

New Tool for Maintenance and Management of Ports and Harbours Bathymetry

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Abstract

Marine software packages have traditionally focused on processing and cleaning bathymetric data, chart production, and the use of these charts in navigation systems. However, the effective management of a waterway does not stop there. In addition to displaying bathymetry, buoys, and other chart features, a waterway management system must account for items such as shoal detection, planning, dredging operations, monitoring, and business documents such as channel usage reports. The managers and operators of these waterways are continually tasked with combining this information in order to make sound decisions on the operations within the waterway. To address these needs, a new application has been developed that allows the user to integrate all of this information into one system providing a centralized tool for the effective management of ports and waterway bathymetry.

Introduction

There is increasing demand for space in ports and waterways for use by recreational users, tourism and commercial shipping. Although traffic density is on the rise, the international trend in commercial shipping is towards fewer vessels yet larger "megaships". Since 1970, the carrying capacity of container ships has grown from 1,100 to over 8,500 Twenty-foot Equivalent Units (TEU) resulting in an increased vessel length from 660 to over 1200 feet and an increased vessel draft from 30 to 46 feet. This continued growth in vessel size is not in response to increased vessel traffic -and thus maximization of port capacity- but improved economics achieved by larger vessels (Mills, 1999). Consequently the draft's of these megaships are approaching the maximum depth of many ports. Hence the accuracy of the port's bathymetry is vital for safe navigation. Furthermore, recent studies in Delaware River and Bay System, in Portland, Oregon, and in Tampa, Florida, USA showed an increase in revenues from \$36,000 to \$288,000 for each additional foot of draft for large container ships (NOAA, 1999). Such economic incentives warrant accurate and up-to-date information about water levels and obstruction maintenance to ensure that deeper draft megaships may operate safely and be efficient in delivering their cargo to ports.

To accurately know the spatial dimensions of a port or waterway, hydrographic surveys must be conducted. Until now, the marine software industry has provided port authorities -and the hydrographic community in general- with software packages for the acquisition and post-processing of bathymetry data. In turn, cleaned bathymetry is used in dredging packages as well as the production of Electronic Navigational Charts (ENCs). ENCs are used in Electronic Charting System and Electronic Charting and Display Information System (ECDIS) to aid in determining the vessels under keel clearance. Several producers of multibeam transducers claim to attain accuracy's of approximately 1% of the vertical depth, hence in many ports this is in the order of inches which is critical information for megaships with deep drafts. Furthermore, the advent of multibeam technology has catapulted bathymetric datasets into magnitudes of gigabytes of data. Engineers have found these large datasets difficult to manage and visualize efficiently so they may ensure the most up-to-date information is provided to their users, the captains of commercial vessels. Perhaps an even larger challenge for port managers is the integration of such bathymetry datasets with all other pertinent information for the day-to-day port operations to make safe decisions under given time constraints of the shipping industry.

To address these issues in visualization and management of bathymetry for port and harbour maintenance, CARIS, a Canada-based software development company and market leader in Marine Information Systems has developed CARIS BEAMS (Bathymetric Engineering and Management System). CARIS BEAMS is designed to be an efficient tool for engineers who work on the daily operations of maintaining bathymetry and dredging, as well as managers who wish to efficiently overview the 'big picture' of the port's daily operations within a centralized system that can link to all pre-existing database information concerning the port. BEAMS displays a customized visual representation of a port's bathymetry based on a bathymetric model of processed high-density multibeam and/or processed singlebeam data. BEAMS can also incorporate such data as sidescan sonar, navigational aids, structures and obstructions, notice to mariners, and channel usage reports. Other functions in BEAMS includes a dredging utility for volume calculations and surface comparisons, a

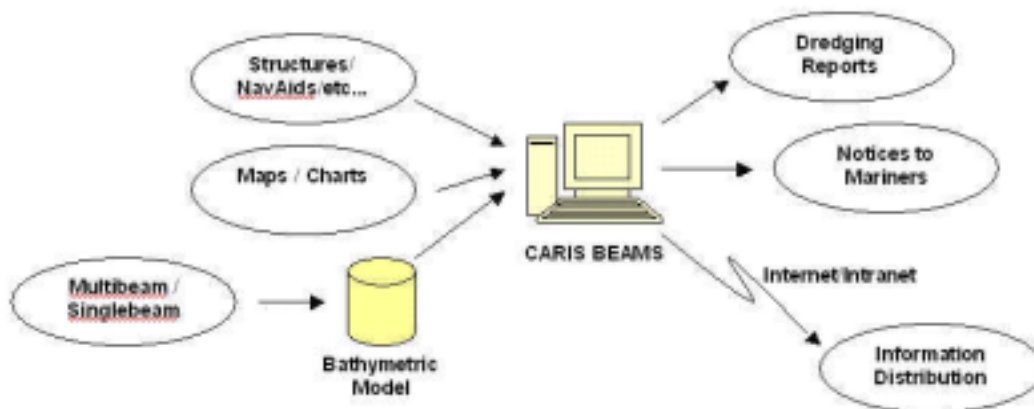


Figure 1. CARIS BEAMS Workflow.

utility for contour generation for shoal detection and several others for editing, printing, plotting and a mark-up layer for planning maintenance. In addition, CARIS BEAMS can display multiple vector and raster charts formats for base mapping and can link to any existing port documents and databases via an ODBC connection.

Evolution of BEAMS

CARIS BEAMS has evolved from many years of experience working with port and waterway authorities worldwide. A large contributor to the product is the Waterways Development Group of the Canadian Coast Guard. In particular the Laurentian Office who is responsible for safety and navigation of St. Lawrence River which is 2,300 miles long. This large artery is used by container ships to deliver cargo to Eastern and Central Canada and United States. The Canadian Coast Guards has an intimate working knowledge of marine shipping industry and their needs in ports, harbours and waterways management. They have agreed to take an active role in the design, testing and implementation of CARIS BEAMS.

Centralized Bathymetry Access

CARIS BEAMS allows for heterogeneous sounding data to be centralized. The centralized location at which the bathymetry is stored is called the repository, which allows for a seamless transition between soundings whose origin may be from different post-processed proprietary formats. The repository is a bathymetric model that can be visualized and analysed for waterway management and maintenance operations. The repository contains the most up-to-date representation of the seafloor and is accessible via an internal network or Internet. The repository allows users to distinguish between different bathymetric layers (eg. different surveys) as well as storing statistical and user defined attributes.

The hierarchical design of BEAMS has been engineered so that levels of information may be assigned and defined by the user. Over time the sediment budget of a river or estuary will change the bathymetry of the waterway and this information can be managed in a simple yet organized fashion. The levels within a repository include section(s) and project(s). For example, the geographic extent of the repository could be the state of Virginia, the section level would represent individual harbours of Virginia and the projects could be numerous individual surveys for each of the harbours. The soundings imported into a project can be filtered and/or edited where necessary in BEAMS prior to being committed to the repository of the entire waterway. This design facilitates the management of data entering the system in a layered fashion without being blindly added to existing bathymetry.

Multi-User Access

CARIS BEAMS has also been designed to be scalable which is a major requirement of present software development. This ability allows the number of users to work and query a given repository to be one or many. As demand increases, more users can be added to the system simply by registering and connecting to existing repositories. In addition, multiple client stations can utilize and build on the same repository resulting in increased productivity.

CARIS HHcoded Tiles

In its more than twenty years experience with hydrographic and national charting agencies, CARIS has worked and developed numerous geomatics technologies. One such technology incorporated into CARIS BEAMS is CARIS HHcoded Tiles, an innovative method of storing, managing and visualizing soundings.

CARIS HHcoded Tiling process is based on Morton numbering and creates representative variable-sized 'tiles' from irregular input points and in BEAMS, these input points are soundings. Grouping dense soundings into tiles has optimized the response time and resources required to quickly display and manipulate soundings. A group of soundings encompassed within one tile can be graphically represented based on several statistical parameters including minimum, maximum, mean, median, standard deviation and count.

The innovative design of the HHcoded Tile has also added a number of features to the traditional way of storing and retrieving bathymetric information. One of these features is the ability to store attribute information on the individual soundings. These attributes not only help the users store meta-data (eg. survey vessel identification, date, time, etc.) on the soundings but also allow them to apply display filters on the bathymetry to represent different scenarios based on these attributes. These attributes of the soundings can then be used to isolate or filter out the desired view (*see Figure. 2*).

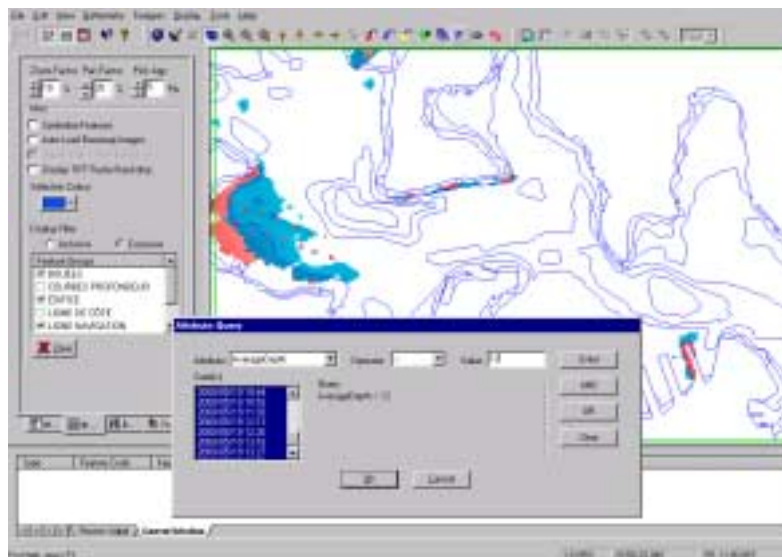


Figure 2. Bathymetry with display filter applied based on depth.

Soundings can be displayed by the graphic tiles or by their original vector point values. Dynamic colour ranges can be used to categorize the bathymetric representation. For example, users can choose to draw soundings starting at shoal soundings value in red and deeper soundings blue, or assign fixed colour to depth relationships (see *Figure. 3*). A number of resolution options are available including maximum resolution, custom resolution or automatic resolution setting designed to optimize the drawing performance relative to the area to be displayed.

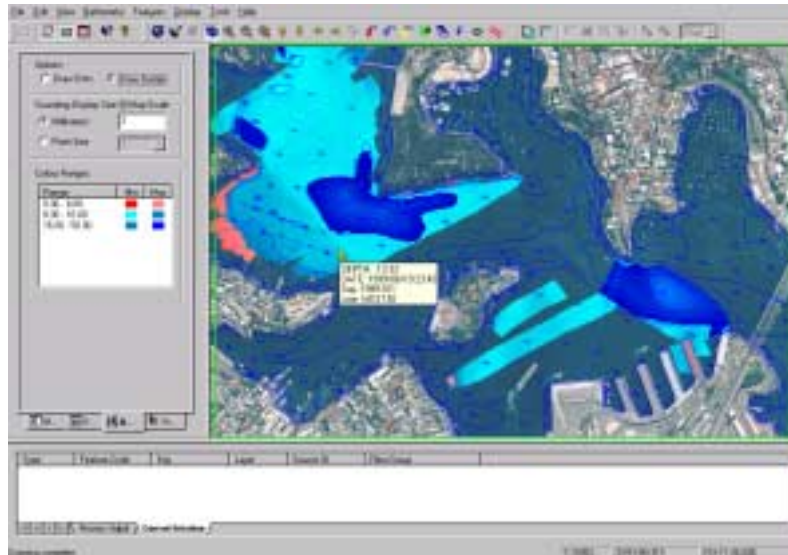


Figure 3. Bathymetry showing colour bands spread over depth

Multiple Format Display

In attempting to understand the physical extent of a port or waterway it is advantageous for port engineers and managers to overlay their bathymetry information on hydrographic and topographic charts which act as a point of reference or basemap. These charts are frequently produced by different National Charting Agencies that do not always follow the same standards of coordinate systems nor use the same Geographic Information System (GIS) hence differing proprietary data formats. The incorporation of such information then requires lengthy transformation of charts often resulting in loss of information and duplication of data. To avoid such a costly process it would be more feasible if charts could remain in their native formats.

To address these issues, CARIS BEAMS simultaneously supports the display and analysis of multiple vector and raster chart formats which may be of differing scales. For example, users could seamlessly view a S-57 ENC chart, a BSB Raster Nautical Chart and a land map in vector format without data conversion. In addition, coordinate systems can be reprojected on the fly.

Shoal Detection and Bathymetric Volumes

The nature of ports necessitates the careful management of dredging. Ports are typically located on rivers or bays where they receive large deposits of sediment from river runoff and/or longshore drift due to ocean circulation. To ensure safe navigation, shoals must be detected. Shoal detection can be facilitated using CARIS BEAMS for the creation of contours from the tiled soundings. In addition, contours of regular and irregular intervals and profiles of the bathymetry can be created.

Safe navigation also requires maintenance of ports and waterways which requires costly dredging operations. To evaluate the cost and the labour requirements of these operations, an estimation of the volume of sediment to be extracted is usually required. BEAMS accomplishes this through use of a channel template created to the engineered dimensions of the port or waterway in question. For accuracy, the hyperbolic paraboloid is used in volume calculations. Pre-dredging surveys are imported into BEAMS and compared with the corresponding channel template which is the desired depth per area and calculation of the volume of sediment to be dredged. Post-dredging surveys are also useful in surface comparisons and quality assurance to determine how much material was removed in overdredging or remains in underdredging.

External Data Integration

CARIS BEAMS is also capable of connecting to multiple external databases via ODBC connections within a network. Elaborate queries can be performed on both geo-referenced information (eg. buoy location) or non-spatial information (eg. vessel maintenance). The query results will appear in a grid window on the screen and georeferenced features selected graphically. The query results can also be saved to an external file to be included in a report.

Information Distribution

Another beneficial feature of CARIS BEAMS is its ability to disseminate information over a network and to outside clients via the Internet. This is achieved by using CARIS' latest Internet-mapping tools that allow the client to easily access a bathymetry service including meta-data located in the repository.

The flexibility of this Internet-mapping functionality not only allows the sharing of bathymetry, it can also combine other information from differing agencies and data providers. This can be very useful for coastal zone managers trying to merge information such as bathymetry, topographic charts, cadastral, environmental and ecological layers. This Internet mapping can read native formats and reproject on-the-fly with maps at various scales while leaving the data where it originated, thus achieving remote access without the duplication of data. Another major benefit of this Internet-mapping technology is that it ensures

security of the transfer of information to the Internet plus the original data can not be changed because the data is not physically transferred to the Internet client.

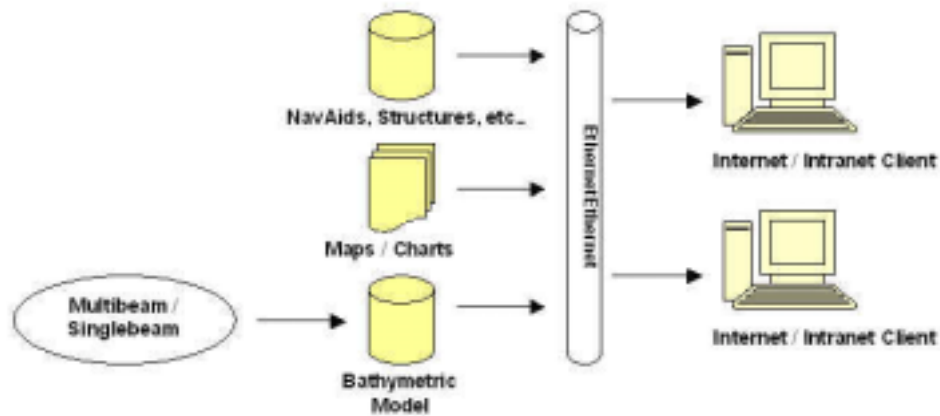


Figure 4. Information Distribution through the Internet.



Figure 5. An example in the St. Lawrence River combining BSB Raster Nautical Chart overlain by channel vector information, the National NavAids database and the Regional Shoals Database viewed in this seamless environment and distributed over the Internet with CARIS BEAMS. All data courtesy of the Canadian Coast Guard.

Conclusion

CARIS BEAMS combines the tools for bathymetry engineering and management with accessibility and ease of use of Internet mapping and distribution. With the help from end-users and industry experts from North America and overseas, this collaboration between the software developer and the end-user has proved extremely helpful in generating a product that meets the users needs for the maintenance and monitoring of port and waterway bathymetry.

Acknowledgements

Figures 2 & 3. Data courtesy of: Defense Science and Technology Organization, Australia, Copyright: Land Information Centre, Bathurst, NSW, Australia.

Figure 5. Data courtesy of: Canadian Coast Guard, Waterways Development Group, Laurentian Office.

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