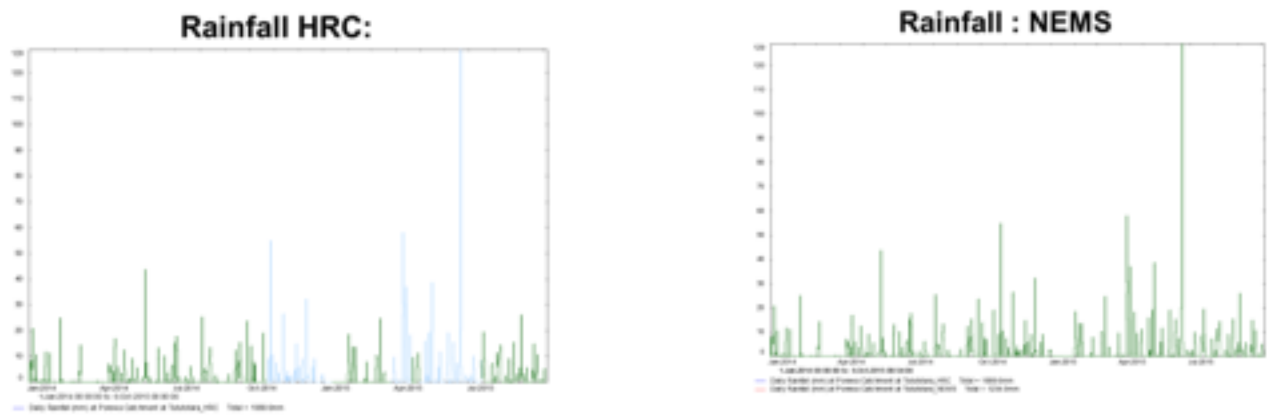


Figure 8: Comparison between the HRC and NEMS standards for collection and processing of the data. In this case, the HRC has a lower tolerance of acceptable deviation between the Primary Reference Gauge (i.e. Check Gauge) and the Primary Intensity Gauge (e.g. an OTA or TB3 intensity rain gauge sensor). Resulting in a lower Quality Code (QC) assigned to the data.

At present, HRC have taken a 'draw a line in the sand' approach as it is the most effective in regards to time management (back quality coding from one standard to another is time consuming) but is not necessarily the final decision. Because NEMS is currently in the process of being reviewed to create the second version for each standard, the requirements may change, resulting in shifts of quality for the data. Therefore, the concept is not set in stone, but has a degree of fluidity to it meaning back applying a new standard may not be the best way forward.

## Summary

Throughout the New Zealand history of environmental monitoring, we have gone through a centralised system of data collection, processing and delivery that was acceptable at that time as it met the needs of their end-users. However, following decentralisation, and the growing end-user needs, this no longer kept up with what was requested. This resulted in National Environmental Monitoring Standards, a federated data system with a National Quality Code Schema. The implications of NEMS will allow end-users to fully engage with the data, and stimulate the end-users to investigate the data further along with the associated metadata, which can be ignored or forgotten come analysis time. The consistent measurement standards, once adopted by all, will allow easy comparison and contrasting of environmental data. Individual agencies can have immediate benefits of implementing the NEMS, as shown by Horizons Regional Council, but also challenges if they already have their own schemas in place; the question still remains as to how we will integrate historic datasets with the new measurement standards.

## Acknowledgements

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# Use of smartphone apps in groundwater field data collection

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## Abstract

*With greater focus on groundwater resources than ever before, and advances in monitoring technologies, the site visit has evolved from collecting a single water level at each bore, to encompass a range of additional parameters, information about the site, asset management and safety information. With the growth of the data record per site, the challenge to ensure the quality, consistency and completeness of groundwater field data grows as field programs evolve. Following industry trends, we are now collecting more data, at more sites, and with a requirement to continuously improve on the quality of the data. App technology represents an ideal solution to capitalise on the features of the existing hardware already being carried by field parties, to improve the efficiency, consistency, quality and volume of groundwater data.*

## Introduction

The core measurement of any groundwater site visit is the Standing Water Level, and the collection of this measurement has traditionally been via a simple paper field sheet accompanied by the date and time, with a column for any additional comments. The paper field sheet, whilst still in use, has been progressively brought into the digital age utilising the predecessor to the smartphone - the 'palm pilot', or through the use of small ruggedized laptops. The primary reason to visit a groundwater bore remains (in most cases) to collect a water level and quality measurement, however with significant travel times between sites, there is an opportunity to add value to measurements by collecting a lot more data and information at the site, without an appreciable increase in the overall time spent on the field program.

Additional measurements and information support the readings, allowing the measurements to be further checked, validated, queried and explained, thus improving the overall quality of the dataset.

The visit is also an opportunity to collect information regarding site safety and access, improving the safety of field personnel for future visits, and if managed in a structured manner, ensures information transfer about site access can be passed between field personnel, allowing better planning and preparation, and safety and access information can be easily reviewed by supervising personnel.

With additional measurements and information being collected, the visit also presents an opportunity to track the condition of the monitoring bore from an asset management perspective to identify and record any maintenance requirements.

Whilst the trend to collect more data per site has the potential to improve in all of the aforementioned areas, to realise these benefits, and get the full value of the additional data, the process for collecting the additional data needs to be carefully structured, otherwise there is a risk of just collecting data for data's sake. Going from a single water level per site to encompass all the additional information about a site and the visit, the overall volume of data has therefore grown, and there is a significant challenge to securely and systematically record, transfer, store and review large volumes of data to maximise the quality, minimise losses, and make it quickly and easily accessible for the project personnel, field personnel and the end-user. It is also important to feed data and information back into the program to inform future visits and measurements.

With the increased volume and usage of groundwater field data, the flow of data has therefore grown in complexity, and smartphone apps and their connected databases and management interfaces represent a way to convey field personnel through the numerous additional requirements, ensuring nothing is missed, adding minimal additional time in preparation or onsite, real-time checking of measurements and minimal post-visit input.

The use of traditional paper field sheets means a duplication of effort and potential for the introduction of transcription errors, with handwritten field data generally being manually typed into a database. We set out to develop our own custom smartphone application to streamline the scheduling, collection and presentation of groundwater monitoring data. The use of smartphone apps can provide an intuitive workflow for technical staff to collect environmental data in the field, ensuring nothing gets missed, and providing information to the field operator as they move through the workflow. Rather than being controlled by separate systems, the workflow can also integrate controls on safety, quality, environmental and legal requirements of any field-based task.

## Key Features

Our app, developed in-house with assistance from an app developer integrates with a server-based SQL database and can exchange data in either direction whenever there is appropriate mobile data coverage. The application utilises the device's location services (GPS), data services and camera to deliver the following key features;

- Nearest bore – Identifies the bore closest to the user. This feature greatly reduces the likelihood of data being entered against the wrong bore ID and proximity warnings are displayed if the user attempts to enter field data when not physically at the expected location.
- Historic data graphs – Historic data is presented to the field officer as a reference. The current reading is plotted instantly on the hydrograph to allow for real-time field data validation against historic measurements.
- Photographs – Automated categorisation and naming of photos.

A series of supporting web-based applications have also been developed, allowing administrators to interface with the database to schedule tasks, check metadata and validate monitoring data.

- Web-based database – Used by Project Managers to plan runs, schedule work, optimise routes and review safety systems. Stores all historical records as soon as they have been collected in the field;
- Data validation – Used by Data experts to view the measurements collected in the field and check them against the historical record. Accept, amend or reject measurements for release to your client. Check and add comments before release;
- Data viewing portal – Used by clients and Project Managers to view monitoring data, photographs, maps and other bore metadata. Check photos prior to being released to the client;
- Image Manager – Search for bore photographs by date, bore or photo type.

Smartphone technology is being used as the platform for a custom developed application that has streamlined the collection of groundwater data from the field, resulting in improved efficiency, safety and data quality. By comparison with 'off the shelf' alternatives, working closely with a developer has made it possible to tailor solutions specific to requirements.

## Pre-Run Activities

The field workflow is controlled from the pre-run planning stage, when field personnel are typically in the office preparing to undertake the monitoring run. The key features as shown in Figure 1 allow for the following aspects of the planning to be controlled, and a series of lockouts ensure the app workflow cannot continue without completing each phase of the planning activities:

- Monitoring Run selection – A monitoring event or run is made available only during the period specified that the event needs to be undertaken, controlling the timing of monitoring;

- Equipment Selection – Based upon the tasks allocated to a specific monitoring event, the field personnel select the appropriate measurement equipment, including those required for check / verification readings. For instance, if the task of 'bore depthing' is scheduled for the monitoring event, then field personnel will be prompted to select the particular depthing tagline to be used for the event. It is not possible to proceed to the next part of the workflow until all the required equipment has been selected. Once selected, the equipment is 'checked out' for use, and cannot be selected by another field party. Equipment is linked to our calibration database, therefore ensuring only in-service equipment within calibration are being utilised;

- Quality Controls – critical components of the Ventia Quality Management system are built into the workflow and field personnel are required to answer a series of questions to confirm they have undergone the appropriate training and planning activities prior to undertaking the monitoring event.

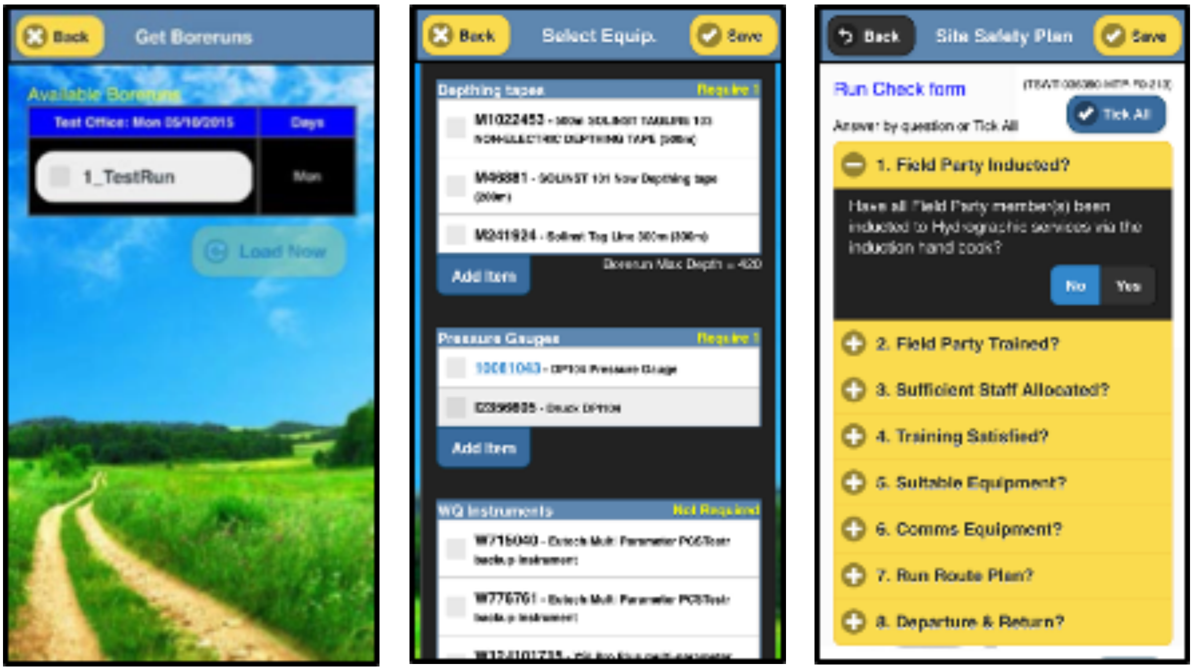


Figure 1: Pre Run Planning, Equipment Selection and Safety / Quality Checks.

## Safety Controls & Task Instructions

Safety processes and checklists, previously controlled by paper field sheets, are now integrated into the app workflow, allowing safety processes such as site safety checklists, risk assessments and Personal Protective Equipment reminders to be built into the workflow. Figure 2 shows an example of the checks and task allocation fields.

On large monitoring programs featuring potentially thousands of bores, it is important to note the most basic of information - whether or not a bore could be accessed. This simple question reduces a lot of unnecessary work when compiling final datasets. Should a site have access issues, this is flagged and an opportunity to provide additional supporting comments, with a selection of pre-filled options available, or the option for freeform text.

The list of tasks are pre-entered by the works coordinator, and appear in the workflow as mandatory fields for data entry. Any mandatory task that cannot be performed is noted with a supporting explanatory comment entered to feed the information back to the works coordinator, downstream reporting teams and ultimately the client. This process ensures that all scheduled measurements are collected, and nothing is missed.

In addition to the mandatory pre-set tasks allocated to each individual bore, free-form tasks can be selected from a task library for addition, if, for instance, resolving a maintenance issue that has been observed onsite would be assisted by the collection of additional data such as a depth measurement, additional photos, an ad-hoc water quality measurement or similar.

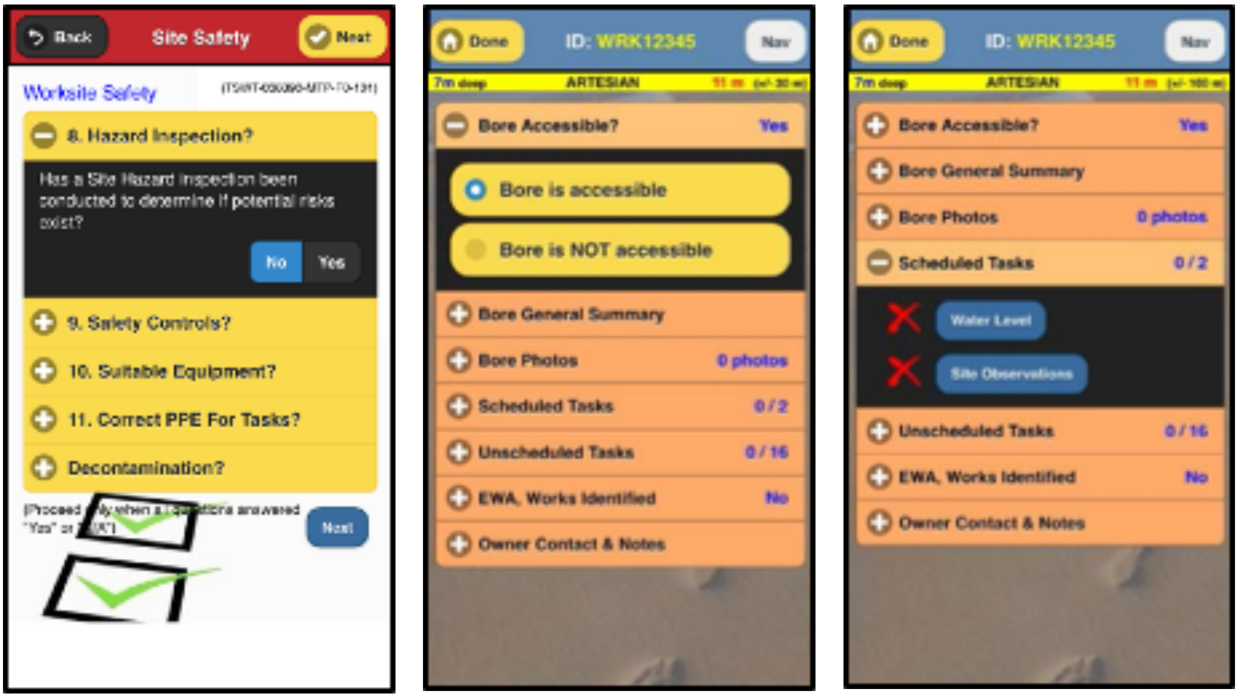


Figure 2: Site Safety and Task Instructions Screens.

## Data Collection & Onsite Data validation

The aforementioned planning, safety and quality controls all contribute to improvements in data quality through increased validation, completeness of records and additional supporting information, this leads to greater rigour in the data being collected, and therefore an increased level of confidence in the data being collected. Once through these phases the workflow leads into the data collection screens. Whilst other screens are built into the complete workflow, Figure 3 presents a subset of the main screens available to field personnel:

- Water Level & Water Quality – utilising mobile cell connectivity back to the primary database, all measurements are validated onsite. If a measurement is entered which is outside historic bounds, or changed significantly from previous measurements, then the user is alerted to check the measurement and provide a secondary measurement as confirmation. A hydrograph is also displayed which allows for a visual assessment of historical measurements and data can alternatively be viewed in a table. The quality of data is further controlled by imposing the number of significant figures.

- Reportable Observations – dependent on contractual and business rules, certain observations or events may constitute a 'reportable' observation where nominated personnel must be notified of the event, such as the project manager, the safety team, or the client. Should such an event occur, this is entered into the notifiable observations field, and the works coordinator receives an immediate email notification, allowing follow-up with the relevant contacts, and also allows follow up with field staff whilst still on site to capture any additional information not captured initially.

- Maintenance requirements for asset management – any additional maintenance requirements that cannot be closed out on the visit are recorded, with all relevant measurements, photographs and comments recorded to facilitate accurate scoping and costing of the maintenance works to be completed.

Additional data fields not discussed here include water quality, bore depth, headworks and infrastructure measurements, scheduled, unscheduled and maintenance photographs.

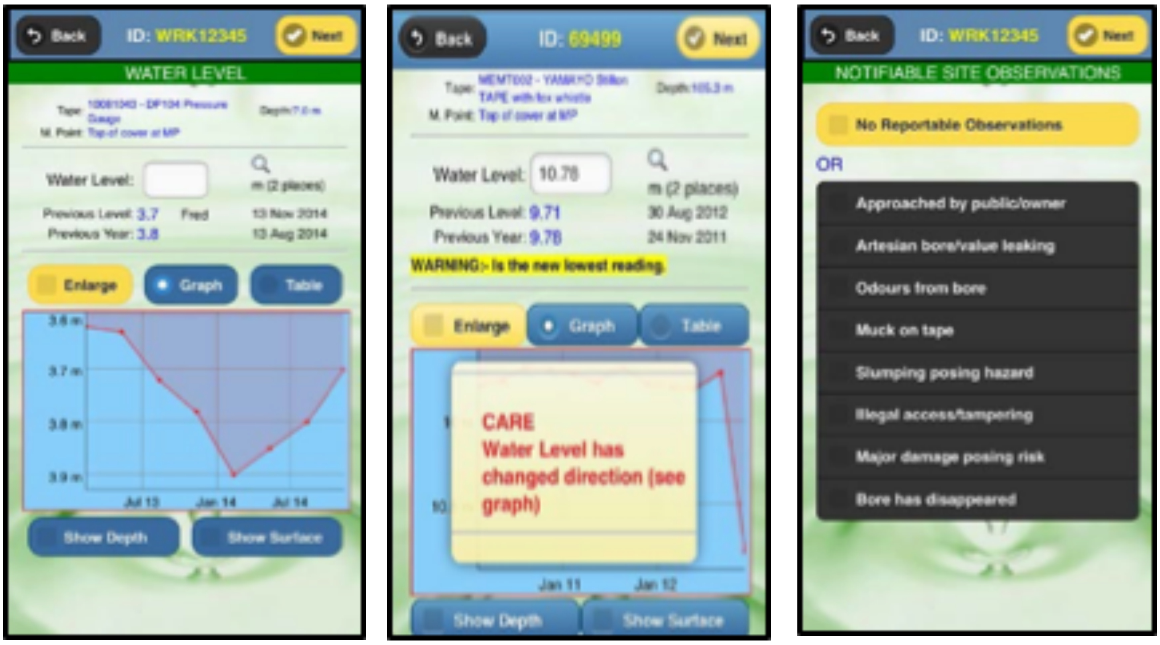


Figure 3: Data Collection Screens.

## Run Finalisation

Once all tasks have been completed at all allocated bores within a run (or at least accounted for by way of explanatory comment), then the user finalises the run as Figure 4 shows. At this point the user is given the opportunity to review a summary of the tasks completed on the run, check any not done and submit the run for finalisation. This process is secured via a password, as a way to ensure that the run cannot be inadvertently finalised before they actually intend. Once the run has been finalised, a new run can be downloaded if available to the user.

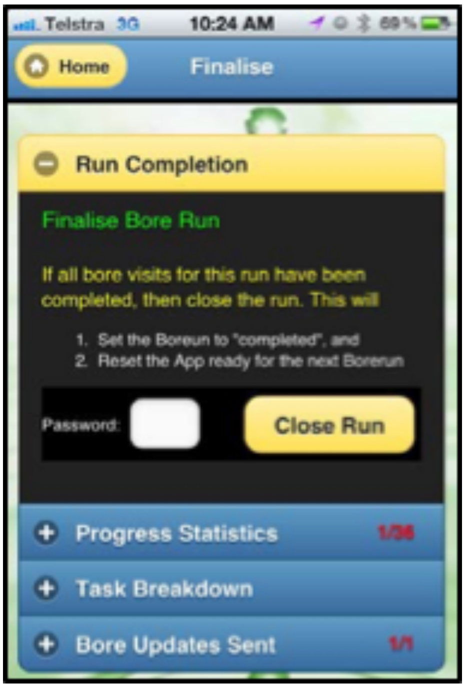


Figure 4: Run finalisation.

## Additional Interfaces

Whilst this article deals specifically with the smartphone app, the app is not a stand-alone utility and is at the centre of a broader system which encompasses Run Optimisation & Mapping, Scheduling, Data Validation, Data Display and Image Management.

## Route Optimiser

Route Optimiser uses site location data and client scheduling requirements to plan works schedules and determine the most efficient route between bores. It reduces the time taken to complete observations across vast bore networks, improves safety for our field team and increases data accuracy. Route Optimiser connects directly to our field staff via the 3G/4G cellular network and acts as a control point for allocating and releasing monitoring activities. The web-based application optimises travel routes and works schedules using a wide range of parameters including area, timing and bore type with results viewable in the application, or via exported spreadsheets. Route Optimiser references live Google maps so future changes to bore locations are easily accommodated, while the route can be tailored for changes in the road network. Route Optimiser is the central database for all field data. As monitoring occurs, a historic record of measurements and observations is built up within the database over time. The database can also store historic datasets provided by the client.

## Bore Portal

Our groundwater specialists check every measurement collected by our field team using Bore Portal, a web-based data-validation tool. It connects to the database in Route Optimiser to bring together historical information including hydrographs, maintenance and other comments which enables our specialists to query all new readings outside of historical parameters. Every measurement undergoes desktop validation before being released as the final reading.

## Water Level Monitor

Water Level Monitor displays all of the data stored in Route Optimiser in an intuitive user-friendly website directed at data end-users. The Water Level Monitor website can access information on all groundwater monitoring sites including charts, tables, maps, all water level readings ever recorded at a site, and all photos taken of a site. Users can quickly and easily examine and validate data and review groundwater trends within an operational area.

## Challenges

One of the key challenges of imposing rigorous controls and project-level customisation when developing smartphone software is balancing this with the right amount of flexibility for an organisation. If client requirements are to change, or the app is to be utilised for projects with a different set of data collection, safety, quality or other requirements, then the software needs to be able to be easily adaptable to the new requirements.

Another challenge in developing software in-house is that whilst strong links are built with the software developers, the knowledge of the mechanics behind the software is centralised within a few key project staff and the developer(s). This contrasts with the structured support programs and the training manuals, online tutorials, help libraries and user forums which are commonly available through larger, but more generic software products.

## Benefits & Conclusions

This paper deals largely with the detailed benefits of each feature, however these features all ultimately flow through to real improvements in data quality, data consistency, completeness of data collection and efficiency, with a more systematic approach. Since implementation, we have observed a marked decrease in the number of site revisits and data queries, a significantly better set of outputs, and increase in. Smartphone apps are relatively low-cost to produce, and highly customisable to our exact needs. When changes are required, these are usually completed with no or little additional cost.

The interface is highly intuitive, and therefore requires very little training in the actual use of the software. The app carries the user through the process, which ensures nothing is missed, and smart reminders and feedback to the user ensures the highest quality data is collected, and safety processes can be integrated into the workflow, rather than being viewed as an additional piece of paperwork.

The hardware required, being the smartphone is already an essential tool of any field operator, and the app is able to exploit all the features of the smartphone, including the camera, accelerometer, touchscreen, cell (mobile) and satellite connectivity. All of these features are embedded into the workflow, showing the ability of field data collection apps to realise the true value of all of the technology we carry in the palm of our hands.


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# Potential Applications for Unmanned Aerial Vehicles in River Hydrography

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## Abstract

*Unmanned Aerial Vehicles (UAVs), also commonly called drones are a relatively low cost aerial sensing platform that allows a number of tasks to be performed at a much lower cost to conventional aerial methods or in such a way that potentially enhances or simplifies current methodologies used by field hydrographers.*

*UAVs take many forms and each configuration has inherent benefits and deficiencies related to their flight capabilities. In the field of river hydrography due to the topographies experienced, the ease of operation and the scale of areas being considered, an assessment of the available technology shows that the multi-copter configuration to be best suited to potential applications.*

*Potentials for UAV use include site mapping, 3D modelling of micro-catchments, remote installation inspection, safety applications in high risk work such as flood gauging, temporal recording of site condition such as vegetation cover and geomorphology, payload carrying, marketing, new site selection and site condition monitoring.*

*Certain limitations must be considered in UAV application, regulations controlling the use of private and commercial drones are about to be updated in Australia, with the aim to both enhance public safety and reduce red-tape, potentially simplifying both private and commercial drone use.*

*Many other factors also need to be taken into consideration such as Occupational Health and Safety, privacy and no-fly zones outside of those in CASA regulations. Drone use must also take into account possible negative effects to native wildlife which may have their life-cycles disturbed through UAV interference.*

*Currently advanced remote sensing devices available for UAVs tend to be expensive, and there are technological limitations which can make it quite costly to enhance drone use with a selection of different camera types and other sensing equipment. With the current popularity of UAVs it is expected that this will change, with both commercially available affordable options, and with the growing popularity of amateur technology hacking making more sensing options available at a competitive price point.*

*A practical test of deploying a UAV in the field was conducted using a DJI Phantom 3 quad-copter and an assortment of software applications tested to enable the mapping of an operational NSW site (Mann River at Jackadgery). Utilising android apps, a cloud-based system and a windows software application, field aerial photography was collected at the site which allowed the construction of orthorectified photogrammetry in high definition.*

*This was further processed into a 3 dimensional map of the micro catchment and a digital elevation model constructed which could, with further work, serve as a reasonably accurate basis for establishing site cross sections, longitudinal sections and development of high-stage rating tables in a much more time-efficient manner than using current ground-based survey methods.*

## Unmanned Aerial Vehicles

It has become popular in recent years to refer to UAVs as 'drones' though this term can also encompass land and water based remote controlled vehicles such as the Ocean science Q Boat, currently in operation by WaterNSW hydrographers, for that reason it is more correct to use the term Unmanned Aerial Vehicle as it is far more descriptive of the technology.

UAVs come in a number of different configurations, but these can be broken down into 3 categories:
- Winged
- Rotary Wing (includes helicopter-style and multi copters)
- Lighter than air (weather balloons, blimps)

### Winged UAVs

These include both electric and petroleum driven propellers fitted in either a pull or push configuration to some sort of convention winged airframe. Benefits off the winged UAV include speed, increased stability in windy conditions, long flight times and large payload capacity. They can be more difficult to fly due to their speed, they work better at higher altitude and they can be susceptible to collisions at lower altitudes as they must be continually in motion.

### Rotary Wing UAVs

These can take the form of a conventional (if downsized) helicopter, or as is most common, in a multi rotor configuration using anything from three to eight or more propellers mounted vertically to enable vertical take-off and landing (VTOL). Rotary wing UAVs are most commonly electrically powered, though there are petrol driven models, usually in the simpler conventional helicopter-style configuration.

The rotary wing provides an exceptionally stable platform for a suite of remote sensing devices, simple operation when combines with on-board GPS and smart controls and simple deployment as they can be launched from very small patches of ground.

### Lighter than air UAVs

These can be considered to include weather balloons, Blimp-style airships and some hybrid multi-rotor designs.

Typically used more for atmospheric observation these can be some of the cheapest UAVs available, though they are limited in speed and direction control as their size and low mass makes them very susceptible to wind and thermal currents.

### Hybrid UAVs

A number of hybrid vehicles exist which seek to address the benefits of one configuration with the pitfalls of another, such configurations involve winged body types with articulated wings or propellers to enable VTOL and hovering abilities and airships with steerable attachments.

## Regulations

Australia was one of the first countries in the world to regulate UAVs back in 2002 (RPAS Training and Solutions) with part 101 of the Civil Aviation Safety Regulations which governs the safety of operation of unmanned aircraft, balloons and rockets. This even served as a template for many other nations to follow.

Technology has, however, quickly outpaced regulation and a new amendment to this regulation is due to be passed in September 2016. From this point UAVs will be known as RPAs (Remotely Piloted Aircraft) (Civil Aviation Safety Authority) and new regulations separating aircraft size and type of use will regulate if the use will require licensing.

When using a very small (less than 2 kg) aircraft for non-commercial gain, the regulations are simplified and allow very precise and easy to follow instructions to ensure safety. In short, these regulations allow:
- Flight to a maximum ceiling of 120 m;
- Flying within line-of-sight only;
- Not flying over populous areas;
- Maintaining clearance of 30 m horizontal and 10 m vertical to people;
- Staying at least 5.5 km away from any controlled Aerodrome;
- Not flying over areas where emergency operations are underway.

Airspace in Australia is regulated by CASA, but other restrictions may also apply such as National Parks which generally require permission due to potential effects on fauna and public nuisance; each state's National Parks department clearly displays drone operation requirements on their websites as in Figure 1. This is also covered under the Environment Protection and Biodiversity Conservation Act 2000, reg 12.27.

1. NPWS may grant consent for the recreational use of drones in a park when:
   - they will not annoy or cause risk to visitors, including the privacy of visitors
   - they will not be a nuisance or cause risk to wildlife
   - they will not interfere with park management operations, and
   - the drone user operates only in the area covered by the consent.

2. Park managers can inform visitors that consent is required to use drones in a park by:
   - signs at a park entrance or at locations in parks
   - written notices given to visitors, or
   - oral directions issued to visitors.

3. If consent is granted, and before using a drone in a park, visitors should check the **Alerts page of the NPWS visitor website** for the latest advice about fires and floods affecting parks or park closures.

4. Access to parks may be restricted or prohibited on days of heightened fire danger - ie. when the fire danger rating is 'Very High' or above.

5. Drones - if the park manager has granted consent for their use - should always be flown consistent with CASA's ***Flying with Control?*** (PDF 380KB) rules for recreational drone users. That means they must be flown in line-of-sight (ie. visible to the operator); not over populous areas; not within 5.5 kilometres of an airfield; and at least 30 metres from other people.

Figure 1: National Parks and Wildlife Service (NSW) Policy for drones in parks (Office of Environment and Heritage 2016).

Other restricted airspace can include military bases and other Commonwealth properties of significance. Drone manufacturers are becoming proactive in limiting the flight zones of UAVs by injecting firmware updates and software limitations that create virtual fences around restricted flight zones which will stop a drone in its tracks if it attempts to fly into such areas. Such technology being adopted by DJI, the largest recreational drone supplier in the world, is quickly adaptable and can be updated to cover short-term restrictions such as bushfires, major events and national security requirements (SZ DJI Technology Co. Ltd. n.d.). The technology is currently in use in the USA, China and parts of Europe, but is in the process of being rolled out to other countries.

Other resources are available to drone operators to assist in flying legally; a useful application "DroneComplier" is freely available on android and iOS which will warn an operator of any nearby restrictions on airspace.

## Potential Applications

The most obvious application potential for UAVs in river hydrography are those that enhance or simplify current field operations, some of which can be time consuming and labour intensive, where the uses of a lightweight drone will be of benefit.

### Remote Asset inspection

Due to the often rugged and relatively inaccessible locations that river monitoring stations are located, it can be difficult to access some assets for periodical inspection. Distant controls combined with fast flowing water, solar panels and antennas on high structures, radio hopping facilities and cableways can all present significant time investment and WHS considerations for inspection. A UAV can quickly allow inspection and recording in high definition of these assets and provide a digital record of condition.

### Payload delivery

Traversing a river with a wire can be difficult and dangerous from a boat, whereas a UAV allows a light line to be accurately delivered to a location on the opposite bank for a wire to be pulled across.

### New site investigation

Surveying river reaches for potential installation of a new site can be time consuming and often involves many kilometres of hiking and wading along rivers and creeks with all sorts of potential hazards. A drone can quickly fly a section of a river and provide real-time video or aerial photography for viewing on the spot or downloaded for later desktop interpretation. Orthophotography can be uploaded live to cloud services such as DroneDeploy to process photography into a 3D terrain map.

### High definition aerial photography

Most hydrographers will relate the fantastic tool Google Earth is, but the imagery is often limited, both in age and in definition. A UAV allows rapid capture of aerial photography and video in high definition allowing sub centimetre resolution; this is a great resource for recording site characteristics and tracking channel morphology and bankside vegetation changes over time.

### Gauging Section Selection

As every hydrographer knows, the condition of a gauging site relates directly to the quality of the data measured, it is often difficult to select an appropriate cross section for gauging a river at different stages, as morphology changes or following a flood. A drone can allow a rapid assessment of nearby river reaches that could take hours to inspect by foot or vehicle and provide a higher quality history of record for a site.

### Aerial mapping and channel surveying

UAVs offer a fast option for mapping micro catchments that can allow for temporal evidence of channel features and other hydrological parameters and provides accurate comparison of channel changes over time.

Software allows for photography to be easily manipulated into 3 dimensional surfaces from which channel slopes, cross sections, surface roughness coefficients, vegetation density indexes and many other parameters can be derived or inferred.

## Aerial Investigation of Mann River at Jackadgery

As a trial, a site was selected to obtain aerial photography from which a software package could be trialled to produce a 3 dimensional map of a micro catchment with the hope of delivering an accurately derived surface to enable a flow estimation to be made. The software selected was Pix4D mapper, a Windows based program with both Android and IOS apps for field deployment and the UAV used was a DJI Phantom 3 Standard UAV.

The site selected was 204004, Mann River at Jackadgery; this is a wide, easily accessible stretch of the lower Mann River with minimal aerial obstructions, a number of accurate bench marks and a known stable stage-discharge relationship. The course of the investigation also showed a number of deficiencies in using this site such as the lack of recent gaugings in the medium section of the rating and no high flow gaugings undertaken for the last 30 years. In addition no recent cross sections have been surveyed nor any record of the calculations for the rating extension.

The first mission was flown on June 6, 2016 which allowed for initial photography to be obtained; this introduced some useful data on how to go about planning and gathering a further mission, primarily due to hardware limitations of the software that was being used. Working initially in an Android environment the software had communication difficulties with the drone and the IOS app was unable to render correctly on an iPhone 4S screen. As nearby interference prevented the drone being flown manually (and the inaccuracy this would introduce in supplying suitably overlapped photography) a secondary app, DroneDeply was used to plan transects and upload to the drone.


Figure 2: UAV transect of Jackadgery site showing Station (A), Sensor (B) and Control (C).

The initial flight exposed one major deficiency; which was the lack of Ground Control Points (GCPs). As the drone uses consumer level GPS, it does not record its position in space very accurately, as the software used triangulation of ground features to map those features into three dimensional space, the inaccurate positioning of the drone introduces significant surface irregularities in the rendered surface. As a result the derived surface had one bank almost a full meter higher than the other and the rendering had the river running uphill.

The second mission flown on June 16, 2016 utilised the three station benchmarks as known GCPs to improve the rendering of the map. Each benchmark was defined by an A3 page of paper placed upon it with a printed cross for targeting.


Figure 3: Primary Station benchmark (left). Ground Control Point target (right).

The second rendered surface was much better, but still with some inaccuracy with around 300 mm difference in surface water elevations on opposite banks. As all the known GCPs were on the left bank there was insufficient spread of known ground points for an accurate rendering. With time being a major consideration as these sorties were being flown on routine field trips it was decided that the right bank elevations could be improved with the use of the known stage height on the day.

By locating easily identifiable topographical features on the right bank (rocks, vegetation) and identifying their location with handheld GPS the software could improve the interpolation of the right bank sufficiently for a desktop modelling, though, ideally further right bank GCPs would be required for a more accurate map.

The use of these virtual GCPs resulted in a much more representative rendering, though further limitations of the software were revealed.

In the first flight the day was overcast, the second was very sunny and the sky was filled with lots of high altitude cirrus clouds. In the first instance, the water surface was a featureless expanse of grey which was basically ignored by the software as there were no points of interest that could be interpolated. On a sunny day the water surface was mirror-like from above, reflecting all the sky features perfectly and introducing a problem for the software.

The three dimensional modelling works by identifying ground features which are visible in multiple overlapping photographs from different airborne locations. The angles relative to each feature are calculated and from these, the point triangulated in space. From this, a point cloud is produced and further rendering can transform the point cloud into a TIN (triangular irregular network). As the relative position of the reflected images on the water surface changes for each successive aerial photograph, the software interpolates these points as being wildly out of position, either as high above, or deep below the water's surface.

These excess points can be manually clipped from visual displays, but are not removed from the calculation dataset. The software currently does not offer a practical solution other than editing after the initial rendering is done; as the initial processing of the data was taking around 6 hours, with multiple iterations required this could be a major time saver in processing aquatic environs. The company was contacted to see if a feature can be added to draw a polygon around such surfaces to exclude them from processing, but no reply has yet been received.

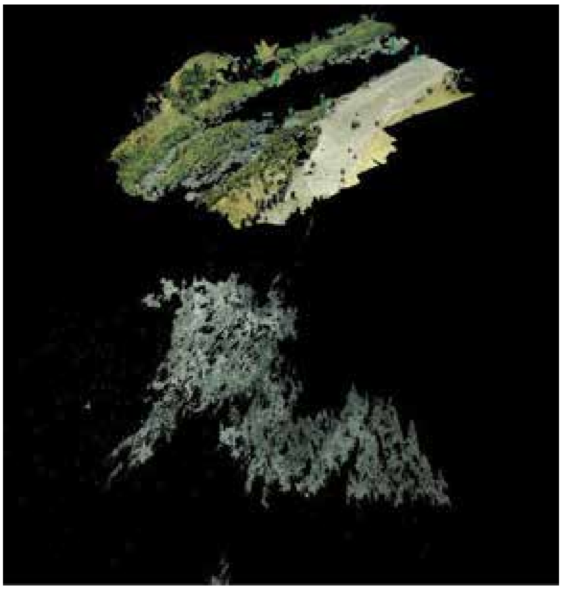

Figure 4: Pre-processing of point cloud showing terrain model with superfluous data interpolated by cloud reflections on water surface.

Processing of data from the second deployment resulted in sufficient data to generate a suitable three dimensional surface of river reach for further investigation. Primarily the task was to attempt to extract a cross section with which to estimate flow at a given stage.

In order to estimate flows from the interpolated surface, transects were drawn in perpendicular to the river flow and set at 4 elevations (95 m through to 97 m). From this the software is able to output an area between the water surface on the day and the selected elevation (adjusted to gauge height). Summing the measured flow on the day of the photography to the calculated area multiplied by velocity (derived from the current station rating curve) provided an estimated total flow.

**Table 1. Flow estimations from interpolated surface***

| Elevation (m) | Gauge Height (m) | Area (m3) | Velocity (m/s) | Calculated Flow* (ML/d) | Rated Flow (ML/d) | Calculated Flow Deviation from Rating (%) |
|---|---|---|---|---|---|---|
| 94.000 | 1.895 | 180 | 0.6 | 11065 | 11980 | -7.6 |
| 95.000 | 2.895 | 281 | 1.6 | 40579 | 43280 | -6.2 |
| 96.000 | 3.895 | 298.2 | 1.9 | 92346 | 88996 | +3.7 |
| 97.000 | 4.895 | 354.2 | 2.25 | 170584 | 152478 | +11.9 |

*In addition to 1735 ML/day base flow at 1.020 m GH.

As can be seen in table 1, these calculated flows compare favourably with the current rating curve, although a limit of approximately 5 m gauge height exists because the drone transects did not extend far enough up the slower sloping left bank to extrapolate any higher.

## Lessons Learned

It became clear quite quickly that although a UAV allows rapid collection of data, this data is not very useful without a concise plan to begin with. Site selection is very important, having the necessary surveyed ground control points performed in advance, planning suitable transects to cover a suitable area of a river reach, having an advanced understanding of the limitations of the chosen software in advance of data collection and, above all, having the right equipment available to ensure deployment, data gathering and processing can be done in a timely fashion.

## Moving Forward

In the future it is intended to conduct further work at the Jackadgery site, specifically accurately locating extra ground control points to improve accuracy of the interpolated map, to undertake cross section and long section surveys and to attain further gaugings to further improve the middle upper rating curve. Extending the mapping coverage to encompass full stage range and extrapolating a cross section to cover the full flow range of the site will hopefully further prove the technology.

Ongoing improvements to the Pix4D software package along with feedback provided to the company following this trial should enhance the applicability of the program for aquatic environments and simplify data processing.

At this stage there has been no company investment into the technology; data has been gathered with a personally owned drone and software and apps have been sourced that are free, or provide a short-term use of full functionality for an introductory period.

The Pix4D suite of applications appears to be the best suited to hydrographic applications, but has a significant cost which can be billed as $350 USD per month or a one-off charge of $8700 USD for unlimited and which can be installed on up to 2 devices. The cost of UAVs starts at around $1200 for a DJI Phantom standard, $2500 for a DJI Phantom 4 which included collision avoidance technology or as much as $15000 for more advanced commercial-level drones.

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