Article



The UK Civil Hydrography Programme
Changing the Mould

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A review of Gardline Hydro's experiences during the first season of work on the UK Civil Hydrographic Programme using new multi-beam based hydrographic survey specifications introduced by MCA and UKHO to meet the requirements of IHO S-44 Order 1.

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Abstract

The Civil Hydrographic Programme (CHP) is funded by the government agency responsible for maritime safety in the United Kingdom (UK), the Maritime and Coastguard Agency (MCA). The CHP is now a major element of the UK strategy for delivering valid source data for maintenance of British Admiralty charts and associated nautical publications. Under the CHP, commercial survey companies such as Gardline Hydro compete for surveys of predefined areas on the UK continental shelf.

Résumé

Le programme hydrographique civil (CHP) est financé par l'agence gouvernementale responsable de la sécurité maritime au Royaume-Uni (RU) et l'Agence maritime et la garde côtière (MCA). Le CHP est à présent un élément majeur de la stratégie du RU pour la remise de données sources valables pour la tenue à jour des cartes de l'Amirauté britannique et des publications nautiques associées. Dans le cadre du CHP, les compagnies hydrographiques commerciales comme Gardline Hydro se font concurrence pour les levés de zones prédéfinies sur le plateau continental du RU.

Resumen

El Programa de Hidrografía Civil (CHP) es financiado por la agencia gubernamental responsable de la Seguridad Marítima en el Reino Unido (UK), la Agencia Marítima y Guarda Costa (MCA). El CHP esa hora un elemento principal de la estrategia de UK para la entrega de datos fuente válidos para mantener las cartas del Almirantazgo Británico y publicaciones náuticas asociadas. Bajo el CHP, compañías de levantamientos comerciales tal como Gardline Hydro, compiten por los levantamientos de áreas pre-definidas sobre la plataforma continental de UK.

Up until 2003, CHP surveys were conducted utilising single-beam echo sounder (SBES), sidescan sonar and magnetometer as primary survey sensors to meet Admiralty Survey standards, based upon IHO S-44 but with additional military survey objectives.

During 2003, MCA in consultation with the United Kingdom Hydrographic Office (UKHO) introduced a new set of updated survey specifications for CHP use, based primarily upon use of multi-beam echosounder (MBES) techniques to achieve IHO S-44 Order 1 standard (referred to henceforth as 'NEWSPEC'). The drivers behind this transition included: the MCA's objective to ensure that surveys are conducted as efficiently as possible taking advantage of new technology; the perceived benefits of a digital bathymetric dataset and ancillary data which can be made available for a number of other applications in addition to maintenance of navigational charts e.g. strategic environmental assessment.

During 2004 Gardline Hydro was awarded two '3rd Party' hydrographic survey contracts based on NEWSPEC, the first of which commenced in March 2004.

These contracts have presented a new set of challenges to the company, with the introduction of state of the art instrumentation, software, and the associated development of survey techniques to meet the specification whilst maintaining operational efficiency and quality control of data acquired.

This paper describes some of the technical issues encountered during the first survey season in 2004, and looks at developments for 2005.

Scope of Work

Four areas have been contracted by MCA to be fully surveyed during the period 2004-2005:

- Western Approaches to the English Channel (approximately 8,800 km²), 50% completed in 2004
- Eastern Approaches to Firth of Forth (2,300 km²), completed in 2004
- Cape Wrath to Solan Bank, and Solan Bank to Fairisle Channel (6,100 km²), scheduled 2005.

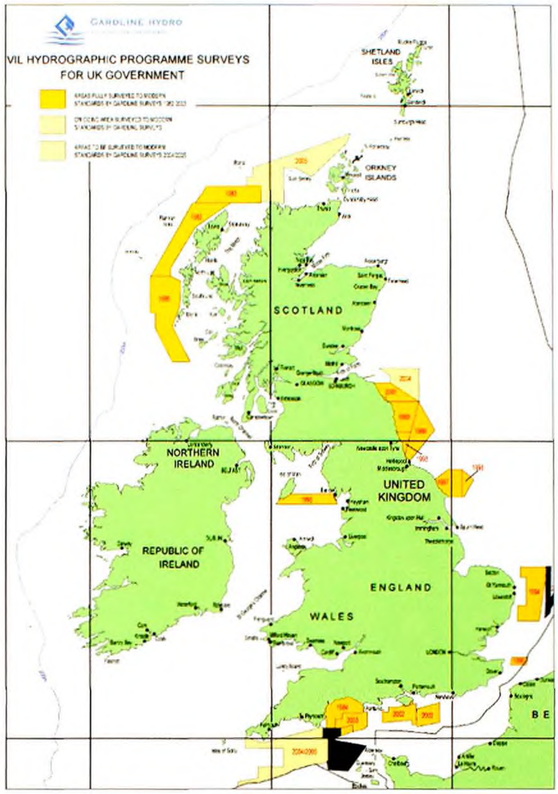

Figure 1: 2004-2005 survey areas (yellow).

These are the largest commercial nautical charting surveys performed using MBES technology in the UK to date, and the first to employ a new set of survey specifications jointly developed by MCA and UKHO to achieve IHO S-44 Order 1 standard.

Waterdepths within the areas to be surveyed range from drying heights to 205m West of Orkneys. The majority of depths are greater than 40m (Figure 1).

Assessment of Survey Specifications

NEWSPEC introduces a number of changes to the Hydrographic Instructions (HIs) on which CHP contracts were previously based and which referred to Hydrographic Quality Assurance Instructions for Admiralty Surveys (HQAI) - both documents issued by UKHO and which, up to 2003, specified use of SBES and sidescan sonar measurements to achieve the objectives.

NEWSPEC draws on the Land Information New Zealand (LINZ) 'HYSPEC' interpretation of IHO S-44 for assessing the quality of MBES data. A comparison of some key areas between currently used specifications is summarised in Table 1 below.

As can be seen, both NEWSPEC and NOAA either meet or exceed the S-44 standard, however more attention is devoted to specifying data density and object detection requirements, which reflects the need to regulate the use of modern multi-beam bathymetry and side-scan sonar systems.

It is worth noting that the version of NEWSPEC referred to herein may be varied in future to suit different areas and circumstances e.g. reducing the seabed sample spacing to suit varying ground conditions. However, the intention is that the standard will in any event not fall below S-44 Order 1.

A key feature of NEWSPEC is the ability for the survey contractor to determine the best method of achieving the specification, a less prescriptive approach which enabled Gardline to make best use of current technology to optimise survey efficiency.

Approach

Following a review of proven MBES systems available during the contract period, Gardline selected the Kongsberg Simrad EM1002 95kHz system to achieve both the bathymetric and object detection requirements. The key features of the EM1002 system were: its ability to achieve optimum swathe coverage in the anticipated range of water-depths; a suitably fast ping rate; and the ability to acquire data in 'equidistant beam spacing mode', whereby soundings are equally distributed across the specified swathe width, rather than concentrated in the centre of the swathe.

The principal benefits which emerge following transition from the traditional SBES and SSS based approach, to MBES based operations under NEWSPEC may be summarised as follows:

- No requirement to tow SSS => reduced risk of equipment loss, and increased survey speed (up to 10 kts achieved in 2004)
- Line spacing may be increased to achieve the sounding density => fewer lines required in deeper water
- No inter-lining required in depths shoaler than 40m
- Wreck investigations to determine least depth using MBES much quicker than SBES (reduced no. of lines)
- Much improved digital bathymetry dataset as final deliverable
- Reduced density of seabed samples

Item	IHO S-44 (Ed. 4)	NOAA (March 2003)	NEWSPEC
Vertical Accuracy	$[0.5^2 + (0.013 \times depth)^2]^{1/2}$	$[0.5^2 + (0.013 \times depth)^2]^{1/2}$	$[0.5^2 + (0.013 \times depth)^2]^{1/2}$
Horizontal Accuracy Of Soundings	5m+5% of depth	5m+5% of depth	<40m : 5m >40m : 5m + 5% of depth
Object Detection	<40m : $2m^3$ >40m : 10% depth	Sonar : $1m^3$ MBES : <40m : >2m x 2m x 1m >40m : horizontal 10% of depth, height 5% of depth	<40m : $2m^3$ >40m : 10% depth
Maximum line spacing	Greater of 3 x average depth or 25m	100% bathymetry coverage or variable set line spacing Max sonar range 100m	100% bathymetry coverage required
Cross-Lines	Not more than 15 times line spacing	Length>8% of total sounding lines	20 x main line spacing
Sounding density	Not specified	3.2 pings per 3m along track, or 10% of depth	<40m : 9 pings per $2m^3$ target >40m : 9 pings per target size 10% of depth*
Sonar survey	100% bottom search	Optional, 200% insonification where specified	Optional, 100% insonification
Sonar survey Speed	Not specified	3 Pings per target (ref. object detection)	5 Pings per target (ref. object detection)
Seabed sampling	Anchorage areas, spacing not specified	<1.2km interval in anchorage, elsewhere 2km interval	10km interval
Magnetometer	Not specified	Not specified	Yes
Wreck Investigation	Not compulsory - Sonar or physical examination	Not compulsory	<60m : SSS and MBES ** >60m : MBES

** assumes MBES used for object detection*
*** wire-sweeping may be required for significant wrecks <40m depth*

Table 1: Survey Specification Comparison – Order 1.

The disadvantages when compared with SBES and sonar based surveys include:

- increased capital expenditure and operating cost of the vessels
- reduced resolution of MBES derived sonar imagery for identification of contacts, especially in depths >40m

Figure 2: MV Ocean Seeker in Falmouth.

From a performance perspective, NEWSPEC has certainly achieved MCA's financial objective, i.e. a significant reduction in the cost of survey per km^2. Whilst it is difficult (and often dangerous) to generalise with so many variables to consider, in areas with typical depths greater than 60m we estimate reductions in the order of 25% have been achieved when compared with the traditional SBES and sidescan sonar approach. In shoaler depths the benefit would be expected to diminish or even reverse.

One interesting fact that has emerged from this year's survey concerns weather tolerance. Using the same vessels in both cases, in order to meet NEWSPEC we have found that MBES data in the event are equally prone to degradation due to the combined effects of sea noise and vessel motion when compared to SBES and towed sonar. We had expected MBES (hull mounted) to be a little more weather tolerant. Possible reasons for this are discussed further in the next section.

Survey Vessels

Two vessels were employed during the 2004 season: MV *Ocean Seeker* (Figure 2) and MV *Elinor TH*, both owned and operated by Gardline.

The priority for Gardline was providing a survey spread with maximum tolerance to severe weather, since the CHP 3rd Party contracts are priced on a turnkey basis inclusive of weather standby.

The length and stability of the vessel are critical factors in its ability to continue working in the typical sea states found in exposed locations such as the Western Approaches. *Ocean Seeker* benefits from a LOA of 83m and GRT of 1943T. However, *Elinor* at 54m LOA and GRT of 959T has also proved itself a surprisingly stable platform. In both cases the ballast condition has a marked effect on MBES performance.

Also of importance is the location and design of the MBES transducer which was required to be installed on both vessels. Two designs were adopted for the EM1002 transducer, both located approximately one third along the vessel from the bow. A hydrodynamic blister mount was used onboard *Ocean Seeker* (Figure 3); however, this proved to be susceptible to aeration along the transducer face in marginal sea states.

MV *Elinor* featured a modified design without the hydrodynamic housing, which, although simplified, suffered less from aeration (Figure 4). The limiting

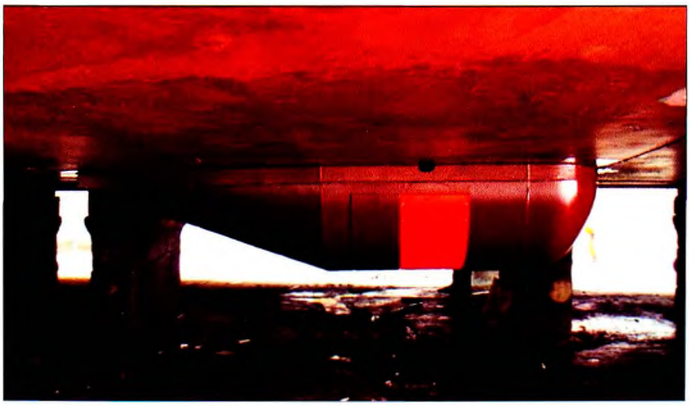

Figure 3: EM1002 transducer mount: Ocean Seeker.

Figure 4: EM1002 transducer mount: Elinor TH.

Figure 5: RV Triton (Picture courtesy of QinetiQ).

factor with this installation has proved to be the attitude sensor's ability to measure and remove vessel motion, a function of vessel size and transducer location rather than transducer design.

Kongsberg Simrad Seapath 200 attitude systems were employed to compensate for vessel motion, with dual MRUs located over the transducer and at the centre of gravity.

The 2005 survey season will see the introduction of Gardline's latest vessel acquisition, the RV *Triton* (Figure 5). At 90m LOA and 22.5m beam, the world's largest motor powered trimaran will provide an ideal platform for survey operations. Originally designed to assess the sea-keeping performance and structural design of the trimaran concept compared to a conventional monohull in rough sea states, the *Triton* will replace the MV *Elinor* performing hydrographic survey work for the CHP using an identical sensor suite.

Integrated Survey System

To meet the demands of the transition to MBES, an Integrated Survey System (ISS) was developed for the project, using a networked server cluster and Gardline's new generation *Voyager5* survey planning, acquisition and processing software.

With the large volumes of data to be gathered, a robust archiving system was required. The main components comprised of a dual-hosted RAID array and a high speed Ethernet network. The size of RAID array was chosen so that the entire season's data could be maintained 'online'. Back-up and data transfer operations were performed with large capacity Linear Tape Open (LTO) technology.

In addition to on-line navigation control, *Voyager5* streamlines the data organisation process and provides additional quality control functionality during survey line planning and data reduction stages.

Data Cleaning

Caris HIPS/SIPS Version 5.4 is currently the preferred data cleaning package for MBES data. A significant aid to processing and Quality Control was the introduction of the Base Surface in this version. This surface, by default, has a number of attributes of which the Shoal Depth is particularly useful for the identification of erroneous depths. Typically, 'fliers' appear as shoal soundings, rather than deep soundings, so this attribute reveals significantly more than the Mean Depth (Figure 6) or even the Standard Deviation.

Caris Notebook was used as the primary interpretation tool for the identification and tagging of seabed contacts. With this tool the backscatter and co-registered bathymetry may be viewed with the user able to scroll through the data to locate contacts. Additional information, such as the list of known wrecks, or magnetic deflection anomalies, may be imported and viewed in conjunction with the MBES data.

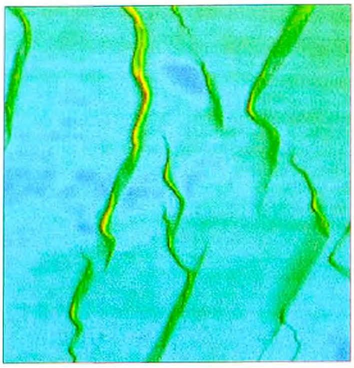

Figure 6: Base Surface Attributes (mean depth).

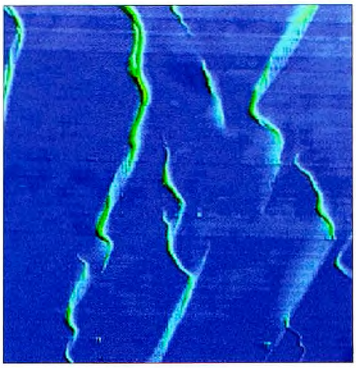

Figure 7: Base Surface Attributes (shoal depth).

The application allows the user to 'tag' contacts, determine the size and orientation, and generate 'snapshot' images of the targets. Information is collated in the (electronic) Contact Book.

Future Plans

CARIS HIPS/SIPS Version 6.0, incorporating CUBE, is to be released in the coming months and will be evaluated for introduction into the CHP data processing flow. This appraisal will be detailed, with the goal being to improve the acquisition to processing time ratio (presently 1:1), improve Quality Control procedures and eventually reduce the number of survey processors.

Tidal Issues - Experiences

Meeting the specified vertical accuracy for reduced soundings in NEWSPEC (see Table 1), posed a significant challenge to the project team, since this relies on provision of accurate tidal data across a large offshore work area.

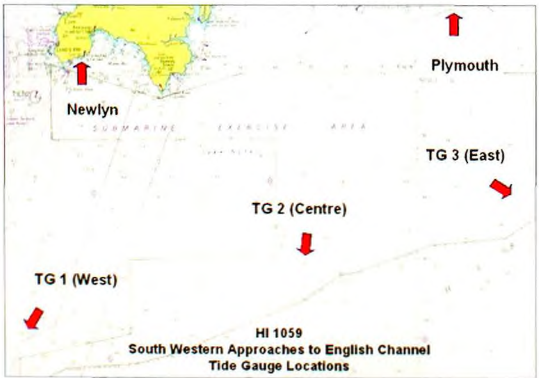

Figure 8: Tide-gauge locations.

In the UK, tidal observations are usually acquired from shore-based gauges which then require co-tidal correction to the work location – a co-tidal model is constructed based on a regular distribution of nodes throughout the survey area. In the past this has been achieved using BA chart 5058 as a data source. This comprises of co-range and co-tidal lines interpolated from archive tidal observations acquired around the UK – these are used to scale the tidal range and adjust for time-differences between shore-based gauge and the work site.

However, the vertical accuracy specification was rarely achieved during previous surveys due to the inherent errors in the co-tidal chart, estimated by UKHO as ±0.5m in range, and 30 minutes in phase; nevertheless, the results were accepted as the best that could practically be achieved using this method.

The following example describes the methodology used in the Western Approaches. In order to meet NEWSPEC requirements, the sounding error budget allowed for a maximum error of ±0.25m in tidal range and 15 minutes in phase (Table 2).

Gardline mobilised two onshore tide-gauges in Plymouth and Newlyn, each fitted with modem and GSM link. Seabed tide-gauges were deployed at strategic offshore locations in each survey area for a 30 day observation period, from which tidal constituents (and co-tidal factors) could be calculated using harmonic analysis. The results were used to

Gauge	Calculated from Gauge		Scaled off BA 5058	
	MHWI	MSR	MHWI	MSR
Newlyn Gauge	4.327	4.814	-	-
Plymouth Gauge	5.246	4.79	-	-
Tide Gauge 3 (East)	5.425	5.776	5.45	5.90
Tide Gauge 2 (Centre)	4.793	5.55	4.75	5.74

Table 2: Derived co-tidal values.

either validate the co-tidal model based on BA 5058, or adjust the co-tidal model if significant differences from 5058 were found which exceeded the sounding error budget.

In the event TG 1 was not recovered and was assumed to be trawled. Onshore gauges have also proved vulnerable to 3rd party interference, and the following system is being implemented for this year. Gardline's Oceanography department have developed a GSM dual tide-gauge system for use when real time tidal data are required. The system requires a 230v mains power supply, available in most ports and marinas, and a point of attachment: either a railing or the wall of building. In the event of a power failure within the port or marina the system will remain fully operational for up to 15 days on internal batteries.

The remote unit is interrogated and downloaded at regular intervals (e.g. daily, hourly, weekly etc) by in-house developed software. This software analyses the gauge status and tidal data, flagging any possible errors. The data from the gauge are converted to Gardline's standard file format prior to being e-mailed to the working vessel. Any data flags generated by the software are logged in the main body of the e-mail allowing any problems to be noticed and corrected quickly.

Should the primary gauge fail for any reason, the secondary gauge can be downloaded in the same way until an engineer is available to repair the system.

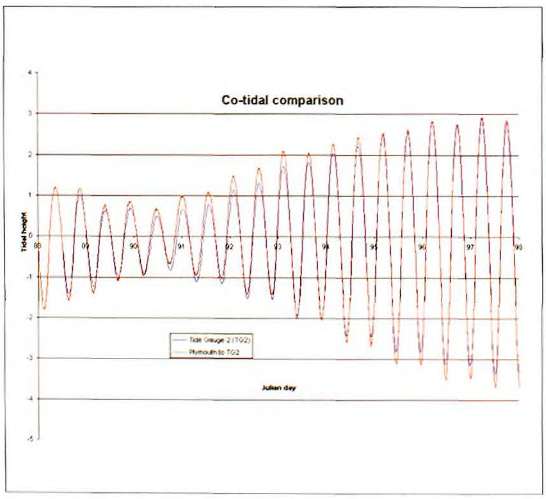

Figure 9: Comparison of tidal data at TG2.

In order to demonstrate that the sounding error budget was in fact met, a two stage approach was required.

Tidal data analysis

The values for mean high water interval (MHWI) and mean spring range (MSR) were extracted from the two onshore and two offshore tide-gauge datasets using the speed and amplitude of constituents S2, M2, M4 and M6. This is only possible where that dataset is sufficient to allow a reliable tidal analysis, preferably greater than 30 days. The values obtained can be seen in Table 2. This shows good agreement between BA 5058 and observed co-tidal values at the gauge locations.

The next step was to compare observed data from the offshore locations with observed data from the nearest onshore gauge corrected to the same location using BA 5058. Figure 9 shows observed data at TG2 (dark blue), observed data from Plymouth TG (red) transposed to the TG2 location using the co-tidal model generated from 5058. The results show good correlation with respect to time in both cases. Range errors vary between Neap and Spring periods, generally less than 0.2m and do not exceed 0.3m which is within the sounding error budget estimate.

Cross-Line Comparison

All bathymetry was reduced to Chart Datum using observed tides corrected to the survey location using BA 5058 derived co-tidal model. Cross-lines were acquired early into the project and processed as a separate dataset.

At regular intervals thereafter, main-line bathymetry data were compared to the cross-lines using a difference surface facility within Caris HIPS. Observed variances were typically better than ±0.3m, confirming the validity of the co-tidal model within the sounding error budget.

Tidal Issues – Future Developments

GPS heights

The recent introduction of high accuracy wide-area DGPS offers the possibility to employ GPS derived transducer 'height' to tidally correct soundings and/or reinforce the co-tidal model. This is an attractive alternative to installation and maintenance of

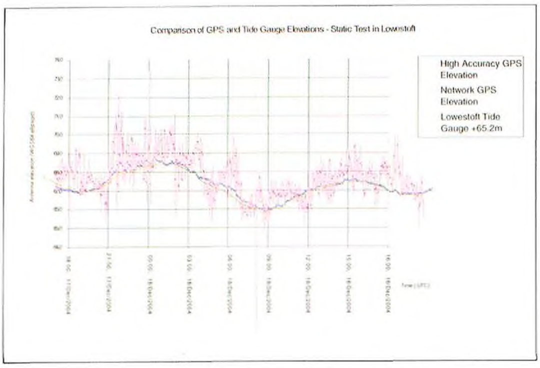

Figure 10: Static comparison of GPS and tide gauge elevations.

onshore and offshore tide-gauges. Gardline recently performed static and dynamic vessel trials of GPS heighting in the vicinity of Great Yarmouth and Lowestoft where permanent tide-gauges are located. Figure 10 shows a sample of the static trials with high accuracy raw GPS elevation (blue) being recorded concurrently with observed tides from the tide-gauge (green) and standard service DGPS elevation (magenta). For comparison purposes, to compare the curve fit, a nominal 'best fit' geoid/spheroid separation (geoid height) was used of +65.2m. Both the static and dynamic results show good correlation (<30cm) between high accuracy DGPS, RTK GPS heighting and tide-gauge data.

In addition to removing vessel motion and system noise, it is also necessary to relate GPS heights (WGS84) to the sounding datum (Chart Datum) which approximates Lowest Astronomical Tide. This can be achieved by application of the geoid/spheroid separation (geoid height), since the geoid approximates Mean Sea Level, the offset from which LAT can be calculated. However, this requires a geoid model of sufficient accuracy not to degrade the GPS derived tidal correction beyond the tidal component of the sounding error budget. At present such a marine geoid model does not exist in the UK; however, UKHO is understood to have launched an initiative which aims to model geoid height with respect to ETRS89 Datum within the UK Continental Shelf. It is hoped that elements of the 2004 and 2005 CHP survey datasets will contribute to this model. This initiative called **ICZMap** aims to improve the accuracy of BA 5058 using a combination of satellite altimetry and tidal models, the results of which are not expected until 2006.

During the interim GPS data may be helpful in validating/adjusting the co-tidal model generated from BA 5058, especially where source data are sparse. Superimposing GPS height data on top of coincident tidal data empirically applies the geoid height. If cross-line analysis indicates a tidal error, GPS height data can identify the nature of the error and potentially enable an adjustment to be performed.

MBES Issues – Data density

Assessing ping density from the MBES system against NEWSPEC is an important function, and more complex to achieve than anticipated, particularly in areas of variable terrain. An added complication involved intermittent ping loss from the EM1002, a technical problem which was solved only after several months' data had been acquired, and which required data gaps to be infilled. Two methods were employed in the event: Fixed bin density query (areas of similar water depth); Variable depth density analysis (areas of varying water depth).

Fixed Bin Density Query

In the first instance ping densities were assessed using binned grid queries within Caris HIPS, the results of which were displayed within the Caris project and output to hard copy to aid 'infill' planning.

For a given depth area (the survey areas were selected for similar depth) a bin size was defined. Bin sizes were based on NEWSPEC requirements (see Table 1). The resultant binned surface had a number of associated statistics such as density (number of depths per cell), mean depth and standard deviation. Density was selected as the pri-

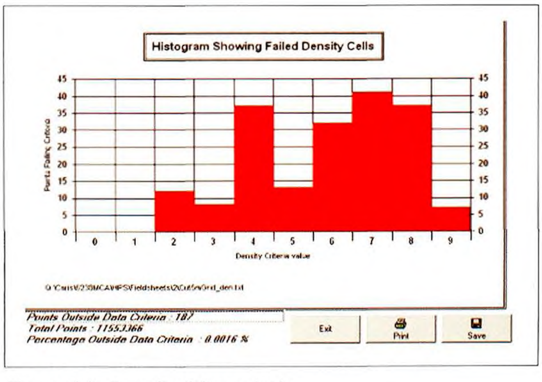

Figure 11: Density QC analysis.

mary cell value. A query was then defined such that a colour was assigned to any cells that failed to meet the specification (9 depths per cell). The result of the query could then be presented as a layer within Caris.

After further data acquisition it became obvious that this methodology would not be appropriate in areas where the water depth changed significantly within an area. A different method was therefore needed to complement the above.

Variable Depth Density Analysis

The problem of deriving useful density figures over variable water depths has been addressed by developing a specific MBES QC module within *Voyager5*. The application uses information from the Caris HIPS project to derive density figures proportional to the water depth. Once this figure has been calculated it is compared with the specification, and a list of density failures is compiled containing position and attribute.

The program also analyses the surface for gaps in the data, where a gap is recorded as a non-existent cell, as opposed to a cell with zero depths. This distinction is actually quite useful in identifying those outages which are due to ping-loss rather than reduced coverage.

The file of rejected cells may be loaded into the *Voyager5* ISS to assist in infill planning, and a QC report is produced as illustrated below (Figure 11). In this example, 187 cells failed from a total of 11.5million (0.0016%).

MBES Issues – Object Detection

To illustrate the effectiveness of the EM1002 object detection capability, MV *Elinor* was diverted from task in July 2004 to conduct a debris search on behalf of MoD (S&MO) following a Tornado ditch in the North Sea. Little remained of the aircraft fuselage; however, scattered debris of less than 1 metre dimensions (as verified by ROV) were detected on the EM1002 in general water depths of 70m.

The following (Figures 12, 13 and 14) illustrates how the ability to manipulate the imagery within Caris can help in the differentiation of natural and unnatural topography.

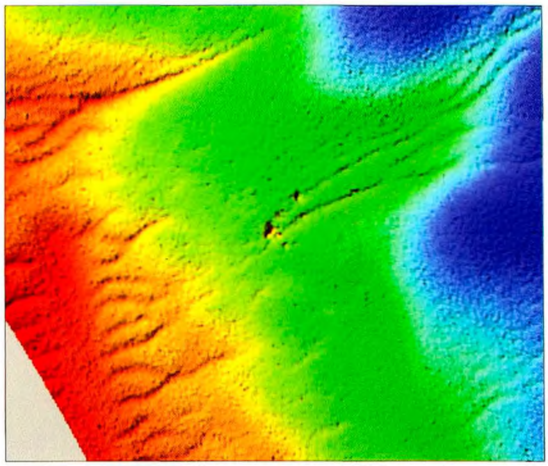

Figure 12: Colour-coded, shaded relief – debris in centre of page.

Figure 13: Greyscale shaded relief illuminated to minimise natural features.

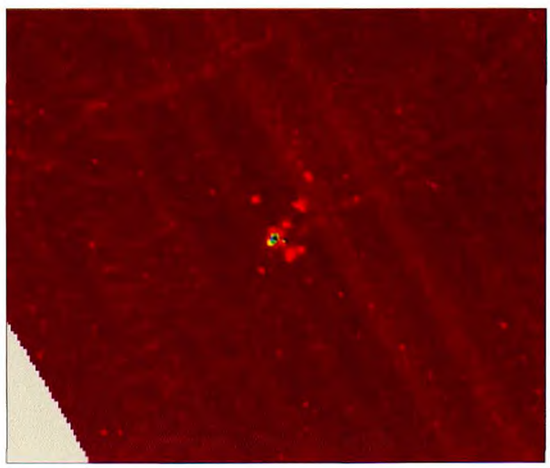

Figure 14: Colour-coded standard deviation.

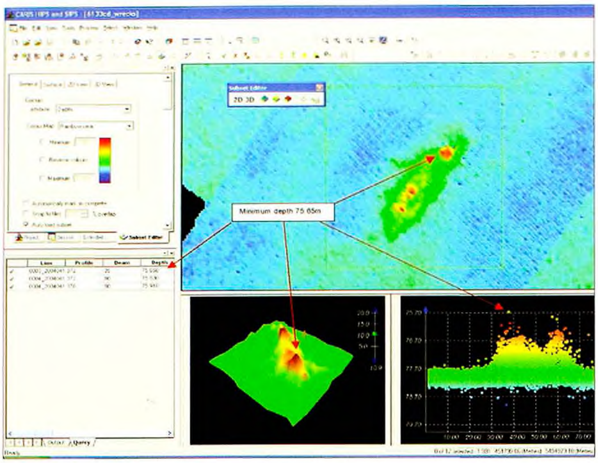

Figure 15: MBES data of wreck viewed in Caris - minimum depth 75.65m.

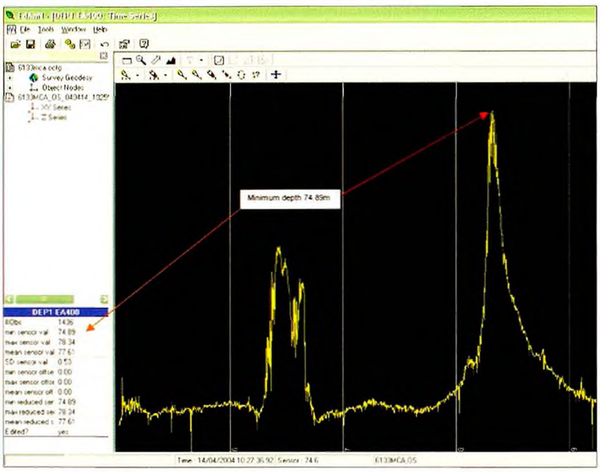

Figure 16: SBES data of same wreck viewed in Voyager5 – minimum depth 74.89m.

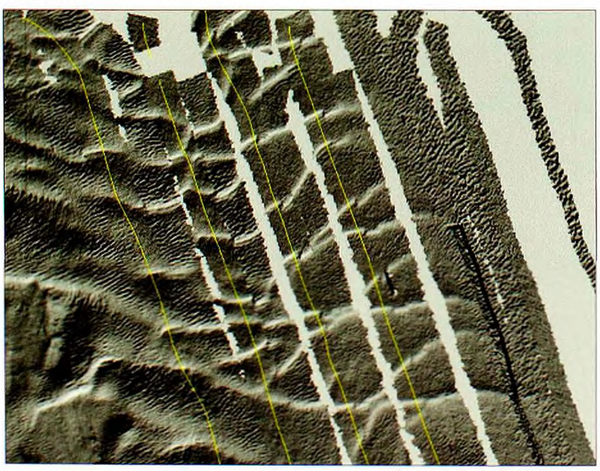

Figure 17: Mobile seabed area – MBES comparison.

The first image provides information on the natural seabed, but the latter two are more useful for identifying the debris.

MBES Issues – SBES Comparison

Comparison of SBES and MBES nadir profile shows that additional features are occasionally detected by SBES, albeit only vertically beneath the vessel, and usually over irregular features such as wrecks (Figures 15 and 16). However, these discrepancies are not considered to degrade the data below the sounding error budget.

Possible reasons for this lack of correlation are:

- Slower ping rate on MBES
- Larger footprint on SBES, footprint on MBES more finite, could miss very fine point objects
- MBES only detecting 'hard' return, SBES shoal depth could be fishing nets.

For wreck investigations, comparisons of SBES + wire sweep vs MBES carried out in 2002 (MCA sponsored 'Project 500') indicated that using an EM3000 MBES was more effective at detecting the least depth than SBES. In depths <40m, however, wiresweep is still required by NEWSPEC to resolve any ambiguity in the least depth derived by MBES.

MBES Issues – Mobile seabed

Mobile seabeds, such as sandwave fields, can on occasion lead to significant errors manifesting between coincident surveys over the same seabed acquired on different dates. It is not unusual to find movement approaching 1 metre per day in extreme cases. Figure 17 shows an area of mobile seabed off Great Yarmouth, acquired by the Royal Navy from MV *Confidante* using Gardline's EM3000D MBES during May 2004 (data courtesy MoD DIJE).

It can be seen that there is a marked discontinuity between lines acquired on one day (highlighted with yellow trackline), and those adjacent lines acquired several days later.

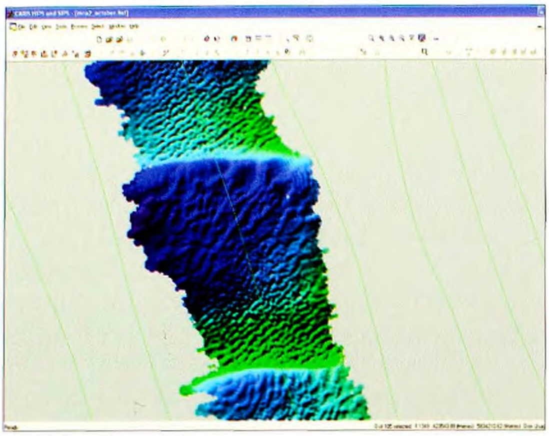

Figure 18: Mobile seabed illustrating megaripples.

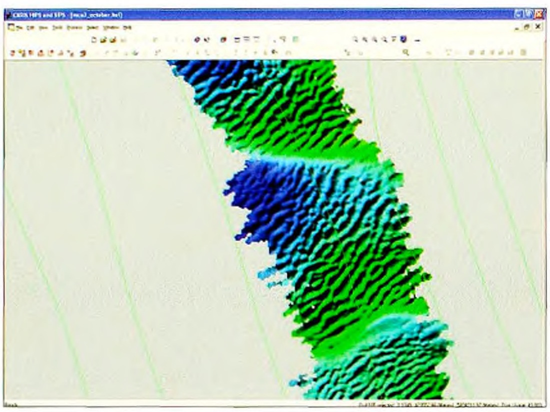

Figure 19: Same seabed one week later.

This problem can only be resolved by accepting that surveys in these areas are only valid at the time of acquisition, and by ensuring that adjacent lines are surveyed sequentially where possible to minimise the effect of short term lateral seabed movements.

Also of interest in this image is the fact that there appears to be less detail shown in the 'yellow' lines. The reason for this was investigated as it was initially thought that there was a problem with one set of data. However, it appears that not only are the sandwaves migrating, but the character of the associated megaripples is also changing (Figures 18 and 19).

Conclusions

- MCA and UKHO have successfully enabled MBES technology to be used in the Civil Hydrography Programme using an innovative specification which meets the IHO S-44 standard yet enables significant cost reductions to be achieved.

- It has been necessary to both invest in new technology and develop new working methods to meet the required standard.

- Key areas are targeted for further development in 2005 to further improve productivity and accuracy of data acquired.

References

[1] Technical specifications vn 1.3 dated April 2004 (MCA/UKHO)

[2] NOS Hydrographic Surveys Specifications and Deliverables dated March 2003(NOAA)

[3] HYSPEC vn 3 (LINZ)

[4] Seamless Data and Vertical Datums (Ruth Adams, UKHO (Hydrographic Journal No. 113)

Acknowledgements

1. MCA, UKHO and MoD (DIJE and S&MO) for permission to release material.

2. Colleagues at Gardline Geosurvey Ltd and Gardline Environmental Ltd for valuable input.

3. Kongsberg Simrad.

4. Caris bv.

5. C&C Technology.

Authors' Note

Conclusions drawn within this paper are the author's and do not seek to represent the views of Gardline, MCA, UKHO or the system manufacturer's.

Biography of the Authors

Cliff Whatrup is employed by Gardline Geosurvey as marketing manager for its Hydro Division based

in Great Yarmouth, UK, which focuses on hydrographic survey and other seabed mapping activities. After graduating from Newcastle University as a surveyor in 1984, Cliff joined Gardline as a hydrographer and after an eight year period as a field surveyor and party chief, transferred to project management duties in 1992, gaining a Diploma in Management Studies in 1995. Cliff was appointed marketing manager of the Hydro Division in 2003 following restructuring of the company. He has been involved in management of ten successive Civil Hydrography Programme contracts.

David Mann holds an MSc. Engineering Surveying and a BA(Hons.) Geography. He has been employed by Gardline Surveys since 1980. He has broad experience as a surveyor and survey programmer. In 2001 he was appointed head of the Survey Support Department and is responsible for providing software support and multibeam expertise to support Gardline operations.

Brian Davidson graduated with a degree in Hydrographic Surveying from Plymouth University in 1991. He started as a surveyor and data processor before eventually progressing to the role of party chief on projects varying from simple single beam inshore surveys to multi-vessel construction support. He has worked for several large survey companies in offshore and onshore roles, before joining Gardline Geosurvey Ltd (Hydro Division) in 2004 and is currently project manager for their Civil Hydrography Programme contract with the Maritime and Coastguard Agency.

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