Internship Report

Optimising the capability of the 'Jon Buoy' for real time monitoring of environmental data in a tidal race.

Dr Ian Ashton
in partnership with Mojo Maritime Ltd.

Optimising the capability of the 'Jon Buoy' for real time monitoring of environmental data in a tidal race.

NERC Internship Report - Ian Ashton, University of Exeter/Mojo Maritime

This internship was supervised by Richard Parkinson and Richard Argall, both directors of Mojo Maritime, with academic support from Dr Lars Johanning. Peter Fido, Jon Csehi and Graham Stewart of Mojo Maritime, as well as Ruud Caljouw of Meygen also provided significant input into the work, through engineering expertise and marine operations experience. Jo Garrett from the University of Exeter, Dr George Graham, Plymouth University, Dr Phillipe Blondel, University of Bath, and Dr Paul Bell from the National Oceanography Centre all provided vital academic input to support knowledge exchange. The author would like to take this opportunity to thank all these contributors for their time and patience. Their input has made this internship an interesting and fulfilling introduction to the practical application of academic research to practical engineering solutions for industry.

Introduction

The core aim of this internship was to bring academic expertise into a team to extend the capability of the Jon Buoy marine renewable energy data collection platform, to enable real time monitoring of tidal current and other environmental data fields. The intern assessed the suitability of the system to integrate new sensors, and undertook a scoping study for further sensors that could be included in future designs. In addition to this process, the intern had a direct input into the design of the next generation of Jon Buoy units to maximise the environmental monitoring that the system can offer. The intern has also overseen a large-scale field deployment to gather initial scoping data from a tidal race, and performed initial verification of supplementary data sets from deployments of Jon Buoy 1. Through this work, the internship has helped Mojo Maritime Ltd expand the scope of environmental monitoring that they can offer as part of the Jon Buoy unit. Despite setbacks due to delays in unit construction, the internship has improved the offer from the next generation Jon buoy unit, through a development path to provide an increased sensor package from the excellent starting position of Jon Buoy 1.

The internship has been hosted by Mojo Maritime Ltd., a leading company in the deployment of marine renewable energy facilities. Mojo has significant experience and expertise in the planning, management and application of marine operations for tidal energy installations. To date, deployments undertaken within this sector have been limited to test devices at select locations. However, during the internship, it was announced that Meygen, had been granted £10 million to support the development of a tidal energy array at the Inner Sound, Pentland Firth, UK. Mojo Maritime ltd work closely with Meygen and will manage the marine operations for the Inner Sound project.

A strong relationship has been built over the last few years between Mojo Maritime and the University of Exeter in Cornwall. As the company engages with Meygen in planning for operations in the Inner Sound, this internship has initiated collaboration with the University in a new field for Mojo, one which is critical to growing to meet the significant challenges presented by large scale array deployments. This is an important step forward for the company, allowing them to increase the offer made to large-scale industry to meet the challenges faced during the next stage of development. Mojo Maritimes ongoing commitment to R&D projects aimed at developing robust yet cost-effective solutions for marine operations in the high-energy areas targeted by marine renewables developers is critical not only for the company to continue to grow, but also for the proliferation of these nascent industries.

1. Activities undertaken

The Internship was timely because its commencement was synchronised with a scheduled design review and update process from Jon Buoy 1 to Jon Buoy 2. The intern undertook a detailed review of the sensors that would be available and suitable for inclusion in a real-time monitoring tool. This process concentrated on potential outputs that would be valuable to marine operations if available in real-time to operational vessels. However, secondary data sets generated for post-processing were also considered, which have the potential to input to reporting against environmental consents.

Two key sensors were investigated:

- **Acoustic monitoring** options for the Jon-Buoy in terms of relevant sensors, and their specifications, and potential outputs for real-time output on-board a vessel. This led to an internal report (appendix A), with a development plan to provide robust, effective acoustic measurements from this system. Within the scope of the internship, development and testing was not possible. However, this does form part of an interesting plan for future work (see below, section 3)
- **Sediment monitoring**. Further research was undertaken to use data returns from the on-board AWAC system to assess the sediment load in the water column, with potential to provide impact data during ground works such as drilling or piling. This is an emerging application for acoustic instruments and has certain severe limitations. Nevertheless, a useful assessment is possible based on the on-board systems, and a development plan was outlined in an internal report (appendix B).

Using the information learnt about other sensors, Ian Ashton participated in design discussions for the Jon Buoy 2. The scope of these discussions was not to change the fundamental operating principles of the Jon Buoy. Therefore, the hull shape, Wi-Fi transmission systems and the navigational aids were decided to be retained for the new units. Instead, the on-board systems that would allow an amelioration of the services that the unit provides were discussed. A key factor introduced by the internship here was the development and specification of a modular electronics system for the buoy (fig. 1), supporting 'plug and play' inclusion of supplementary sensors when required. This is a key enabler for the buoy to provide extra monitoring as and when required.

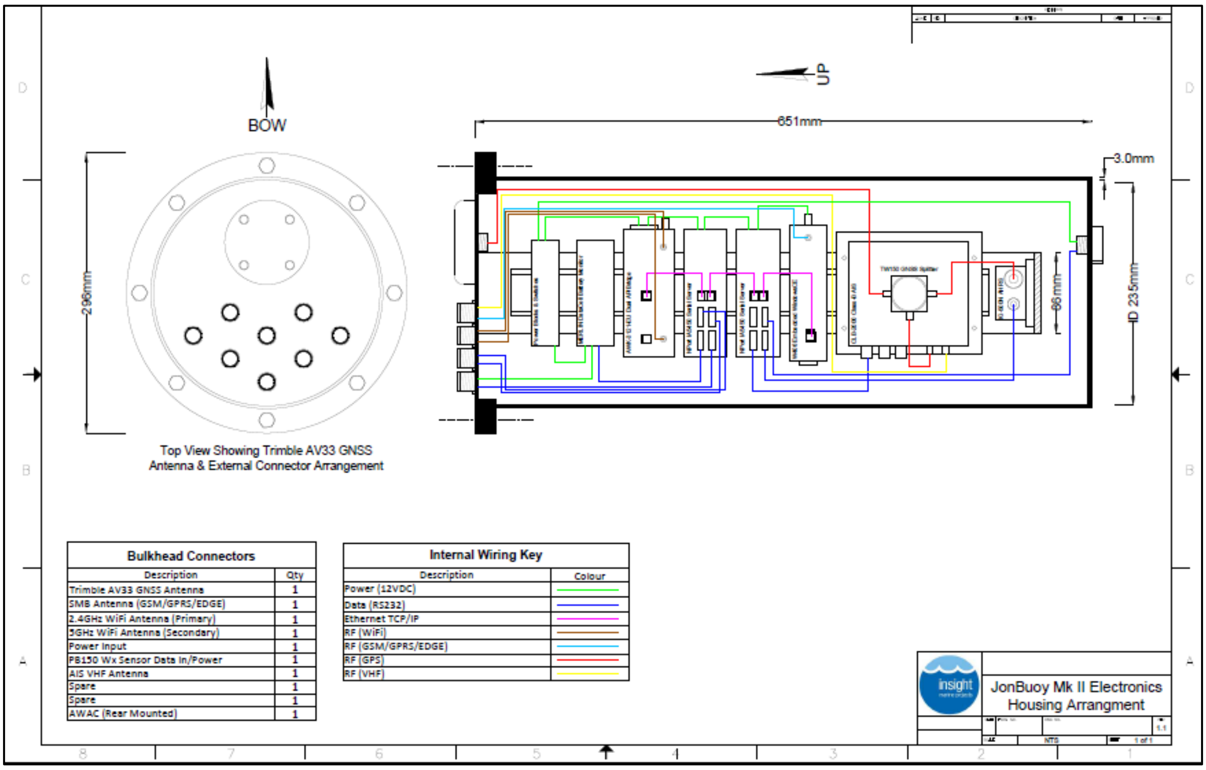

Figure 1. On-board electronics systems for the Jon-Buoy, showing the additional sensors and the two spare ports built in to the new modular system.

Further sensors to be incorporated were discussed, including a PV weather panel giving insolation, wind speed and direction amongst other met-ocean parameters. Ians input to these discussions was the consideration of environmental variables in real-time. This would provide marine contractors with real-time information about their environmental impacts during marine operations, supporting adherence to consents, and enabling feedback to the ongoing process of refining environmental impact consent conditions.

A crtitical aspect of operating the Jon Buoy effectively is the scoping and verification of the physical processes that it is intended to measure. To this end, this internship provided relevant skills to oversee and co-ordinate a field campaign of wave and current measurements at the Inner Sound tidal energy site. This work was with a consortium, including Paul Bell (NOC) from the NERC funded Flowbec project, and Meygen, the developer who holds the lease for this site. Unfortunately, due to construction delays, there was no opportunity to deploy a Jon Buoy at site. Nevertheless, this provided a unique opportunity to develop a detailed knowledge of the environment for which Jon Buoy 2 is being designed. Perhaps most critical here is the co-ordination between parties instigated by the intern, which has delivered a unique spatial data set for this site. From this, tidal and wave models for the site can be validated meaning that data captured from a Jon-Buoy situated at any point in the site can be put into context of the whole site, and positioning the Jon Buoy will benefit from a highly accurate spatial assessment of hydrodynamic conditions. Furthermore, the data sets captured will provide a detailed assessment of small-scale temporal variability, and spatial variability in the form of turbulent structures in the water column. Analysis and interpretation of these data will support analysis of data retrieved from the Jon Buoy, and positioning relative to operational vessels.

2. Impact achieved

This internship has helped the company to consider environmental issues from the outset. Through participating in design discussions, the excellent base design of the Jon Buoy can now be applied to environmental monitoring. This opens up the possibilities of new, cost effective monitoring of marine operations, which will help during planning and consenting, allowing more refined consideration of impacts. The outcome follows Mojo Maritimes commercial philosophy of developing systems and methods to increase working capacity for high energy areas, whilst simultaneously supporting increased monitoring for the reduction of environmental impacts.

The Internship has enabled the company to increase the scope of their instrument. Its robust design and real-time data transfer make it particularly suited to monitoring marine operations. Development of processing systems to enable wave measurement and reporting, and highlighting a development pathway for acoustic and sediment measurements mean that an increased sensor package can now be offered. This will open up opportunities for exploiting opportunities related to other marine operations, and potentially, other sites. The outcome is increased commercial potential for this unit.

Through a valuable academic input into the design and execution of the field work, and initial data analysis, the internship helped the company derive a valuable and unique data set for the Inner Sound. The intern particularly contributed to the co-ordination between parties to get a simultaneous data set and to advise on the spatial placement of these instruments. These data will inform all levels of marine operations, the placement of the Jon Buoy(s) during marine operations, as well as the setup of the instrument. The impact of this data set reaches beyond this internship, improving marine operations planning for mojo Maritime, but also site design and device design for Meygen as well as research into turbulence for the University of Exeter.

3. Possible follow-up activity

Preliminary testing of the Jon Buoy for acoustic monitoring, accuracy of wave measurements and sediment monitoring could be instigated to further develop this potential application. Either through a client, or through a funded scheme, a short campaign of testing and validation would allow calibration of on-board systems and an assessment of precision and accuracy.

An assessment of how the Jon Buoy system can be integrated into the environmental consenting procedures for tidal sites. Establishing which consent requirements can be met using the Jon Buoy, and environmental assessments that can be improved through the use of this system. This could refer to ongoing NERC projects Flowbec and EBAO, which are informing the understanding of marine ecosystems in marine energy sites, to help develop best practice for environmental monitoring of marine operations.

Appendix A - Noise monitoring and mammal detection during marine operations.

Ian Ashton, Dec 2012

It is proposed that the Jon Buoy could offer acoustic monitoring as a modular extension. This would allow the deployment vessel to monitor the noise caused during deployment in real time. Where consents and licenses refer to or limit the noise during deployment and operation, this extension would allow monitoring and reporting against these requirements. The data may also provide information about marine mammal presence in the area. This document describes the Jon Buoy electronic systems with relevance to the installation of a hydrophone, and reviews hydrophones available commercially. The level of service that could be offered is defined, although a key initial consideration will be the level of noise emitted by the Jon Buoy systems themselves.

Marine noise

Marine operations in which Mojo maritime are active will commonly increase the marine noise in an area. This increase in noise is considered in relevant legislation, and forms part of the environmental impact assessment procedure for marine renewable energy deployments. Environmental considerations are related to the sensitivity of marine species to increases in noise, which can alter their behaviour and impact on communications. The inclusion of acoustic monitoring at site, via the Jon Buoy system, would provide an opportunity to monitor the noise levels during marine operations, and normal device operation. This would support reporting against existing legislation. Furthermore, having the data in real time would allow reactive practice when on site. This is not a new idea, with hydrophones commonly deployed from vessels. However, implementation on the Jon buoy simplifies the operating procedures, and also offers continuous assessment of operating noise when vessels are not on site.

Monitoring marine mammals

Marine mammals can be monitored using a passive acoustic instrument. This listens for noise, identifying only animals that emit calls. The frequencies of different species are shown in figure A1. In general, hydrophones are rated between 5Hz and 150kHz. The raw data are spectrally analysed to give a noise spectrum, giving power per frequency. For some sensors, data sets are derived from positive identification of marine mammals over time, within the sensor range. Directionality requires separate sensors and is based on phase difference, or triangulation. Directional hydrophones are available which contains separate sensors all fixed to the same sensor unit. Stat sheet for the iCLOCATE LF (Planet-Ocean 2013) suggests that it provides a bearing for coherent sounds, but it is not certain whether these sensors can effectively resolve range, or their performance for short lived marine mammal noise.

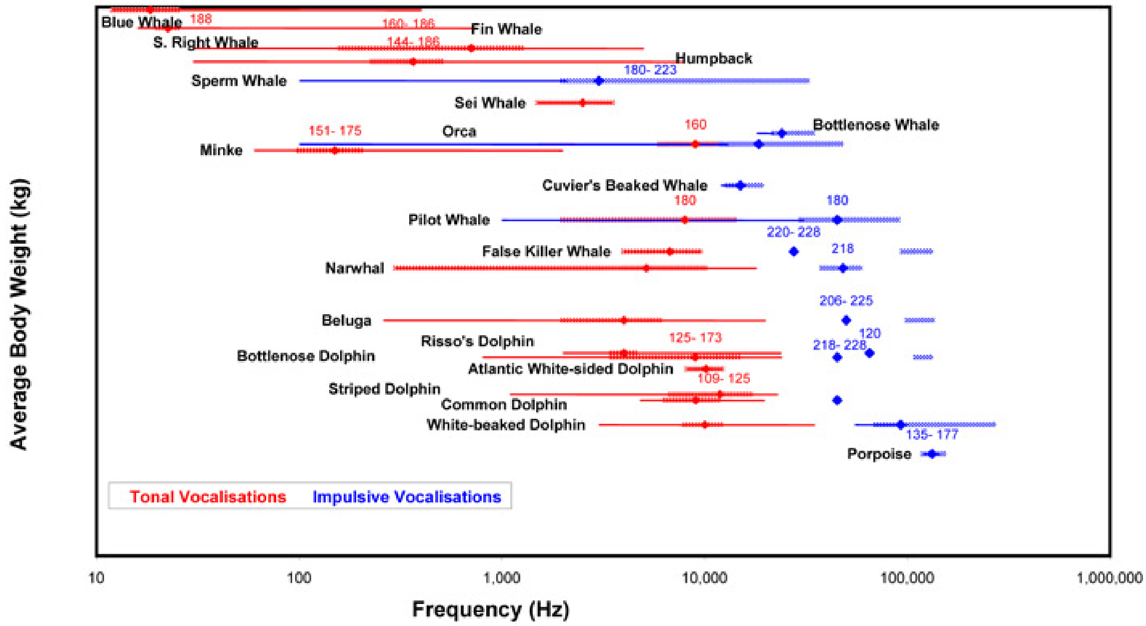

Figure A1. Marine mammal vocalisation ranges (OSB 2013)

Hydrophones using RS232 connections would be readily connected to the Jon Buoy. Real time outputs may only be possible through the proprietary software, which would not be ideal for a single Jon Buoy real-time output module, unless it can be integrated.

These systems potentially allow the Jon buoy to monitor the proximity of mammals in real time during marine operations. However, directional hydrophones that cover the entire frequency range for marine life (fig. 1) have not been identified. Furthermore, range cannot be resolved for single units. Therefore, fitted directional hydrophones will not be sensitive to the full range of vocalisations, and despite picking up certain calls, would not provide a definitive measurement of their presence in the area.

Directional identification and range finding can be further improved using an array of hydrophones. The Jon buoy is of limited size and separation is unlikely to be sufficient to provide a valuable array size. The mooring limb does offer separation, but no method for locating the hydrophones relative to each other is available, which would introduce inaccuracies to the analysis. This is not considered a viable option for Jon Buoy 2. However, this could be re-visited if acoustic monitoring is further prioritised.

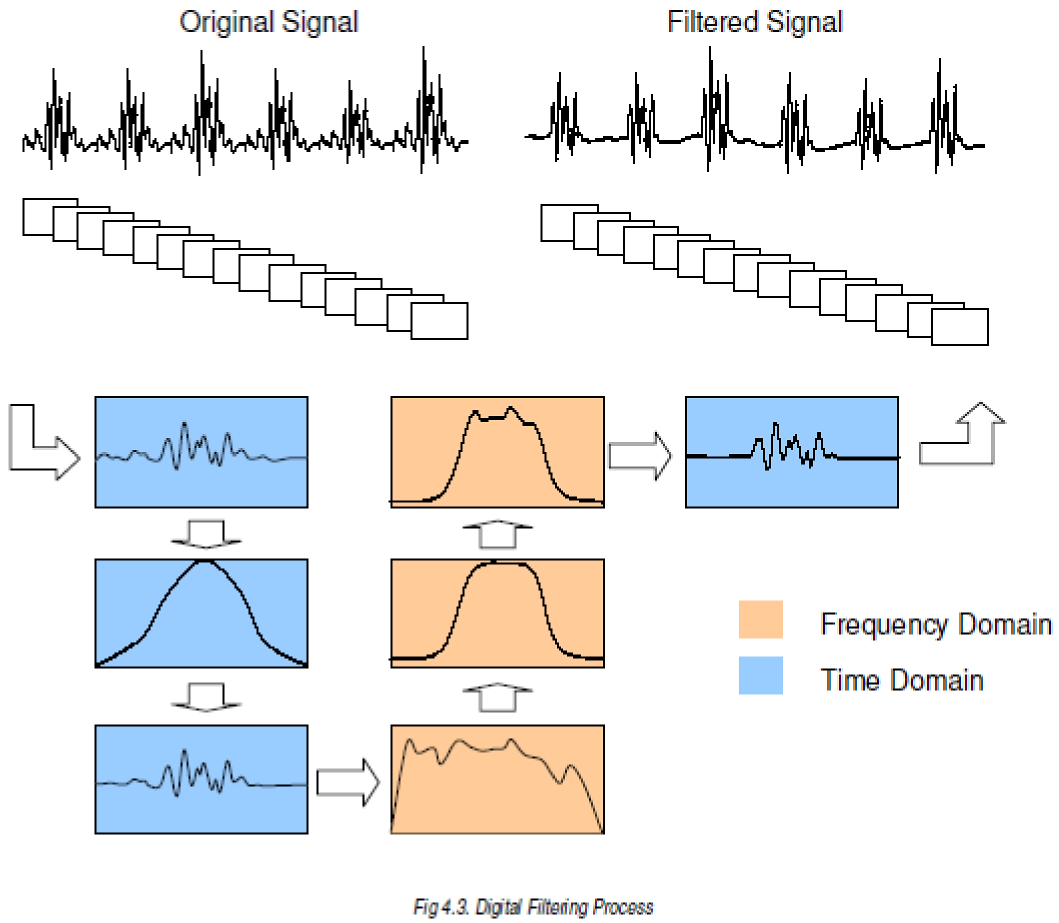

Figure 2. Processing applied to acoustic data (Seamap Pte Ltd 2003)

Figure 2 demonstrates the processing applied to broad-band acoustic data from hydrophones. This would be readily achieved using Matlab. Presuming that the frequencies for target species are well defined (e.g. dolphin clicks), then targeted analysis of the frequency spectra would allow real-time identification of the presence of species, as part of an integrated Matlab software package. Such a system would benefit from validation, perhaps with 'off the shelf' cetacean monitoring such as a Cpod.

Specification

The directional hydrophone, iC LISTEN HF (planet ocean 2013) is a broad band hydrophone providing coverage between 1Hz and 200kHz, which is suitable for almost all marine vocalisations (fig. 1). It has a 12 – 24V DC input, with a power requirement of 500mW. It can be connected to onboard systems using the available RS232 connection, or it has an optional ethernet link. This has the benefit of an internal data logger. Transmission in real time could be achieved although the proprietary software would be required on the on-board computer.

Planet Ocean (2013) *Ocean sonics*, accessed on-line at http://planet-ocean.co.uk/wp/?page_id=270

Ocean Studies Board (OSB) - Division on Earth and Life Studies (2013), *Ocean noise and marine mammals*, accessed on-line at: http://www.nap.edu/openbook.php?record_id=10564&page=13

Seamap Pte Ltd (2003), *CMS Technical Overview*, accessed on-line at: http://www.geophysicalservice.com/Site_Files/My_Files/Reports/Cetacean.pdf (Dec 2012)

Appendix B – Turbidity and suspended sediment

Suspended sediment is an oceanographic parameter of interest. It can be altered during marine operations which can have a direct effect on local sediment paths, marine operations and local pollution. Furthermore, there can be a knock-on effect on marine ecosystems. Therefore, there may be two compelling reasons for a developer to wish to monitor suspended sediment during marine operations:

- To monitor sediment paths, predicting erosion, scour or unwanted accretion
- To comply with, or to report against, regulatory requirements

Acoustic profilers can be used to measure the suspended sediment in the water column, and real-time data could be derived using the AWAC unit already operational on the Jon buoy 1.

Measurements using acoustic instruments

The raw backscatter strength measurement from acoustic pulses gives a measure of the particulates in the water (e.g. Souza 2007, Sassi 2012). However, this cannot be directly related to sediment particle matter (SPM) because the strength of the return will be affected by bubbles in the water column and any other suspended particles as well as SPM. Furthermore, SPM grain size will also affect the returns, not simply the concentration.

In order to derive a measure of the SPM concentrations, the magnitude of backscatter in the returned acoustic pulses must be calibrated against known particle concentrations (Souza 2007). Where the properties of suspended particles at a site are well known, this calibration can be performed under laboratory conditions. Another approach is to gather water samples during operation that can be analysed to provide calibration with measured data (and subsequent extrapolation to all data collected at the site). This latter procedure initially rules out real-time assessments.

The correlation between SPM concentration and backscatter will be badly affected by biological factors and bubbles in the water column (Sassi 2012). It will also be seen to vary from site to site due to the reflective properties of sediments in the different areas. No central calibration database exists with which to estimate the required regression, meaning that a valuable estimate of suspended particle matter concentration is beyond the scope of automated on-board systems, without preparatory work to calibrate the ADCP response.

Outlook for the Jon Buoy

The outcome and outlook for the JonBuoy is that this is a process that could be included into the Jon Buoy systems. As a basic package, the raw backscatter strength can be used to provide an estimate of 'dissolved particles in the water'. However, where marine operations are taking place, especially those sub-sea, it will be difficult to differentiate between bubbles created and sediment disturbed during operations. More detailed information could be derived to assist with sediment surveys or monitoring, where scour, erosion or accretion are key considerations. However, this would require prior surveying at the site.

Prior surveying would involve the operation of the Jon Buoy on site for a period of time, with regular sampling through the water column. Analysis of water samples would derive the SPM concentrations and allow quantified estimates of SPM flow past the sensors. This would not resolve the issue of bubbles affecting the measurements, but the differences between sampled and measured SPM concentration could be used to estimate the impact of bubbles. An initial campaign of surveying at a given site could be used to inform all future operations. This approach may be applicable where the Jon Buoy is to be used for sediment monitoring consistently over a longer period of time.

Requirement for this monitoring

The industry requirement for this monitoring is unclear. However, sediment disturbance can be a major issue, especially in estuarine areas where sediments are carefully managed and can contain pollutants. Strategically, turbidity offers another potential tool for the Jon Buoy platform, which is again uniquely placed to return real time measurements due to its surface position and communication systems. Where significant sediments are moving, deployment of an ADCP on the sea bed is difficult as it is liable to get buried. Therefore, there may be an application in riverine flows. There may also be a specific interest in the near sea-bed zone which cannot be resolved by a bottom mounted instrument. This latter property represents a particular benefit of a top-mounted system.

Recommendations

The strength of return from the AWAC should be included as a secondary real-time data set available via the wifi link, and stored on the data loggers routinely. Where ground works are taking place, this data can be used to estimate the relative increase in sediment load, and the extent of the sediment plume.

For applications where sediment is of particular interest to the client, a campaign of prior sampling should be included. This will involve measurements with the Jon buoy and simultaneous water column sampling. Samples should be assessed for SPM concentration and grain size. Based on the methods of Souza (2007), a calibration co-efficient should be derived. This can be used to give a real-time estimation of sediment released based on Jon-Buoy measurements.

Notably, where ground works are likely to change the sediment size distribution, these calibration curves would become inaccurate. Simultaneous sediment sampling would be recommended for post-processing of the data set, in order to validate and refine the calibration co-efficient during the activities. This would give a more accurate data set for reporting where necessary.

Despite the complexity of the process that would be required to derive a robust calibration co-efficient for the strength of returns and the sediment load in the water column, once derived, the integration this co-efficient into data processing software would be relatively straightforward. It is the authors opinion that this capability should be built into the operating software.

References

M. G. Sassi, A. J. F. Hoitink, and B. Vermeulen, (2012) *Impact of sound attenuation by suspended sediment on ADCP backscatter calibrations.* WATER RESOURCES RESEARCH. In press, doi:10.1029/2012WR012008

Y. Nihei, H. Kitayama, and Y. Harada, *A new monitoring system for sediment transport with H-ADCP measurement and numerical simulation,*

A.J.Souza, (2007), *The use of ADCPS to measure turbulence and SPM in shelf seas,* In proceedings of the 2nd International Conference & Exhibition on "Underwater Acoustic Measurements: Technologies & Results.