Strategic and Cost-Effective Networks of Miniaturised Tide Gauges

Daryl Metters[1], Jake Shayer[1], John Ryan[1], Jessica Bourner[2], Bobbie Corbett[3] and Rodger Tomlinson[4]
[1]Department of Science, Information Technology and Innovation, Brisbane, AUSTRALIA;
daryl.metters@dsiti.qld.gov.au
[2] Gold Coast Waterways Authority, Gold Coast, AUSTRALIA
[3] International Coastal Management, Gold Coast, AUSTRALIA
[4]Griffith Centre for Coastal Management, Griffith University, AUSTRALIA

Abstract
Effective management of complex and dynamic waterways is considerably improved by strategic data collection and the use of this data to enhance understanding. On the Gold Coast, the network of waterways is large and complex and the first stage of a strategic data collection program has been developed and implemented, involving the deployment of miniaturised tide gauges at nine key locations. The program provides tidal levels delivered on–line in near real-time allowing for safe use of the waterways by the community. Over time the program will provide further benefits through collection of long-term datasets allowing investigation of tidal anomalies, inundation from storm surge and flood events and optimisation, assessment and monitoring of dredging programs. The main purpose of the program data output is for assimilation into, and verification of, hydrodynamic models which will enhance understanding of the waterways system and increase the capacity of sediment transport models to assess shoaling behaviour and improve the resilience of the Gold Coast managed waterways.

In order to achieve a dense spatial distribution of water level observations and maximise the data collected within the available budget, an innovative approach to tide gauge instrumentation was implemented. Adoption of downward facing radar sensors provided a high level of accuracy while maintaining low installation and maintenance costs. Existing infrastructure was identified for support of the instrumentation and consisted primarily of aids to navigation. A unique tide gauge design was developed to miniaturise the instrumentation such that it could be securely attached to the navigational aid. The modular design and custom mounting frame allowed for rapid deployment and relocation if necessary. As associated costs for miniaturised tide gauges are considerably lower than more traditional tide gauges, this approach provides greater opportunity to collect comprehensive and strategic datasets as was successfully achieved on the Gold Coast.

Keywords: miniaturised tide gauge, tide, sediment transport, Gold Coast, waterways management.

1. Introduction

The Gold Coast region in Queensland Australia is built around a large, dynamic and complex network of coastal waterways (Figure 1).

The Gold Coast Broadwater is a large and shallow estuary. The hydrodynamics are primarily dominated by tidal flow through three entry points from the open ocean. The fully trained Gold Coast Seaway entrance at the southern end of South Stradbroke Island is the primary navigable access point to the Broadwater. At the northern end, between North and South Stradbroke Islands, Jumpinpin Passage is a shallow southward facing entrance which exists in an essentially unstable state. At the northern end of the Gold Coast, the waterways are connected to the Ocean through Moreton Bay via two main channels that flow around Russell Island.

There are also four rivers that connect a 64 km^2 catchment with the Broadwater: the Logan River enters to the west of Russell Island; the Coomera and Pimpama rivers feed through a complicated network of channels to enter the central waterway; and the Nerang River enters the waterway in the southern reach. This extensive and complicated network of the waterways introduces a large diversity of tidal dynamics [6].

There have been extensive works within the tidal zone including relocation and training of the Gold Coast Seaway, island and mainland reclamation, extensive dredging and nourishment activities, installation of marine facilities and construction of revetment walls. All of these changes may alter the tidal dynamics of the waterways. Planning of new works in the sub-tidal zone must consider any consequent alterations to the waterway dynamics through modelling of the works.

2. Strategic Hydrodynamic Data Collection Program

The Gold Coast Waterways Authority (GCWA) is responsible for balancing the safe, sustainable and efficient enjoyment of the waterways with the protection of environmental values. The importance of sound research and understanding is recognised as being critical to achieving these objectives.

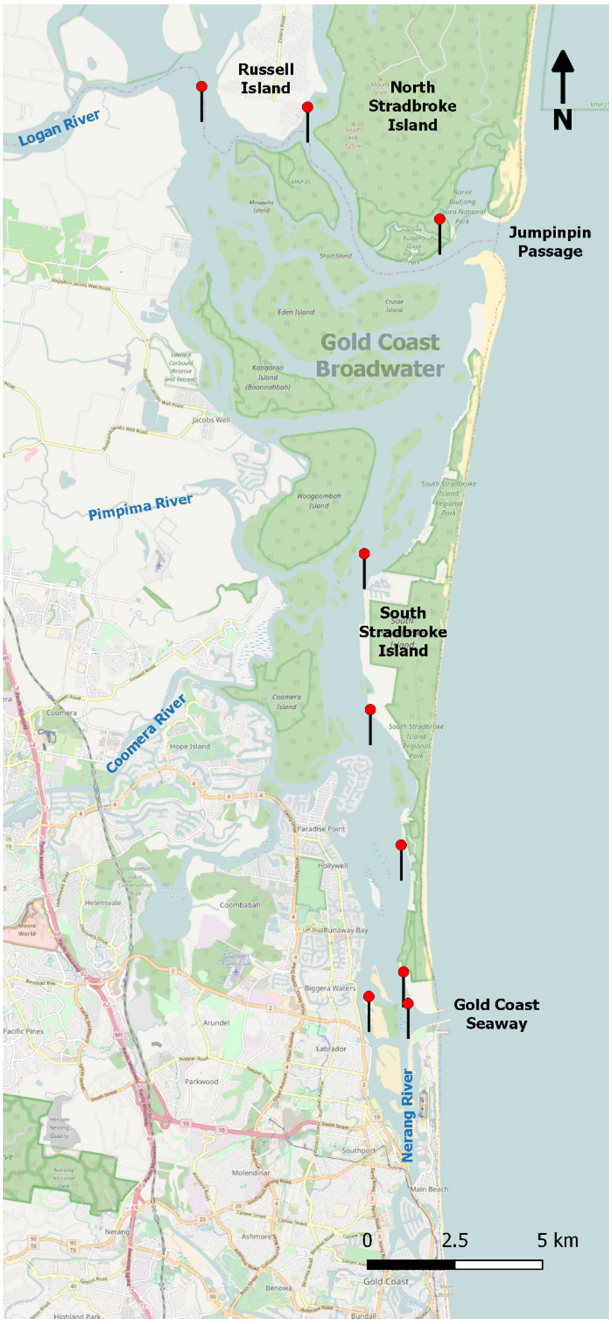

Figure 1 Tide gauge locations throughout the Gold Coast Broadwater installed as part of the Strategic Hydrodynamic Data Collection Program.

As such, a Scientific Research and Management Program (SRMP) has been implemented. The objective is to strategically manage information, develop understanding regarding waterways behaviour, optimise sustainability of project works (particularly dredging) and identify scientific priorities to meet GCWA strategic objectives including data compilation, field data collection, analysis and modelling.

One component of the SRMP is a strategic hydrodynamic data collection program. Review of existing data, gap analysis and prioritisation of activities within the available budget was undertaken [1]. This identified that a key priority was the implementation of the first stage, being the purchase and installation of water level monitoring equipment at nine (9) strategic locations within the Gold Coast Broadwater (Figure 1). This network is to be expanded by the future deployment of additional permanent and re-deployable gauges within the riverine systems and the northern Broadwater to more fully describe the hydrodynamics of the region.

The initial tide gauge locations were selected to:

- Define the boundary conditions that drive hydrodynamic numerical models and assist with model calibration and validation. This includes the two direct open ocean boundaries, two links with Moreton Bay to the north and multiple riverine inputs.
- Provide insight into regions of known hydrodynamic complexity including Gold Coast Seaway, Russell Island and near the expected hydrodynamic “null point” between northern and southern sections of the Broadwater.
- Provide continuity between locations selected for other purposes to better evaluate propagation of storm surge through the southern Broadwater.

The developed hydrodynamic models are expected to be utilised to assist with: risk assessments (e.g. determine vulnerability of key tidal assets or the influence of closure of the Jumpinpin entrance); project planning and impact assessment (e.g. optimising dredging strategies and ensuring major projects meet requirements); and provide a general understanding of natural processes.

Development of accurate and reliable hydrodynamic models is also critical to developing sediment transport models, which would enable assessment of erosion prone areas, shoaling patterns and dredging strategies.

This information and capacity is critical to the management of resilient waterways in such a dynamic and complex system, particularly a sensitive urban environment with diverse usage and significant development pressures.

While short-term deployments of tide gauges are traditionally adopted for model calibration, long-term deployments and relocatable gauges with publicly available data were recommended as it provides significant additional benefits, including:

- more valuable data as accurate, continuous and concurrent with other datasets
- lower long-term costs compared with periodic re-deployment of hired gauges
- enhanced waterways accessibility & safety and improved public awareness

- improved efficiency of marine projects, particularly dredging
- provides baseline and monitoring data for major projects
- assist disaster management during storm surge, flood and tsunami events
- improve understanding through analysis of tidal anomalies
- inform assessments of natural variability including climate change
- validate, update and expand existing tidal planes, and improved tide predictions within the network
- provide tidal data to support a range of other projects and research by GCWA, City of Gold Coast and other organisations.

Locations were selected generally based on the objectives of the tide gauge network. To eliminate the need for additional permanent infrastructure within the waterways and maximise data collected and reducing unnecessary costs, final specific locations were selected based on existing infrastructure (Figure 1). As aids to navigation such as channel marker beacons and cardinal marks (owned and maintained by GCWA) are common throughout the Gold Coast's extensive waterways, sizes are reasonably standardised and they provided ideal and substantial piles on which to secure the tide gauges.

3. Tide gauge design

Measurement of water level has changed in modern times to be totally autonomous with respect to remote logging and communication of data. Water level sensors have evolved to be non-mechanical in nature with no working parts in the water. This allows remote sensing of water level from a supported sensor platform. Sensors of this type use time of flight of either acoustic, microwave (radar) or light (laser) sensors to back calculate the distance to the water surface from the sensor [4].

The advent of miniaturised computing has seen the size of field based loggers and data communications reduced to a fraction of the size of historic tide gauge instrumentation.

The design of the light tide gauge (LTG) used here (Figure 2) incorporates five main components:

(1) microwave based open to air sensor; VegaPuls WL61
(2) data logger with integrated power regulator; Campbell Scientific CR200X
(3) modem; Maestro M100
(4) power supply; Solar panel (20w) and battery (24Ah)
(5) PVC pipe housing capped at both ends.

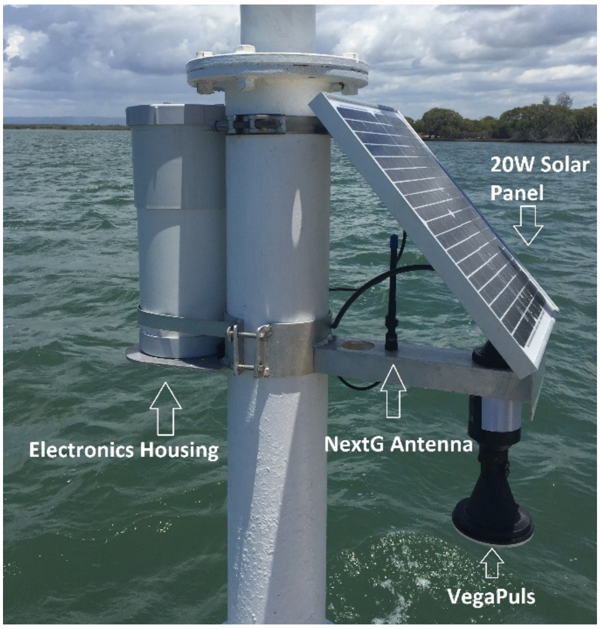

Figure 2 The light tide gauge (LTG), showing the modular design for easy redeployment.

The data logger, modem and battery were contained inside the PVC pipe for protection from the weather. The pipe was sealed at one end and had a threaded end cap at the other. A VegaPuls WL61 sensor was attached to the underside of an extension bar with a solar panel attached on the top side of the bar.

The waterway is a low energy environment compared to the Gold Coast beaches. The Vegapuls WL61 sensor is a high frequency microwave sensor (K-band) suitable for measuring water level under low energy (calm) conditions [5].

The modular design of the LTG facilitates an easy and rapid gauge deployment method, and can provide easy redeployment to new sites if required. The whole of the LTG was attached to either a 0.5 m or 1.0 m pile extension depending on the height of the pile flange above the Highest Astronomical Tide (HAT) level. These were bolted between the upper marker/light of the beacon and the lower pile support (Figure 3).

Communication of data is via nextG (3G) mobile network and one minute data points are downloaded to a remote server every 10 minutes. The decision to utilise 150 mm PVC pipe to house the LTG was due to the low cost and waterproofness as well as the shape, colour and physical size being consistent with the existing beacon post. This reduces visual impact and potential impact on the primary function of the aid to navigation.

Figure 3 East Russel Island LTG installed below the marker on the existing navigation beacon.

The data-logger program was designed to power cycle (restart) the modem once a day as a precaution to ensure recovery from lock ups and hence reducing the need to visit each gauge when lock ups occur.

As the sensor measures the distance to the water, the logger program uses the level of the sensor above lowest astronomical tide (LAT) to reduce the output to water level in metres above LAT, the tidal datum across Queensland.

4. Tide gauge installation

The tide gauges were commissioned in October 2016. Each setup was built at the Queensland Government Hydraulics Laboratory, then attached to the relevant section of extension pipe and left on test for one week prior to the install. The installation process at each site involved the removal of the top marker, levelling of the flange face of the lower pile support by RTK to gain an AHD level at each site (Figure 4), mounting of the top marker to the LTG extension and then mounting of the top marker and extension back into place on the lower pile. This process took about 30 minutes at each site and was facilitated by the GCWA barge and crane. At two of the sites the LTGs were mounted on more substantial 600 mm diameter steel piles on the pile cap (not reported on here).

Figure 4 RTK reading on the lower flange

The sensor of each LTG was levelled in to local Primary Survey Marks (PSM) in order to achieve a high level of accuracy with respect to the LTG datum. The initial levelling with RTK was done to give an estimate of tidal datum to enable public presentation of the data prior to levelling to PSMs. The accuracy of the RTK level is ±2–3 cm [7] whereas levelling from PSMs is closer to ±1–2 mm [3].

5. Data Availability

The collected data is being made publicly available in near real–time on a web-based platform (see Figure 5)[2]. This format enhances maritime safety and accessibility by providing a tool for planning of vessel movements within the waterway. It also enhances public awareness of tidal variability.

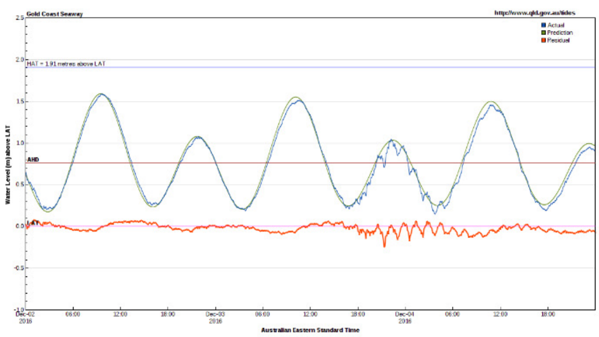

Figure 5 Near real–time display of water level, predicted tide and residual, as displayed on–line [2]

The raw data is also automatically provided on a weekly basis directly to GCWA where it is compiled for use as part of ongoing and future tidal analysis and numerical modelling projects by GCWA and others.

6. Cost

While actual costs vary depending on location, costs for this project included in-kind support by GCWA and a nominal annual fee for ongoing data management and presentation. Associated costs for miniaturised tide gauges are considerably lower than a single short-term (8 week) deployment of more traditional hired pressure-type tide gauges which are mounted underwater and therefore require regular inspection, cleaning and manual data download. As such, deployment of LTG gauges is very cost-effective.

7. Conclusions

The new and innovative design of the LTGs installed in the Gold Coast waterways has successfully provided a dense spatial array of accurate water level measurements within a limited budget. This approach provides greater opportunity to collect long-term, accurate and cost-effective datasets in other locations, as has successfully been achieved on the Gold Coast.

The data provided by the tide gauge network will provide invaluable inputs to hydrodynamic modelling and, in turn, sediment transport modelling. Comprehensive analysis of the data and assessment of modelling results will enhance the existing understanding of the behaviour of Gold Coast waterways now and in the future and enable GCWA to proactively manage the waterways in an informed and efficient manner.

The availability of the data to the public in near real-time is seen as a considerable benefit and directly promotes safe access of the waterways.

8. Acknowledgements

This project was implemented by Department of Science, Information Technology and Innovation (DSITI) in partnership with Gold Coast Waterways Authority (GCWA), Griffith University and International Coastal Management.

9. References

[1] Corbett B., Mulcahy M. and Hughes L. (2015). GCWA scientific research and management program strategic hydrodynamic data collection program (SRMP-007). Griffith centre for coastal management, research report no. 177.2.

[2] Department of Science, Information Technology and Innovation (2017). Tide Monitoring Sites, online at: https://www.qld.gov.au/environment/coasts-waterways/beach/tide-sites/

[3] Elhassan I. and Ali A. (2011). Comparative study of accuracy in distance measurement using: Optical and digital levels. Journal of King Saud University Engineering Sciences, Volume 23, Issue 1, PP 15–19.

[4] IOC (2006). Manual on Sea-level Measurements and Interpretation, Volume IV: An update to 2006. Paris, Intergovernmental Oceanographic Commission of UNESCO. 78 pp. (IOC Manuals and Guides No.14, vol. IV; JCOMM Technical Report No.31; WMO/TD. No. 1339) (English).

[5] Metters D. and Ryan J. (2016). Comparison between C-band and K-band radar sensors; experiences from Queensland. In Manual on sea level measurement and interpretation, Volume V, supplement: practical experiences, pp 5–11.

[6] Mirfenderesk H. and Tomlinson R. (2007). Numerical modelling of tidal dynamic and water circulation at the Gold Coast Broadwater, Australia. J.Coastal Research Special Issue 50, 277-281.

[7] Smartnetaus (2017). What is the RTK (Real Time Kinematic) accuracy?, online at: http://smartnetaus.com/home/index.php?q=node/6.