Canadian Hydrographic Service Hydrographic Information Network

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Key words:

ABSTRACT

The Canadian Hydrographic Service (CHS) commenced the Hydrographic Information Network (HIN) initiative during the early 1990's. This was in response to the operational demands created as a result of the transition from conventional to digital operations. The primary focus of HIN was to coordinate the development and implementation of systems, methodologies and resources to support the CHS digital hydrographic office, to provide for the management and dissemination of digital information and to ensure the long-term persistence and integrity of CHS information holdings. HIN has focused on the design and implementation of four integrated database systems to meet the requirements of managing source data, water level information, products and CHS meta-data. A high level overview of the HIN initiative is presented together with the overall goals of the program and the current status of the initiative.

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1. INTRODUCTION

The primary mandate of the Canadian Hydrographic Service (CHS) is to chart Canada's navigable waters and provide products and services to support safe navigation in Canada's waters. Canada has a charting responsibility for 243,792 kilometres of coastline, 755,000 square kilometres of freshwater and 6.55 million square kilometres of continental shelf and territorial waters. The CHS has offices in four Regional centers with the Headquarters in Ottawa, Ontario. The regional centers are located in Pat Bay, British Columbia; Burlington, Ontario; Mont Joli, Quebec and Dartmouth, Nova Scotia. The Nova Scotia facility has a satellite office in St. John's, Newfoundland and CHS has 300 employees nationwide.

Since digital data acquisition and chart production was introduced during the 1970's there has been significant advances in both the data acquisition and chart production capabilities of the CHS. The introduction of the multi-beam echo sounding system during the early 1990's has enabled CHS to conduct 100% bottom coverage surveys with unprecedented accuracy and detail. The CHS SIMRAD EM3000 Multi-beam Swath Sounder has the capability of gathering in excess of 2,800 million depth measurements during a typical three month survey. The CHS currently has five of these systems which can acquire more than a terabyte of digital information each year to process and manage.

Management of the digital information has been a challenge for the CHS since the introduction of digital data acquisition and chart production capabilities. Many studies, evaluations and projects were carried out over the past three decades by the CHS to address digital data management. It was realized that the digital data management and dissemination would be a major undertaking for the CHS and would require the coordination and pooling of resources. Consequently, the Hydrographic Information Network (HIN) initiative was undertaken to provide direction and coordination of CHS efforts that are essential for addressing the data management and dissemination requirements.

2. HYDROGRAPHIC INFORMATION NETWORK (HIN) OVERVIEW

Early database management systems and associated hardware were not amenable for managing large volumes of spatial data economically and efficiently. With the development of the Relational Database Management Systems (RDBMS) in the 1980's and the price/performance advances in computers and data storage in the 1990's it was realized the information could be managed in an effective and efficient manner at an affordable cost.

The CHS developed the concept of the HIN in the early 1990's. The initial objective was to manage all source and product information including the associated meta-data in a relational database environment. Although the meta-data and product information had been addressed in a digital manner (not RDBMS initially), the hydrographic source information presented

special challenges due to the very large volume of spatio-temporal data acquired with sweep and multi-beam sonar systems.

The development of the Helical Hyperspatial data code (HHCode) {VARMA 1990} by the CHS and the subsequent integration of this technology in a commercial RDBMS environment (ORACLE^{TM}) enabled Very Large Spatial Data Storage systems to be developed using RDBMS technology.

In addition, the Web technology of the last decade has enabled the CHS to access data stores that store and manage the ancillary source information necessary for making CHS products such as the Nautical Paper Chart and the Electronic Navigation Chart (ENC).

The result of these technological advances enabled the CHS to begin to build the components necessary to manage the digital information. The core components of HIN that are in development or currently implemented are:

a) CHS Directory (CHSDir) was implemented in 1993. The primary role of this database is to store all the meta-information for CHS data sources and products.
b) The Source Database (SDB) {FORBES 1999} has been in development since 1997. This database addresses the management of bathymetry and the additional source objects CHS requires for producing products. The bathymetry portion of the database is currently being implemented.
c) The Product Database was implemented in 1998 and manages the CHS ENC products.
d) The Water Level data management components are being developed. Currently the Benchmark database has been implemented.

The databases are implemented using ORACLE^{TM} Version 8 RDBMS. The PDB and the SDB are using the spatial components of ORACLE^{TM}. These individual systems will be described in more detail and an overview of the HIN concept can be seen in Figure 1.

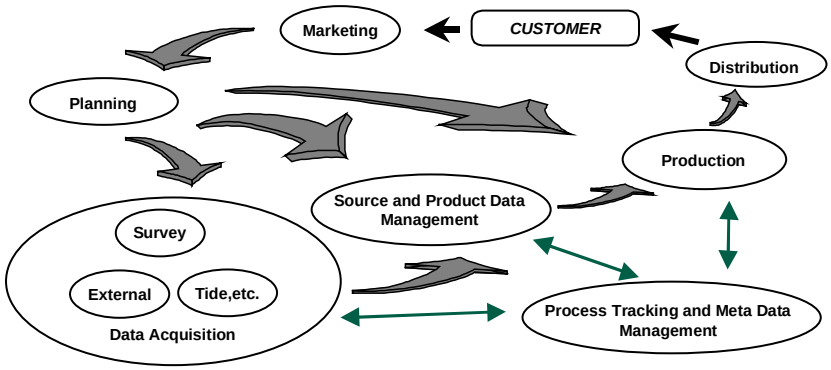

Figure 1 HIN Conceptual Diagram

3. MANAGEMENT AND CO-ORDINATION OF HIN

The management and co-ordination of HIN is a significant program for the CHS that is national in scope. One of the requirements is to liaise and cooperate with both the private and public sector. The primary objectives of HIN are to:

a) Serve as the base for operations and support of the digital hydrographic office.
b) Provide access to and dissemination of CHS digital data and information.
c) Ensure the persistence and integrity of the CHS digital data and information.
d) Enable access to external digital data and information.
e) Provide a mechanism for the maintenance of CHS digital data and information.
f) Ensure the provision of appropriate infrastructure and tools.

The HIN Working Group (HIN WG) is made up of representatives from all the CHS Regional offices and CHS Headquarters. The primary mandate of the working group is to address issues related to the research, development and implementation of Geo-spatial Information Management Systems (IMS). These systems are developed and implemented to support the management of CHS information and data for the CHS business lines.

The reporting relationship with other CHS working groups and committees is portrayed in Figure 2.

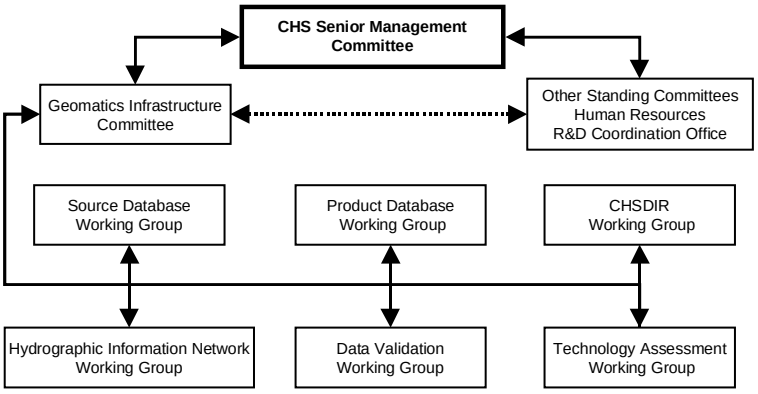

Figure 2 HIN Committee and Working Group Structure

The HIN WG reports and makes recommendations to the Geomatic Infrastructure Committee (GIC). Upon approval by the GIC the recommendations are then submitted to the CHS Senior Management Committee for review and final approval.

4. HIN INFORMATION MANAGEMENT COMPONENTS

The primary HIN components and their relationship to each other and external data sources are shown in Figure 3.

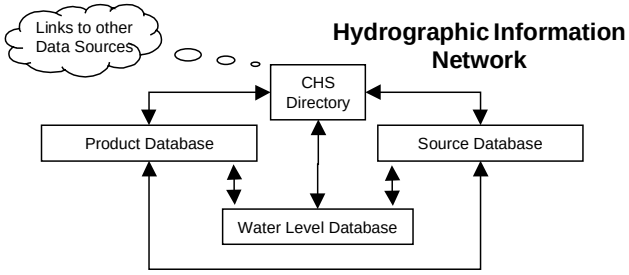

Figure 3 HIN Information Management Components

CHSDir is the meta-database for sources and products and is the highest level access to the information stored in the SDB and the PDB. These databases are designed to interact with CHSDir and also to access data sources and information external to CHS. These external information are used in CHS products but CHS is not the custodian of the data nor directly responsible for the service provided. An example of this type of information is the Canadian Coast Guard (CCG) Aids Program Information System (SIPA) database for maintaining navigational aids information.

CHS does not wish to duplicate information that is the responsibility of other government departments or agencies. There is no advantage to duplicating data storage unless the data must be altered significantly to incorporate the information in CHS products. In addition, the currency and synchronization of the data is always an issue.

4.1 CHS Directory

The ORACLE™ based CHS Directory is the oldest of the current suite of HIN databases. It is a national meta-data database with the appropriate tools to access and maintain accurate, up-to-date information regarding source data, Notices to Mariners (NTM) and CHS products. It evolved from the previous document management system, the CHS Source Directory System (SDS). CHSDir was developed in the early 1990's and the SDS tables were migrated to the new CHSDir structure. There has been ongoing development and enhancements to CHSDir managed by the CHSDir Working Group and HIN. The most recent upgrade was the implementation of the NTM component. Existing NTM database information was loaded into CHSDir and a link to the CCG SIPA database was established.

4.1.1 Key Components of the CHS Directory Database

CHSDir is a meta-data base 'plus' in that it is used to store information about CHS source data and documents, products and has additional functions and tools for planning and production. Additional information such as chart formats and other planning documents are maintained in CHSDir. For chart production and NTM there are tools to monitor the production progress and in the case of the paper chart milestones, timelines and actual production times are recorded. This function is particularly useful near the end of the production process as the national quality control and printing tasks are centralized and CHS staff needs to monitor the incoming workload carefully to minimize backlogs or queues.

The main components of CHSDir include the Source Document Directory, the Products Directory, Product Maintenance and NTM.

The Source Document Directory contains all meta-data related to existing and incoming source data that may be used in CHS products. The Products Directory contain all meta-data relating to all CHS products including Nautical Paper Charts, ENC, Natural Resource Maps, Sailing Directions, Small Craft Guides, Tide and Current Tables and other special charts and publications. The Product Maintenance component provides a link between source documents, NTM and CHS products. This enables CHS to establish and record an audit trail of updates for every product.

The NTM component records draft notices data, facilitates the generation of the notice, tracks the progress and distributes the notice to the CCG for publication. For navigational aids changes initiated by the CCG, the CHSDir tables are automatically populated with appropriate data from the SIPA database. Staff is notified of these new notices and then uses the tools in CHSDir to generate the notice for publication.

4.1.3 Future CHSDir Development

An analysis of the CHSDir database is underway to address the tighter coupling and integration of CHSDir with the other HIN databases. The analysis will also investigate the requirement for extended functionality in CHSDir. This work will be completed by March 31, 2002.

4.2 CHS Source Data Base

This initiative was started in 1997 and was the result of a strong commitment by the CHS to support the research and development associated with the HHCode and its subsequent integration in the ORACLE™ product. The technological challenge for the development of this database was the very large volume of spatial data collected by the CHS multi-beam sonar systems and the desire to manage this information effectively in the RDBMS environment. The unique characteristics of the HHCode and its use in the ORACLE™ product were a key factor in resolving this problem.

4.2.1 Development Strategy and Objectives of the SDB

The key objectives of the SDB are to:

a) Ensure the data access meets CHS business requirements.
b) Enable CHS to manage large volumes of source data effectively.
c) Provide predictable response times and exceptional performance for spatial queries.
d) Ensure data scalability, integrity, independence, and security.

The challenges posed by this initiative resulted in the program being split into two phases. Phase I addressed the large volume Bathymetric Data and Phase II addressed other types of source objects (points, lines, areas).

4.2.2 Building the Bathymetric Data Archive

CHS and CubeWerx Inc., Hull, Quebec developed the bathymetric data archive. The product is called CubeSTOR™ Archive and is implemented using ORACLE™ Version 8.

The bathymetric archive uses HHCode technology and the principle of data partitioning {ORACLE 1995} to perform fast spatio-temporal data access to a very large data store. This technique is used to store the data in multiple partitions (tables) that dynamically and automatically subdivide when the data is loaded and the volume of data points in a given partition exceeds a preset threshold. The HHCode structure supports this scheme based on the data-grouping characteristic of the HHCode data type.

This approach for the storage of very large spatio-temporal data {FORBES 1999} has the following benefits:

a) The primary benefit of data partitioning is to ensure consistent and timely spatio-temporal query performance for Very Large Databases whose growth rate is not predictable.
b) The partitioning of data sets facilitates database access by localizing the data and it also allows users to place partitioned tables off-line in files when the data is inactive. Only data that is active remains on-line, minimizing the high-speed storage resources. For very large data storage requirements, it is advantageous to place the information off-line on lower cost storage media when the data is inactive.

4.2.3 Infrastructure for the Archive

Each of the CHS Regions (excluding HQ) has acquired the same infrastructure to support the CubeSTOR™ Archive. The environment is built on the client-server model and consists of a Compaq ES40 server with a minimum of two CPUs and the Tru64-Unix operating system. The ORACLE™ database and the CubeSTOR™ Archive are resident on this server.

The SDB client desktop is currently implemented using NT Version 4 and ORACLE™ client forms. Helical Systems Ltd., Dartmouth, Nova Scotia provides additional functionality including the HHViewer and HHTools for three-dimensional viewing and editing of the spatio-temporal data.

The data storage utilizes a Redundant Array of Independent Discs (RAID) system capable of storing approximately 1.5 terabyte of data and expandable to 17.2 terabytes (utilizing 180 Gbyte Disc Drives) as the data storage requirement grows. The process automation, auditing and reporting (i.e. workflow) is implemented using the Session Layer developed by Holonics Data Management Group Ltd., Hull, Quebec.

4.2.4 Implementation of the Archive

The bathymetric archive and associated components was delivered to the four Regional CHS offices in March 2001. The delivery included operational training and documentation. Each

of the Regions is independently becoming familiar with the product and they are assisting each other with the implementation by regular communication. In addition, as seen in Figure 2 the Source Database Working Group is a medium for supporting and assisting in the implementation process.

4.2.5 Completion of the SDB Phase II Component

Figure 6 is a conceptual view of the SDB Phase I and Phase II architecture.

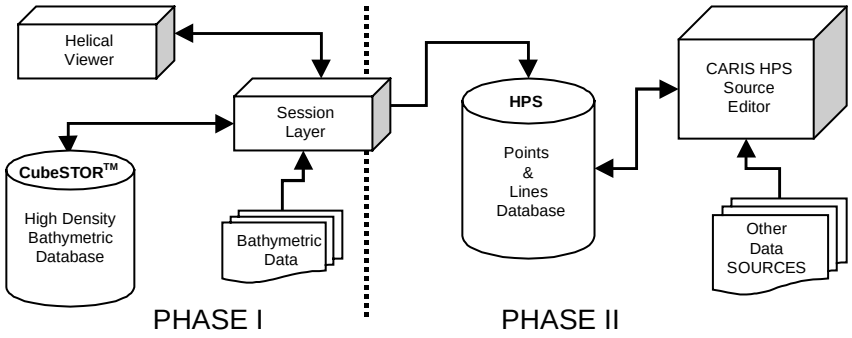

Figure 6 Overall SDB System Architecture

Phase II for the SDB integrates the Commercial off the Shelf (COTS) CARIS Hydrographic Production Source (HPS) database with the Phase I CubeSTOR™ Archive.

The HPS database is implemented using the ORACLE™ RDBMS. It addresses the additional hydrographic point and line objects and attributes necessary for managing the CHS source information used in the production of CHS nautical charts and ENCs. Included in this system is an interactive editing capability (CARIS Source Editor) for all objects and their attributes and the edits are committed as transactions in the HPS database. The objects have a time stamp and multiple versioning of the hydrographic objects and audit capabilities are supported at the object level. Inherent in the design is ensuring that there are no duplicate objects (same spatio-temporal HHCode for an object with identical attributes) and this is maintained by testing the uniqueness of the spatio-temporal component (HHCode).

The history of objects in the database is stored and previous versions of an object may be viewed. Objects that are deleted are merely flagged for delete but still exist in the database. In addition there is a one to many mapping of source objects. This means one source object may be in one or more products.

The full SDB Phase I and Phase II system will be implemented in the CHS Regional offices during 2002/2003.

4.3 CHS Product Data Base

The S-57 Product Database (PDB) was developed in 1997 and implemented in all the CHS regions in 1998. The development of this database was a significant change for CHS from a

file management approach for producing and maintaining products to a data management solution. Initially the database managed only S-57 datasets for ENC production but its role is now being expanded to other types of products.

The primary functions of the PDB are to:

a) Provide dataset management.
b) Support the production and maintenance of products.
c) Provide the workflow and quality assurance necessary for the release of products.

4.3.1 Product Database Objectives

The key objectives of the PDB are:

a) Creation of a repository for the generation of products from a common S-57 based maintenance infrastructure.
b) Support the tracking of feature objects from their source to their use in products, and maintain a history of their changes.
c) Provide a mechanism to ensure that all data used in the S-57 based products is properly safeguarded and that data integrity between the spatial and the non-spatial information is fully maintained.
d) Support the planning and monitoring of the S-57 production process.

The PDB interfaces with a client based desktop system that supports the manipulation, editing and maintenance of hydrographic objects for a given product or product maintenance cycle. The tool sets used are the CARIS Hydrographic Object Manager (HOM) for managing the objects and their attributes, CARIS ECVIEW for viewing the S-57 product and ChartNet to support the product quality assurance and release mechanisms. The PDB also interfaces with the CHSDir meta-database for retrieving and storing information relevant to the production and maintenance of the S-57 ENC.

The PDB also uses the initial concept of a Session, which can be described as a set of work activities carried out during a defined time period that produces a specific deliverable. The two different Session types are the Maintenance Session and the Product Generation Session.

4.3.2 Key Components of the Product Database

Figure 7 shows the five components of the PDB.

The central component is the S-57 Object and Product Repository. This is an integrated multi-user ORACLE™ database and each CHS Region has this repository. It provides an environment that supports the storage of CARIS Object Manager data and CARIS files together in an archive dataset.

The Dataset Versioning component supports storing data in the repository (check-in) and extracting data from the repository (check-out). The data integrity for the CARIS files and the Object Manager data is maintained based on the access permissions and the security associated with the data in the repository. This feature provides the necessary audit trail information required, tracking the Sessions in which objects are created and/or deleted.

The Product Configuration component provides the capability to define products of different types including but not limited to the S-57 ENC, DNC, and the Nautical Paper Chart. The version of the dataset used to generate the given product is tracked at the Session level. The intent is to support one step automatic product generation.

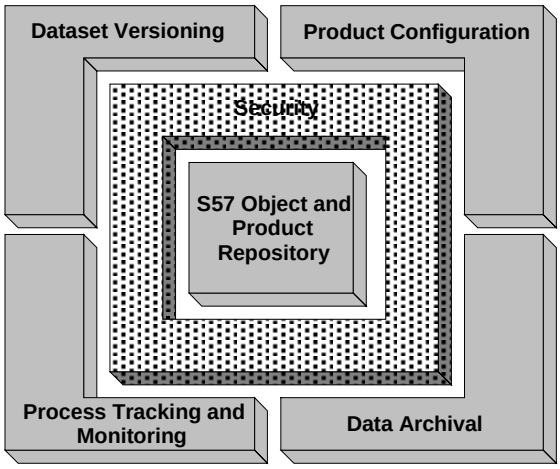

Figure 7 Components of the PDB

The Process Tracking and Monitoring component provides Quality Control (Q/C) review and approval. Checklists may be defined for different processes, progress may be tracked based on the checklists and also specific information about the datasets and products can be stored.

And finally the Data Archival component supports the archival of superseded objects and also archives dataset files. These objects or datasets may also be restored.

In addition to the components previously described, all the Q/C activities performed by HQ and the Regions are tracked in the S-57 PDB. The three release levels supported are:

a) Regional Q/C.
b) HQ Q/C after the Regional Q/C is complete.
c) Release to Nautical Data International, Inc., St. John's, Newfoundland (the CHS authorized value added reseller and distributor of CHS digital data and products) for product distribution and sale after HQ Q/C. The released files are automatically moved from the Regional server by ChartNet.

4.3.3 Product Database Infrastructure

The database portion of the PDB built by Holonics Data Management Group Ltd., Hull, Quebec, is implemented in each Region on a Compaq server and the Tru64-Unix operating system using ORACLE™. While the initial implementation of the PDB was developed as a Unix client-server application, it is currently being re-deployed as a web-based ORACLE Forms™ application using a central ORACLE™ 9iAS application server housed on an NT Version 4 server.

4.3.4 Product Database Development and Enhancements

The planned enhancements for the product database in 2001/2002 include the investigation and feasibility of migrating the HOM and S-57 PDB to the CARIS Hydrographic Production Database. This approach means that the source data from the SDB and the product data from the PDB reside in a homogeneous data model that uses the latest ORACLE™ spatial capabilities. As described in the SDB implementation, the application supports full object and attribute editing functionality directly on the database and also provides auditing capabilities for tracking edits and providing multiple versions of objects and their history. This approach also facilitates the integration of the SDB and the PDB.

4.4 Water Level Data Management

The water level information collected by the CHS is used to determine the tidal constituents and related vertical datums in tidal waters, and to determine the specified vertical datums in non-tidal waters. The analysis of this information is used to determine the primary vertical reference surface i.e. Chart Datum (CD). In coastal waters, CD is targeted to Lower Low Water Large Tides - the lowest predicted water level, averaged over 18.6 years. This datum is used as a low water reference plane, common for all CHS products. Whereas CD is used for transforming all bathymetric information to a collective reference plane, all clearances and elevations are reduced to a corresponding Datum of Elevations, targeted to Higher High Water Large Tides. In Canada's inland waters, clearances and elevations are reduced directly to the low water CD.

The International Hydrographic Organization (IHO) has voted to adopt Lowest Astronomic Tide and Highest Astronomic Tide as international harmonized datums. The IHO has also received a recommendation to standardize clearances and elevations in non-tidal waters to a high water reference surface. These initiatives will have great impact on CHS products in the next few decades.

The water level information and related data currently available is addressed by the following data sources:

a) CHS Vertical Control Benchmarks are held in an ORACLE™ database at the Marine Environmental Data Service (MEDS), Ottawa, Ontario. All historic tidal constituents are in a database at MEDS (using flat file architecture) and managed by CHS personnel. To-date, Atlantic Region benchmark and constituent information has been entered and validated. The other CHS Regions are expected to complete their tidal constituent data entry and validation in the next 6 months, however, benchmark loading and validation may take significantly longer.
b) Water levels from the Permanent Water Level Network and the temporary water level gauges are archived at MEDS in a large file management system. All this information is stored on the current CD. It should be noted that substantial re-processing of historic data sets and attendant statistics is required upon an adjustment of the vertical datum.
c) CHS Tidal Predictions are available on the World Wide Web but are restricted to a

running 3-day window. Plans for commercial (official) stand alone digital tide tables are being made.

d) CHSDir currently contains information fields to transform bathymetric source data to CD. The Atlantic Region have been populating these fields for several years. This task is presently handled by a variety of stand-alone file management techniques in the other Regions.

The management of vertical datum is a manual process for all CHS Regions. The automation of datum management would result in more efficient, consistent and effective production and would substantially reduce the risk of error due to incorrect vertical transforms.

4.4.1 Management of Water Level Information Using Digital Elevation Models

With the advances in remote sensing and the availability of Differential Global Positioning System (DGPS) information, it is now possible to develop high-resolution digital elevation models. The CHS is using these technologies as part of an alternative strategy for vertical datum management {WOODWARD 1998}. Traditionally datum has been viewed as static planes of reference, but in reality these datum are changing and periodically require adjustment. The development of 3-D models that are related to an ellipsoidal reference surface (World Geodetic System 1984 was recommended by the IHO for a global vertical reference standard) that supports the use of separation models for datum management. This approach has the following advantages:

a) Automated transformation of bathymetric data to well defined vertical datums (referenced to an absolute, time invariant and seamless reference surface).
b) Minimal disruption and digital processing for referencing new and historical bathymetry to new vertical datums. The use of separation models supports this approach and minimizes the human intervention necessary to transform the information. This further enhances the integrity of the transformed data.
c) Supports the concept of “data fusion” and an ENC display with real time water level transform referenced to a user selected vertical datum.

The CHS is presently using the DGPS measurements to calibrate the tidal stations in Canada. This survey work is necessary to construct the ellipsoidal separation models for several tidal datum surfaces including Mean Water Level and a variety of high and low water datums.

SUMMARY AND CONCLUSIONS

The HIN initiative has been a major undertaking by the CHS to meet its information management and dissemination requirements. The program has realized a number of accomplishments. These include the development of HHCode to allow for the efficient management of large volumes of spatio-temporal data in a conventional RDBMS environment. The CHSDir and the PDB have been implemented and are operational in all of the CHS Regions. The bathymetric portion of the SDB is being implemented and the points and lines component is currently in the final stages of development. The benchmark and constituents portion of the Water Level Database is implemented with the remaining portions

under development. These systems will comprise the backbone of the CHS strategy to manage information and meet the requirements of its clients.

This is an ongoing program and the future initiatives will concentrate on refinements of the current systems that are in place and the closer coupling and operational integration of the key components of HIN. For the next stage a contractor has been tasked to evaluate the current systems, their operational requirements and make recommendations for the next phase of HIN.

HIN has been and will continue to be the 'vehicle ' by which the CHS will continue to traverse the 'Digital Highway'.

REFERENCES

Forbes, S. Burke, R., Day, C. E., Varma, H. P., Building a CHS Bathymetric Data Warehouse, International Hydrographic Review, Monaco, LXXVI(2). September 1999.

ORACLE7 MultiDimension User's Guide, Version 1.3.2, May, 1995.

Varma, H.P., H Boudreau, and Prime, W., A Data Structure for Spatio-Temporal Databases, IHO Review Monaco LXVII(1), January 1990.

Woodward, Michael J., O'Reilly, Charles T., Varma, H.P., Management of Vertical Datums (Transformation of Hydrographic Data for Diverse Applications) 1998.