Article

THE NEW IHO S-102 STANDARD CHARTING A NEW FRONTIER FOR BATHYMETRY

By Ed Kuwalek **(IIC Technologies)**, Louis Maltais **(Canadian Hydrographic Service)*** & Marc Journault **(CHS)***

Soundings and contours are the only official way data producers can push bathymetric information to the wide hydrographic community. The introduction of the S-102 standard for bathymetry will enable many possibilities within the community of bathymetry users. Liaising with the International Hydrographic Organization's (IHO) Transfer Standard Maintenance and Application Development (TSMAD) Working Group, the Canadian Hydrographic Service (CHS) and the US Naval Oceanographic Office (NAVO) has led the development and practical testing of this revolutionary standard, officially called the Bathymetric Surface Product Specification S-102. In partnership with IIC Technologies, GeoNet Technologies, and CARIS, CHS created one of the first prototypes of S-102 datasets, using the CARIS Bathy DataBASE software suite. A portfolio of 86 high definition bathymetric charts was subsequently produced within a few weeks, successfully validating a specification that will potentially change the manipulation of bathymetric data we've known for years.

Les sondes et les isobathes constituent la seule manière officielle qu'ont les producteurs de données pour diffuser les informations bathymétriques à l'ensemble de la communauté hydrographique. L'introduction de la norme S-102 pour la bathymétrie offrira de nombreuses possibilités à la communauté des utilisateurs bathymétriques. Les liaisons avec le groupe de travail de l'Organisation hydrographique internationale (OHI) sur la maintenance et le développement d'applications de la norme de transfert (TSMAD), avec le Service hydrographique canadien (SHC) et avec le Service océanographique naval des USA ont conduit au développement et à la mise à l'essai de cette norme révolutionnaire, officiellement appelée Spécification de produit pour la bathymétrie surfacique, S-102. En partenariat avec IIC Technologies, GeoNet Technologies et CARIS, le SHC a créé l'un des premiers prototypes des ensembles de données de la S-102, à l'aide du logiciel Bathy DataBASE de CARIS. Un portefeuille contenant 86 cartes bathymétriques en haute définition a ensuite été produit dans les semaines qui ont suivi, validant avec succès une spécification qui modifiera potentiellement la manipulation des données bathymétriques connues depuis des années.

Los sondeos y las curvas de nivel son las únicas fuentes productoras de datos de forma oficial que pueden hacer llegar la información batimétrica a la vasta comunidad hidrográfica. La introducción de la Norma S-102 para batimetría permitirá varias posibilidades en el seno de la comunidad de los usuarios de batimetría. La coordinación con el Grupo de Trabajo de la Organización Hidrográfica Internacional (OHI) sobre el Mantenimiento de la Norma de Transferencia y el Desarrollo de Aplicaciones (TSMAD), con el Servicio Hidrográfico Canadiense (SHC) y con el Servicio Oceanográfico de la Marina de EE.UU. (NAVO) ha guiado el desarrollo y las pruebas prácticas de esta norma revolucionaria, oficialmente denominada Especificación de Producto para la Batimetría de Superficie S-102. En asociación con IIC Technologies, GeoNet Technologies y con CARIS, el SHC creó uno de los primeros prototipos de las colecciones de datos de la S-102, utilizando la serie de programas informáticos "Bathy DataBASE" de CARIS. Un catálogo de 86 cartas batimétricas de alta definición fue producido posteriormente en pocas semanas, validando con éxito una especificación que cambiará potencialmente la manipulación de los datos batimétricos que hemos conocido durante años.

High Definition Grid Bathymetry (HDGB)

In shallow water, ship navigation and manoeuvring demands cautious decisions made with the best information available. In these circumstances, the most recent details of the seafloor are usually considered essential. A three dimensional "picture" of the bottom would provide this capability; this representation is referred to as High Definition Gridded Bathymetry (HDGB).

The grid bathymetry can be described as a Navigation Surface (Smith 2003) or a Digital Terrain Model (DTM) of the seafloor in the form of regular rectangular meshes. By its nature, the resolution or the density of bathymetric data collected usually varies according to the depth range and it would be contentious to assign a quantitative value to the term "high definition" for bathymetry. The context of HDGB used in this article is simply defined as a much higher resolution than what is available on the navigation charts. For the source bathymetry of a multibeam system, the resolution can be similar to the insonified footprint. For digitized legacy data, the resolution could be equivalent to field sheet density.

The existing tools used to process and manage bathymetric data can generate and combine grid datasets for chart compilation and contour generation. A bathymetric gridded dataset can also be a product by itself, created for different usages such as hydrodynamic modelling, spatial data analysis with GIS, coastal management with land DTM, or marine navigation.

To develop a HDGB product for navigation, CHS adopted a collaborative approach where navigators and software manufacturers were informed of the intentions and consulted for specifications of a future product. For the consultation, prototype datasets were produced and made available in a simple format for experimentation and trials. The work of the IHO TSMAD WG on the new Geospatial Standard for Hydrographic Data (S-100) (IHO 2010) was promising and CHS decided to use it. S‑100 is a framework standard for the registration, maintenance and capture of hydrographic geospatial data and product specifications. It is a flexible standard, based on the international ISO 19000 series of geographic standards. CHS and NAVO worked together to draft and propose a product specification for grid bathymetry based on previous work done by the Open Navigation Surface group. The standard is named the Bathymetric Surface Product Specification and identified as S-102.

At the 3rd IHO Hydrographic Services and Standards Committee (HSSC) meeting in November 2011, the TSMAD WG invited the HSSC to approve the final draft of S-102 and instruct the IHB to submit it to IHO Member States for their endorsement. Subsequently, the IHO Circular Letter 10/2012, requested the Member States to review and consider the draft edition of S-102 which is available IHO website (www.iho.int). In April 2012, the S-102 product specification was adopted.

To partition HDGB coverage, allow unambiguous dataset exchange and to facilitate the updates, CHS intends to implement a systematic tiling scheme with three levels of resolution. Each tile is comprised of 1000 by 1000 grid cells. The level 1 (harbour) is 0.02º x 0.02º, level 2 (coastal) is 0.1º x 0.1º, and level 3 (overview) is 1º x 1º. For the low and mid latitudes, the orientation of the tiles fit the meridians and parallels with an origin based on a round number in latitude and longitude. Figure 1 shows an example of the tiling scheme.

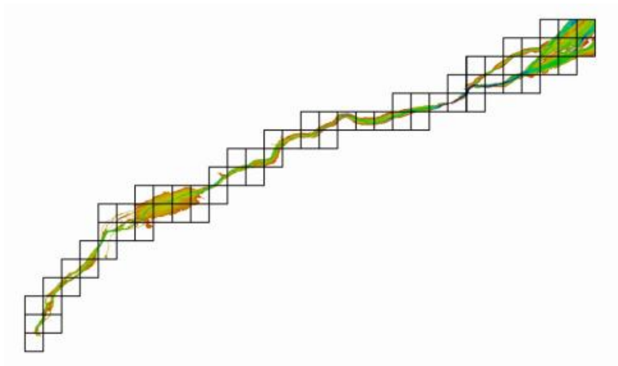

Figure 1: Example of a level 2 (coastal) tiling scheme for the St. Lawrence River

Production of datasets for trials

In January 2011, CHS contracted IIC Technologies and GeoNet Technologies to produce a portfolio of 86 HDGB datasets based on the draft version of the IHO S-102 product specification. Developing a uniform, high definition bathymetric surface for the St. Lawrence River between the ports of Quebec and Montreal was the key goal for the project. As this was the first attempt to produce a large number of datasets based on this new product specification, the project provided an ideal opportunity to validate the feasibility of S-102 production in practice.

The main requirements for the portfolio included creating seamless data coverage with a final surface grid resolution of 0.0001º (approximately 8 metres) divided into 0.1º x 0.1º tiled datasets. The final bathymetric surface needed to be created by integrating a variety of source datasets available for the area. These ranged from sparse sounding sets to much higher resolution grid data for channels. ENC-derived high-water lines were included along with the corresponding drying spot values. The intention behind using all available source data was to integrate all information in a complete dataset, capable of significantly enhancing the information already available on the ENC cells. The project required the deliverables to be provided in multiple formats including CARIS Spatial Archive (CSAR), Bathymetric Attributed Grid (BAG) and 32-bit GeoTiff files to cater to a variety of potential end users.

The production processes consisted of four main stages:

i. source data assessment and preparation,
ii. point data processing,
iii. surface data integration and conflict resolution, and
iv. final product surface extraction and export.

For the first stage, all source data was assessed and prepared for production. CARIS S-57 Composer and BASE Editor were used to create all auxiliary components, such as the tiling scheme, coverage, and breakline vector layers. The same tools were also used to cut all data sources into individual data tiles to facilitate their efficient processing.

During stage two, the XYZ point data was loaded into BASE Editor and used to build a TIN model. This model was enhanced by the addition of the high-water-based breakline vector layer. Subsequently, a high resolution bathymetric surface was interpolated from the TIN models for each dataset.

All project goals were successfully achieved and the required portfolio of 86 HDGB datasets was efficiently produced, confirming the feasibility of HDGB data production using the currently available CARIS production tools.

Generation of S-102 Bathymetry Grids

As described above, the interpolated grids from the point data are combined with the high definition grids from the ship channel to produce the final grids for each cell, in the CSAR format, which are then exported to the desired carrier format of the grid. The draft S-102 standard follows the principle of separating the "carrier" from the "content" which means that the encoding of the grids will be flexible. Following that principle, the CARIS software tools provide choices for export formats. At the time of this S-102 prototype work, the choices were:

Figure 2: *S-102 Production Process – Stages (i) to (iv)*

In stage three, the additional high definition surface data available for channels was merged with the product surface data created in stage two. This was achieved by using rule-based conflict resolution tool available in BASE Editor.

For the final stage, the coverage polygon was used to extract the final product surface, effectively facilitating a complete river bank to river bank data coverage. CARIS BASE Editor was used to export CSAR and BAG deliverables and CARIS Easy View was used to export 32-bit GeoTiff rasters. Figure 2 illustrates the key stages of the data production process used during the project.

- 32bit Floating Point GeoTIFF format. This option for a carrier format is available from the GDAL open source library (www.gdal.org). The 32bit floating point option is used so that the depth values can be encoded without loss of precision.
- BAG format. At the time, the CARIS Bathy DataBASE (BDB) v3.1 was supporting BAG v1.3. The support for BAG format is possible through the API provided by the Open Navigation Surface Working Group (www.opennavsurf.org) of which CARIS is a participant. Since then, BDB has been updated to support BAG v1.4. CARIS is currently working with the ONSWG on BAG v1.5, which will be supported when finalized and released.

Metadata

Adjusting this production line to match the coming S-102 standard is going to require the creation of metadata that is compliant with the S-102 profile. The details of the S-102 metadata profile are still being developed but many aspects of the content are already known. Fortunately, this area has received significant attention over the past two years at CARIS with the creation of the metadata profile for the CSAR format that is compliant with the ISO 19115 / 19115-2 standards and using XML encoding from ISO 19139. Drafts of the S-102 standard indicate that its metadata profile will share many of the same elements that are already being populated in exported CSAR metadata XML files.

The draft of the S-102 metadata profile indicate that most of the core metadata elements in the profile, each of which will be identified as mandatory, conditional or optional, will be selected from these ISO 19115 metadata packages.

Evolution of CARIS BDB and S-102 Software Tools

Bathymetry management has improved lately. New tools will enable the use of scripts to automate some functions. S-102 when pushed to the maximum could be the source bathymetry layer that the hydrographer uses for chart compilation. Once new source data is validated and incorporated in the database, users will be able to automatically generate S-102 datasets. Having the S-102 dataset updated continuously opens new possibilities. Instead of manually combining different bathymetry sources, choosing resolution and defining other parameters, the S-102 dataset could be used to compile chart products, post on the web, and do considerably more than is possible now. With predefined grid resolution and extents, these new functions will be able to automatically update the S-102 datasets. This is a key element, especially for achieving a fast turnaround time from survey to bridge. The only manual intervention is to assess if the new information is valid. Once that is done, one can launch the scripts and moments later you are in a position where the S-102 dataset are fully updated and ready to be used in many ways.

S-102 Gridded Bathymetry on the Web

The CARIS web mapping solution, Spatial Fusion Enterprise (SFE), supports the discovery and dissemination of high definition bathymetry through the Internet using Open Geospatial Consortium (OGC) (www.opengeospatial.org) standard formats. S-102 bathymetric datasets residing in the CARIS BDB database as CSAR grids are requested by SFE through a specialized bathymetry web service. The CSAR format was designed with the optimization required for web distribution of this type of data in mind. OGC requests are made from any OGC-capable client. The SFE Server handles the OGC request and returns the relevant information residing in the bathymetry database. SFE currently supports the OGC Web Map Service (WMS), Web Map Tile Service (WMTS) or Web Coverage Service (WCS) for bathymetry data: it is the WCS that provides download capabilities for the grids including options for the format to be received from the download. Efficient browsing and simple query capabilities are increasingly being provided through the use of WMTS which is a variant on the traditional WMS protocol which chunks data into image tiles. These tiles are cached on initial draw so that the next time an image request is made, the tile is drawn from cache rather than going back to the database – a much faster method to display the results.

Use of S-102 for navigation

With S-102 it will be easy for hydrographers to quickly provide navigators with HDGB data sets to enrich and update the information of their ENC's. Partitioned into standardised geographic cells, the provision of updates also becomes easier: an entire new cell with the new bathymetry can be supplied which supersedes the previous tile.

One possible way to implement HDGB for navigation use is to add the S-102 data in the background, overlapping the S-101 data but without the display of S-101 soundings, depth areas and contours. Figure 3 shows such usage.

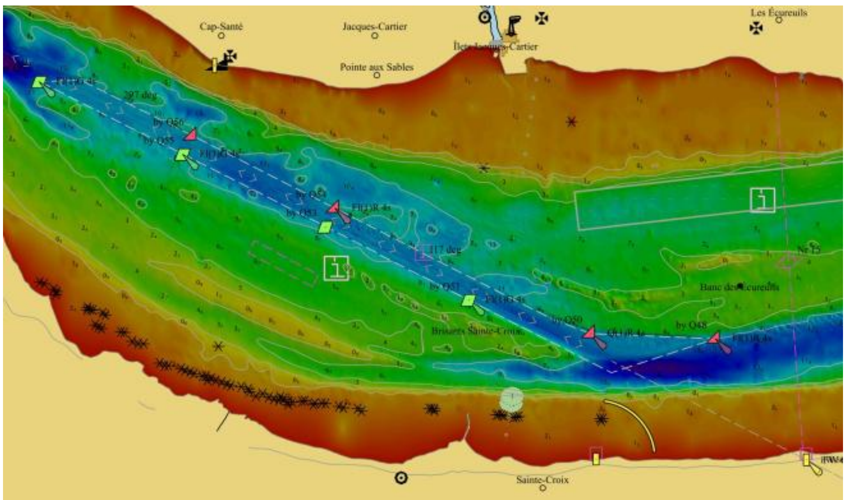

Figure 3: *Filtered ENC and S-102 in background.*

However, electronic chart systems can do more than just display the data. The HDGB can be used to:

- generate safety contour on the fly;
- compute the available water column by the addition of water level (tidal data) on top of the bathymetry; and calculate a dynamic under keel clearance, etc.

The exploitation of HDGB in an innovative way is left to the users and the software industry. CHS and its partners wish to involve them at an early stage of design to consider feedback from the user communities.

Getting ECS and ECDIS manufacturers on board

The upstream work is done. The method to generate S-102 data efficiently is known and at a speed that is impossible to achieve using traditional methods. S-102 will be the fastest way to provide new bathymetric information to the mariner - not just the notices to shipping, but the complete survey coverage that was done by the survey vessel. Before S-102 adoption by the IHO, manufacturers were shy to jump into development. The product specification has been adopted recently and it is time for the manufacturers to get on-board with S-102. Many of the functions that hydrographers use in their professional acquisition survey software will end up in ECS and ECDIS. Displaying grids and applying water levels in real-time are critical functions that have been used in survey software for years and should now be available with the software used by mariners. Navigation is so tight these days with ever increasing vessel size that mariners need those functions to make well informed navigation decisions.

Ship bridge simulators

When the prototype dataset was ready, data was offered to a navigation simulator center. No clear direction was given on how to use the data. As a first step, the simulation center decided to replace the bathymetry model of the simulator with the S-102 dataset. The previous model was based on traditional contours so they realized that using S-102 would be beneficial to their simulator, improving the quality of the overall simulation. Simulation centers are the ideal way to test how S-102 can be integrated on the ship's bridge. ECS and ECDIS manufacturers could propose displays and functions that would be tested in these simulation centers to evaluate how this information could be portrayed to improve safety of navigation. Simulator work is a new tool available to speed up development on the manufacturer side.

Conclusion

The IHO S-100 framework standard represents a step foreword for electronic navigation products and services. This flexible standard is a building block to rethink the way hydrographic offices (HO) can deliver their official data and services. This ongoing S-102 experiment clearly shows how modern tools and standards enable quick delivery of rich bathymetric information. Work on the manufacturer side needs to start and some early discussions are progressing.

When mariners start working with S-102, they will experience a level of detail for bathymetry never seen before. We need to work with that community of users because they have a need for better information and will put pressure on manufacturers for development. Using the latest technologies available from CARIS (BDB and SFE) we will work at implementing the efficient updating and distribution of S-102. Easy access and updating is critical if we want users to work with the latest and best available information.

Biography of the Authors

Louis Maltais has been for the Canadian Hydrographic Service (CHS) for 13 years. He is involved in numerous R&D projects, implementing solutions to improve productivity, efficiencies and better meet the clients' needs. *Louis.Maltais@dfo-mpo.gc.ca*

Marc Journault has been for the Canadian Hydrographic Service for 28 years. He is manager of the Quebec region's Marine Geomatics Division, responsible for technological support and development in the fields of hydrographic surveys, nautical publications and marine services. *Marc.Journault@dfo-mpo.gc.ca*

Ed Kuwalek is the Director of R&D at IIC Technologies in North Vancouver, Canada. Mr. Kuwalek has 18 years of experience in the field of nautical charting, electronic-chart production systems, and spatial data conversions. He has been involved in the technical leadership of many industry-leading projects and is an active participant in the IHO Transfer Standard Maintenance and Application Development (TSMAD) Working Group. *edward.kuwalek@iictechnologies.com*

References

CARIS, www.caris.com
Geospatial Data Abstraction Library (GDAL), www.gdal.org
1. IHO (2010). Universal Hydrographic Data Model S-100, www.iho.int
2. Smith, SM (2003) The Navigation Surface: A Multipurpose Bathymetric Database, Master Thesis, Center for Coastal and Ocean Mapping & Joint Hydrographic Center, University of New Hampshire.
Open Geospatial Consortium (OGC), www.opengeospatial.org

Page intentionally left blank