

Australasian Hydrographer **April 2017**



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HYDROGRAPHERS
ASSOCIATION

AHA

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JACQUIE BELLHOUSE

Editor's Introduction

Welcome to the April 2017 Issue of the AHA Journal after what has been a pretty hectic first quarter.

In today's pages you will find a short overview of the first AHA fellowships. Awarded to those members who have made significant contributions to the association over the last decade, the inaugural list now has seven highly distinguished ambassadors for the Hydrographic industry.

Our first paper entitled "Out of Control" by Peter Waugh is the winner of the 2016 Alex Miller award. Alex Miller was a hydrographer credited with being the driving force behind invigorating the AHA in the late 1990s and early 2000s. Following his passing Alex's efforts were recognised by the Association through the Alex Miller award for Best Conference Presentation.

The final two papers have been included in recognition of a number of recent noteworthy events across Australia and New Zealand. Just in case you missed them:-

This summer, while Sydney, Brisbane and Canberra experienced their hottest summers on record, Western Australia experienced its wettest since records began in 1900. In February this culminated in wide spread flooding from Karratha in the state's north to Esperance in the south. These floods resulted in 2 deaths and areas from the Pilbara to the Swan Valley and the Goldfields-Esperance region, being declared Natural Disaster zones.

In mid-March over 50 nationwide and New Zealand participants attended the ADCP Regatta organised by ALS and the AHA. Quite a timely event as I imagine that a number of participants were soon able to test their skills and knowledge thanks to the impact of ex-Tropical Cyclone Debbie.

In late March Cyclone Debbie caused wind damage and flooding between Bowen and Mackay. It also caused major flooding in the south eastern parts of Queensland and north western New South Wales. At least six flood related deaths were reported by the media in New South Wales.

In early April an area of low pressure and high tropical moisture from what remained of Cyclone Debbie resulted in torrential rain in parts of Northern New Zealand. This resulted in unprecedented 1:500 year flood events on the Whakatane and Rangitaiki Rivers and the evacuation of 2000 residents.

With the breadth and impact of the of flooding events over the past 4 months I thought it timely to include the paper *Remote River Level Monitoring and Alarming for Highway Flood Inundation – Queensland State Highway Network* by Paul Hart, Graeme Jones and Chris Russell. I think it is a great example of the proactive measures State Road agencies and Councils have implemented to provide more effective and timely highway flood inundation warning.

Sadly in late March I also noted an article on the death of a Hawks Bay Regional Staff member after his vehicle left a rural farm track and rolled. Michael, an ex-colleague of our own Associate Fellow Krystal Hoult and New Zealand's equivalent of a Hydrographer, left behind a wife and two young children.

With this in mind *Safety in hydrography – The impact of innovation and technology*, by Allan Garland, is a great example of the measures we can take on a day to day basis to ensure that our co-workers can return to their loved ones at days end.

Regards
Jacque Bellhouse
Journal Editor

BILL BARRATT

From the President

Taking AHA to the next level

What is the true meaning of “value”?

As a member based organisation, the AHA Committee have pondered that question at length.

AHA seeks to add value, be valuable, offer value for money and also show that we value as well. Let me give just a few examples.

ADD - ALS Global, who organised the 2017 ADCP Regatta approached AHA to help organise and market the event. The expectation was a turnout of around 16–20 participants. By combining our resources and reach the actual participation rate exceeded 50. We hope to partner with many other events during the year that cater to industry needs nationwide. We are also open to offers to collaborate.

BE - During the recent floods a distressed lady rang the office in desperation saying she could not get through to anyone who could tell her about anticipated water levels in her area. She had tried and, at best was put on hold. We were able to link her with a local authority and she received the personal attention and advice she needed. Subsequently AHA created a portal for water levels nationally.

OFFER - AHA is acutely aware of the need for training and developing courses that meet industry needs nationwide. In selecting an RTO to work with, we sought a provider that understood the not-for-profit philosophy and could offer training at a reasonable rate. We hope to soon announce that collaboration and the benefits we offer members. Whilst on training, we have sought expressions of interest from organisations and individuals who can offer their skills for training. We now have a panel that we will work with to develop, deliver and assess our courses.

VALUE - AHA also values the contribution of organisations and individuals. We now have over 20 partners that we value and work with. We also recently acknowledged the valuable work of several individuals by recognising them as Fellows and Associate Fellows. You can read more about that in the Journal.

So, what is the true meaning? As a non-profit, I would argue it is to be relevant and responsive. We take nothing for granted and appreciate the support and work done to provide services to the industry.

I also value your feedback and comments, so please connect with us on social media or get in touch directly.

Regards

Bill Barratt

AHA President

AHA Accreditation: Citations for AHA Fellows and Associate Fellows

Background

Last year, the AHA Committee realised the need to recognise members who have made a significant contribution to the profession and association.

There are two major levels of accreditation:

- Fellow of the AHA
- Associate Fellow of the AHA

Fellows of the AHA can also be offered life membership as additional recognition for their contribution to the Australian River Hydrographic Industry.

The Committee has determined the first fellowships to people who have made significant contributions to the association over the last decade.

The citation are on the following pages.

Fellows of the AHA (with life membership)

Bill Steen

Bill commenced as a hydrographic assistant with the NSW Department of Water Resources in 1979, where he continued until moving to the ACT administration in 1986, and after privatisation of ACT hydrography, continued with Ecowise until 1999.

In 1999 Bill moved to Hydsys as Sales and Marketing Manager, becoming General Manager of Kisters in 2004 which role he still fills.

Bill's AHA involvement goes back a long way.

In the 1980s, Bill was AHA NSW Branch Secretary. After his move to Canberra he served many years as ACT representative on the AHA Committee. He assumed the role of Chair in 2007 and continued in this role until December 2015.

Under Bill's watch, AHA has grown significantly, now holding professionally run biennial conferences.



Paul Langshaw

Having previously worked as a hydrographer at Sydney Water, Paul set up his own company Rainman Recycled Water in 1998.

Paul was appointed to an AHA training subcommittee in 2002, becoming a member of the AHA Committee and national training coordinator in 2007, where he continued until December 2015.

As national training coordinator, Paul has brought great passion to developing the professionalism of hydrographers. He represented AHA at Government Skills Australia to see development of a nationally recognised Diploma level course. He established and coordinated the Hydrographic Basics course. His efforts led to recognition of Hydrography in the Australian New Zealand Standard Classification of Occupations (ANZSCO) and issuance of code "311415 HYDROGRAPHER"

Measures, analyses and maintains the flow and quality of water in rivers, lakes, stormwater and sewage, and surveys and maps oceans, seas and rivers.

Paul was project officer preparing the drafts of the National Industry Guidelines for Hydrometric Monitoring, now published by the Bureau of Meteorology.



Fellows of the AHA

Bill Barratt

In 1961, Bill commenced work as a hydrographic assistant with the NSW Water Conservation and Irrigation Commission. Initially, the job was in the Hunter Valley, then in Sydney and Armidale. In 1967 he moved to the Latrobe Valley in Eastern Victoria, as a hydrographer and in 1972 became senior hydrographer. During this period he introduced new generation instrumentation to Victoria and had the Latrobe Double Drum Traveller winch developed by Hydrological Services.

In 1978, Des Sherlock, from HS recruited Bill to provide technical support to customers and to develop an export market. Bill became CEO of the company in 1992, remaining there until his retirement in 2005. Under his leadership, HS grew to be a world market leader in hydrological instruments and equipment.

Bill has presented technical papers at conferences and carried out training in over 20 countries around the world.

Bill has served on the AHA Committee since 2005, being appointed as President in December 2015. Bill has attended every AHA conference.



Max Hayes

Max worked for Latrobe Valley Water and Sewerage Board in the construction area. In 1969, he transferred to the hydrographic section, as a hydrographic assistant. In 1972, Max became a hydrographer and in 1982, the senior hydrographer. He remained in this position until 2000, when the Board was terminated.

Max then started his own company, Gippsland Hydrographics, engaging in contract hydrographic and water sampling work for various authorities. In 2008, he semi-retired, but still does some water quality sampling.

Max served for many years as Victorian representative on the AHA Committee and has served as Treasurer for approximately 30 years, a record of commitment that will probably never be matched!



Mic Clayton

Mic served as AHA Publicity Officer from 2002-2009. His achievements included producing the AHA Journal in an improved format, with a higher standard of technical articles. Mic also developed the website through several iterations, finally moving it to a modern content management system.

Mic was a member of the steering committee overseeing the drafting of the National Industry Guidelines for Hydrometric Monitoring, now published by the Bureau of Meteorology.

Mic has continued to be proactive in developing the hydrographic profession. He is the most prolific author in the AHA journal and has 19 technical articles published on the AHA website, and has introduced initiatives such as the ADCP regatta held in 2015.



Associate Fellows of the AHA

Michael Whiting

Michael is currently Water resource assets project manager at the WA Department of Water.

Michael has many years of AHA involvement, first as the West Australia representative from 2001, and serving as Secretary from 2006 to 2011.

Michael introduced the first electronic membership database for AHA. He was a driving force behind our 2010 Perth Conference.



Krystal Houtt

Krystal began work as a hydrographer in New Zealand in 2004 and over the years has worked for Government, equipment manufacturers and consultants in New Zealand, Victoria and NSW.

She served as AHA Secretary from 2011 to 2014.

Krystal was a driving force behind the AHA 2012 Melbourne and AHA 2014 Sydney conferences, her efforts no doubt contributing to the success of those events and was awarded a bespoke trophy to acknowledge her exceptional service to AHA following her resignation as Secretary in 2014.



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Out of Control: Real Time PPP Correction Service for Remote Area Bathymetric Data Collection

Peter Waugh

Dept. Environment and Natural Resources, Darwin, NT

**Winner of the Alex Miller Award,
18th Australian Hydrographers Association Conference
Canberra. 24–27 October 2016**

Abstract

The Northern Territory Department of Environment and Natural Resources have developed integrated surface-groundwater models to better inform management decisions relating to water resource allocation.

Due to the remote nature of the Northern Territory (NT) and resultant site access issues, data available for the construction of these models is spatially sparse, resulting in significant interpolation of hydrological and hydrogeological features.

In order to increase resolution of the hydraulic gradient and better define the interface between surface and groundwater resources, a longitudinal survey was undertaken of the primary channel thalweg for both the Roper and Katherine-Daly Rivers. Project objectives included determination of river bed height to an accuracy of ± 0.200 m Australian Height Datum (AHD) along the non-tidal length of both rivers.

With poor river access, no survey control points (benchmarks) along most of the survey area and no communication network, conventional Real Time Kinematic (RTK) Differential Global Navigation Satellite System (GNSS) techniques using a base station over a known point would be prohibitively expensive and time consuming.

Utilising a new satellite based precise point positioning correction service for GNSS survey; a longitudinal section was completed for both rivers within the required accuracy limits and within a suitable timeframe and budget without the need for establishing a dense network of survey control points to achieve required project accuracies.

This paper will provide an overview of the technology, and the two different techniques that were used to undertake each survey.

Introduction

In recent years the Northern Territory (NT) Government has sought to increase economic development with a particular focus on diversifying agricultural production through horticultural development in regional areas. In order to better manage increasing water extraction for economic development the NT Government has established eight water control districts over regions currently undergoing or proposed for increased economic development. Control districts are subject to intensive monitoring and resource assessment of both groundwater and surface water assets to ensure reliable water supply for consumptive use while protecting the environmental and social values associated with the NT's iconic waterways.

Surface and groundwater resources in the NT are typically highly connected involving complex relationships between various groundwater formations and surface water systems. To better understand the relationships between these systems and the overall impacts of water extractions the NT Government has developed integrated surface-groundwater models to better inform management decisions on water resource allocations. Due to the lack of infrastructure and communications networks throughout much of the NT these models are of a relatively low resolution having been developed from data sparsely distributed over large spatial extents. Many of these datasets exist in a local datum and have been coarsely integrated into a common datum through maps or uncorrected GPS measurements with vertical uncertainty up to ± 30.0 m.

To facilitate refinement of the hydrological models, a program for the collection of additional survey and hydrological data was requested, including the collection of a longitudinal section survey of the Katherine-Daly and Roper Rivers to better define the groundwater/surface water interface and the surface water hydraulic gradient within a vertical uncertainty of ± 0.200 m AHD.

Lack of survey control infrastructure in the study areas is a significant impediment to the collection of highly accurate level data in a common datum. The requirement for all level data to be collected in AHD to allow integration with existing topographic and hydrogeological data is a key objective for the project. With no existing survey control network, no communications network and poor access to most of the study areas, conventional RTK Differential GNSS methods would be difficult to implement and are considered prohibitively expensive. This paper outlines the emerging GNSS technologies and techniques used to collect the required data within the requested accuracy limits, and within limited project budgets.

1. Overview of GNSS Positioning Systems

Global Navigation Satellite System (GNSS) is a generic term incorporating all satellite positioning systems and includes GPS (US), GLONASS (Russian), Galileo (EU) and Beidou (China). While many are familiar with GPS technology, these equivalent navigation systems have been under development for years. At present all systems outlined above have some operational satellites. These satellite constellations are complementary and many receivers now on the market are enabled to receive signals from multiple or even all systems.

The advantage to receiving signals from multiple constellations is redundancy. Users of GNSS receivers are far less likely to suffer from signal interference or dropout than users of a single constellation such as GPS. For hydrographic applications, where the view of satellite constellations is often limited due to geology or other riparian interference, the redundancy of multiple constellations is a significant advantage. A GNSS enabled receiver is required in order to take advantage of multiple constellations but be warned, some instrument suppliers will charge additional fees to access the additional GNSS constellations using a GNSS enabled receiver despite them being free-to-air services.

Like GPS, GNSS position measurements can have different levels of accuracy. Below is a brief outline of levels of accuracy that can be achieved using GNSS technologies.

1.1. Standard GNSS Navigation (uncorrected)

Most vehicle and handheld GNSS navigation systems provide an uncorrected position and are accurate to within ± 10.000 m in the horizontal plane and ± 30.000 m in the vertical plane. This is suitable for recreational and general navigation use only.

1.2. SBAS and WAAS – Not Available in Australia

Space Based Augmentation Systems (SBAS) and Wide Area Augmentation Systems (WAAS) were initially developed for the aviation industry to meet requirements for vertical guidance systems. They have since expanded to provide improved accuracy for any GPS or GNSS receiver programed to receive SBAS or WAAS corrections. Regularly marketed as differential GPS/GNSS, SBAS or WAAS corrections reduce positional uncertainty to ± 3.000 m in the horizontal plane and ± 9.000 m in the vertical plane. Almost all GPS and GNSS receivers available on the market today are capable of receiving SBAS and WAAS corrections, as advertised by many instrument suppliers in the hydrographic industry; however **as of the writing of this paper in late 2016, there is no free-to-air SBAS or WAAS available in Australia.** SBAS and/or WAAS currently operate throughout North America, Europe, Russia, Japan and the Indian sub-continent. All correction services available in Australia are subscription services. Unless the user sets up their own base station, they will not be able to access any GPS/GNSS corrections without a subscription to a correction service.



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Occasionally, users in Australia may receive a stray SBAS signal on their GPS/GNSS receivers from the geostationary SBAS satellites in the northern hemisphere. These corrections cannot be used reliably in Australia as they are based on differential measurements thousands of kilometres away, and are applicable only for the region for which that SBAS has been established.

Geoscience Australia is currently working towards an SBAS for Australia, with planning for a pilot program (known as the SBAS test-bed) due to commence in 2017. However even with a favourable pilot program and evaluation, it is likely to be several years until any SBAS is available for use in Australia. Further information about the progress of this system can be found on the Geoscience Australia website on the following link:

ga.gov.au/scientific-topics/positioning-navigation/positioning-for-the-future/satellite-based-augmentation-system (accessed 2016-11-30)

1.3. Static Survey

This is the standard technique used to establish new survey control points. A receiver is set up over the control point to be established and set to log position data from the GNSS constellation over a set period. Where single frequency receivers are used, a second receiver must occupy a known control point within 15 km of the new control point and set to log position data for the known point simultaneously to the first receiver. Receivers must be tracking a minimum of four satellites, common to both receivers, for the duration of the survey (usually minimum of 2 hours, however the longer the better). After the survey, data from both receivers is post processed to determine the position of the new control point, usually within an accuracy of up to ± 0.020 m in the horizontal and vertical planes.

If a dual frequency receiver is used, the surveyor is able to take advantage Geoscience Australia's online post processing AUSPOS tool. AUSPOS accesses data from Australia's CORS network to correct satellite clock and orbit errors using a technique known as Precise Point Positioning. This means only a single receiver is required. The receiver logs positional data over the new control point for a minimum of 4-hours (optimal 6-hours). Logged data is post processed through AUSPOS and the position of the new control point determined to around ± 0.020 m in the horizontal and vertical planes. As no local control point is required, this technique can be used to establish a highly accurate control point anywhere.

1.4. Real Time Kinematic (RTK) Survey

RTK surveys are a differential survey commonly used to undertake survey operations and consists of a base station and rover. A base station GNSS receiver is set up over a known survey control point and set to log GNSS positions. The difference between the known point and the GNSS position is determined and a correction sent via radio link to the rover. The rover is another GNSS receiver used to collect the positions of features included in the survey. GNSS positions are collected by the rover and the correction from the base station applied to achieve positional data accurate to ± 0.020 m in the horizontal and vertical planes.

The accuracy of the RTK correction reduces with distance to the base station as the errors acting on the GNSS position are relative to the angle of incidence to each satellite (among other things). As a result the range the rover can move from the base station and still achieve survey grade positions is usually considered to be from 10-15 km. However, radio range is usually the limiting factor for RTK survey, with most radios transmitting corrections limited to 5 km line-of-site.

RTK Correction Services

Over the past decade, Network RTK utilising a network of Continuously Operating Reference Stations (CORS) delivering differential corrections through mobile internet have proliferated throughout parts of southern and eastern Australia. Figure 1 shows areas currently covered by Network RTK in Australia. Users with access to Network RTK do not require a base station in order to receive differential corrections. Corrections are transmitted through the internet so the GNSS receiver must be able to have a sim card installed to access the mobile phone network. Access to Network RTK is through a subscription service.

As with conventional RTK survey, users of Network RTK operating within the Network RTK coverage area are able to achieve GNSS positional accuracy up to ± 0.020 in both the horizontal and vertical plane.

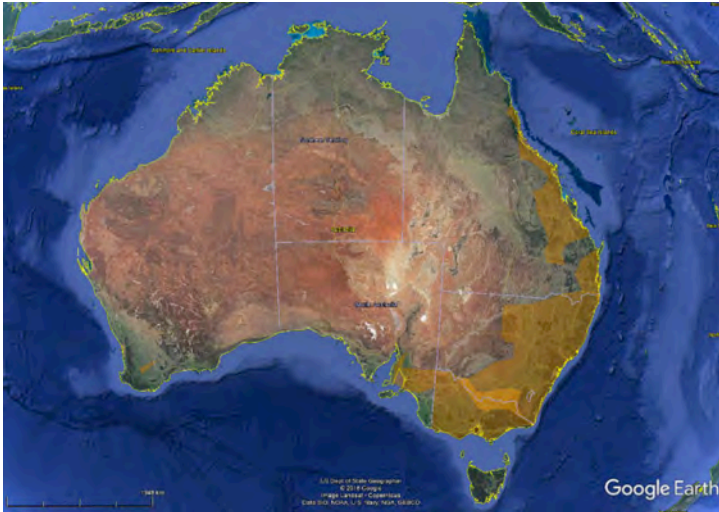


Figure 1: Network RTK coverage in Australia 2016.

1.5. Real time Precise Point Positioning Correction Service (RTPPP)

Precise Point Positioning (PPP) is a relatively new correction technique. Rather than using base-stations to determine the difference between observed position and actual position, PPP uses a series of CORS to determine the error in time and position for each GNSS satellite, allowing corrections for clock and position error to be calculated at a central processing centre. PPP requires far lower density of CORS than differential correction services, and as the corrections are for satellite time and orbit, they are absolute. This means that, theoretically, the corrections are valid everywhere a GNSS position can be achieved, not just in a network coverage area. PPP is able to provide uncertainty levels in the centimetre and decimetre level, and even sub-centimetre for static applications.

Until recently, PPP has only been available for post processing. Static and RTK data can be sent off to a web based PPP service and the corrected positions returned. However, recent innovations have seen several proprietary real time PPP correction services becoming available with positional uncertainty ranging from ± 1.000 m to a survey grade ± 0.020 m horizontal and ± 0.040 m vertical depending on the level of service. All of this without the need for a local survey control network. Instead a network of CORS, located around the planet, transmit GNSS satellite clock and position errors to a central processing hub. Corrections to satellite orbit, clock and other adjustments are calculated in real time then transmitted via an L-band satellite to the client GNSS RTK receiver. The client GNSS RTK receiver then applies these corrections to the data being received from the GNSS satellites. Figure 2 shows how Trimble's proprietary RTX system operates.

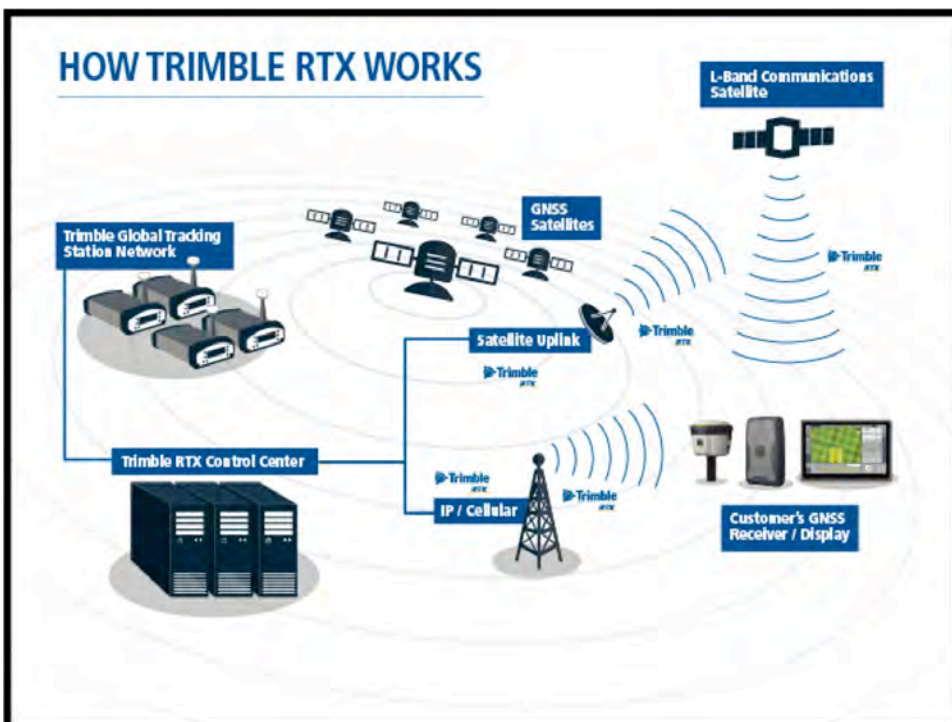


Figure 2: Trimble RTX Satellite Based RTPPP Correction Service.

Several Real Time Precise Point Positioning correction services are available in the ± 1.000 m to ± 0.1000 m uncertainty range, such as Omnistar and TerraStar services, however at present the author is aware of just two operating RTPPP capable of achieving survey grade positions within ± 0.050 m. Trimble's RTX service (Released 2012) and Hemisphere's Atlas service (Released 2016). All space based RTPPP correction services currently available are subscription services.

1.6. Limitations with Real Time Precise Point Positioning Correction Service's

Identified limitations for satellite based RTPPP corrections requiring consideration and/or mitigation during data collection include:

- Correction Drift – Despite PPP purportedly providing an absolute correction, there does appear to be a drift between observation collected using RTPPP and the post processed results from static survey of the same point. From observations taken by the author and instrument supplier, a linear drift from control point values appear to occur as the user moves away from a CORS used for RTPPP. Observed values near the CORS are accurate, however observations taken away from the CORS drift up to 20 mm/100 km. This is possibly due to differences in the computational algorithms used by RTX and AUSPOS. As the drift appears to increase linearly with distance from the CORS, it can be accounted for however further work will need to be conducted to establish the nature of the drift. By undertaking a static survey at selected locations during the survey in conjunction with RTX observations at the same point, the magnitude and direction of drift can be estimated and accounted for.
- Correction signal interference - It was found that the correction signal from the RTX satellite (located to the north of Australia) can drop out where interference from landscape features occurs. While GNSS constellation visibility was extremely robust, never dropping below 10 satellites visible under normal field conditions, the single RTX satellite required a relatively clear horizon to the north—not always possible when navigating a river through common riparian landscape features.

2. Remote Area Bathymetric Survey

Bathymetric data fundamentally consists of two linked datasets—depth and position. While depth data collection capability varies widely with the range of instruments available on the market, from lead line to multi-beam echo sounder and side scanner, each depth sounding must have an accurate position attributed to it in order for it to be meaningful.

Contemporary coastal and inland bathymetry utilises differential RTK GNSS to collect accurate positional data on-the-fly to attribute to each depth sounding. This requires access to a differential correction source using coastal beacons, Network RTK or stand-alone GNSS base station. All differential correction sources must be referenced to an established survey control point or control network from which corrections can be calculated and transmitted to the RTK Rover unit on the survey vessel. The range of the vessel from the control point must be within 10 km – 15 km for the differential correction to be relevant, or less if relying upon standard short wave radio communication to transmit the correction. Radios typically have a range up to 5 km line of sight. However, at best a range of 2 km from the base station could be reasonably expected along a river for a reliable differential correction to be sent through radio communications.

The ability to undertake bathymetric survey in remote locations is not particularly complicated. With relatively little preparation an accurate control point can be established anywhere by undertaking a static survey with a dual frequency GNSS receiver. Control points established using optimal static survey procedures have a measurement uncertainty of ± 0.020 m in the horizontal and vertical planes. The control point can then be occupied by a base station to send differential corrections to a rover unit on-the-fly, providing positional accuracy within the horizontal and vertical axis of ± 0.020 m. Numerous limitations to this scenario exist when undertaking a longitudinal section over a large spatial extent for a waterway in remote areas. These include:

- Survey Control Network density
- Survey site access
- Project budget

2.1. Survey Control Network Density

With short-wave radio communications generally limited to about 2 km along waterways, a control point and base station would need to be established approximately every 5 km in order to provide minimum coverage for conventional RTK survey of the study areas. The Roper River—measuring 210 km from its headwaters to the tidal zone—requires 43 control points to be established along the river, while the Katherine-Daly River requires 71 control points to cover the 350 km from Katherine to Daly River Police Station. Due to the remoteness of the study areas, these control points would need to be established using a dual frequency GNSS receiver and post processed static survey techniques as outlined in section 1, requiring 6 hour occupation for maximum accuracy.

2.2. Survey Site Access

Poor access to most of the survey area would require survey officers to make their way through uncertain terrain with survey equipment to each control point location. Including the 6 hour occupation time for static survey, just one control point is likely to be installed in a day. Control points would need to be revisited twice more—before and after the bathymetric survey—to assemble and disassemble the base station equipment for the survey.

For much of the Roper and Katherine-Daly Rivers, access can only be achieved by boat and can only be achieved heading downstream in a light vessel that can be portaged over control features. Time taken to navigate from an entry point to a recovery point can be several days. Figures 3 and 4 show the types of obstacles encountered while navigating these waterways. Consequently this cannot be considered a suitable method for repeat site access.



Figures 3 & 4: One way navigation requires portage over control features and blockages.

2.3. Project Budget

When considering the time and resources required to establish a survey control network of suitable density along the length of a river using static survey techniques, along with revisitation to install base station instrumentation and carry out the bathymetric survey itself, costs rapidly escalate beyond most reasonable project budgets. Early in the project planning it became clear that conventional RTK survey techniques would not be practical for undertaking longitudinal sections in remote locations with limited access.

3. Satellite Based RTPPP Correction Service for Bathymetric Survey

The request for accurate longitudinal section surveys on both the Roper and Katherine-Daly Rivers to facilitate refinement of the hydrological models led to a review of conventional and alternative technologies to allow key objectives of the surveys to be achieved within a reasonable timeframe and budget.

Key objectives for both surveys included:

- Provision of long section bathymetry data of primary channel centreline to establish river bed slope and better define the surface/groundwater interface.
- Provision of georeferenced bathymetry measurements in AHD for integration with other model components. Minimum required accuracy of ± 0.500 m, desirable accuracy of ± 0.200 m.
- Quantify measurement uncertainty for data collected.



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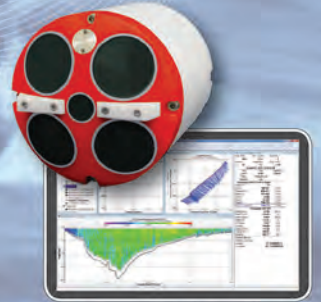
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In the absence of any survey control network or terrestrial differential correction service in the survey areas, and with poor access to most of the study areas, space based correction services were considered most likely to provide cost and time effective survey grade positions over a large spatial extent. After discussions with various manufacturers and instrument providers, a Trimble R10 Dual Frequency GNSS Receiver and Trimble's CenterPoint® RTX satellite based correction service were selected as capable of meeting the project requirements as well as a broader range of departmental activities, particularly the alignment of all remote monitoring sites into a common datum (such as bores) and to undertake rapid cross sections in remote locations, some of which can extend for several kilometres across floodplains.

Significant assistance was provided by the Trimble supplier who showed great interest in what was seen as a novel application for the relatively new RTX technology. Testing of the equipment under a range of scenarios was undertaken to ensure the correction service was capable of providing the required survey accuracy under the conditions expected on the long section surveys. Several limitations were identified at this time allowing mitigation measures to be built into the project planning. These limitations were outlined in Section 1.6.

The rapidly developing nature of the technology meant different techniques were employed to achieve the key objectives for both surveys. Prior to January 2016, Trimble's RTX service was not capable of continuous survey. Each location required a minimum occupation of 3 epochs (approximately 3 seconds) to collect accurate position data. While this is sufficient for most terrestrial survey requirements, it is not sufficient for collection of bathymetric data where the vessel is constantly in motion. Since January 2016, continuous survey capability through the RTX service meant position data could be collected continuously, simultaneously with depth soundings. As a result two different techniques were successfully employed in order to achieve the required outcomes for the two longitudinal surveys conducted on remote river systems in the Northern Territory. These include:

- Rapid establishment of control network
- Continuous RTK survey data collection

Depending on site and technical limitations, either or both techniques may be successfully deployed to undertake bathymetric survey in remote areas to achieve bathymetric data accuracy within ± 0.200 m of the required datum.

3.1. Rapid Establishment of Control Network

Satellite Based Differential Correction Services can be used to establish survey control points to a vertical accuracy of ± 0.050 m once system convergence has been achieved—usually within 20 minutes from start-up—instead of the 4-6 hour occupation required for conventional static survey techniques. This significant time saving means multiple control points can be installed in a day as opposed to a single control point using static survey. Control points can then be used to set up a base station for conventional RTK, or where hydraulic conditions within the waterway are sufficiently stable and uniform, water level can be surveyed in from the control point to provide the reference datum for depth soundings. This technique may not be sufficiently accurate where a constant head slope exists along the waterway, however where a pool-control sequence occurs with no discernible head loss across the length of the pool, it is possible to obtain highly accurate levels using this method. Where control points are installed, water levels should be surveyed using a dumpy level during the bathymetric data collection to accurately determine water level at that point and time. Where continuous RTK is not available through the satellite correction service, this method allows an accurate survey control network to be established rapidly. Figure 5 shows the establishment of a control points at Roper Bar for the Roper River Longitudinal Survey using Trimble's RTX correction service.

As continuous survey was not available using Trimble's RTX service until 2016, this method was successfully used for the Roper River Longitudinal Survey as outlined in the case study below.



Figure 5: Establishing benchmark at Roper Bar using Trimble RTX service.

3.2. Continuous RTK survey data collection

Since January 2016, Trimble's RTX service has allowed continuous RTK positions to be collected using satellite based corrections. This is a significant technological advancement for bathymetric data collection where the survey vessel is constantly in motion. Trimble's RTX service is now able to be used in the same way as conventional RTK systems to allow continuous survey grade data collection. For rivers where continuous head loss occurs throughout the system, the ability to collect accurate position data on-the-fly is essential for determining the water level from which depth soundings are taken. In the absence of continuous RTK data collection, interpolation of water levels between sparse control points is required, potentially introducing significant errors and uncertainty into the survey.

While survey grade corrected positions can now be achieved through the Trimble RTX service, an independent measure of positional accuracy is required. This can be achieved in two ways:

- Survey Control Points—Good survey practice requires control redundancy by tying known control points into the survey wherever possible. Typically, the magnitude of errors across the known control points is used to determine the level of uncertainty within the survey, and normalisation of surveyed positions using Reduced Mean Square (RMS) techniques to distribute corrections for measurement errors throughout the surveyed positions.
- Record measurement uncertainty by utilising data collection software capable of receiving \$GNGST (\$GPGST) NMEA strings. The \$GNGST string provides a positional measurement uncertainty known as the Sigma value, which is a statistical calculation of total uncertainty from all inputs to the position calculation, including pseudo range and differential corrections. The Sigma value is essentially 1 standard deviation of the calculated position. ± 2 standard deviations of the calculated position make up the 95% confidence interval of the position observation.

Both of these techniques should be employed to determine positional uncertainty when undertaking bathymetric survey.

4. Case Studies – Roper River and Katherine-Daly River Surveys

For both surveys, access to the survey area was limited with few roads or tracks into the study areas. For much of both survey areas, access is only possible by water using a light portable vessel able to be manhandled over control sections and shallows, and through blockages from flood debris etc. In most cases navigation is only possible in the downstream direction.

4.1. Roper River Longitudinal Survey 2014/15

Flowing 355 km east from Mataranka to the Gulf of Carpentaria, the Roper River is a remote, unregulated and highly complex river system. Characterised as a series of deep pools separated by natural bedrock controls rather than having a continuous bed slope typical of most rivers, approximately one quarter of the non-tidal Roper River consists of un-navigable braided channel sections with poorly defined primary channels and high evapotranspiration (ET) losses. Dry season baseflow is entirely derived from water discharged from the Tindal Limestone Aquifer which is intersected by the river between Mataranka and Elsey Station, a distance of approximately 32 km. For the next 180 km to the upper extent of tidal influence at Roper Bar, there are no further dry season inflows into the river. This results in river discharges decreasing downstream from Elsey Station during the dry season due to losses from ET, with measured end-of-dry season discharge at Roper Bar approximately half that measured at Elsey Station. Figure 6 is a map of the Roper River survey area.



Figure 6: Map of Roper River Survey study area including installed benchmark locations.

4.1.1. Survey Control

Except for three gauging stations located along the river, no survey control points exist within the survey area. With no discernible head loss through each pool during baseflow conditions, and very little variation in water levels during the late dry season, it was determined that pool water levels could be utilised as a stable datum from which soundings were collected, with each pool being tied into AHD at the time of survey. Horizontal positions from an uncorrected GNSS instrument were considered sufficient for the purposes of the long section.



Figure 7: Control point on bedrock control.

Prior to the collection of bathymetric data, a series of survey control points were installed at accessible locations along the length of the Roper River. 120 mm rock bolts were securely fixed into exposed bedrock to ensure control point stability consistent with current Australian Standards. Using Trimble's RTX correction service, a total of 25 survey benchmarks were installed over an 8-day period. Benchmark positions were established in GDA94 for the horizontal datum and AHD for the vertical datum accurate to within ± 0.050 m in both the horizontal and vertical axis. Figure 6 shows the location of survey control points established for the survey, while Figure 7 shows a typical control point installed in a bedrock control.

With some pools extending up to 18 km in length, control point density was far lower than that required if using conventional RTK. Where control points could not be installed due to poor access, dumpy level survey would be used to carry the AHD level down consecutive pools, tying pool levels into control points where available.

4.1.2. RTX Correction Service Integrity (Correction Drift)

To determine the level of correction drift for the survey area, three control points established for the longitudinal section were tied into AHD using both the RTX correction service and through static survey. A correction drift of -0.075 m was found to occur at Mataranka (400 km from Darwin), ranging to -0.100 m at Roper Bar (600 km from Darwin).



Figure 8: Static survey using Trimble R10.

Based on the observed drift, all control point AHD values were adjusted up between 0.075 m and 0.100 m depending upon the control point distance to Darwin. Figure 8 shows the Trimble R10 set up for Static Survey midway along the Roper River at Moroak Station.

4.1.3. Bathymetric Data Collection

The longitudinal section survey was undertaken over a two week period in September 2015, towards the end of the dry season when conditions were most suitable for water level stability and site access.

A Tritech P/A500 depth sounder was the primary instrument used to collect depth measurements, with an operational range of 0.1 m to 10.0 m. An RDI 1200 kHz ADCP was used as a secondary instrument for redundancy. The ADCP averages depth measurements over 4-sensors with an operational range between 0.35 m and 25.0 m. For the purposes of the Roper River long section both instruments were selected for their different operating ranges, with dual bathymetry data streams being collected simultaneously throughout the survey project.

Instruments were mounted to a purpose built bracket and deployed amidships on a portable 3.7 m survey vessel. Instruments were spaced 0.300 m apart in a fore and aft configuration to ensure consistent data collection. Data from both instruments was streamed into a laptop computer running the RDI WinRiver II ADCP software. Figure 9 shows the instrument configuration mounted on the survey vessel.



Figure 9: Bathymetric instrument configuration.

Position Measurements

Horizontal position was measured using an uncorrected Hemisphere A100 GPS unit mounted above the depth sounding instruments. While measurement uncertainty for uncorrected GNSS is typically ± 10.000 m, this was deemed sufficient for the requirements of the longitudinal section where the focus was primarily on accurate elevation.

Pool water levels were tied into AHD on the day of bathymetric data collection using a dumpy level to survey from an installed control point to the surface of the pool level. Where necessary, consecutive pool surface levels were surveyed relative to each other, then tied back into AHD at the next accessible control point. For most areas, pool surface levels were surveyed into multiple control points, providing redundancy of survey control and improving confidence in the overall survey control network. Figures 10 and 11 demonstrate the process of surveying pool water levels into AHD using a dumpy level. Where possible, upstream pool water level and downstream pool water level were surveyed for each benchmark to allow normalisation of AHD levels, and provide datum continuity throughout the survey area.



Figures 10 and 11: Surveying pool water levels into AHD using Dumpy Level.

Bathymetric Data Collection Software

RDI's WinRiver II software was used to collect depth sounding and GNSS positions during the bathymetric data collection. WinRiver II collects simultaneous data streams from the ADCP instrument, auxiliary depth sounder instrument (Tritech PA500) and pairs them with positional data from the external GPS unit (Hemisphere A100). Data collection can be viewed in real time, and reprocessed later using either of the depth data streams or a combination of both. The WinRiver II software allows manual input of transect endpoints to account for non-surveyed sections, and also displays transect distance calculated through bottom tracking or GNSS. Instrument pitch and roll are measured using the ADCP's inbuilt inclinometer for each data point collected. Effects of pitch and roll are removed in real time to display actual depth from the transducer head for both instruments.

4.1.4. Data Processing

Bathymetric Datum Control

Field surveyed water levels were calculated from control point AHD levels collected using Trimble's RTX service. All surveyed pool levels tied back into control point AHD levels within the ± 0.050 m RTX measurement uncertainty, providing confidence in the technique adopted to establish vertical control. Based on pool levels, control point AHD values were normalised to ensure datum consistency along the river. Surveyed pool levels were also normalised. All adjustments for normalisation were within the uncertainty calculation (± 0.050 m) for each control point, so that all adjustments to control points and pool water surface levels were within ± 0.050 m of the original surveyed AHD value.

Bathymetric Data

Bathymetric data was post processed to remove data spikes, redundant data points and to splice multiple transects into a single transect file representing the thalweg for each pool surveyed. WinRiver II was used to analyse the raw data for data spikes and redundant data from the start or end of each transect. Data spikes typically occur due to echo soundings from woody debris accumulated within the channel. As these do not represent true bed level they were removed so as not to affect depth averaging.

4.1.5. Positional Data Uncertainty

Uncertainty is introduced wherever a measurement is taken within the bathymetric data collection process. For positional uncertainty, these include:

- Horizontal position in GDA94 using non-corrected GPS (< 10.000 m).
- AHD measurement uncertainty using Trimble RTX correction service was calculated individually for each control point at the time of establishment within the Trimble survey software (Trimble Access). Uncertainty is based on the Sigma value and is the calculated 95% confidence interval for the observed level. All established control points had a calculated uncertainty of < 0.050 m.
- Correction drift was measured using static survey and varied between -0.075 m and -0.100 m across the survey area. The greatest measurement uncertainty for the static survey used to calculate correction drift (at Roper Bar) is ± 0.032 m.
- All level surveys undertaken by dumpy level were performed to department standards and calculation of reduced levels for all surveys were within required error bounds for dumpy level survey of ± 0.005 m.
- Daily water level fluctuations were analysed for two monitoring stations along the Roper River. As expected, measured water level variations in the monitoring pools was limited to 4–8 mm per day. Recorded variations are attributable to diurnal cycles of heating and cooling of the water in the pool rather than as a result of changes to discharge. With no rainfall during the survey period, this is considered indicative of water level variations throughout the study area.

Calculation of maximum possible vertical uncertainty for pool levels to AHD, adjusted for RTX correction service drift, can be calculated by adding the maximum uncertainty for control point uncertainty (RTX), maximum uncertainty for control point static survey (Static), maximum water level variation (WL) and maximum water level survey uncertainty (Survey):

$$\begin{aligned} \text{Vertical Uncertainty} &= 0.050 \text{ (RTX)} + 0.032 \text{ (Static)} + 0.008 \text{ (WL)} + 0.005 \text{ (Survey)} \\ &= \pm 0.095 \text{ m} \end{aligned}$$

Calculation of total depth measurement uncertainty for bathymetric data collected during the Roper River Long Section Survey, including depth instrument uncertainty, was calculated to ± 0.105 m.

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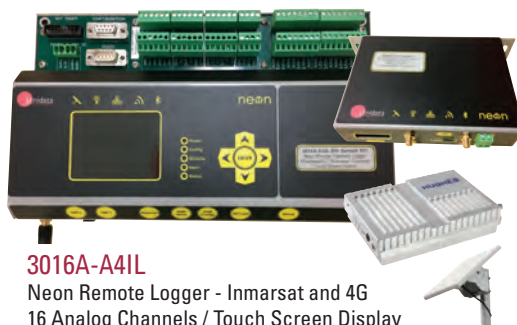
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Assumed 95% CI for Horizontal Uncertainty in GDA94 < 10.000 m

95% CI for Vertical Uncertainty in AHD < ±0.105 m

Calculated vertical measurement uncertainty was well within project objectives of ±0.200m. Measurement uncertainty should be considered within the context of assumptions made during data collection and processing. These assumptions are outlined below.

4.1.6. Assumptions

- The surveyed boat course represents the deepest part of the channel (thalweg). It is impossible to know where the deepest part of the channel actually is without a full bathymetric survey of the channel.
- An assumed depth of 0.200 m was given to water depth over hydrological control features. Actual depth over controls was highly variable, typically in the region of 0.100–0.400 m.

4.1.7. Results and Discussion

A stable, accurate survey control network was successfully installed along the Roper River for the benefit of the Roper River Survey and also for any future survey work to be carried out in the catchment. Figure 12 shows the control point locations including observed AHD level, level corrected for PPP drift and finally assumed level to normalise control points so that a consistent datum exists throughout the study area.

BM ID	Easting	Northing	Observed AHD [RTX]	RTX Error	Adjusted AHD (DIT. DIT)	Normalised AHD	Difference	Survey Pool	Surveyed Water Level (mAHD)	Benchmark ID	Normalised Water Level (mAHD)	Difference
BM_conf	301174.5	8348144	115.071 ± 0.047		115.153	115.153	0.000	1		112.116 BM_conf	112.116	0
TBM01A_V	303609.7	8348182	112.551 ± 0.045		112.628	112.628	0.000	1A		110.678 TBM01A_Wabalarr	110.678	0
BM03	307046.6	8347324	107.747 ± 0.037		107.824	107.824	0.000	2		110.361 TBM01A_Wabalarr	110.361	0
BM06	307530.7	8346805	106.517 ± 0.047		106.595	106.595	0.000	2A		109.512 TBM01A_Wabalarr	109.512	0
BM12	113615.9	8346596	101.785 ± 0.044		101.864	101.864	0.000	3		107.818 BM03	107.818	0
BM13	115285.9	8347307	99.671 ± 0.050		99.750	99.750	0.000	4		107.5 BM03	107.5	0
BM14A	117987.3	8345767	100.346 ± 0.046		100.425	100.425	0.000	5		107.162 BM03	107.162	0
BM14	120316.4	8345828	96.946 ± 0.026		97.026	96.996	0.030	6		106.402 BM06	106.402	0
BM15	121009.7	8345593	96.35 ± 0.046		96.430	96.465	-0.035	7		106.171 BM06	106.171	0
BM16	123401.8	8346115	96.049 ± 0.038		96.129	96.173	-0.044	13		96.818 BM12	96.818	0
BM17	126459.8	8351874	99.7 ± 0.038		99.781	99.781	0.000	14A		97.079 BM14A	97.079	0
BM19	358798.4	8360331	68.364 ± 0.052		68.450	68.450	0.000	14		97.002 BM14	96.972	-0.03
BM21	368207.3	8359543	60.457 ± 0.037		60.544	60.544	0.000	15		96.442 BM14	96.412	-0.03
BM23	395947.1	8361498	40.001 ± 0.043		40.093	40.093	0.000	15		96.377 BM15	96.412	0.035
BM23_1	395949.6	8361512	41.536 ± 0.045		41.628	41.628	0.000	16		95.801 BM15	95.836	0.036
BM24	397792.2	8370534	36.169 ± 0.047		36.261	36.261	0.000	16		95.792 BM16	95.836	0.044
BM24_1	397792.3	8370634	36.225 ± 0.044		36.317	36.317	0.000	17		95.377 BM17	95.377	0
BM25_GP	397800.9	8370646	36.724 ± 0.046		36.816	36.816	0.000	19		64.078 BM19	64.078	0
BM25	397800.9	8370646	36.662 ± 0.045		36.754	36.754	0.000	21		56.712 BM21	56.712	0
BM26	404077	8377084	35.444 ± 0.049		35.537	35.537	0.000	27		12.163 TBM27	12.163	0
BM27	426085	8386088	19.115 ± 0.044		19.212	19.212	0.000	33		4.959 BM32	4.985	0.026
BM32	432289.5	8380484	5.755 ± 0.043		5.853	5.879	-0.026	33		5.003 BM33	4.985	-0.016
BM33	431276.4	8379663	5.927 ± 0.037		6.025	6.009	0.016	34		3.915 BM35	3.915	0
BM35	432078.3	8378035	4.7 ± 0.045		4.798	4.798	0.000	35		2.476 BM36	2.504	0.028
BM36	435500	8375659	3.298 ± 0.037		3.396	3.424	-0.028	36		2.446 BM36	2.474	0.028
BM37	437155.5	8375127	2.401 ± 0.042		2.499	2.510	-0.011	37		2.463 BM37	2.474	0.011
BM38	439415	8375955	2.669 ± 0.048		2.768	2.724	0.044	37		2.239 BM37	2.25	0.011
BM40	447034.8	8373366	1.586 ± 0.037		1.686	1.686	0.000	38		2.294 BM38	2.25	-0.044
								38		2.12 BM38	2.068	-0.052
								39		1.961 BM40	1.961	0

Figure 12: Raw survey levels and normalised survey levels.

Observed control point level integrity has been confirmed through connection of pool levels to multiple control points, including through carrying of the reference datum into river reaches where no survey control points were installed. Reconnection of pool levels at multiple control point show that on all occasions the reduced level of the control point was within the observed uncertainty calculated during the differential RTX connection to AHD and GDA94.

Figure 5.6.1 shows surveyed bed levels averaged for each pool compared to the estimated bed slope used in the original model. Significant differences in elevation exist, particularly in the upper reaches where the river intersects the Tindal Limestone Aquifer. This can lead to errors in modelled discharge due to the size of the modelled interface between the river and the aquifer.

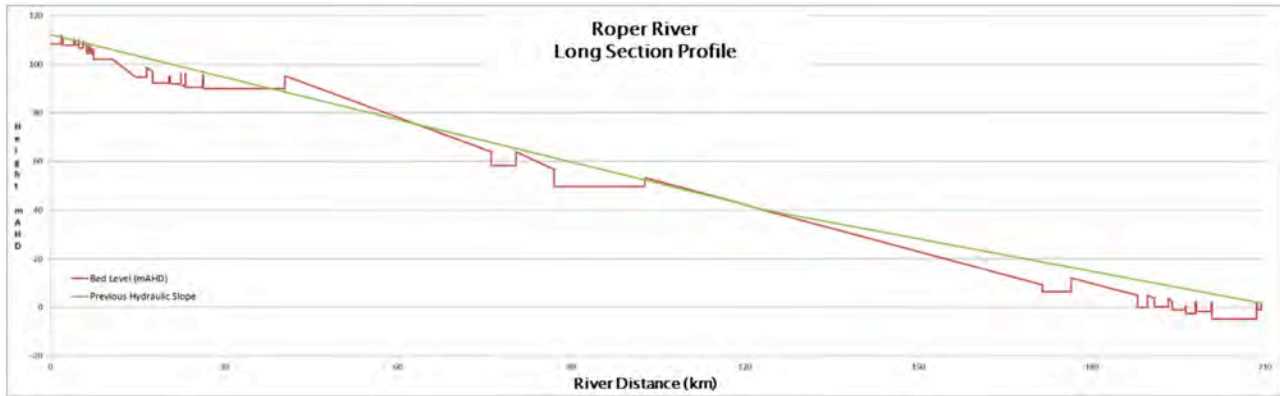


Figure 13: Surveyed bed level in AHD vs assumed bed level from surface/groundwater model.

4.2. Katherine/Daly River Longitudinal Survey 2016

Flowing from the Arnhem Land Plateau, the Katherine River runs south-west for approximately 250 km to its confluence with the Flora River where the combined flow becomes the Daly River. From here the Daly River flows north-west for a further 370 km to the Bonaparte Gulf. Figure 14 shows a map of the study area. The river distance for the longitudinal survey, from Katherine to the Daly River Police Station at the extent of tidal influence on the Daly River, is 350 km.

The Katherine-Daly River is typical of many river systems exhibiting a continuous bed slope throughout its length punctuated by rapid head loss over control features. The river is navigable downstream from Katherine in its entirety during higher flows, however during low flows numerous constrictions and sandbars within the river make it navigable only by small craft able to be portaged over shallow sandbars and lowered over control features.

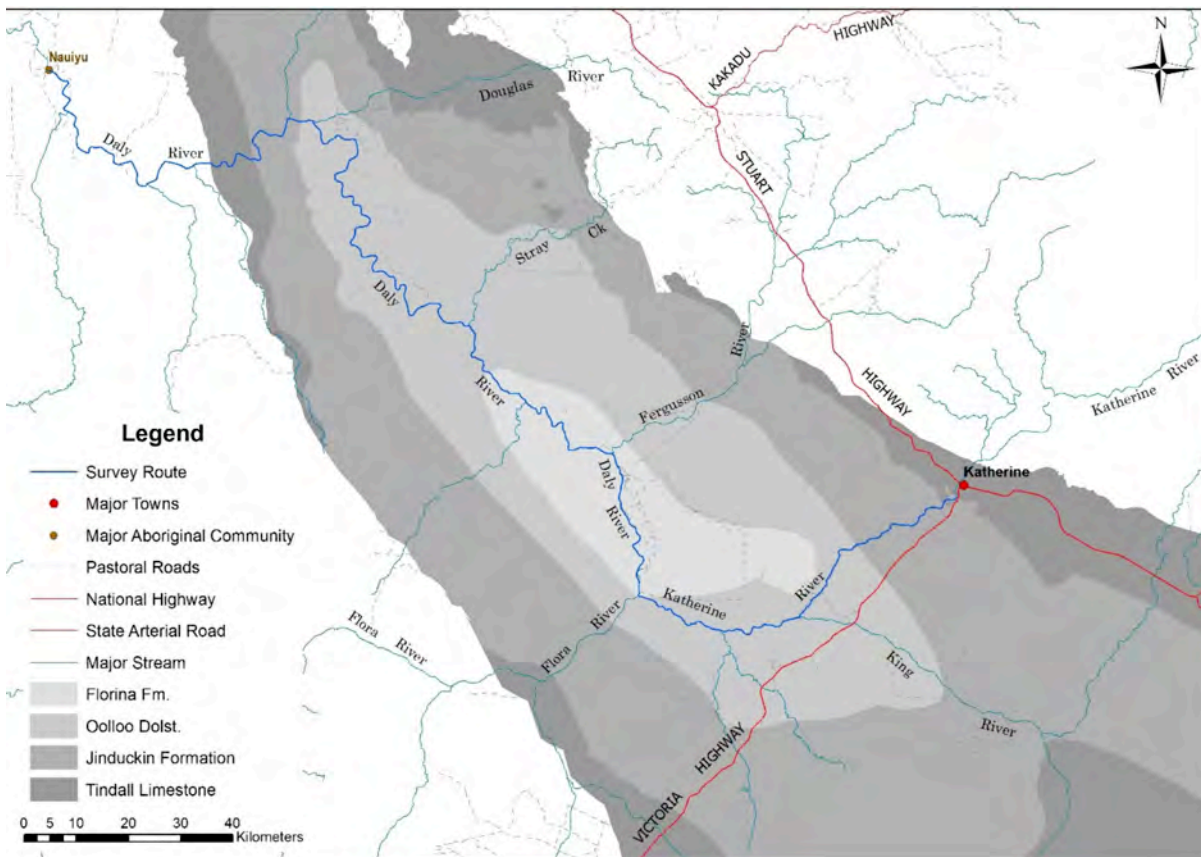


Figure 14: Map of Katherine-Daly River Survey Area.

The Katherine-Daly River intersects two major aquifer systems over the survey area, the Tindal Limestone and Ooloo Dolostone. Discharges in the river increase heading downstream due to inflows from groundwater and tributaries.

4.2.1. Survey Control

Due to the continuous flood slope and head loss along the Katherine-Daly Rivers, a true continuous RTK data collection solution was required with the ability to provide accurate positions in the horizontal and vertical axes to required uncertainty levels. With the firmware upgrade in January 2016, Trimble's RTX service was able to collect continuous RTK positional data. This new capability was tested thoroughly on a reservoir near Darwin with all vertical positions collected falling within a 10 mm range over several transects of the reservoir.

With no terrestrial survey control points for most of the survey area, the following measures were taken to verify the accuracy of RTK positional data collected through the Trimble RTX service:

- Survey control points established using static survey techniques overnight during bathymetric data collection fieldwork. A dumpy level was used to measure water level at the same time and location as bathymetric positions collected using Trimble RTX service.
- Utilise HYPACK software for bathymetric data collection. HYPACK offers advanced geodesy settings and allows the capture of \$GNGST (\$GPGST) NMEA strings.

4.2.2. RTX Correction Service Integrity (PPP Drift)

Observations for correction service drift over a control point were not undertaken during the Katherine–Daly River Longitudinal Section. Instead it was thought that the comparison between water levels surveyed from the control point to water levels collected through the RTX correction service could be used to determine the magnitude of this drift. While an estimate can be made of the PPP drift using this technique, it is difficult to differentiate between the different sources of error to attribute a specific measurement of correction drift. It is important to always take correction service drift observations on the control point during the bathymetric survey. As with all things hydrographic, repeatability reduces uncertainty.

With discrepancies between water levels from control point surveys and bathymetric survey typically around -0.100 m, no corrections for correction drift have been applied for this survey.

4.2.3. Bathymetric Data Collection

The longitudinal section survey was undertaken over a three week period in May–June 2016, early in the dry season when water levels were sufficiently high to aid navigation, but comprised largely of baseflow to avoid significant fluctuations in water level during the survey.

Depth Measurements

A Tritech P/A500 depth sounder was used to collect depth measurements, with an operational range of 0.1–10.0 m. This was considered sufficient for the Daly River which is shallower than the Roper River. The RDI 1200 kHz ADCP was not used due to communication issues with the HYPACK software.

Position Measurements

Horizontal and vertical position was measured using the Trimble R10 Dual Frequency GNSS Receiver with RTX correction service. \$GNGST strings were collected for each position measurement to provide a measure of positional uncertainty. 95% uncertainty of positional measurements varied from ± 0.030 m where a good horizon to the RTX satellite was available, to ± 2.000 m in areas where corrections from the RTX satellite were interrupted due to horizon interference from riparian vegetation or geological features. With the RTX satellite sitting to the north of Australia, higher accuracies were typically achieved on the Daly River which is wider and flows to the north-west, than on the Katherine River which is narrower and flows to the south-west. Figure 15 shows instrument configuration.



Figure 15: Trimble R10 GNSS Receiver and Tritech P/A500 Depth Sounder.

Bathymetric Data Collection Software

HYPACK was selected as the data collection and processing software due to its advanced Geodesy settings and powerful post processing tools. HYPACK is a complete bathymetric software package, with an expansive suite of instrument drivers provided to allow full utilisation of industry specific instruments. Non-standard instruments able to output generic NMEA sentences are also accommodated. Of particular interest were HYPACK’s ability to collect and record NMEA \$GNGST strings, allowing positional uncertainty to be applied to the measured positions (Figure 17), and the ability to install datum transformation equations and models within HYPACK to collect accurate horizontal and vertical positions based on the latest calculations between the GNSS datum and GDA94/AHD datums (Figure 16). In Australia, these transformation models are developed and maintained by Geoscience Australia.

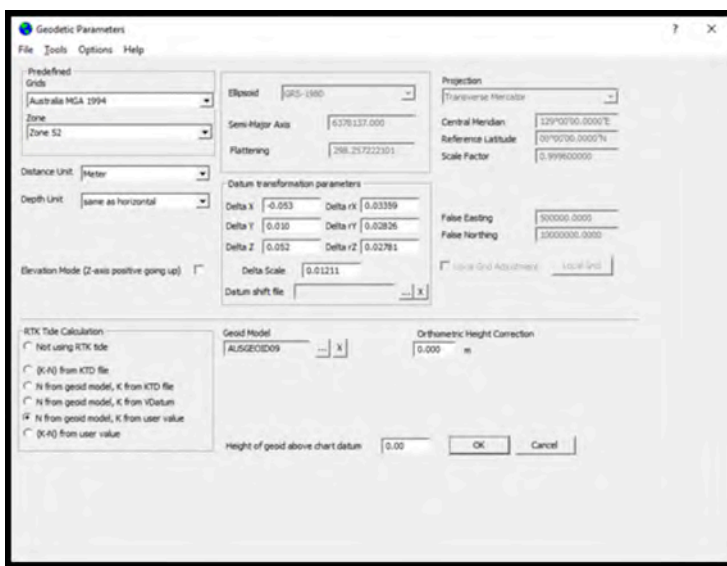


Figure 16: Geodetic Parameters setup in HYPACK.

Record	DBL	Latitude	Longitude	GPS Elevation	Geoid Separation	Time	Dip	GPS Mode	Standard Error X	Standard Error Y	Standard Error Z	Total Error	Raw Depth	Tide Corr	Corr. Depth
1343	322.85	13 52 40.2881 S	131 02 34.2063 E	61.00	46.29	13:40:11.64	0.7	5	0.01	0.01	0.01	0.13	-0.55	12.97	12.20
1344	323.26	13 52 40.2987 S	131 02 34.2140 E	61.00	46.29	13:40:11.84	0.7	5	0.01	0.01	0.01	0.13	-0.58	12.97	12.17
1345	323.47	13 52 40.3039 S	131 02 34.2194 E	61.00	46.29	13:40:11.94	0.7	5	0.01	0.01	0.01	0.13	-0.57	12.97	12.18
1346	323.67	13 52 40.309 S	131 02 34.2235 E	61.00	46.29	13:40:12.04	0.7	5	0.01	0.01	0.01	0.13	-0.62	12.97	12.13
1347	323.88	13 52 40.3144 S	131 02 34.2278 E	61.00	46.29	13:40:12.14	0.7	5	0.01	0.01	0.01	0.13	-0.62	12.97	12.13
1348	324.09	13 52 40.3195 S	131 02 34.232 E	61.00	46.29	13:40:12.24	0.7	5	0.01	0.01	0.01	0.13	-0.62	12.97	12.13
1349	324.30	13 52 40.3251 S	131 02 34.2362 E	61.00	46.29	13:40:12.34	0.7	5	0.01	0.01	0.01	0.13	-0.62	12.97	12.13
1350	324.51	13 52 40.3305 S	131 02 34.2406 E	61.00	46.29	13:40:12.44	0.7	5	0.01	0.01	0.01	0.13	-0.62	12.97	12.13
1351	324.72	13 52 40.3359 S	131 02 34.2448 E	61.00	46.29	13:40:12.54	0.7	5	0.01	0.01	0.01	0.13	-0.60	12.97	12.15
1352	324.93	13 52 40.3413 S	131 02 34.2491 E	61.00	46.29	13:40:12.64	0.7	5	0.01	0.01	0.01	0.13	-0.61	12.97	12.14
1353	325.13	13 52 40.3466 S	131 02 34.2533 E	61.00	46.29	13:40:12.74	0.7	5	0.01	0.01	0.01	0.13	-0.66	12.97	12.09
1354	325.34	13 52 40.352 S	131 02 34.2575 E	61.00	46.29	13:40:12.84	0.7	5	0.01	0.01	0.01	0.13	-0.67	12.97	12.08
1355	325.77	13 52 40.363 S	131 02 34.262 E	61.00	46.29	13:40:13.04	0.7	5	0.01	0.01	0.01	0.13	-0.71	12.96	12.03
1356	325.98	13 52 40.3684 S	131 02 34.2705 E	61.00	46.29	13:40:13.14	0.7	5	0.01	0.01	0.01	0.13	-0.67	12.97	12.08
1357	326.19	13 52 40.3737 S	131 02 34.2747 E	61.00	46.29	13:40:13.24	0.7	5	0.01	0.01	0.01	0.13	-0.64	12.97	12.11
1358	326.39	13 52 40.3791 S	131 02 34.279 E	61.00	46.29	13:40:13.34	0.7	5	0.01	0.01	0.01	0.13	-0.63	12.97	12.12
1359	326.60	13 52 40.3845 S	131 02 34.2832 E	61.00	46.29	13:40:13.44	0.7	5	0.01	0.01	0.01	0.13	-0.62	12.97	12.13
1360	326.82	13 52 40.39 S	131 02 34.2875 E	61.00	46.29	13:40:13.54	0.7	5	0.01	0.01	0.01	0.13	-0.63	12.97	12.12
1361	327.03	13 52 40.3954 S	131 02 34.2917 E	61.00	46.29	13:40:13.64	0.7	5	0.01	0.01	0.01	0.13	-0.67	12.96	12.07
1362	327.23	13 52 40.4008 S	131 02 34.2958 E	61.00	46.29	13:40:13.74	0.7	5	0.01	0.01	0.01	0.13	-0.66	12.97	12.09
1363	327.44	13 52 40.4063 S	131 02 34.3 E	61.00	46.29	13:40:13.84	0.7	5	0.01	0.01	0.01	0.13	-0.63	12.97	12.12
1364	327.65	13 52 40.4117 S	131 02 34.3042 E	61.00	46.29	13:40:13.94	0.7	5	0.01	0.01	0.01	0.13	-0.64	12.97	12.11
1365	327.85	13 52 40.4169 S	131 02 34.3082 E	61.00	46.29	13:40:14.04	0.7	5	0.01	0.01	0.01	0.13	-0.69	12.96	12.05
1366	328.27	13 52 40.4278 S	131 02 34.3178 E	60.99	46.29	13:40:14.24	0.7	5	0.01	0.01	0.01	0.13	-0.75	12.96	11.99
1367	328.48	13 52 40.4322 S	131 02 34.321 E	61.00	46.29	13:40:14.34	0.7	5	0.01	0.01	0.01	0.13	-0.74	12.96	12.00
1368	328.69	13 52 40.4366 S	131 02 34.3252 E	61.00	46.29	13:40:14.44	0.7	5	0.01	0.01	0.01	0.13	-0.67	12.97	12.08
1369	328.90	13 52 40.441 S	131 02 34.3294 E	60.99	46.29	13:40:14.54	0.7	5	0.01	0.01	0.01	0.13	-0.64	12.96	12.10
1370	329.11	13 52 40.4455 S	131 02 34.3336 E	60.99	46.29	13:40:14.64	0.7	5	0.01	0.01	0.01	0.13	-0.60	12.96	12.14
1371	329.32	13 52 40.45 S	131 02 34.338 E	60.99	46.29	13:40:14.74	0.7	5	0.01	0.01	0.01	0.13	-0.61	12.96	12.13
1372	329.53	13 52 40.4604 S	131 02 34.3422 E	61.00	46.29	13:40:14.84	0.7	5	0.01	0.01	0.01	0.13	-0.57	12.96	12.17
1373	330.16	13 52 40.4767 S	131 02 34.3598 E	61.00	46.29	13:40:15.14	0.7	5	0.01	0.01	0.01	0.13	-0.58	12.97	12.17
1374	330.58	13 52 40.4876 S	131 02 34.3634 E	61.00	46.29	13:40:15.24	0.7	5	0.01	0.01	0.01	0.13	-0.66	12.97	12.09
1375	330.79	13 52 40.493 S	131 02 34.3677 E	61.00	46.29	13:40:15.44	0.7	5	0.01	0.01	0.01	0.13	-0.78	12.97	11.97
1376	331.00	13 52 40.4985 S	131 02 34.372 E	61.00	46.29	13:40:15.54	0.7	5	0.01	0.01	0.01	0.13	-0.77	12.97	11.98
1377	331.22	13 52 40.5039 S	131 02 34.3764 E	61.00	46.29	13:40:15.64	0.7	5	0.01	0.01	0.01	0.13	-0.75	12.97	12.00
1378	331.43	13 52 40.5093 S	131 02 34.3807 E	61.00	46.29	13:40:15.74	0.7	5	0.01	0.01	0.01	0.13	-0.70	12.97	12.05

Figure 17: Measurement Uncertainty observations (Sigma Z) in HYPACK from \$GST strings.

4.2.4. Data Processing

Bathymetric Datum Control

Static surveys for control points were processed through Geoscience Australia’s AUSPOS system. Water level surveys conducted during data collection were calculated and compared to the water levels collected during bathymetric data collection at the same time and location of the water level survey. Figure 18 shows the control point height, the surveyed water level, the water level measured during bathymetric data collection and the difference. The Sigma Z value is the uncertainty measure from the bathymetric position. This is equivalent to 1-standard deviation and should be doubled to determine the 95% confidence interval for the observed water level during bathymetric data collection.

Benchmark	Latitude	Longitude	Height (mAHD)	AHD Uncertainty (m)	Water Level AHD	Water Level Bathymetry	Sigma Z	Difference
GallopingJack_BM	191582.155	8390325.907	80.492	0.059 RTX	79.94	79.85	0.38	0.09
TFS_Taypark_BM	14 42 40.82925 S	131 54 10.77207	67.121		61.996	61.98	0.1	0.016
FlorinaUS_BM	14 35 36.13434 S	131 42 52.31878	55.911		53.529	53.4	0.01	0.129
FlorinaDS_BM	14 26 01.85949 S	131 40 09.51212	46.638		45.37	45.26	0.02	0.11
DorisvaleCont_BM	14 21 46.43871 S	131 22 23.37918	41.846		41.007	40.84	0.01	0.167
DDRFCullen_BM	13 51 43.83916 S	131 11 07.14772	19.978		19.25	19.16	0.01	0.09
G8140041Control_BM	13 53 36.83302 S	130 47 50.04039	7.835		6.273	6.16	0.01	0.113

Figure 18: Surveyed water level vs water level measured using Trimble RTX correction service.

The results show the greatest discrepancy between the control point surveyed water level and water level collected during bathymetry was 167 mm at Dorisvale Crossing. This water level comparison is actually less reliable than the other surveyed water levels due to the surveyed level being in a backwater immediately below the crossing, while the closest water level collected during bathymetric data collection occurred 70 m downstream. While this is poor survey practice the comparison water level was kept as it demonstrates the surveyed water level is still very close to the levels measured during bathymetry.

All other surveys show the discrepancy between water levels surveyed from the control point and water levels collected during bathymetry are within ± 0.200 m including uncertainty from the control point survey and the RTX correction. It is noted that for all bathymetric levels where a high quality level was collected (Sigma Z < 0.100 m), the discrepancy to the water level surveyed from the control point was around -100 mm. This is in the same direction and of similar magnitude to the correction service drift calculated for the Roper River survey and is an indication of the PPP drift of the RTX for the Katherine-Daly River survey. No adjustments for correction service drift were made for this survey.

Bathymetric Data

Bathymetric data was post processed using HYPACK to normalise water levels, thin data and to remove data spikes and redundant data. Processed data was then copied into Microsoft Excel for data presentation and graphic representation of channel centreline (thalweg), and to distribute to clients in an easily accessible format.

Where bathymetric water level measurements were inconsistent and subject to large Sigma error values, interpolation of water levels between high quality measurements was required. Interpolated levels were then applied to the depth soundings to provide bed levels in AHD. Where this occurred the data quality was downgraded accordingly depending upon the level of uncertainty and vertical difference between levels used for interpolation.

4.2.5. Positional Data Uncertainty

Difference in water levels from control point surveys and water levels collected using Trimble RTX service during bathymetry were all within ± 0.200 m including observed uncertainty for the control point static survey and the observed RTX Sigma Z values. The only exception to this was the surveyed water level at Dorisvale Crossing as already discussed, where the calculated total uncertainty was ± 0.235 m.

Due to differences in the quality of positions collected using Trimble RTX during the bathymetric data collection, bathymetric data quality was categorised according to known uncertainty as follows:

- < 0.200 m — High quality data;
- 0.200 – 0.500 m — Medium quality data;
- > 0.500 m — Poor quality data.

4.2.6. Assumptions

Assumptions made during data collection and processing include:

- The surveyed boat course represents the deepest part of the channel (thalweg). It is impossible to know where the deepest part of the channel actually is without a full bathymetric survey of the channel.
- An assumed depth of 0.200 m was given to water depth over hydrological control features. In fact depth over controls was highly variable though typically in the region of 0.100 – 2.000 m.

4.2.7. Results and Discussion

Figure 19 shows the surveyed hydraulic slope for a section of the Katherine River between Florina Station and the confluence with the Fergusson River. Water level is colour coded to reflect the quality of the water level observations using Trimble's RTX correction service. Measurement uncertainty is provided in HYPACK using the Sigma values transmitted from the GNSS receiver and take into account corrections from the RTX service.

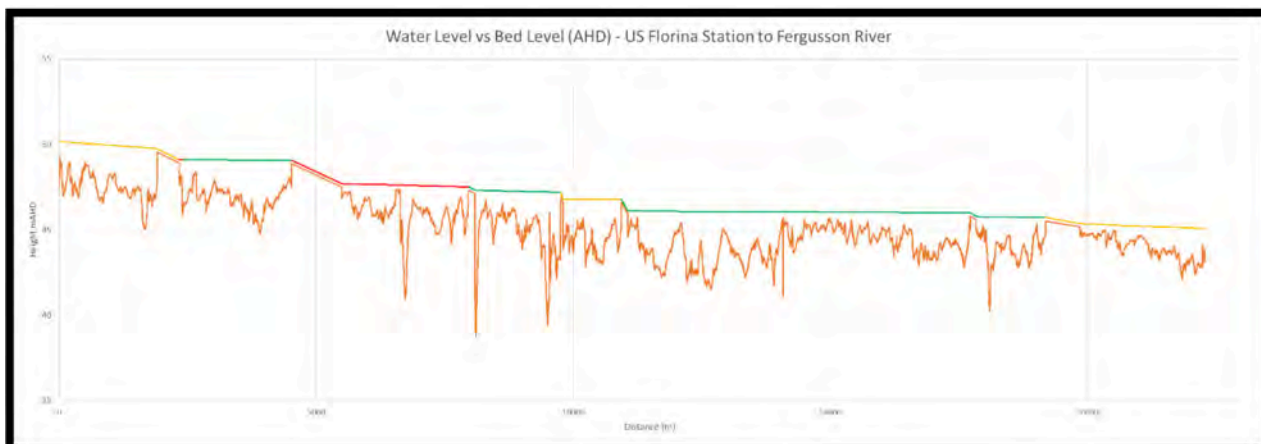


Figure 19: Surveyed hydraulic slope and bed level for section of Katherine River.



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Trimble's RTX correction service for continuous RTK position measurement was capable of providing bathymetric positions within the required uncertainty limits under ideal conditions. Comparisons to surveyed water levels from established benchmarks at selected locations showed positional data collected during bathymetric data collection to be within the project requirements (± 0.200 m) where positional uncertainty provided by the RTX observation (Sigma Z) was of a high quality (< 0.100 m).

Measurement uncertainty is likely to be significantly reduced if correction service drift at the survey location is accounted for, with total positional uncertainty from RTX observations likely to be within ± 0.100 m. In order for this to be confirmed, it is essential that RTX observations are taken for each control point where static survey techniques have been used to establish position.

Significant positional errors can occur with Trimble's RTX service where interference to the satellite is experienced, such as reduced northern horizon due to riparian or geological features. Where large errors exist, alternative methods must be used to determine water level and, ultimately, river bed levels.

5. Conclusion

The ability to collect real time positional data at resolutions of ± 0.050 m or better in the vertical and horizontal planes without the need for local survey control network or communication network is a significant development for position dependant data collection in remote areas, particularly where data collection is over a large spatial extent. The recent development of continuous survey capability is particularly beneficial for bathymetric data collection where the vessel is constantly in motion.

Real time PPP correction services have been demonstrated to be capable of providing an accurate RTK solution for collection of position data without a local survey control network. Positional uncertainty is excellent for absolute positions over a large spatial extent, however an understanding of correction service performance at the survey site is required in order to obtain highly accurate results. Performance of the correction service will be impeded by distance to the CORS network used by the correction service, and by local conditions that may interfere with the correction signal being received from the satellite.

Performance limitations relating to distance from the CORS network are typically regional, and can be mitigated through the establishment of control points using static survey to determine the difference between static survey position and position observed using the satellite correction service at those control points.

Performance limitations relating to correction signal interference will be local, the result of landscape features impeding the line of sight to the correction satellite. For bathymetric survey this is likely to be riparian features such as dense vegetation or geological features. Mitigation techniques for loss of correction signal may include interpolation of data over areas of lost correction signal, or installation of a control point and use of conventional RTK utilising a base station. Use of appropriate data collection software is required in order to detect loss of/poor correction signal. Mitigation techniques used will depend upon the accuracy requirements of the survey and the nature of the survey location itself.

Good survey practice requires the ability to provide some confidence in the surveyed positions by tying in known control points. While space based corrections are able to provide highly accurate positions without local control network, there is still a quality assurance requirement to tie the survey into some form of established terrestrial control. For any remote survey undertaken using satellite based correction service, it is recommended that some survey control points be established using static survey to ensure measurement uncertainty is within the stated bounds, and to determine the correction service drift. This may be a single control point for a survey over a small spatial area, or a low density network over a large spatial area.

No GNSS technologies provide the relative accuracy required for site specific survey such as instrument calibration, CTF measurements etc. These measurements require a higher level of accuracy than any GNSS technologies are capable of providing and a higher order of instrument precision is required, such as calibrated dumpy level or total station.

Space Based Differential Correction Services are capable of providing a sufficiently high resolution positioning solution suitable for the collection of bathymetric data where water levels are not constant over the surveyed area, with position uncertainties well within ± 0.200 m - the uncertainty level typically attributed to high quality remotely sensed data (i.e. aerial photography and satellite images). As with all surveys, the positional uncertainty requirements will be project dependant and instruments used will reflect the accuracy requirements stated within the project brief.

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Remote River Level Monitoring and Alarming for Highway Flood Inundation – Queensland State Highway Network

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Paper presented to 18th Australian Hydrographers Association Conference Canberra. 24 – 27 October 2016

Abstract

On average 15 people die in Australia every year as a result of floods, 10 of these attempting to drive through flood water. Despite ongoing public awareness campaigns to educate the community of the dangers of driving through floodwaters, such as Queensland (QLD) Governments: “If it’s Flooded, Forget it” campaign, the number of fatalities continues to rise. Subsequently, proactive State Road agencies and Councils, including QLD Transport and Main Roads (TMR) have implemented river level monitoring and alarming to provide highway flood inundation warning lead time allowing timely road closures.

QLD TMR are currently trialling such a system for their State Highway Network using battery powered Remote Telemetry Units (RTUs) combined with a water level sensor (pressure transducer).

The remoteness of many creek and river crossings along the QLD’s State Highway network makes physical inspection of water levels and assessment of road inundation ineffective during flood events. Therefore, remote monitoring and alarming has huge potential to:

- *Save TMR time and money through remote monitoring, rather than frequent site visits;*
- *Reduce health and safety risks of staff inspecting waterways and roads, and;*
- *Save lives of drivers and passengers prevented from driving through the flood waters.*

The Problem

Australia is a naturally hazardous place and floods seem to be occurring with increasing frequency and magnitude. Too many Australians are dying each year attempting to drive through flood waters. Community education campaigns seem to be having little effect, and whilst they remain important, many proactive authorities are now looking at near real time flood monitoring in remote locations to enable timely and effective road closures.



Plate 1: An attempt to drive through floodwater.

The Solution

Near real time monitoring of waterway levels and alarming at critical flood thresholds, to inform of possible road inundation is one solution being trialled by TMR.

The remote location of many river road crossings and the nature of waterway level monitoring creates a number of challenges needing to be met by any solution: No mains power (requiring battery powered devices), monitoring devices likely to be submerged for days at a time (requiring IP68 rated equipment), and time consuming and costly site visits (requiring highly reliable monitoring equipment with minimal ongoing operation and maintenance and remote configuration capabilities).

TMR are undertaking a trial on Breakfast Creek, Brisbane, utilising the following combination of technology and software to enable remote monitoring, data visualisation and management:

- Battery Powered, 3G, IP68 Remote Telemetry Unit (RTU);
- Pressure Transducer for water level sensing;
- A web based data visualisation and management Platform.

Battery Powered RTU

- 3G Tri-band modem (850, 900 & 2100 MHz)
- Multiple protocols supported: DNP3, Modbus, FTP
- DNP3: Level 2, 3 and parts of 4 compliant
- IP68 up to 4 metres for 4 days
- 5 real time monitoring sensors
- Software configurable I/O: AI, CI & DI
- Up to 4 Passive Voltage inputs, 2 Active Loops inputs and 5 digital inputs
- Flexible I/O configuration
- RS232, RS485 and SDI-12 serial communications
- 5+ years battery life
- Provides remote configuration and upgrading of firmware
- Dynamic trending and dial in capability
- Internal immersion sensor
- Automatic switchable internal/external antenna
- Auto detection and switching to an external power source.
- Rapid installation with integrated bracket



Pressure Transducer

Pressure Transducers are frequently used within the water industry as a simple, low cost means of water level sensing. The pressure sensors are submersed in the waterway and detect changes in pressure as their relative depth increases and decreases, enabling them to determine water level.

- 0-10 bar range, 0-20 bar range available
- Stainless steel construction
- WRAS approved
- IP68
- Quick release coupling



Web Based Data Visualisation and Management Platform

The data visualisation and management platform or ‘top-end’ being used is an attractive option for utilities, Councils or organisations that don’t have ClearSCADA or want an alternative data visualisation and management platform. The platform allows the end user to monitor their assets at 3 levels:

- Estate View;
- Site View; and,
- Outstation View.

Data trends, thresholds and alarms can be viewed and managed in near real time. RTUs can be configured remotely via Palette.

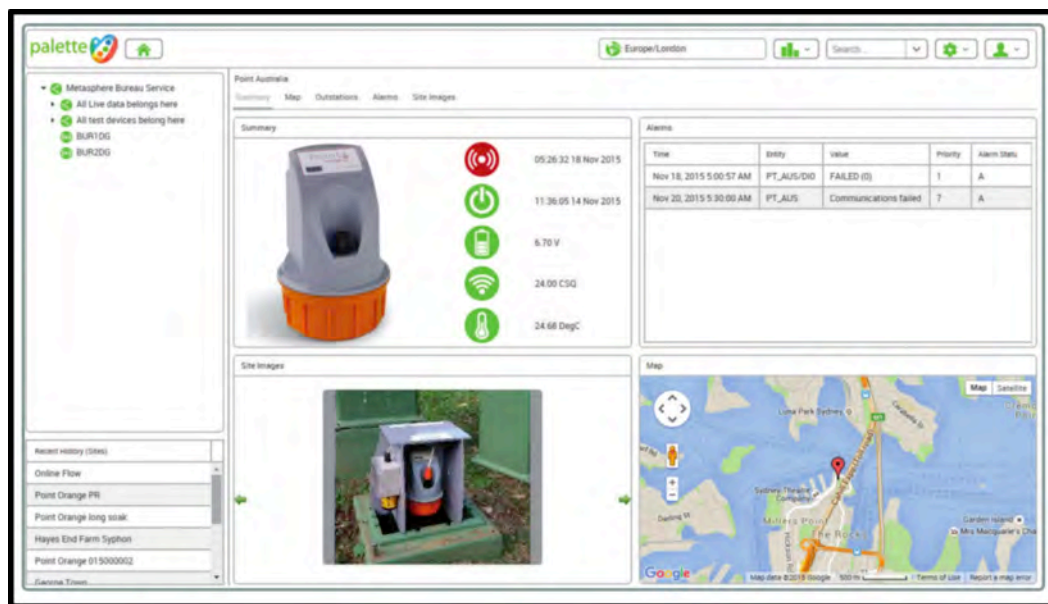


Figure 1: Typical 'Site View'.

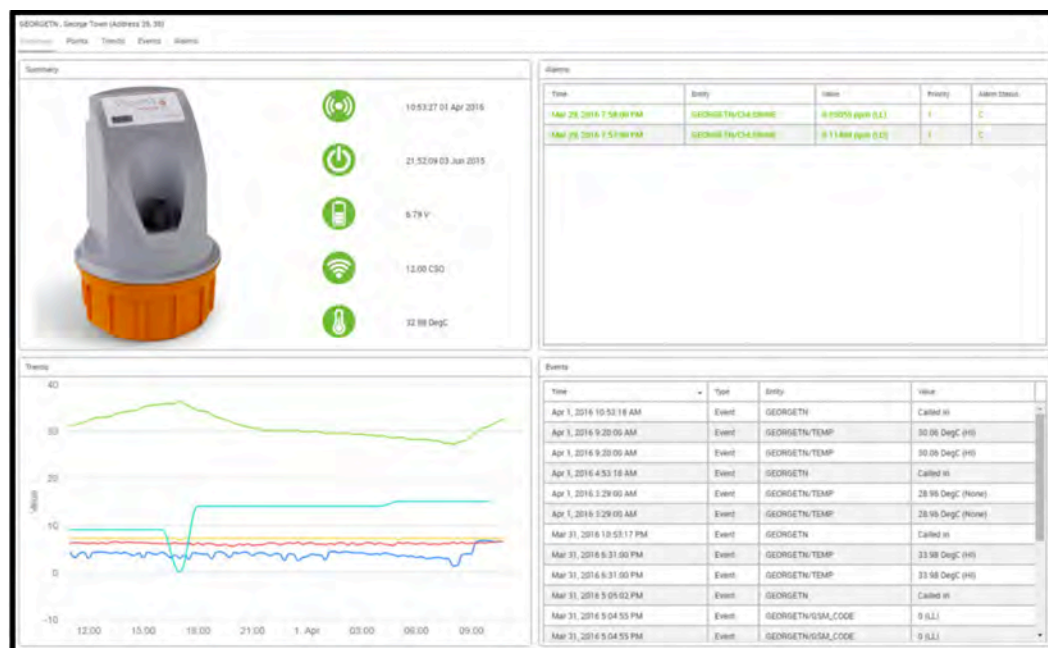


Figure 2: Typical 'Out Station View'.

Typical Configuration

A typical application configuration during low flows is for the RTU to power up the water level sensor every 15 minutes and take a measurement, with the value being saved in the RTU memory. The RTU then dials into the 'top end' once a day and transfers and displays the level data.

The RTU does however report on exception. When a pre-set level threshold is exceeded an alarm is sent (via email or SMS) and the RTU can dynamically trend to take data readings at pre-set more frequent interval, every 5 or 1 minute for example. The RTU can also be configured to dial in and transfer the data more frequently when in the 'alarm' state. This allows the high flow events to be captured and the RTU battery power is called upon when it's most needed. Most importantly it allows the TMR end user, viewing the data to see it in near real time and manage their highway network accordingly.

Typical Challenges:

The main challenges are in the accurate installation and set-up of the monitoring equipment, and establishment of correct alarming thresholds. Key challenges include:

- **Setting Alarm Thresholds** – adopting the right water level at which to raise alarms and trigger actions related to the road network i.e. potentially close, is a critical issue. The correct threshold needs to balance the two following, often conflicting issues: be low enough to provide sufficient lead time for subsequent decisions to be taken, whilst high enough for the alarm to be met with confidence that action is required i.e. not too many false alarms (where the alarm is raised but the road doesn't actually flood). The correct water level to set as the alarm threshold is best determined through hydrological analysis, practical experience and a trial installation.
- **Site Access** – Installation sites, either on or immediately upstream of highway bridge creek crossings are often difficult to access for landowner reasons, or because they have been fenced off to the public on health and safety grounds. Site access will be different at each location and needs careful planning and permissions obtained if it is not to hold up the installation.
- **Health and Safety** – the safe working and return home of all involved should be everyone's No. 1 priority. Installing RTUs and water level sensors can involve working at height, in and around water and close to roads. Pre planning, prior site knowledge (through SWMS and Site Risk Assessments), and a well trained and equipped installation team are all crucial to preventing health and safety risks from materialising.

Key Benefits

Key benefits of the above application include:

- The ability to better manage the road network, reduce the chance of drivers attempting to drive through flood waters, and ultimately save lives.
- Reduced cost due to:
 - removing the need for mains power;
 - quick installation time;
 - fewer site visits due to remote monitoring, and;
 - relatively little ongoing operation and maintenance requirements.
- Reduced water utility staff health and safety risk due to:
 - fewer site visits due to remote monitoring, and;
 - relatively little ongoing operation and maintenance requirements.

Conclusions

The QLD State Government is proactively seeking ways of reducing deaths from people driving through floodwater through remote monitoring and management of water levels at highway creek crossings. Initial trial results demonstrate this has the potential not only to save lives but save the QLD State Government time and money and reduce staff health and safety risks.

Safety in Hydrography – The Impact of Innovation and Technology

Allan Garland

Ventia Utility Services, New South Wales

**Paper presented to 18th Australian Hydrographers Association Conference
Canberra. 24 – 27 October 2016**

Abstract

In the hydrographic industry our staff are both our most precious asset and greatest resource. Like with all other industries it is necessary to expose our staff to a variety of hazards, to collect the data our business and clients require. How we identify and control these hazards to reduce exposure risk is essential to ensuring the ongoing health and safety of our workers.

In the last decade new technologies and smart initiatives have introduced a wide variety of safety innovations to the hydrographic industry. These innovations impact the way we identify hazards, and how we determine the most appropriate control. Of a greater benefit, the technology and initiatives have opened the door to a suite of new innovative controls available to the industry today.

To identify hazards Ventia has introduced smart hazard identification tools based on energy sources integrated into a modified START card, and further enhanced through smart phone integration. In any incident, it is the uncontrolled state change of an energy source that is ultimately the source of the hazard. By identifying and controlling the energy sources, the tool provides workers with both a system that allows previously hidden hazards to be identified and effective controls implemented.

Through significant advances in technology and innovation over the last decade, a suite of new options to control hazards is today available to all Hydrographers. Many tools such as improvement in vehicle safety, the development of tracking and alert systems, and safer tools and equipment have been developed for use across multiple industries. These controls are often introduced through natural attrition of old equipment or introduced as new strategic safety measures. The introduction of the SPOT personal tracker to the business is a key example of a strategic new control measure that has had a dramatic impact on the way we monitor and support our staff in the field. Other systems have been developed specifically for the Hydrographic industry and include examples such as the variety of acoustic flow meters. The use of these units in place of traditional measuring gear dramatically reduces the hydrographer's reliance on excessively heavy cableway equipment and eliminates the manual handling issues that hydrographers traditionally faced.

To complete the hazard identification and control process, Ventia operates a continuous improvement cycle. This cycle drives innovation and improvement, and is essential to ensure we can identify and introduce new measures to further protect our workers in the future. This proactive approach to safety also leads to a workforce with an exceptionally strong safety culture. This culture empowers our employees to continually act in a safe manner in the knowledge that their employer considers their safety above all else.

Hazard Identification

High worker safety is typically achieved through the effective identification and control of hazards. A hazard can only be controlled if the hazard is first identified. While effective management can identify and control hazards before our workers even start their day, the unpredictable nature of our environment still requires a proactive approach to ensure new hazards are identified. A worker’s ability to identify hazards can be related to capability, age, experience, and, training (Bahn, 2013) and further impacted by short term effects such as stress, workload, fatigue, time of day and weather. A variety of tools can be used to aid worker’s identification of hazards.

Case study – The START Card

Ventia has traditionally utilised form based tools to aid our workers in identifying hazards in their workplace. In 2007 the business introduced the Run Safety Checklist. This form allowed workers to use a simple checklist to confirm critical controls were in place and provided an opportunity to identify and control any unique hazards that may have been observed. The document proved reasonably effective at documenting and controlling hazards, however ongoing reviews of the data indicated the tool was not very effective at identifying new hazards. In 2013 the business began to explore other options for hazard identification. Initially a number of internal options were considered, in particular the START card used by our Remediation group. The card had proven to be a very effective tool for this group, however their works focussed primarily around the control of risks around large plant and harmful chemicals at a single location and did not offer the process required for the hydrographic group. The answer was instead found in the mining industry. This process utilised a different approach where key energy sources were listed along with a number of practical keywords. A worker could quickly review the energy source list in their environment and effectively identify anything unusual as well as new hazards. The example found was focussed on energy sources in a mining environment, however it offered sufficient inspiration for our senior team to develop their own card based on energy sources experienced in the environmental industry. An example of the START card is found in figure 1. The card has proved effective with a variety of new hazards identified regularly since its inception. The card was further enhanced in 2015 when it was integrated into Ventia’s in house smart phone app “Site Runner”. This app has allowed the card to be completed on any Smart Phone and has been linked to a back end database. The database allows data to be interrogated for trends, significant hazards and usage and is a powerful tool for supervisors in managing risks in their projects.

START CARD – IDENTIFY THE NEW HAZARDS												
Name:	Date:											
Job Location:												
Task Description:												
Consider the energy sources, what are the hazards?												
<p>Gravity - elevated equipment, working at heights, slopes, fallen tree limbs</p> <p>Water - speed, river height, conditions</p> <p>Electrical - all types (electric shock potential)</p> <p>Mechanical - mobile equipment, moving parts</p> <p>Chemical - gases, liquids, solids (water, methane, acetylene, solvents)</p> <p>Pressure - air, water, gas, noise</p> <p>Thermal – hot/cold surfaces</p> <p>Radiation - sun light, UV</p> <p>Body - includes lifting, pushing, pulling, climbing, positioning</p> <p>Biological - includes wildlife, viruses or bacteria</p>	<p>WMS/ JSEA No:</p> <table border="1" style="width: 100%; height: 100%;"> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> <tr><td> </td></tr> </table>											

Figure 1: Excerpt from the Ventia START card booklet.

Like all hazard identification tools the START card relies on operators to complete it. This has and will continue to be a weak link in any safety system and the business continues to explore new opportunities that may provide a better hazard identification system. Until then the START card will continue to be a strong hazard identification tool for our workers.

Hazard Control

In Ventia, the hierarchy of controls is used to manage hazards (figure 2). The hierarchy of controls lists overarching control options from the most effective to least effective. Selection of a control that sits high in the list will provide the highest level of control and reduces the need to apply additional controls to manage a hazard.

In Ventia the hierarchy of the controls is further split by a line that isolates administrative and PPE control measures. These “below the line” control measures are both considered ineffective as they provide the lowest level of protection and unlike their “above the line” cousins require human input to ensure they are used and are effective. To minimise the use of these controls all practical “above the line” controls should be considered before implementing a “below the line” control.

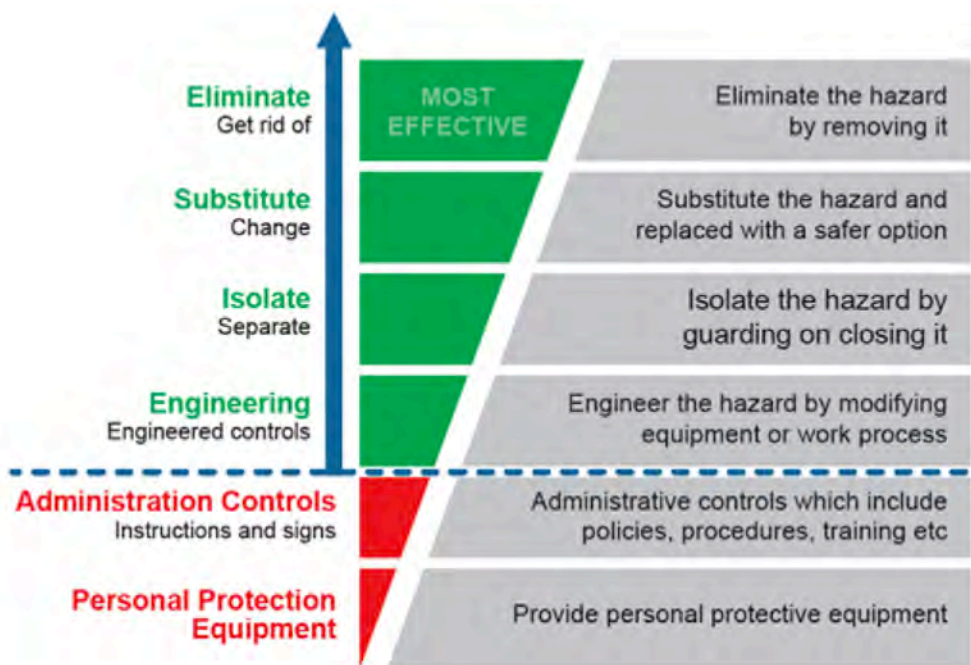


Figure 2:
The hierarchy of controls used in Ventia (Ventia, 2016).

Over the last 10 years, Ventia’s hazard identification and control tools have introduced a wide variety of new techniques and innovations to the business. A summary of key initiatives along with case studies of specific examples is provided below.

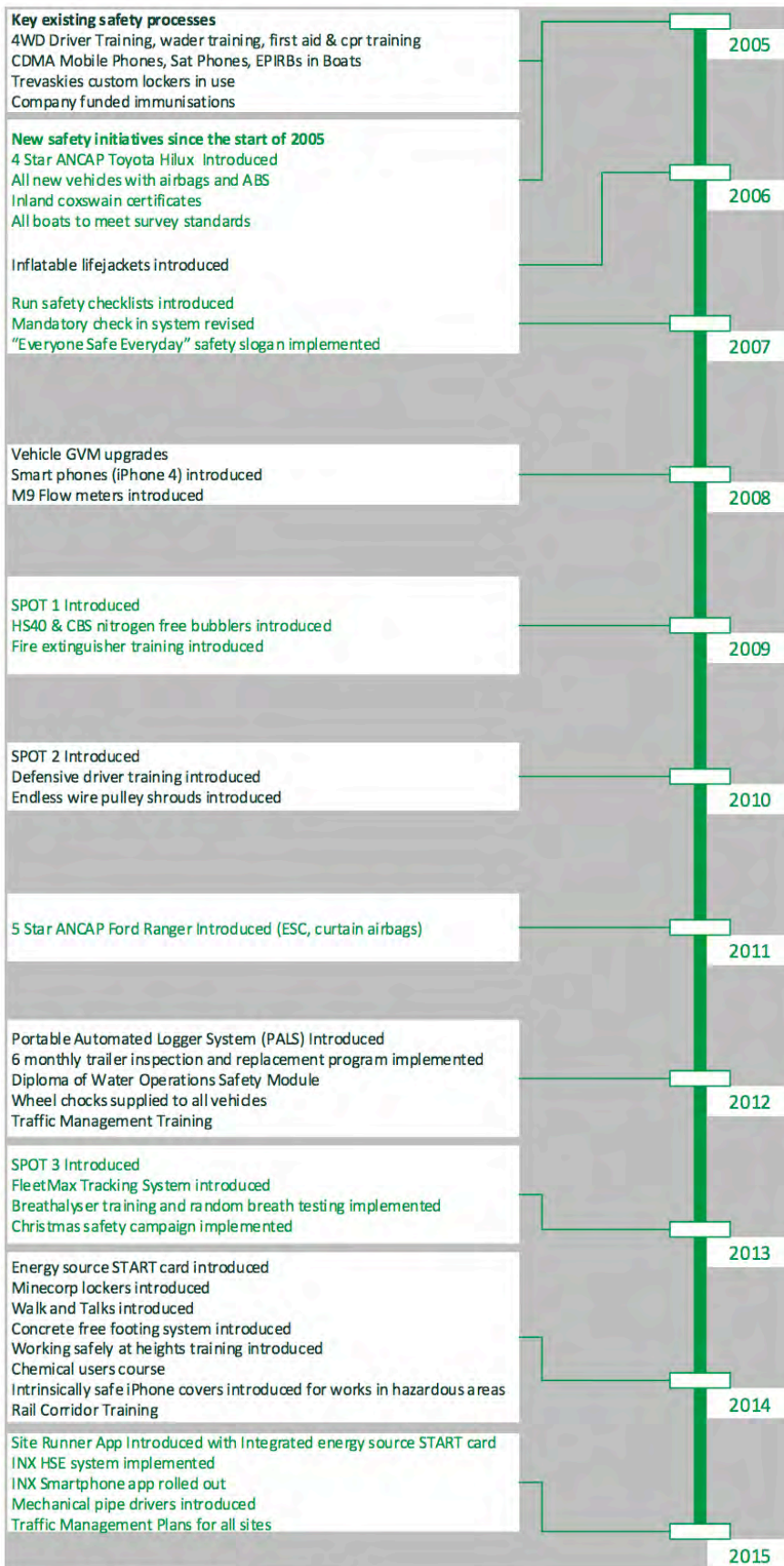


Figure 3: Ventia's timeline of safety.

Case study – Travel and Vehicle Safety

Ventia's hydrographic vehicles on average travel over 1.5 million kilometres each year. On average, this represents approximately 40,000 kilometres each hydrographer will travel over the course of a year to sites and areas sometimes never visited by others. A hydrographer will experience a wide variety of driving terrains including open highway, city traffic, dirt roads, 4WD only tracks, and travelling through flood waters. The risks associated with this activity are large and without effective controls a significant incident is only a matter of time. Through the hierarchy of controls discussed above, elimination of the risk would provide the most effective outcome. While in reality this is impossible to achieve, the elimination of unnecessary travel is a viable opportunity to reduce the risk. With most works requiring routine monthly servicing, the business has undertaken a variety of office and field based studies to determine the most efficient run order for our workers. Today this includes proprietary software that allows sites to be digitally mapped and run orders determined based on a variety of criteria. A number of runs require staff to travel over 300 km from their home base and therefore overnight stays are essential for these runs. The proactive run planning ensures overnight locations are selected to provide a balance between an effective work day and managing the safety risks associated with travel.

With excess travel eliminated from works schedules the business has next considered how we can further control the risks. The answer has been found through substitution and engineering of the vehicles we use.

Vehicle Design

Utes, have long been the preferred choice of most hydrographers as they offer a strong combination of load carrying capacity and off-road capability. However, the safety features of utes have long lagged behind passenger vehicles with similar levels of safety only previously offered in top spec models. In 2011 the playing field somewhat levelled with the introduction of the VW Amarok, the first model wide 5 star ANCAP ute in Australia. Continued refinements of Australian Design Rules for utility vehicles in recent years has brought them closer in line with passenger vehicle standards (Australian Government, 2016). As a result of government rules and market competition, the 5 star ANCAP trend has continued to present day with almost all Utes on the market now 5 star rated.

The introduction of 5 star ANCAP Utes has seen dramatic changes to the safety requirements of vehicles for use in some industries. Recognising the initial safety benefit, this new ute has also driven significant cost savings in some industries. A key example to date is BHP Billiton's review of mine spec vehicle requirements. In previous years a mine spec ute required an aftermarket roll over protection system (ROPS). This is an expensive system to install and while it improves the safety of occupants in the event of a roll over, crash test data suggests the system in turn decreases safety in high speed collisions increasing the propensity of the vehicle rolling onto its roof (Global NCAP, 2012). With the introduction of a number of 5 star ANCAP Utes to the market, mining giant BMA has taken the industry leading step of banning the use of ROPS in favour of minimum 5 star Ancap Utes (Global NCAP, 2012). While this initiative was led by BMA, it is expected in time that most other mining bodies will eventually follow suit. As the mining environment is responsible for a large percentage of all new ute sales, benchmarking vehicle safety requirements at this level will have significant market impacts.

In the last decade vehicle design and safety has undergone a radical transformation. In 2005 Ventia operated a fleet of Holden single cab 4WD utility vehicles (utes). The newest models featured a driver side airbag and ABS brakes however in most the best safety feature was the simple seatbelt. Other model utes in the market shared similar levels of safety and the lack of safety features was the norm for utility vehicles at this time.

Ventia's vehicle selection policy is based on four key criteria in order of importance being safety, fit for purpose, price and features. This policy has resulted in almost all Utes from 2012 having a 5 star ANCAP rating. This has also resulted in the exclusion of "tougher" utes offered by Toyota and Nissan as the utes do not meet the businesses minimum safety standards and the additional off-road capability is insufficient to justify their purchase.



Figure 4: A pictorial timeline of vehicle improvements over time. From top to bottom Toyota Hilux 1998, Holden Rodeo 2001, Toyota Hilux 2007, Ford Ranger 2015.

Today Ventia's hydrographic group operates a fleet of automatic 5 star ANCAP rated Ford Ranger utes with certified suspension upgrades and accessory packages. All vehicles are available with automatic transmissions only to reduce the incidence of unexpected vehicle movement when parking brakes are not correctly applied.

The utes are fitted out by a specialist mining vehicle company in Queensland with accessories designed to handle mining environment conditions along with other safety features this industry drives. This includes a pair of custom built equipment lockers, LED amber flashing lights, fold down Symbolic Worker road signs, reversing camera, reversing squawker, certified gas bottle mounting points, GPS vehicle tracking system, upgraded front and rear suspension and all terrain tyres. Features such as bull bars and winches are included as optional extras only where required as these features detract from the safety rating of the vehicle. The individual weight of each vehicle with all accessories is calculated and marked on the vehicle so operators can monitor what equipment they load into the ute to ensure it is not overloaded.

The innovative design of the vehicle and its accessories ensures the vehicle is the safest, fit for purpose and well equipped vehicle ever offered to our hydrographic group.

Case Study – SPOT Tracker

The SPOT tracker today is a critical tool in the Ventia safety arsenal. Simple in design and use, the tracker offers an almost certain communication link for staff to the outside world. Combining telemetry through Globalstar communications satellites and positioning from United States GPS satellites the system allows staff to send a variety of messages with a single push of a button. Each device is capable of transmitting 4 unique, messages to report the current status of the staff member:

- OK – this message is used during routine check ins and confirms the staff member is safe and the works are running according to plan.
- CUSTOM – this message is used to indicate a staff member is ok but running late.
- HELP – this message indicates a staff member requires non urgent assistance such as a vehicle breakdown
- SOS – this message is used in an emergency to call for urgent assistance for a medical emergency or life threatening situation. This message is also independently monitored by the Australian Search and Rescue Authority (SAR) to ensure an emergency response is initiated in the unlikely event personnel do not initiate it internally.

A key secondary safety feature of the device is the transmission of a breadcrumb trail of the unit's current location allowing supervisors identify a staff member's current location and predict their next destination. In the event a staff member fails to call in during a routine check-in the supervisor can use this breadcrumb trail to identify the staff member's current location and coordinate an appropriate emergency response as per predefined emergency procedures.

Worldwide the SPOT system has been used to trigger over 4,000 rescues (Figure 5) (SPOT, 2016). While the business has never had a cause to formally trigger the system, the successful use of the device to assist in such a large number of rescues provides confidence in the reliability of the system. In some cases, employees continue to carry satellite phones in addition to the SPOT tracker. However, these devices are today considered a secondary safety tool due to the reliability issues faced when using these devices in rugged terrain.

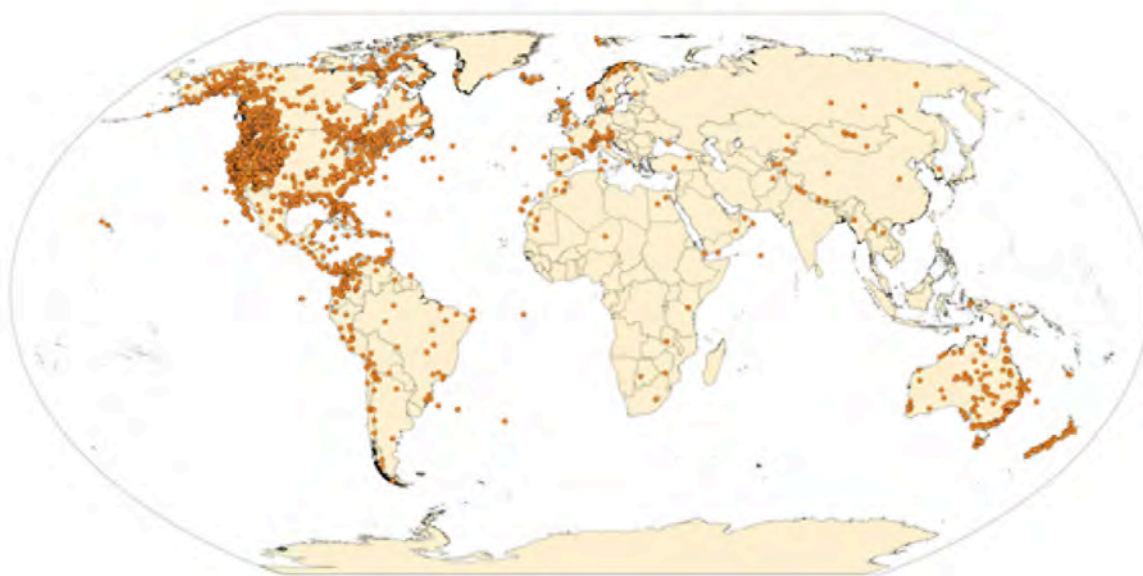


Figure 5: SPOT rescues triggered worldwide (SPOT, 2016).

In 2015 Ventia introduced a new emergency response audit tool. The tool in effect runs emergency drills for staff in the field and tests the responsiveness of supervisors. The tests can range from a simple missed check in to a full blown emergency situation. In many cases there is little or no notice of the upcoming drill making the test as realistic as possible. To date the responses of the teams have been excellent and validate the emergency response processes put in place.

Case Study – PALS

The Portable Automated Logger System (PALS) was developed by Ventia in 2012 as a major safety initiative to improve the safety of flood personnel (Garland, 2012). The idea was first coined by staff member Rohan Oliver following the 2011 Victorian floods. With the support of our client Department of Environment, Land, Water and Planning (DELWP), 10 PALS were fabricated and deployed into the 2012 Broken Creek flood. The PALS allows operators to deploy a temporary, real-time water level monitoring system into a flood area within 1 hour of arriving on site. The data then collected by the device allows for the real-time monitoring of floodwaters in that area and importantly eliminates the need for staff or emergency workers from having to access the area during a flood to monitor water levels particularly during night periods.



Figure 6: PALS – The original design (left) and a simplified more durable version today (right).

Continuous Improvement

Safety is a cycle of continuous improvement (figure 7) and as such Ventia are continuing to explore new opportunities to provide our workers with a safer workplace. It is this action of continuous improvement that will continue to see new safety initiatives and technologies implemented.



Figure 7: Continuous Improvement Cycle (Ventia, 2015).

The business is currently exploring a variety of new initiatives to further improve worker safety. Key examples include:

- Transition of work vehicles to a 100% ANCAP 5 rated fleet.
- Roll out of hardwired vehicle tracking to all vehicles.
- Improved run pre-diagnostic systems to allow workers to be correctly equipped for site works and to reduce return visit travel requirements.
- Exploration of drone technology to remove workers from potentially hazardous situations (figure 8).



Figure 8: Exploration of drone technology.

Safety Culture

Even the best safety tools will be ineffective if your workforce has no interest in adopting them. Termed the “Safety Culture” it is the values employees hold that will impact how new and smart safety initiatives and approaches are adopted.

In a busy workplace safety is often the first task skipped in the demand to meet deadlines. This is especially true in workplaces where productivity is valued above all else. In these workplaces employees are often reluctant to speak up about a safety issue for fear of the repercussions the issue will cause to productivity. In other workplaces a poor safety culture exists due to complacency around perceived risks and hazards. Exposure of workers to a consistent hazard without incident can result in a perceived reduction in the likelihood and consequences of a hazard. Unchecked, in time this will result in a significant incident. Complacency around hazards is a major issue for the hydrographic industry, a key example being the change in river conditions between base flow and flood, however a strong safety culture can offset this issue.

A truly strong safety culture can only be achieved when safety is valued above all else. This is the approach adopted by Ventia and has delivered strong safety outcomes not only for our environmental group but across the business as a whole. The strength of the safety culture is most apparent when the business adds a new service project to the company portfolio. Often in these projects there is a contractual requirement to retain much of the incumbent workforce and therefore the safety culture of the previous contractor is temporarily and unavoidably adopted within the new project. A significant spike in near misses and incidents is the initial outcome and these slowly taper off as the Ventia Safety Culture is adopted. The process takes time and can be years before a new workforce truly accepts the ideologies of their new business. Similarly, a strong safety culture within a well-established business can be quickly lost and a cycle of continuous improvement is essential to ensure the safety values of a business continue to be upheld.

Conclusion

Even in a cost driven world, a business should identify the safety of their employees and subcontractors as paramount above all else. A smart business will arm their employees with the correct techniques and support to ensure hazards are effectively identified and the risks appropriately classified. Armed with the knowledge of the hazard this can be effectively controlled using a variety of smart and innovative controls. Additionally, where a hazard cannot be controlled, an employee can actively choose to not undertake a task with the assurance the company will support an employee's proactive approach to safety despite the loss of revenue or in the hydrographic world the loss of data.

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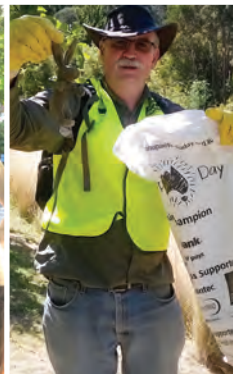
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