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Needs for Professional Hydrography in the Caribbean Towards Risk Reduction in Maritime Navigation

Keith Miller

Department of Geomatics Engineering and Land Management, The University of the West Indies, St. Augustine, Trinidad and Tobago, West Indies; E-mail: Keith.Miller@sta.uwi.edu

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Abstract: *With a focus on the Caribbean Sea, the needs of hydrography and national economic benefits are explored. Expectations in terms of data requirements are identified and components where shortage often exists are acknowledged. It is anticipated that shipping activities will increase in both density and size of vessels, the need for professional staff capable of functioning with accepted survey standards is then fundamental to maritime safety. While the majority of states that have territorial ownership of some part of the Caribbean Sea are signatories to the Safety of Life at Sea (SOLAS), questions arise as to whether the requirements for provision of hydrographic data to the international community are being maintained. The need for professionally qualified staff to maintain state services is identified, and there is also a need for surveying operations to be undertaken by professionals, where a professional refers to those having undertaken a recognised programme of study.*

Keywords: *Hydrography Caribbean Navigation Charting*

1. Introduction

In modern terms, the formal definition for the discipline of hydrography is given by the International Hydrographic Organisation (IHO, 2015a) as: *"Hydrography is the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defence, scientific research, and environmental protection".*

The science originated from the need for charting as a requirement for safety of navigation with survey voyages being undertaken during the 19th Century to chart the coastlines of the World. Perhaps the most notorious voyage was that of HMS Beagle, which was made famous by the presence of Darwin, but the primary purpose of the mission was to chart the waters in the entrances to primary ports within the Southern hemisphere. Almost a century later, as a direct consequence of the tragedy of the Titanic in 1912, the international convention for the Safety of Life at Sea (SOLAS) was introduced. SOLAS today requires contracting states to take responsibility for aspects of safety of navigation within their territorial waters to include deployment of navigational marks, dissemination of navigational information, and to perform hydrographic surveys. In resolution A/RES/58/240, the United Nations (2003) recognised that hydrographic surveys are critical in navigation for safety of navigation at sea and hence in environmental protection.

By its nature shipping is international, so standards to which hydrographic data is acquired and the way in which resulting navigational information is presented to the mariner must be international. The IHO (2015b) exists in this capacity: *"The vision of the IHO is to be the authoritative worldwide hydrographic body which actively engages all coastal and interested States to advance maritime safety and efficiency and which supports the protection and sustainable use of the marine environment"* and offers standards and protocols to ensure the quality of hydrographic information provided to the international community meets this objective. Amongst the publications: IHO (2008) offers standards for conducting surveys; IHO (2000) provides transfer standards for digital hydrographic data; and, IHO (2012) addresses issues relating to production and distribution of data for modern electronic charting systems.

2. Shipping Density in the Caribbean

The location of the Caribbean Sea within Central America and the presence of the Panama Canal places primary international shipping routes within the region. Furthermore, the island nature of many states means that shipping is a requirement for movement of goods and the presence of natural resources within some territories makes shipping essential to the economy. The estimated number of internal shipping movements within the Wider Caribbean Region (WCR, which includes the Gulf of Mexico) for 2007/8 is shown in Figure 1, this

excludes shipping beyond the region, hence Panama canal traffic is not included. Internal shipping accounts for about 73% of the total movements within the WCR. Density of traffic within the Caribbean Sea is highly focussed on locations as shown by shipping routes and density in Figure 2. The image from MarineTraffic (2015) clearly shows areas of particularly heavy traffic around Trinidad, Curacao and the entrance to the Panama Canal.

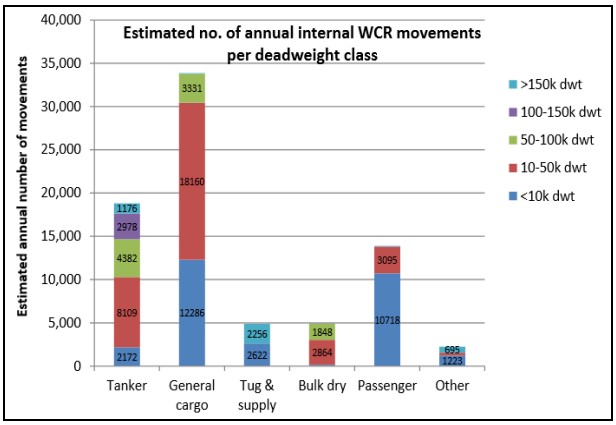

Figure 1. Internal shipping movements in the Wider Caribbean Region by class and type
Source: Algell, Bakosch and Forsman (2012)

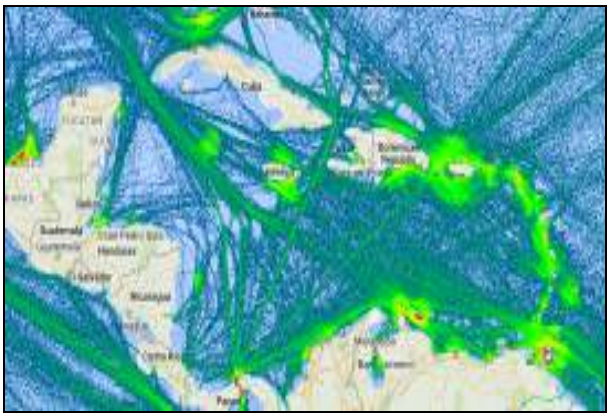

Figure 2. Shipping density in the Caribbean, for the second period of 2013. (Source: MarineTraffic (2015))

At one instant in December of 2014 a variety of shipping traffic was observed around Trinidad and Tobago (see Figure 3) with cargo vessels and tankers moving to the North using port facilities on the West coast of Trinidad and smaller vessels servicing the offshore industry to the East. An instantaneous snapshot from the Gulf of Paria provided in Figure 4 shows that the traffic includes vessels carrying dangerous goods (DG), vessels towing structures associated with the offshore industry and a high speed ferry servicing the Trinidad to Tobago route. There is a second high speed service between Port of Spain and San Fernando in Trinidad that has to make its way through the high density traffic on the west coast of the country. Maritime traffic around Curacao also consists primarily of tankers servicing the Isla refinery and cargo (see Figure 5).

Figure 3. Traffic around Trinidad and Tobago.
Source: MarineTraffic (2015)

Figure 4. Identification of traffic on the West coast of Trinidad at one instant

Figure 5. Traffic around Curacao. (Source: MarineTraffic, 2015))

In May of 2011, under the International Convention for the Prevention of Pollution from Ships (MARPOL), the Caribbean Sea was designated a special area with regulations governing the disposal of garbage by shipping. The Association of Caribbean States has established a Caribbean Sea Commission with the aim of ocean governance within the region (ACS, 2015).

3. Economic Basis for Hydrography

In their report for the Asia-Pacific Economic Cooperation, APP and Globalworks (2009) used economic models to suggest that there is always direct economic benefit from investment in hydrography. Further case studies are listed by the International Federation of Surveyors (2011). The level of return is dependent on factors associated with potential for shipping services and foreign trade with the return given by improvement in efficiency of services that encourages an increase in shipping traffic. Navigable waterways need to be maintained, and the depth of water available to access a port is important. For example, in terms of cargo vessels the change in tonnage per centimetre in draught (TPC) is given by $A \times d/100$ where A is the surface area of the vessel and d is the density of water. Considering the surface area of vessel typically passing through the Panama Canal, a change of 30 cm in navigable depth would accommodate an increase of about 2000 tonnes in cargo.

In addition to cargo vessels of various types, Brida and Aguirre (2008) estimate that the Caribbean accommodates 40% of the global cruise industry. A study of the economic impact of cruise spending for the 2011/12 cruise season in the Caribbean undertaken by BREA (2012) states that transit passengers spent $1.38 billion (an average of $93.21 per person) at each location, while spending at the home port was $104.4 million, $155.62 per person.

Shipping traffic in the Caribbean comprises cargo and tankers integrated with cruise liners and smaller vessels used in fisheries as well as local services. A wide range of sectors contributing towards the overall economy of the region are heavily dependent on shipping. Maritime disaster could have significant impact on both human life and on the environment, which is critical to the tourism industry. With the expansion of the Panama Canal (Canal de Panama, 2015) to increase the size of the locks allowing larger vessels to pass and the addition of a further lane that is intended to double capacity, the density and size of shipping traffic through the Caribbean is expected to increase.

Further developments are proposed with the addition of another canal through Nicaragua (Watts, 2015). These developments provide opportunity for economic growth in the Caribbean region, there is economic advantage in increasing the depth of ports to accommodate larger vessels. Nicholson (2015) explains how ports in some Caribbean States are already aligning with the development and considers the increase in risk of maritime disaster that comes as a consequence. A primary requirement for risk reduction is the provision of information to the mariner, the source of such data is derived from hydrographic services.

4. Hydrographic Requirements under SOLAS

The SOLAS convention broadly addresses the issues associated with safety at sea, with regular updates to requirements. Under SOLAS Chapter V, Regulation 9 refers specifically to hydrographic services with the following obligations:

1. *"Contracting Governments undertake to arrange for the collection and compilation of hydrographic data and the publication, dissemination and keeping up to date of all nautical information necessary for safe navigation.*
2. *In particular, Contracting Governments undertake to co-operate in carrying out, as far as possible, the following nautical and hydrographic services, in the manner most suitable for the purpose of aiding navigation:*
   a. *to ensure that hydrographic surveying is carried out, as far as possible, adequate to the requirements of safe navigation;*
   b. *to prepare and issue nautical charts, sailing directions, lists of lights, tide tables and other nautical publications, where applicable, satisfying the needs of safe navigation;*
   c. *to promulgate notices to mariners in order that nautical charts and publications are kept, as far as possible, up to date; and,*
   d. *to provide data management arrangements to support these services.*
3. *Contracting Governments undertake to ensure the greatest possible uniformity in charts and nautical publications and to take into account, whenever possible, relevant international resolutions and recommendations*
4. *Contracting Governments undertake to co-ordinate their activities to the greatest possible degree in order to ensure that hydrographic and nautical information is made available on a world-wide scale as timely, reliably, and unambiguously as possible."*

The first two items relate to acquisition and management of data and services while compliance with items 3 and 4 requires that staff associated with the provision of information to the maritime community work within international standards. There is not necessarily a requirement to host acquisition systems and acquire data within the state, services can be contracted out, but there is a need to manage data in house. Irrespective of how data is acquired, the State has responsibility for quality assurance of data and provision of information to the international community. There is then a requirement for professional staff within the State to manage operations.

Hydrographic surveys are expensive, the cost of a single fitment using modern survey equipment would exceed 250,000 USD and the purchase and maintenance of a vessel requires further capital outlay as well as ongoing costs. For these reasons it is also expensive to contract services. A survey undertaken for dredging of a

small port in the Caribbean recently cost close to 10,000 USD. This was performed using lower cost equipment and without heed for quality assurance measures required under SOLAS. Numerous surveys of this type are conducted within the Caribbean, with contracts being issued by port authorities for engineering purposes (such as dredging or construction) and resulting data being used for this application alone. Surveys are conducted, but the data is not necessarily acquired to international standards and is not always being made available to improve safety of navigation.

5. Status of Hydrography in the Caribbean

Not all territories can be expected to provide the capacity to produce charts, particularly in instances where territorial waters are small. In such cases major charting agencies internationally take on the role of charting using locally acquired data. In the case of small territories of the Caribbean, the United Kingdom Hydrographic Office (UKHO) takes on the primary charting responsibility through publication of Admiralty charts. As a measure of quality of information provided on charts, the Admiralty details the age of data used in compilation, Figure 6 shows the situation for Admiralty Chart 474, Port of Spain and Approaches. Much of the data for the Gulf of Paria was acquired prior to 1940, and some in the 1960's.

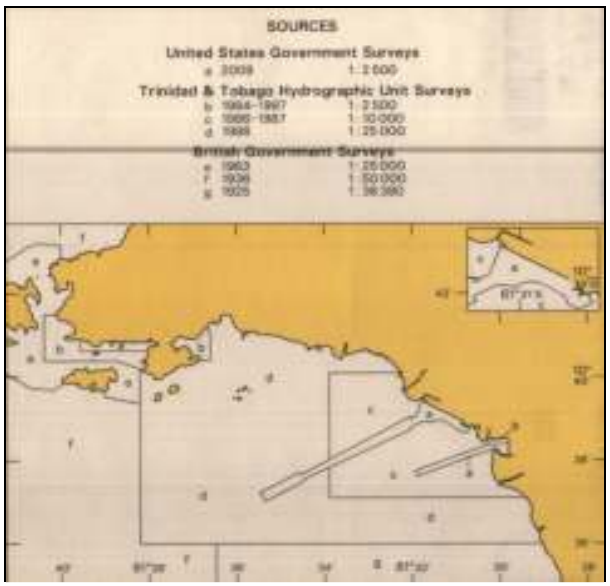

Figure 6. Age of data used in charting the Port of Port of Spain and approaches (Source: UKHO (2010))

A Hydrographic Unit that was established in the early 1980's under United Nations funding (Holden, 1986) and acquired data in more critical navigational areas through that decade. Loss of staff led to demise of the Hydrographic Unit. Prior to a visit to Trinidad by President Obama in 2009, the United States agencies surveyed the channels leading in to Port of Spain for evacuation purposes and this data consequently appears on charts. Otherwise, the charts may have still shown channel depths of 10 m, in spite of their having been dredged to 12.5 m in 1999, an operation that was undertaken to accommodate ships able to pass through the Panama Canal.

Depths are a dominant feature on a chart and for navigational safety reasons these are shown to the level of Lowest Astronomical Tide (LAT). Typically land survey datum, which is usually defined as Mean Sea Level (MSL) is used to establish a level for referencing hydrographic surveys, with the data then being reduced to the published offset from LAT. In many instances within the Caribbean, MSL itself was crudely determined using short term data sets, which has led to errors in charted depths. Masters of cruise liners reported incidents of ships touching the seabed on manoeuvring within a port in Grenada, the resulting investigation undertaken by Neale (2007) revealed a discrepancy between true MSL and that adopted as the land survey datum. In Bridgetown, Barbados, it was been established by Miller (2010) that an error of about 0.43 m was made in interpreting the observations that led to determination of MSL. Fortunately in this case the mistake erred on the side of safety. In developing a geoidal model of the Caribbean, Smith (1999) also comments on the lack of reliability in realisations of mean sea level throughout the Caribbean territories.

Due to natural movement of sediments, vertical displacement to topography and human disturbance, the seabed is dynamic. Survey data that details the seabed topography has a lifespan, and in many ports dredging is required to maintain depths. Charted depth in the channel can also be disturbed by obstructions, for example large objects that fall from ships unnoticed can restrict the depth of the waterway. In the approaches to a port and surrounding waterways the seabed can be littered with debris such as wrecks, remains of disused platforms, and so on, that can extend close to the sea surface. Further hazards to maritime activities such as fishing and anchoring of vessels exist due to installations on the sea floor. Figure 7 shows a sonar image of an abandoned platform within the Gulf of Paria, this was found while performing a debris survey that was conducted to identify obstructions prior to launch of a high speed ferry service. In spite of the finding this particular debris item in 2005, it is still shown on Admiralty Chart 483 with corrections to 2014 as a platform equipped with lighting; data acquired has never been forwarded to charting agencies. As electrical generation sources move offshore to harvest wind, current and wave energy the sea is becoming more cluttered with obstructions to navigation. Beyond initial surveys, the maintenance of hydrographic services for charting is a full-time role to monitor change, manage databases and ensure that corrections are propagated throughout the maritime community.

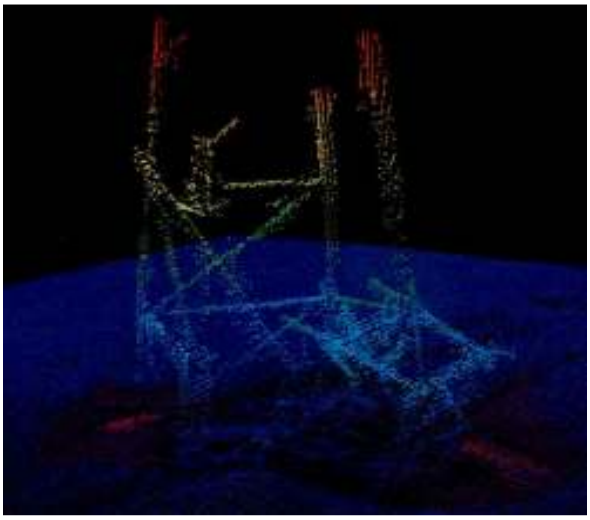

Figure 7. Sonar image of debris in the Gulf of Paria.

In support of their vision, the IHO are keen to promote the requirements for hydrography internationally, and to develop capacity building initiatives. Technical visits are offered to assess of the status of hydrography nationally and make recommendations for development. The UKHO cooperate with many territories of the Caribbean towards technical support. The last technical visits were made in 2006 and covered 14 territories in two phases. Reports from the UKHO (2006a and 2006b) found generally that services such as maintaining aids to navigation, publishing notices to mariners and matters relating to maintenance of ports were being carried out as required.

Otherwise, a number of particular problems were identified in:

- Montserrat - a grounding that had taken place outside of the channel had not been reported, volcanic ash encroachment into the sea had also not been documented for charting purposes and positions for two buoys marking an artificial reef were not adequately provided.
- Anguilla - chart coverage of a primary channel was based on lead-line data acquired more than a century old and three jetties had been constructed without communicating changes to charting authorities.
- Antigua and Barbuda - a number of coastal developments had taken place, including a new fishing harbour that remained uncharted.
- Turks and Caicos - access to a main cargo port was found to be in close proximity to uncharted banks with a few soundings shown and major construction work was underway on a new dock that even at that stage required notification for charting purposes.
- Cayman Islands - uncharted developments included a new wharf, extension to a jetty, additional berths and installation of submarine cables, also, a navigational light had been demolished by a hurricane.
- Grenada - a number of coastal developments including new jetties, a new marina, relocation of a shipping terminal and restrictions on anchoring were all unreported for charting purposes.
- St Vincent and the Grenadines - a number of changes had been made to navigational lighting, which had not been reported to charting authorities.
- St Kitts and Nevis - it was recommended that surveys be conducted in a number of areas to check the impact of a recent hurricane in terms of both depth and debris.
- Dominica - a substantial number of new developments had taken place along the shoreline that remained uncharted.

Surveys of primary channels within existing ports were considered as being up to date and checks on depths are typically being made using basic equipment. These findings are supported through a review of Admiralty Notices to Mariners. For example, UKHO (2015) refers to a chart of Grenada detailing alterations made to the port area and navigational marks, these were reported by the port authority for a survey where professional surveyors had been contracted to perform the work with their findings also detailed in the notice. These changes are incorporated into later editions of the corresponding chart.

However, during the UKHO technical visit the team noted that in numerous locations facilities had been developed both within and outside of port boundaries that remained uncharted. Information provided in technical reports is obtained from visual inspection and discussion with authorities, content then focuses on coastal development and engineering surveys conducted within the port, much of the bathymetry beyond that obtained for dredged channels dates back to surveys conducted decades ago. It is now nine years since the technical visits took place and more recent anecdotal evidence from the region suggests that changes to navigational features are still not being adequately reported. A subsequent visit by staff from the National Oceanographic and Atmospheric Administration (NOAA, 2011) to Belize revealed that a local hydrographic unit that had appeared promising in 2006 was suffering from lack of maintenance of equipment. In 2014 further visits were made by staff from the UKHO to many of the other locations visited in 2006, reports have yet to be published.

Success stories come from Barbados and Jamaica. Barbados Port Incorporated contract out their survey work and are commended by the UKHO on their delivery of data to the charting authority for updates to charts, whether this is due to staff within the port authority appreciating the need, or down to professional conduct of the survey company used is unclear. Jamaica

is reported to have a strong team of qualified hydrographers working within the National Land Agency with equipment available, while they are covering the ports and passing information to the charting authority there was need for a national charting programme to cover areas beyond the ports. It appears that the key to success in Barbados and Jamaica is attributed to the use of properly qualified staff.

6. Standards of Competence

Acquiring and presenting quality data is fundamental to its use in navigation. Specialist courses exist within the discipline of hydrography, some accredited with professional bodies. Accreditation typically involves professional bodies or local accreditation boards awarding recognition to a programme on the basis of compliance within a general discipline. There is typically some flexibility for the programme team to provide an aim and objectives with reviewers considering content on its merits and requirements within the discipline. However, the international nature of the hydrography and nautical cartography mean that international standards are required and the process is different.

In support of educational requirements for hydrographers and nautical cartographers to work to internationally recognised practices, the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC) provides standards and offers recognition to courses that are found to comply with the standards. Membership of the IBSC is made up of ten (10) representatives, four from the International Federation of Surveyors (FIG), four from the IHO and two from the International Cartographic Association (ICA). Standards of competence are provided in terms of theoretical content and skills based components for programmes, and it is programmes rather than individuals that are recognised. Standards exist at Category A (professional) and Category B (technician) level for the disciplines of both hydrography and nautical cartography. The IBSC meets annually to review programmes that are submitted for recognition, programmes found to be in compliance with the standards are awarded recognition for a period of 6 years.

Lists of currently recognised programmes in hydrography and nautical cartography at Categories A and B are available from the IHO (2015c) website. Programmes are offered by three different types of ornagisation: (i) government agencies or navy establishments with national responsibilities for hydrographic surveying and charting; (ii) educational establishments such as universities with recognition being awarded to academic programmes; and, (iii) commercial organisations. Recognising the need for the disciplines of hydrography and nautical cartography the IHO (2015d) offer various capacity building initiatives. A number of government employed staff from the Caribbean region have travelled overseas to complete sponsored category B programmes, fewer have been awarded funding to undertake programmes at category A level. Using alternative funding sources (including self-funding) it is typical for one or two graduates from The University of the West Indies (UWI) each year to progress to a category A hydrography programme through enrolment on a university Masters' degree overseas, however, given lucrative opportunities in the offshore industry few return to the Caribbean to work. There is then a shortage of professionally qualified hydrographic surveyors working regionally in hydrographic services for applications in navigation.

7. Risk Reduction Measures

In support of hydrographic operations, data that is provided by shipping under the Automatic Identification System (AIS) is useful. Under SOLAS, vessels over 300 gross tonnes and all passenger ships are required to carry AIS, a system that provides at least identification, position, speed and direction of the vessel. It is primarily used within navigation to enhance radar targets acquired by other vessels and by Vessel Traffic Services (VTS). However, statistical analysis of historical AIS has proved beneficial in hydrography; Figures 2 to 5 herein are derived from AIS data.

Recognising the potential risk of maritime disaster to life and the environment in the Pacific, the Land Information New Zealand, under the New Zealand Foreign Affairs and Trade Aid programme, commissioned a study to assess areas of particular hazard. Riding, Webb, Rawson and Grover (2013) used AIS data as a primary source to examine shipping movements. Factors such as shipping density, confines of navigational waters and environmental vulnerability were used within Geographic Information Systems (GIS) applications to classify areas according to risk vulnerability. Results are used to identify priority areas for surveying and charting. There is further potential for such results to enhance navigational safety, for example in the definition of traffic separation schemes for shipping. Such schemes are often implemented in congested waterways to separate vessels heading in opposite directions, but no such schemes exist in the Caribbean Sea.

Risk of maritime disaster is being addressed within the Caribbean (Morinière and Réglain, 2012) and a web mapping system has been constructed with the support of MarineTraffic (2015) to display traffic flow. Use of data for risk assessment is a significant step, some of the flaws in AIS data have been recognised, but Riding *et al* (2013) found that a substantial amount of further information concerning ships and their cargo could only be obtained by visiting ports and searching records of movements.

8. Discussion

Maritime accidents in the Caribbean Sea have been rare events. In 1979 the largest ever ship-sourced oil spill occurred off the coast of Tobago when two full tankers collided, fortunately without significant environmental consequences. Such events make the headlines, otherwise there is under-reporting of incidents (Psarros, Skjong and Eide, 2010). A search of the International Maritime Organisation (IMO, 2015) database confined to the last 15 years to find incidents from the Caribbean related to navigation errors in ports or their vicinity found 20 groundings, 8 vessel to vessel collisions and 3 contacts with fixed objects. Details of the cause are often sparse, of those which are available many are attributed to human error, often associated with bad weather conditions, but two that are documented in detail are related to charting. In September of 2009 a bulk cargo vessel was punctured below the waterline while manoeuvring within a port. There had been three hurricanes during the previous year causing partial demolition of a pier and while the facility had been rebuilt, debris from the original remained in the water.

The other incident in 2005 involved the grounding of a vessel under pilotage on a mud bank. With a draught of 6.8 m the vessel should have had sufficient under keel clearance to enter the port, but soundings taken with a lead line from the bow of the stranded vessel showed a depth of 5 m. Both of these incidents occurred within the confines of a port with the hydrography at fault. IHO (2008) standards (and previous editions) require full seafloor searches within such areas to find obstructions and would be normal to conduct a survey after construction work. For the grounding, while the sea floor topography does change, and can do so rapidly in the confines of a large river, a reduction in depth of at least 1.8 m within a port of the Caribbean would not be expected.

Under SOLAS the contracting governments are responsible for the provision of hydrographic services within their territorial waters. Survey data, including bathymetry and aids to navigation, must be available for chart production and mariners notified of any changes through approved channels. In contracting out survey work, professional surveyors are aware of the requirements and normal practice would involve passing survey information on to relevant authorities. However, there is anecdotal evidence to suggest that contracts are being issued to commercial operators where staff do not hold recognised qualifications. This applies equally to state owned ports where surveys are often conducted for dredging purposes and to privately owned facilities.

It is also evident from UKHO (2006a and 2006b) visits that responsibilities within the majority of states within the Caribbean are divided between different agencies. While the port authority may have responsibility for hydrography within the port, the waters beyond the confines of the port fall within the jurisdiction of another agency. While these areas are generally deeper and less restrictive for manoeuvring, the methods used to acquire bathymetric data on which charts are based is now antiquated. Furthermore, there are changes taking place such as that shown in Figure 7 where an object once fitted with lighting as a navigational warning is now reduced to a set of crumbling steel members that protrude from the sea bed to a few metres below the sea surface. Hydrographic services are needed at national level to manage data associated with bathymetry and obstructions, this is a requirement under SOLAS and improvements to the efficiency of the service would encourage shipping activity, hence improve the economy.

Recognising deficiencies that exist in hydrographic services in particular regions globally, the IHO capacity building programme has gained support from governments of at least Japan, Korea, the UK, the USA, Brazil, Mexico and Norway with the provision of training programmes and technical support. As developments of the Panama Canal are underway some governments within the Caribbean are now preparing for an increase in shipping density and size, but there seems to be lesser acknowledgement of the associated requirement for improved hydrographic services. The Association of Caribbean States have made the connection between the vulnerability of the Caribbean Sea and increased risk in maritime accidents in the region, however as an organisation they have no responsibility for hydrographic services. A regional risk assessment programme should not be a precursor to justifying hydrographic surveys that are themselves a requirement of international convention. Such studies have a useful purpose in developing mitigation strategies towards risk reduction.

9. Conclusions

Hydrography is a specialised profession that has a wide range of applications in offshore and coastal operations. Within charting the hydrographer plays a key role in providing information to the mariner that is critical in the practice of navigation. As shipping is international the standards adopted in conducting hydrographic surveys, compiling data and presenting it to the user must follow international protocols. The International Hydrographic Organisation exists to define such standards and to ensure compliance standards also exists for the education of professionals. These standards are regularly updated to reflect developments in technology, and standards of competence are regularly revised for alignment with educational practice.

Within the Caribbean there is a shortage of professional hydrographers working towards charting, to some extent this is due to higher income opportunities that are available in other applications such as the offshore industry. Where hydrographic surveys are conducted they are typically for purposes such as

dredging or coastal development with the engineer responsible considering the application alone and unqualified personnel undertaking the work, the results are rarely passed on to the relevant charting authority. Primary ports are then maintained by dredging to the specifications indicated on the chart with other developments within the ports and along other stretches of coastline going uncharted. There is however an obligation to deliver quality data to the international community, which raises a liability issue in case of accident and for this reason it is essential that recognition is given to international standards when awarding contracts for hydrographic surveys.

A lack of staff with internationally recognised qualifications working within the government sector regionally is the primary reason for non-compliance with SOLAS requirements. Compliance in communication with charting authorities is better in both Jamaica and Barbados where qualified staff have been retained. By contrast, in the cases of Trinidad and Tobago and Belize where specialised hydrographic units have been established using external support, these services have not been sustained. The economy of both of these territories is heavily dependent on shipping and economic studies have shown that effective navigational information can impact on shipping activity. There is a need to undertake risk assessment analysis as a priority at a regional level, to identify territories that are most vulnerable to maritime disaster and to develop a regional plan for improvement in hydrographic services accordingly.

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Author's Biographical Notes:

Keith Miller *is senior lecturer of the Department of Geomatics Engineering and Land Management at The University of the West Indies (UWI). Following industrial experience in development of instrumentation for hydrography, Keith undertook studies to PhD at The University of Plymouth in the UK and from there joined the academic staff to undertake teaching and research in hydrographic surveying. In 1999, Dr. Miller moved to the UWI where he works in the areas of geodesy and hydrography. He is a member of the Chartered Institution of Civil Engineering Surveyors and serves as a FIG representative on the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers.*

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