Canadian Hydrographic Service

HYDROGRAPHIC SURVEY MANAGEMENT GUIDELINES

PREFACE

The advent of satellite positioning, multi-transducer and multibeam echo sounding systems and sophisticated data processing tools have drastically modified the way hydrographic surveys are conducted. Management tools such as ISO 9001 have also had an impact on the methods used to ensure quality assurance.

The Canadian Hydrographic Service (CHS) Survey Standing Orders, as they were written in the 1980’s and 1990’s, no longer reflect the standards and the methods of work required to properly conduct a hydrographic survey. After review, the requirements for the completion of a hydrographic survey have been divided into three separate documents.

The *CHS Standards for Hydrographic Surveys* is the document that specifies the requirements for hydrographic surveys in order that hydrographic data is collected according to specific standards. This document quantifies the accuracies required, depending on the use of the data. All CHS hydrographic surveys must adhere to the various standards listed in this document.

The Quality Management System *(QMS) Hydrographic Survey Procedures* detail the procedures, the methods, the equipment and the steps required to obtain the accuracies specified in the *CHS Standards for Hydrographic Surveys*. There may be small regional differences but the regional QMA procedures ensure that the CHS standards are being met.

This document titled *Hydrographic Survey Management Guidelines* serves as a link between the CHS Standards and the regional QMS Hydrographic Survey Procedures.

This document makes reference to various documents produced and maintained by the Canadian Hydrographic Service. To obtain more information on those documents, please contact the Canadian Hydrographic Service.

http://www.dfo-mpo.gc.ca/Contact_e.htm

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Record of major Changes

N.	Date	Section	Description
1	2013--05-30	Many	Add references to “CUBE Bathymetric data Processing and Analysis (CHS February 2012)” in many places in the document.
2	2013-04-05	3.1	Remove references to fieldsheets (as they’re not produced anymore) and scales.
3	2013-04-05	3.2	Change the labeling of the survey orders to be consistent with IHO S44, Edition 2008 and CHS Standards for Hydrographic Surveys, Edition 2, 2013.
4	2013-04-05	3.3	Add “CHSDir, BDB and HPD extracts” in the list of pertinent documents.
5	2013-04-05	3.4	Add “TPU Information” in the list of Tidal Information.
6	2013-04-05	4.0	Add an example of TPU information.
7	2013-04-05	4.1	Add precision in the calibration of sound velocity probes.
8	2013-04-05	4.2.1	Replace “Total Propagated Error (TPE)” by “Total Propagated Uncertainty (TPU).
9		5.1	Remove reference to “GPS Survey Standing Order” and add a reference to national and regional GPS positioning agencies.
10		5.2	Remove references to LAT and HAT as they’re not official yet.
11		5.3	The whole section has been re-written to better define the use of GPS.
12		6.1.1	Add multibeam echosounder in the list of systems to check with a bar check.
13		6.1.1.2	Add a paragraph detailing how and when collect SVP data.
14		6.1.3	Add a note to say that calibrated motion reference unit is mandatory for MBES and MTES.
15		6.1.7	Add a reference to “CUBE Bathymetric data Processing and Analysis (CHS February 2012)” and remove processing steps.
16		6.1.10	Add clarification on the management and processing of LiDAR projects.
17		6.1.12	Replace the shoal examination depth limit (50m instead of 40m).
18		6.1.15.1	Change the wording to better define the use of GPS in water level reduction.
19		6.3.2	Add a note on the use of volume backscatter to detect least depths over wrecks.
20		6.7	Remove references to LAT and HAT.
21		6.16	Remove “Proof of signature” and the last paragraph (details of the notebook content.
22		10.0	Remove C-DGPS definition and replace TPE by TPU.
23	2019-11-22	6.1.7	Multibeam work updated. Survey instructions require backscatter be logged

24	2019-11-22	6.1.9	Field Survey Instructions require that the IFMS backscatter be logged.
25	2021-02-02	Many	Amended documentation to reflect change in terminology from Notices to Shipping to Navigational Warning, amendments to accurately note Crown-Indigenous Relations and Northern Development rather than Indigenous and Northern Affairs.
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1 Introduction

This document details the requirements for the completion of a hydrographic survey. Along with the February 2021 *CHS Standards for Hydrographic Surveys,* it supersedes the previous edition of the CHS Hydrographic Survey Management Guidelines (November 2019).

These guidelines are not meant to replace the February 2021 *CHS Standards for Hydrographic Surveys* nor the existing *CHS QMS Hydrographic Survey Procedures* but are to be used to assist in the completion of the various tasks required to undertake a hydrographic survey. Here's a description of the 3 levels of documents pertaining to hydrographic surveys.

- *2021 CHS Standards for Hydrographic Surveys*

  National document describing the various precisions required for the various features collected by the Canadian Hydrographic Service or his delegate.

- *2021 CHS Hydrographic Survey Management Guidelines*

  National document describing the methodology to be used to meet the various standards described in the *CHS Standards for Hydrographic Surveys.*

- *CHS QMS Hydrographic Survey Procedures (per CHS quality management system based on ISO 9001)*

  Series of regional detailed procedures and forms taking into account the distinctive environment of each region (work flow, vessels, systems, processes, etc.). These procedures refer to the 2 previous documents.

The following documents were used as references when preparing these guidelines:

- International Hydrographic Organization (IHO) Reprint No. 19 - Guidelines for the Preparation of Specifications for Hydrographic Surveys
- New Zealand's Standards for Hydrographic Surveys (HYSPEC) v3-2001
- National Ocean Service (NOS) Hydrographic Surveys-Specifications and Deliverables-2003
- Engineering and Design – Hydrographic Surveying 2002 by USA Corps of Engineers
- CUBE Bathymetric data Processing and Analysis (CHS February 2012)

2 Hydrographic Survey Instructions

All hydrographic survey projects should have project instructions defining the work to be done. Detailed survey instructions should be written once the survey project has been approved and is scheduled to be executed.

2.1 Field Survey Instructions

The purpose of Field Survey Instructions is to list the work to be done and provide supplementary information not covered in the CHS standards, the regional Hydrographic Survey QMS procedures or other documents issued by CHS. The survey project instructions should be approved by the Manager of hydrographic surveys.

The details included in the survey project instructions will vary depending on the nature of the survey and its complexity, however, they should include:

- a general description of the project,
- the purpose of the hydrographic survey (CHS use, external client),
- the history of the area (existing charts, previous work, etc.),
- the area to be surveyed including limits, the survey order (Table 1 of the CHS *Standards for Hydrographic Surveys*), survey method, technology, data density, etc.,
- the horizontal and vertical geodetic references to be used,
- the accuracies to be attained (survey order), as defined in the CHS *Standards for Hydrographic Surveys*,
- instructions for water level (tidal/non tidal) observations and reduction of soundings (usually separate instructions written by the Tides and Water Level Unit – see § 3.4 Tidal Instructions),
- data processing and digital submission instructions,
- where applicable, instructions for designating a safety officer and the compliance of the Canada Labour Code,
- reporting (when, types of reports, statistics required, etc.).

If the project is carried out by the CHS, the following information could also be added:

- list of participating staff,
- commencement and termination dates,
- sounding platforms that will be used,
- if work is carried out for an external client: a copy of the Partnering Agreement or contract, the date the product is expected, details of deliverables (digital, paper, format, etc).

If the project is carried out by an independent firm for the CHS, the following information must also be added:

- specific data formats and instructions on submission of data,
- request to use specific equipment and processing packages,
- delivery dates for products,
- summary reports on methodology and equipment used,
- quality control reports, including all pertinent records (field notes, etc.),
- a copy of the Partnering, Agreement or Contract.

Additional requirements or modified survey instructions resulting from information and requests that were not available or known at the time the original instructions were written could be issued during the course of the survey.

2.2 Survey completion

In normal circumstances, a hydrographic survey should be planned and executed in a manner that will allow completion of all phases of the field work as the initial sounding coverage progresses. The initial sounding coverage should not progress far ahead of the other essential elements required to complete a specific area (shoal exams, bottom samples, range lines, positioning of fixed aids and conspicuous objects, etc.) as completed areas can readily be used to create or update CHS products.

If, during the course of a hydrographic survey, the Hydrographer-In-Charge (HIC) considers that the work specified in the survey instructions cannot be completed, he/she should plan to ensure completeness of a particular portion of the survey area.

3 Survey Planning

Before leaving for the field, the HIC and his team will have to plan the work to be done, gather all pertinent information required to accomplish the various tasks and verify that all the equipment to be taken to the field is in proper working order and calibrated. In advance, ensure medicals are completed, pertinent risks identified and work procedures read/signed by employees, and all required training completed before tasks are taken on.

In some cases it may be desirable to visit the area prior to the actual survey to establish personal contacts, accommodations and temporary offices (if required) and gain some appreciation for the work area.

It is sometimes required to obtain authorizations to work in some areas such as parks, reserves, etc. In such cases, it may be required to consult the relevant authorities (Crown-Indigenous Relations and Northern Development, Parks Canada, etc.) to be well informed of good practices and keep good relations with these entities.

See *CUBE Bathymetric data Processing and Analysis (CHS February 2012)* .

3.1 Data Representation

CHS has discontinued producing physical fieldsheet for hydrographic data.

The digital world has greatly altered the concept of scale. Digital hydrographic data can be represented at various scales for internal use. However, digital hydrographic data shall be submitted at the best possible resolution (refer to CUBE Bathymetric data Processing and Analysis (CHS February 2012)).

The codification of the data on a digital hydrographic dataset should be done according to the specifications found in the current version of the digital coding guide. This is to ensure proper representation of the features in the dataset.

Note that line spacing is no longer determined according to the scale of the survey but by the depth and the seabed characteristics of the sounding areas as determined by the survey order (see Table 1 of the *CHS Standards for Hydrographic Surveys.)*.

3.2 Survey order

The accuracy requirements for various areas to be surveyed are listed in *CUBE Bathymetric data Processing and Analysis (CHS February 2012),* Table 1 – Standards for Bathymetric Data, Table 2 – Standards for Positioning of Navigation Aids and Important Features, both found in the *CHS Standards for Hydrographic Surveys*.

The order to which the survey area will be surveyed must be determined prior to leaving for the field. This determination will dictate the accuracies, the bottom coverage, the line spacing and the required detection capability required for the acquisition of the bathymetric data.

Critical areas such as shallow water in harbours, berthing areas, and associated critical channels with minimum under-keel clearances, or engineering surveys, or where a full bottom search is required, should preferably be surveyed using multibeam or multi-transducer systems. Single beam echo sounders augmented with the use of side scan sonar may be used. Closer line spacing may be necessary in order to provide the best possible coverage for the higher orders. The work must be done according to the accuracies and specifications detailed for Exclusive Order, Special Order, Order 1a and 1b or Order 2.

In less critical areas, sounding lines using single beam echo sounders may sufficiently cover the area to be surveyed using the line spacing stated in Table 1 – Standards for Bathymetric Data of the *CHS Standards for Hydrographic Surveys*, and multibeam or multi-transducer systems employed without overlap between adjacent track lines could also be used. The work must be done according to the accuracies and specifications detailed for Order 1a and 1b, Order 2 or Order 3.

The survey order, the type of echo sounders used, and the line spacing will help determine the amount of work to be done and provide a time and resource budget for the project.

3.3 Pertinent documents

Charted bathymetric information may come from a variety of sources, some of which do not originate from the CHS. The bathymetric data obtained from a new survey must be compared to the existing source documents and publications. Obtain a list of the documents that were used for the preliminary analysis of the project.

The following is a list of documents and publications which should be brought into the field. Depending on the nature of the project, it may not be necessary to have on hand all the documents and publications listed below.

- copies of the latest corrected edition of the charts for the survey area
- a list of specific chart investigations requested by the Chart Production section
- a list of specific queries and updates requested by the Sailing Directions unit
- copies of previous field sheets and source plans, if any (preferably in digital form)
- up to date aerial photographs and topographic maps of the area
- a copy of related publications for the area of work: Sailing Directions, Tide Tables and Monthly Water Level Bulletins, List of Lights, Buoys and Fog Signals, non-government publications that provide information to boaters.
- listings of the positions of all horizontal control points and conspicuous objects in the area of work as well as their descriptions (from GSD, provincial governments, CHS, etc.)
- a listing of the elevations of all vertical control points in the area of work as well as their descriptions (from GSD, provincial governments, CHS, etc.)
- listing of the latest position of fixed and floating aids (from CCG database - SIPA).
- all necessary file numbers, etc., obtained from HDC/Data Management
- CHSDir, BDB and HPD extracts

Agencies such as Small Craft Harbours, Port Authorities, Transport Canada (Navigable Waters Protection Act), Public Works, local authorities, etc. should be contacted in order to obtain information on upcoming construction, dredging operations, etc. in the area to be surveyed

Reference documents pertaining to the operation and calibration procedures of specific equipment as well as owner's manuals of the various equipment used during the survey should be on hand.

There should also be on hand other reference documents such as working conventions, administrative rules and procedures, safety manuals and regulations that govern hydrographic surveying, etc.

3.4 Tidal instructions

It is customary to submit a hydrographic survey project to the Tides and Water Level Unit who in turn analyzes the request and produces specific instructions for the project. This should be done well in advance so that the requested information will be ready well ahead of the departure date.

These instructions should contain the following:

- sounding datum
- datum of elevations
- how soundings will be reduced (water level staff, water level gauge readings, co-tidal chart, predictions, etc.)
- time zone to utilize

- location of permanent water level gauges (tidal/non-tidal) in the area of work and a copy of their inspection history
- a statement specifying if datum is to be determined by water level transfer and from which reference station
- location where temporary water level gauge should be installed
- requirements for long term water level observations
- TPU information should be provided
- other specific requirements such as tidal stream or current observations

All work is to be done in accordance with the procedures and accuracies stated in the *CHS Standards for Hydrographic Surveys* and the *Canadian Tidal Manual*.

4 Error management and equipment calibration

The management of uncertainty consists of several steps and elements. The main uncertainty management steps are:

- Pre-analysis (survey design), where an estimate of the error contributions from random error sources is made in order to determine whether the equipment proposed for the survey will allow the resultant survey to meet or exceed specifications (refer to "*CUBE Bathymetric data Processing and Analysis (CHS February 2012)*"),
- control of errors through calibration and good survey practices,
- evaluation, where the survey results are analysed to determine whether surveys specifications have been met and
- documentation, where individual objects, such as soundings, navigational aids, etc., are given uncertainty attributes, and/or the metadata elements of uncertainty for the whole survey project are documented so that potential users may determine if the data set is fit for their particular purpose. For example, TPU contributors such as the SBET RMS error data file, the tidal uncertainty, Vessel configuration file, etc.

The main uncertainty elements are:

- Systematic errors or biases, which are due to system offsets that have not been properly accounted for by proper survey procedure such as system calibration,
- random errors, which are due to noise in the measurement process used,
- blunders or accidental errors, which might be due to system failures, environmental conditions and human errors that are beyond our ability to control.

4.1 Systematic Errors

Systematic errors can be reduced to negligible levels through careful calibration procedures prior to each survey. In addition, a verification that systematic errors or biases are mitigated should be conducted regularly (daily in some cases) and whenever changes are made to hardware, software or firmware as the survey progresses.

All equipment to be used during the field survey must be field-tested and, if need be, calibrated prior to leaving for the field survey site. No matter how well an instrument may have been adjusted when it left the manufacturer or the maintenance shop, there is always the possibility of damage to equipment during shipping due to vibration, shock or temperature change. Some equipment may also require field testing on site prior to survey operations. Users should refer to the various owners' manuals and to the QMS hydrographic survey procedures to ensure that the instruments are properly tested and functioning according to established specifications.

As a minimum, the following should be done:

- GPS receivers are to be checked over known control monuments
- All distance-measuring equipment shall be checked against a calibration baseline. The baseline should be of a higher accuracy than the manufacturer's specified accuracy. Additionally a zero constant value for the instrument should be established.
- Barometers and psychrometers must be calibrated.
- Range finders should be checked against known distances.
- Theodolites shall be checked for errors due to poor horizontal collimation, parallax, vertical index error and for other instrumental imperfections. All moving parts shall be checked to ensure proper operation.
- Levels should be peg-tested and rods be calibrated by comparison with a standard.
- The water level gauges and staffs to be used during the survey should be checked.
- Echo sounders should be checked under field conditions, preferably on the work platforms that they are installed on.
- Sound speed profilers must be compared on an annual basis and problematic probes must be calibrated (consult manufacturer for recommended re-calibration interval).
- Bar checks, poles and lead lines should be measured to ensure the distance markers are correctly fastened.

All computers, computer programs, and networks should be checked to ensure their working order in a remote field environment.

The various software packages used to acquire, process and analyze the various bathymetric data collected should be checked to ensure that they work properly and that the approved updates (service packs, hotfixes) and drivers are being used. The latest release versions should be used at the discretion of the Project Manager. Backups for these various software packages should be available and stored in a secure place in case of need.

All instruments will have to be re-verified and if necessary re-calibrated after being repaired or after changes have been made (electronic card replacements, computer adjustments, etc.). A record of repairs and changes shall be maintained.

4.1.1 Calibration of sounding systems

The echo sounding systems will require an initial calibration before the sounding platform is to be operational in the field.

4.1.1.1 *Multi-transducer and Multibeam systems*

Multi-transducer and multibeam systems are complex echo sounding systems and need careful adjustment and calibration prior to leaving for the field.

Alignment and offset parameters (distances) between the various sensors of the multi-transducer or multibeam system and the reference point of the vessel must be physically measured and input into the system's computer. These measurements are usually done after the system has been installed or when some of the equipment has been replaced or relocated.

The following should be done at the beginning of the field season or whenever a piece of equipment is replaced or repaired:

- attitude sensor testing and verification,
- bar check to measure transducer draft,
- transducer or boom alignment,
- gyro alignment determined using accurate land-survey techniques or, other methods such as a patch test,
- squat and settlement tests, and
- check and calibrate the time delays between the positioning system, the recorded soundings and the attitude sensor readings.
- Initiate a patch calibration procedure

A patch test should be done to quantify any residual biases in the initial alignment and offsets. This test consists of running reciprocal lines at various speeds, depths and bottom terrain and comparing the results obtained. Lines run perpendicular to smooth sloping bottom (preferably capturing the apex) will be used to check data latency and pitch. Reciprocal lines run along a smooth flat bottom will verify roll. Lines run on both sides of a defined feature such as a wreck, can determine gyro offset.

The data obtained should be carefully analyzed and adjustments made accordingly. The results of this test should be documented, recorded and made available upon request. Note that this test can also be done in the work area.

More information on patch test calibration can be found in "*The Calibration of Shallow Water Multibeam Echo-Sounding Systems*" by André Godin, 1997.

Once all adjustments and calibrations have been performed, the system should be used to run a series of parallel and perpendicular sounding lines over a reference bottom surface where the depths have been previously determined and verified with an independent system. The results obtained should compare favourably and be within the accuracy requirements of the survey order as specified in Table 1 of the *CHS Standards for Hydrographic surveys*.

Tests should also be run to ascertain that the system can in fact detect targets of the minimum size required by the specified order of the survey.

4.1.1.2 Single beam

Single beam echo sounders installed in the sounding platforms that will be used during the actual survey should be given a trial run to ensure that the echo sounders and the rest of the equipment perform according to their specifications. Bar checking the system to measure draft and verify speed of sound is necessary. Where higher order results are required, system checks such as squat and settlement tests, gyro or attitude sensor alignment and sensor offsets are necessary.

4.2 Random Errors

Random errors (equipment noise), unlike systematic errors, cannot be eliminated. However, it is possible to estimate the affects that random errors will have on the outcome of the survey (pre-analysis), to mitigate or reduce their effects (survey design and instrument selection) and to evaluate the quality of the survey, both as the survey progresses (real-time quality assurance – RTQA) and at the conclusion of the survey. A post-survey assessment allows attribution of each object with uncertainty values and a global assessment of the survey quality for the purposes of metadata creation. This in turn provides users of the data set the information they need to determine if it is fit for their purpose.

Pre-analysis can be done, e.g. using an EXCEL spreadsheet. Values for each random error contribution can be assigned at 1 sigma (standard deviation, RMS, CEP, etc.) and propagated as the square root of the sum of squares (the variances). This is known as propagation of random variances. For single beam echo sounders this is quite simple (e.g. see Professional Paper No. 25 from UKHO). For multibeam echo sounders, it's a bit more complex (e.g. see R. Hare, A. Godin and L. Mayer, "*Accuracy Estimation of Canadian Swath (Multi-beam) and Sweep (Multi-Transducer) Sounding Systems*", 1995).

Several navigation and logging packages have built-in real-time assessment tools that look at standard deviation of the bathymetric surface. Combined Uncertainty and Bathymetry Estimator (CUBE) is an example of a real-time assessment tool implemented in acquisition and processing packages (see § 4.3.1). As new data are added, the standard deviation of the bathymetric surface can be reduced because of the increased number of measurements. Consider that the standard deviation of the mean is always smaller than the standard deviation of a single measurement.

4.2.1 Total Propagated Uncertainty (TPU)

As stated in the *CHS Standards for Hydrographic Surveys*, the accuracy of the reduced depths must be determined. In determining this accuracy all sources of individual errors need to be quantified in order to determine the Total Propagated Uncertainty (TPU). The following are some of the sources of errors that must be considered:

- static draft setting,
- dynamic draft, including settlement and squat,
- speed of sound changes,
- instrumental errors,
- roll, pitch and heave,
- navigation timing,
- water level readings or GPS heights,
- tide or separation models.

Position and depth precision estimates are calculated separately as the square-root of the sum of the variances (root-sum-square (RSS)) from all error sources. This approach assumes therefore that all errors are uncorrelated, unbiased and follow a normal (Gaussian) distribution. In the instances where such an assumption is not valid, an estimate of the error introduced into the estimation process will be given.

As there are some error sources which are not well understood, initial estimates will be based on some elementary testing of a limited number of data sets. In order to validate these estimates, independent ground-truth (validation) data sets will be used as a method of post-calibrating the error estimation process.

In order to estimate the effects of temporal change on bathymetry, the approach of Velberg [1993] is followed. This approach requires that the error due to the dynamic nature of the seafloor is known or can be estimated.

In order to form an error budget, estimates of all independent random errors sources, at the same level of confidence, are required. More information on TPU and the computation process can be found in the document "*Estimation of Bathymetric Accuracy Attributes and their Implementation in the Source Data Base*, 1996, R. M. Hare".

4.3 Blunders

The last category of errors is blunders, or accidental errors. Unlike systematic errors, these cannot be eliminated by careful survey procedures. Unlike random errors, they cannot be estimated in advance of the survey and they cannot be reduced by making additional measurements. Blunders can, however, be detected and removed if sufficient redundancy exists in the survey network and there is sufficient precision in the survey measurements. In control networks, the term minimally detectable blunder (MDB) is often used. For bathymetry, very dense data sets (e.g. high-resolution multibeam) make it possible to detect blunders where they do not fit (statistically) with the values of their neighbours. There are numerous statistical approaches to blunder detection in multibeam data

For single-beam echo sounder surveys, the lack of data density means that detecting small blunders is much less likely. The reliability of multibeam surveys is much higher due to the detection capability. This is the reason such surveys are recommended in harbours, approaches and critical areas.

4.3.1 CUBE (Combined Uncertainty and Bathymetry Estimator)

CUBE uses soundings and their associated uncertainty estimates (see § 4.2) as input and through spatial and uncertainty weighting, while also relying on the very high data density of multibeam data sets, outputs a bathymetry gridded surface and its associated uncertainty (error) surface. In addition, it tracks the statistical hypotheses for each depth point, and where there is more than one estimate, makes an attempt to determine which the most likely value is. This makes it a very powerful tool for identifying and removing blunders in the data. Once these have been removed from the data, CUBE is rerun to generate the final bathymetry and uncertainty surfaces. See "*CUBE Bathymetric data Processing and Analysis (CHS February 2012)*". The uncertainty surface is a quantification of the survey quality, which can be compared against specifications and used as input to the metadata for the survey.

5 Mobilization

Before any hydrographic data can be collected, whenever possible, it will be necessary to recover or re-establish horizontal and vertical control, install (if necessary) and calibrate the positioning (reference) system and install the necessary instrumentation required to record the water level fluctuations.

5.1 Horizontal Control

Horizontal control points may be required in order to reference the position of bathymetric soundings, fixed and floating aids, any conspicuous objects useful for navigation and for surveying shoreline.

To accomplish the tasks mentioned above it may be necessary to install and establish new control points in the survey area. New control points are to be established to the accuracy stated in the *CHS Standards for Hydrographic Surveys*.

If GPS is to be used to obtain positions, the procedures and specifications as stated by the official regional or national Geodetic Agencies must be followed.

For more information on GPS positioning, refer to the appropriate national and/or provincial geodetic agencies.

If conventional ground survey methods are to be used (angles and distances) to obtain positions, methods and procedures from national and/or provincial geodetic agencies should be followed in order to ensure that the accuracies stated in Table 1 and Table 2 of the *CHS Standards for Hydrographic Surveys* are obtained.

5.1.1 Permanently marked horizontal control points

Unless otherwise stated, all new primary shore control points must be permanently marked using a rock or soil post and a tablet stamped and identified using the numbering convention used by the National Geodetic Data Base.

Secondary stations can be marked by a drill hole, iron rod, pipe etc. as they are considered to be of a semi-permanent nature. They should nevertheless be described the same way as permanent control point. (see § 5.1.2 Station description).

All Horizontal permanent control markers are to be identified by SERVICE HYDROGRAPHIQUE - CANADA - HYDROGRAPHIC SERVICE inscribed on the face of the marker tablets. The words should be spaced around and near the perimeter of the tablet face.

Each tablet should be identified using the National Geodetic Data Base (NGDB) numbering system which consists of 8 characters **MYRA9XYZ** where:

- "**M**" is a fixed letter which denotes that the station was established from the year 2000
- "**YR**" is the last two digits of the year the station was established (e.g. 87, 99, 01)
- "**A**" is the single digit number that identifies the province or territory (see Table below) where the control point is established
- "**9**" is the single digit number that identifies the organisation that established the station (CHS=9)
- "**XYZ**" is a three digit number (001 to 999) that identifies the specific marker identification (given by regional HDC offices)

For example, the station number 8739412 signifies: 87 = year of establishment; 3 = Ontario, 9 = CHS, and 412 = individual marker identification digits. Note that the first character "M" is left blank because the station was established prior to year 2000.

The horizontal control point number is to be stamped on the tablet with dies, across the central open area of the marker tablet face centred above "-CANADA"-" and read from the south facing north, the same as "-CANADA-".

ALL station markers are to be placed with "CANADA" to the south so that the markers are read from the south and the "twelve o'clock" position is oriented north.

Listing of Provinces and Territories and their identifiers for Horizontal Control:

Province	**A**
Newfoundland	0
Nova Scotia	1
Prince Edward Island	1
New Brunswick	1
Quebec	2
Ontario	3
Manitoba	4
Saskatchewan	5
Alberta	6
British Columbia	7
Yukon Territory	8
Northwest Territories and Nunavut	9

In cases where reference markers are placed to aid future location of the horizontal control point, they should be referenced and stamped Ref. l, Ref. 2, Ref. 3, etc. They must be described in relation to the actual station.

Each Region is assigned, on an annual basis, a block of numbers 001-999 to use for the XYZ digits.

Each Region will have the responsibility of assigning XYZ numbers for the following areas of work:

- Maritimes — Regional Office should assign numbers for Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick.
- Quebec — Regional Office for the province of Quebec.
- Central and Arctic — Regional Office for Ontario, Manitoba, Saskatchewan, Alberta, Yukon coast, NWT and Nunavut.
- Pacific — Regional Office for British Columbia and Yukon.

The numbers or blocks of numbers may be assigned from one region to another when it is necessary for a region to conduct surveys in areas under the responsibility of another region.

5.1.2 Station description

In order to help in the recovery of permanently marked stations, a clear description of each must be written. All control points must be described as specified in QMS documentation. The general area sketch should show the general location of the marker in relation to adjacent coastline, directions to other markers, etc. The detailed sketch should give distances from the survey marker to conspicuous features and objects so as to easily recover the control point. Photographs should also be taken (see § 6.13 Use of photographs) and included with the written description.

5.2 Vertical Datum

It will be necessary to recover or establish sounding datum in order to properly reduce the soundings to a low water datum (which can be defined as a level which the water level will seldom fall below during the navigation season).

It will also be necessary to recover or establish the datum of elevations in order to reference the elevations of objects (fixed aids and conspicuous objects) and clearances under aerial obstacles (bridges, power lines, etc.).

In tidal water:

- Soundings are reduced to Lower Low Water Large Tide (LLWLT)
- Elevations and clearances are reduced to Higher High Water Large Tide (HHWLT).

In non-tidal waters,

- Soundings, elevations and clearances are reduced to sounding datum.

In some cases vertical datum will have been previously established and it will only be necessary to verify the existing gauge or install a temporary gauge and set it to sounding datum by levelling it from existing bench marks.

In other cases it will be necessary to establish sounding datum in the survey area by water level transfer which involves obtaining simultaneous water level readings from a temporary gauge location and readings from an existing permanent gauge at a distant location.

Specific instructions should have been given by a Tides and Water level representative and included in the Survey Project Instructions.

5.2.1 Water level gauges and bench marks

The permanent water level gauges in the vicinity of the area to be surveyed must be verified to ensure that the water levels recorded are accurate. The existing bench marks and the water level staff in the vicinity must be leveled to ensure that they are stable and have not shifted in elevation. Any significant discrepancies should be reported to a CHS Tidal Officer before sounding operations start.

Temporary gauges, including water level staffs, should be installed and referenced to at least three permanently established bench marks. These bench marks should be referenced to sounding datum, CGVD28 (MSL), WGS84 or GRS80 ellipsoids.

For digital water level gauges, the methods and procedures set out in the owner's manuals should be followed.

All gauges, temporary and permanent, must be checked on a regular basis (daily if possible) to ensure that they are recording the correct water level readings.

All work is to be carried out using the methods, procedures and accuracies set out in the latest edition of the Canadian Tidal Manual so as to satisfy the standards established in the *CHS Standards for Hydrographic Surveys*.

5.2.2 Permanently marked vertical control points (e.g. bench marks)

Unless otherwise stated, all new bench marks are to be permanently established using a metal tablet stamped and identified using the numbering convention used by the National Geodetic Data Base.

All vertical bench mark tablets are to be identified by SERVICE HYDROGRAPHIQUE - CANADA - HYDROGRAPHIC SERVICE inscribed on the face of the marker tablets. The words should be spaced around and near the perimeter of the tablet face.

Each tablet should be identified using the National Geodetic Data Base (NGDB) numbering system which consists of 8 characters **MYRx9XYZ** where:

- "**M**" is a fixed letter which denotes that the station was established after the year 2000
- "**YR**" is the last two digits of the year the station was established (e.g. 87, 99, 01)

- **"x"** is the letter that identifies the province or territory (see Table below) where the control point is established
- "**9**" is the single digit number that identifies the organisation that established the station (CHS=9)
- "**XYZ**" is a three digit number (001 to 999) that identifies the specific marker identification (given by regional HDC offices)

For example, the station number 87L9412 signifies: 87 = year of establishment; L = Quebec, 9 = CHS, and 412 = individual marker identification digits. Note that the first character "M" is left blank because the station was established prior to year 2000.

The bench mark number is to be stamped on the tablet with dies, just below and parallel to the groove inscribed in the tablet face. The letters BM should be stamped and centred above the groove.

Listing of Provinces and Territories and their identifiers for Vertical Control (VC) - e.g. BM – Markers:

Province	**x**
Newfoundland	F
Nova Scotia	N
Prince Edward Island	P
New Brunswick	B
Quebec	L
Ontario	U
Manitoba	M
Saskatchewan	S
Alberta	A
British Columbia	C
Yukon Territory	Y
Northwest Territories	T
Nunavut	V

Each Region is assigned, on an annual basis, a block of numbers 001-999 to use for the XYZ digits.

Each Region will have the responsibility of assigning XYZ numbers for the following areas of work:

- Maritimes Regional Office should assign numbers for Newfoundland, Nova Scotia, Prince Edward Island and New Brunswick.
- Québec Regional Office for the province of Quebec.
- Central and Arctic Regional Office for Ontario and Manitoba, Saskatchewan, Alberta Northwest Territories, Nunavut and Yukon coast.
- Pacific Regional Office for British Columbia and Yukon.

The numbers or blocks of numbers may be assigned from one region to another when it is necessary for a region to conduct surveys in areas under the responsibility of another region.

5.2.3 Bench mark descriptions

In order to help in the recovery of bench marks, a clear description must be written and a horizontal position must be taken. A sketch should indicate the direction and distance between the BM and other prominent structures or features (see Canadian Tidal Manual, § 6.2.2 Benchmarks – descriptions). Photographs should also be taken (see § 6.13 Use of photographs) and included with the written description.

5.3 Positioning system

5.3.1 Real-time GPS method

Real-time differential GPS corrections can be provided by the CCG DGPS, WAAS or commercial networks. But in certain areas where the signal cannot be received or when higher accuracy is required, it may be necessary to install a temporary DGPS or RTK reference station. This temporary station must be installed on a permanently marked control point of sufficient accuracy required by the survey order.

5.3.2 Post-processing GPS method

Post-processed solutions can be obtained by utilizing techniques such as: Post-processed Kinematic (PPK), Precise Point Positioning (PPP), Inertially Aided PPK, etc.

5.3.3 Positioning Quality Assurance

Before collecting data, it may be necessary to verify the parameters and the accuracy obtained by the positioning system. This could be achieved by doing different tests (reference bottom surface, comparison with independent systems, control points, etc.).

The positioning system must be monitored to ensure that the quality of horizontal positioning falls within specifications. GPS software provides monitoring capabilities which can be done on the vessel in real time. Most systems show and log residuals, number of satellites, Dilution Of Precision (DOP), age of DGPS corrections, etc. As long as the Hydrographer monitors this information and acts when accuracy conditions are not met, this should be sufficient. The position of the reference station should be initially verified against a known control point, and a check of the vessel's system, relative to a point surveyed on a wharf or accessible feature, should be done.

5.4 Final check

A final check should be performed to ensure that all equipment is working properly and that the logging systems are correctly logging positions, depths and in some cases water level values and any other data. The positioning system should be checked on a regular basis.

6 Data acquisition and processing

Data acquisition involves the proper collecting and recording of information. Care must be taken so that all written information (descriptions, sketches, calculations, etc.) be entirely understandable to anyone who may be required to process or verify any of the data at a later date.

One of the main requirements of data processing is to be able to ensure or qualify that you are in fact collecting what you say you are collecting and to verify that what is being acquired meets the standards specified for the survey. If a product is to be derived, data processing may be necessary to condition acquired data to meet the product specifications.

Ideally, all acquired data should be processed, coded and validated as the survey progresses. All data shall be processed according to the practices described in the regional Hydrographic Survey QMS procedures in use.

All physical records are to be properly filed and kept in a safe place.

Backups must be made of the data contained in the various computers used for processing. The medium used to store this information should be kept in a different location than the processing room.

Measures should be in place to ensure that all original survey data be taken to a safe place should the processing room aboard a ship or on shore be threatened by fire, flood or other damage.

6.1 Bathymetry

<u>Acquisition</u>

Bathymetric data shall be obtained using equipment capable of attaining the accuracy and coverage defined for each survey (See Table 1 of the *CHS Standards for Hydrographic Surveys* and *CUBE Bathymetric data Processing and Analysis (CHS February 2012)*). For each typical area, the coverage and line spacing shall be in accordance with those specified in the table. In some cases, it may not be appropriate or desirable to follow these recommendations. It is then possible to attain other accuracies or coverage type. The resultant accuracies must then be computed and documented.

The CHS uses a variety of echo sounders to obtain depths. All echo sounders must be properly calibrated in the field before being used to acquire data. Evidence that field calibration procedures were followed must be filed with sounding notes linked to the survey project. During data acquisition, care must be taken to ensure that the true bottom is being portrayed.

In order to systematically sound a specific area, it will be necessary to run a series of parallel lines and log depths obtained from the echo sounder. This work can be done using single beam echo sounders or, if striving for full bottom search, done using multibeam or multi-transducer systems, or with a single beam echosounder augmented with a side scan sonar system.

To attain the accuracies for each survey, all error sources such as: accuracy of positioning, sounder accuracy, sound speed, attitude sensor, water level measurement, distance from tide gauges, etc. shall be taken into account while computing the horizontal and vertical accuracies (refer 4.2.1 Total Propagated Uncertainty (TPU)), as well as the feature detection capability.

To attain the accuracy and detect the targets as specified in Table 1, it is necessary to adjust the data acquisition methodology such as sounder parameters, line overlapping and vessel speed. When determining the speed at which to conduct sounding, the hydrographer must consider the depth of water being sounded, the pulse repetition rate of the sounder and the sounder characteristics. High speed combined with a slow pulse repetition rate may lead to small but significant features being missed, particularly in shallow water. The hydrographer is to adjust the speed so that for the nadir beam of the echo sounder, such that a target as indicated in Table 1 receives a minimum of five pulses of sound from the echo sounder.

During all sounding operations, the following information should be recorded:

- general survey area, project, etc.,
- date,
- vessel name,
- operator (s),
- type of sounding line (regular, check line, shoal exam),
- sounding equipment (positioning, sounder, attitude sensor, etc.),
- initial sounder settings and setting changes (include dates),
- sound velocity profile being used.
- weather conditions, problems, Beaufort Scale value, other vessel traffic (which might impact the data i.e. vessel wake, water level variation), other particularities, etc.

Data processing

All depths and associated features obtained during the survey should be processed and validated as the survey progresses. While validating the data, care must be taken to ensure that the true bottom has been depicted.

A comparison of edited sounding data obtained from regular sounding lines, check lines and shoal exams must be done to resolve any discrepancies that may arise during the survey.

This comparison is also necessary to ensure that, before leaving a survey area, sufficient sounding detail, coverage, and bottom search have been obtained and shown, verified to substantiate the existence or non-existence of shoals and other hazards, and to enable accurate and detailed portrayal of the contours around shoals, critical depths, channels, anchorages, banks, etc. and the detailed portrayal of the bottom. All dangers, shoals and hazards charted on the existing chart(s) of the area being surveyed must be verified prior to leaving the survey area.

Bathymetric data shall be processed to meet or exceed the accuracies defined for the survey (see Table 1 of the CHS *Standards for Hydrographic Surveys* and *CUBE Bathymetric data Processing and Analysis (CHS February 2012)*).

Evidence that field calibration procedures were followed must be found in the files and documents linked to the survey. This includes the calibration of the echo sounder, positioning system, tide gauges, etc.

6.1.1 Corrections for sound speed

Acquisition

A majority of bathymetric data are obtained using acoustic echo sounders where depths are derived from time measurements of an acoustic pulse traveling in a column of water. The velocity of the sound wave in the water column will vary depending on a series of factors, temperature and salinity being the major ones. The depths obtained must be corrected for this variation in sound speed throughout the sounding area in order to compute true depths. A MultiBeam Echo Sounder (MBES) system must have a Sound Velocity Profile (SVP) applied while a Single Beam Echo Sounder (SBES) system or a Multi-transducer (MTES) system may have either a sound speed profile, a single sound speed, or a bar check correction table applied.

Data Processing

Correcting depths for the variation in sound speed throughout the water column may be performed during post processing. A proper record or log should be kept to identify the SVP corrections applied.

Systems employing a MTES or SBES that have a single sound speed set during acquisition will require either bar check or SVP corrections to be applied in post processing, if not already applied during acquisition.

6.1.1.1 Bar check (for MBES, MTES and SBES systems)

Acquisition

A “Bar Check” is the field procedure for calibrating the MBES, MTES and SBES and involves a metal cone or plate device lowered to a maximum depth of 60 meters and recording the true depth versus the measured depth and compiling a depth correction table that will be used later to correct the measured depths.

A bar check can be conducted in one of two methods. In one method, a shallow bar check is performed to verify vessel draft supplemented by a deeper bar check, obtained up to the maximum depth acquired during the daily operation, to ascertain a harmonic speed of sound for the water column. If the bar check cannot cover the depths recorded, then appropriate calibration devices such as velocimeters, etc. should be used.

The other method also includes a shallow bar check to verify vessel draft (deeper bar check may be conducted as a rough check to verify that the system is working at depth) and a default value is set for the harmonic speed of sound. In the latter method, an accurate sound velocity profile (see § 6.1.1.2) is acquired and applied, during post processing, to the sounding record to adjust the default value of the speed of sound at a given depth.

A bar check should be performed daily or more often as local conditions dictate or when moving location.

Data Processing

If the SVP is not entered into the digital echo sounder, the corrections should be applied at the processing stage of the bathymetric data. A sound velocity profile can be derived and applied from the values obtained during a bar check. The corrections are applied during post processing.

Confirm that the bar check provides information to the maximum depth obtained during the daily operation. If a bar check cannot cover the depths recorded, then corrections obtained from a velocimeter or CTD should be applied.

6.1.1.2 Sound speed profiling (for MTES and SBES systems; mandatory for MBES)

Acquisition

When determining the speed of sound in the working area using a sound velocity profiler (a velocimeter or CTD), the probe is lowered to the maximum depth of the site or at a depth at which the acceptably uniform speed of sound is obtained. The resultant cast from a velocimeter or CTD will provide a table listing the speed of sound at recorded depth intervals. The results obtained from the sound speed cast should be entered directly into a multibeam echo sounder if the particular system has that capability. Data acquired with a MBES, MTES and SBES may have the sound speed corrections applied during post processing.

To adequately ensure the survey has minimized the temporal and spatial uncertainty with respect to the water column, sound velocity profiles should be collected as often as operationally possible, and spatially throughout the survey area while also considering seabed relief and other factors that would affect the local oceanography.

The results of these casts should be checked against a second probe or another system in order to verify that the sound speed is correctly being measured. These checks should be performed at least once a week or as the conditions permit.

A proper record or log should be kept to identify the SVP casts acquired during the project including their time, date and their geographical locations. Sound speed profilers should be capable of measuring sound speed to a precision of at least 0.1m / s.

Data Processing

Profile location and time acquired should be recorded in the header of the SVP files in order to apply SVP corrections in post processing.

Profiles should be edited for anomalies or spikes in the data. When applying SVP corrections in post processing, ensure that the data within the profile contains information for depths up to or greater than the soundings being corrected. If required, an SVP editor may extend the profile to depths greater that the soundings being corrected.

6.1.2 Static and dynamic draft

Acquisition

The draft of a vessel may vary on a daily basis from a few centimeters to some decimeters depending on water and fuel consumption, the number of people onboard, equipment, etc. The echo sounders should be adjusted so that the static transducer draft will be applied to measured depths. Changes in transducer draft will have to be monitored during sounding operations and during echo sounder calibration. This value can be set by adjusting the transmission line of the echo sounder (MBES, MTES or SBES) while performing a bar or cone check with the bar set under the transducer at 2 or 3 meters below the surface of the water. Record and apply any horizontal offsets from bar to transducer due to point of displacement and for a vertical offset caused by current.

Draft can also be obtained by measuring the distance between the water surface and the face of the transducer or by using RTK GPS heights to determine the dynamic draft. All vessels are subject to squat and settlement. At certain speeds, the stern of the launch may sink or squat into the water, thus changing the angle and draft of the transducer. This may be less appreciable if the transducer is located near amidships. The use of a speed sensor to measure the Speed Through the Water (STW) is recommended in order to apply adequate dynamic draft to the data. Settlement is the general lowering in level of a moving vessel, relative to what its level would be were it motionless. Settlement is due to the regional depression of the surface of the water in which the vessel moves.

Tests should be performed at various speeds over flat bottom, preferably before the sounding platforms leave for the field. RTK GPS or orthometric leveling heights measured at the transducer location, at rest and at speed increments of one knot (through water), can be used to derive a squat/settlement table. Hydrographers should also be aware of long period changes in transducer draft attributed to vessel fuel consumption or ballasting. Any discrepancies should be noted and corrections should be applied during the acquisition or at the processing stage.

Data Processing

Static and dynamic draft values are to be applied in post processing when they cannot be applied during acquisition. Dynamic draft tables usually take the form of a listing of draft changes versus speed of vessel. A record of applied values is to be kept with the raw data set.

6.1.3 Heave, pitch, roll and yaw

Acquisition

Sounding platforms float on or below the water surface and the position and attitude of onboard sensors will therefore be affected by changes in heading, speed, wave and current action. Position and attitude relative to the platform are described by a platform coordinate system, defined in terms of the direction of the platform and the ground. The x-axis is relative to the centerline of the platform and is positive to the bow. The y-axis is perpendicular to the x and is positive to starboard. The z-axis points to the nadir direction, and is positive downward. Roll is the side to side rotation about the x-axis, pitch is the forward and backward rotation about the y-axis, yaw is the horizontal rotation about the z-axis and heave is the up and down motion along the z-axis.

These parameters are measured using an attitude sensor and are logged and used to correct the bathymetry in real time.

For sounding launches not equipped with attitude sensors, the only practical method of minimizing vessel motion is to set a limit on the maximum allowable sea state under which sounding operations can be conducted.

For MBES or MTES surveys, a properly calibrated MRU (Motion Reference Unit) is mandatory.

Data Processing

Heave, pitch, roll and yaw are logged during the acquisition stage and are to be checked and processed to meet the specifications of the systems used and for the order of the survey specified. Spikes and anomalies within the attitude and heading sensor data should be corrected or removed.

Where consistent anomalies are found a system re-calibration may be required before acquisition continues.

Filtered, latent heave data (e.g. True Heave™), if acquired, is to be applied during post processing. These files are to be referenced with the corresponding raw data files.

6.1.4 Positioning

Acquisition

The positioning system used for sounding operations should be checked on a regular basis. Confidence checks should be done prior to daily sounding operations, after equipment replacement or repair or whenever there is any doubt in the positioning system's performance. The use of mission planning software is recommended. When possible, compare the position obtained against a known position (wharf corner, fixed object, etc.) or by comparing the position against an independent positioning system (survey platform's positioning system, a second independent positioning system, etc.).

Data Processing

Positioning is to be reviewed, and spikes or anomalies not falling within survey specifications must be corrected or removed. When possible, compare the position obtained against a known position (wharf corner, fixed object, etc.) or by comparing the position against the data collected with an independent positioning system (survey platform's positioning system, a second independent positioning system, etc.).

6.1.5 Single beam work

Acquisition

This method consists of acquiring depths using an echo sounder interfaced with a single beam transducer normally mounted in the hull of the sounding platform. Depths obtained from the echo sounder and their corresponding positions obtained from a navigation source are time-tagged and logged onto a computer using a hydrographic navigation software package which, among other things, also allows the launch to be conned along predetermined tracks.

At the beginning of each sounding day, a bar check should to be performed to verify or adjust transducer draft and to acquire values in order to correct the soundings for the varying speed of sound in water; a bar check should also be done at the end of the day to ensure that the sounding parameters have not changed. Bar checks should also be performed if any echo sounder components have been changed or if changes in sound speed and transducer draft are suspected.

Speed of sound corrections may also be obtained by sound speed probe. The results can be logged in the acquisition software and duly noted so that the results may be applied in post processing.

The sounding line pattern should be set so that the lines are run as perpendicular as possible to the natural bathymetric contours of the sea floor. The line spacing should be chosen to conform to the values contained in Table 1 of the *CHS Standards for Hydrographic Surveys*. In the vicinity of wharves, lines are to be run as perpendicular as possible to the wharf face. Additional lines should be run along the wharf face.

In most cases, based on water depth, the echo sounder used should be operated at the highest pulse rate possible. The speed of the vessel should be such that a bottom target receives enough pulses to detect a specific target size as specified for the different Survey Order in Table 1 of the *CHS Standards for Hydrographic Surveys* (generally, 5 pulses (or pings) of sound on a target should ensure detection of most of the significant features).

Data Processing

Applicable regional Hydrographic Survey QMS procedures must be employed. An outline of the steps required in post processing single beam work entails applying: bar check or, SVP data, attitude sensor data and navigation corrections, dynamic draft tables and then removing noise or other anomalies from the sounding data. In most cases where a dual frequency system is used, the highest frequency recorded with the echo sounder shall be selected as the primary depth record when possible and used when post processing depths. The soundings are to be attributed according to the *CHS Product Specification and Coding Guide (PSCG)*.

Check lines are to be compared against the regular sounding pattern and used to verify that the acquisition project is meeting the specified survey order. Sounding line patterns and spacing should also be reviewed for conformance with the values prescribed in Table 1 of the *CHS Standards for Hydrographic Surveys.*

According to Survey Order in Table 1 of the *CHS Standards for Hydrographic Surveys*, review the raw data to ensure that the bottom target receives enough pulses as specified by the specifications.

6.1.6 Multi-transducer work

Acquisition

This method consists of acquiring depths from a series of transducers mounted in the hull and along retractable booms, which when lowered to the water surface are perpendicular to the ship's centerline. Multi-transducer sounding systems are run using sophisticated computer software systems that record set-up and corrections parameters as well as attitude sensor data so that corrected depths, positions and other required information may be logged.

The system needs to be calibrated before sounding operations can begin. Each transducer array may obtain a different value on the same target. This means that every transducer must be measured, calibrated and compensated for. A series of very close lines on a flat bottom should be run to ensure a consistent bottom measurement from all the transducers. This calibration should be performed at least twice a year or when any changes in the configuration of the system are suspected or occur.

On a daily basis, only one transducer is to be used to verify sound speed using a bar check and all other transducers are to be set to this reference transducer.

The speed of sound through the water column can be measured using sound velocity profilers, the results of which are entered into the sounding system's processing unit.

The line spacing will depend on the coverage required. The necessary coverage should be specified in the Field Survey Instructions.

A multi-transducer system requires an attitude sensor so the depths obtained from all the transducers can be calculated at their true position. Vessel attitude relative to the X, Y and Z platform coordinate system must be measured. Yaw, will affect the position of the soundings when the sounding platform deviates from its centre line. Any defects in the platform attitude measurements shall be detected during the acquisition stage. As it is difficult to correct this kind or error, all the affected lines must be resurveyed.

Another parameter, which might have to be factored in, is the fact that the vessel draft may decrease as fuel is consumed during sounding operations. In this case, changes in draft will have to be monitored over time. A good knowledge of the platform's draft variation is essential. A draft variation table must be established for each platforms and applied either during the acquisition or the processing.

Data Processing

Applicable regional Hydrographic Survey QMS procedures must be observed. An outline of the steps required in post processing multi-transducer work entails:

- review and correct attitude sensor data and navigation,
- apply draft corrections, dynamic draft,
- apply latent heave data (e.g. TrueHeave™),
- apply SVP corrections,
- attribute TPU values,
- apply water level reductions, and
- remove noise or other anomalies from the sounding data.

Sufficient coverage and sounding density should be ensured to meet the specified survey order. The soundings are to be attributed according to the PSCG.

Check lines are to be compared against the regular sounding pattern and used to verify that the acquisition project is meeting the specified survey order. Check line patterns and spacing should also be reviewed for conformance with the values prescribed in the Standards. (See the *CHS Standards for Hydrographic Surveys* § 7.4).

6.1.7 Multibeam work

Acquisition

Multibeam work consists of acquiring depths from an array of narrow beams formed from a single or dual transducer system. Normally this system is hull-mounted, however pole-mounted systems are also common.

Depth data must be corrected for vessel attitude relative to the X, Y and Z platform coordinate system.

Sounding lines should be run parallel, as much as possible, to the natural bathymetric contours of the sea floor. The line spacing and survey methodology will depend on the required coverage. See *CUBE Bathymetric data Processing and Analysis (CHS February 2012)*.

Survey instructions require that the multibeam backscatter be logged and may be required to be rendered at the end of the survey.

Data Processing

Applicable regional Hydrographic Survey QMS procedures must be observed. Detailed procedure can be found in *CUBE Bathymetric data Processing and Analysis (CHS February 2012)*.

Check lines are to be compared against the regular sounding pattern and used to verify that the acquisition project is meeting the specified survey order. Check line patterns and spacing should also be reviewed for conformance with the values prescribed in the Standards. (See the *CHS Standards for Hydrographic Surveys* § 7.4).

6.1.8 Side scan sonar work

Acquisition

Side scan systems are generally used to satisfy the full bottom search requirement when conducting single beam surveys. However, they may be employed in multibeam or multi-transducer surveys when a higher resolution of potential hazards to navigation is required. Spacing of the survey lines must be sufficient to ensure the full insonification of the bottom.

Side scan sonar is best suited for searching for obstructions such as wrecks, where small features may be present within the water column, like mast structures, suspended buoys and other pinnacle-like hazards to navigation. The high-resolution functionality of side scan sonar is most suitable for sensing small targets, which may not otherwise be detectable by multibeam or multi-transducer systems.

Hull or pole mounted systems are recommended as heave, pitch, roll and yaw can be collected with an attitude sensor and values applied to the sounding data.

Although the heights of targets may be approximated, side scan sonar should not be used for depth determination but as a reconnaissance tool to seek out targets and seabed anomalies requiring more detailed and accurate investigation by survey echo sounders.

Data Processing

Applicable regional Hydrographic Survey QMS procedures must be observed. Care must be taken in the interpretation of side scan records in order to identify true targets from anomalies such as surface returns (sea clutter, waves and vessel wakes), multiple echoes, cross talk or marine animals. Vessel attitude corrections need to be applied to data acquired from hull-mounted systems in order to create a clean digital mosaic of the side scan records.

Where side scan is employed within a single beam survey to detect features between sounding lines, any features found should be recorded and communicated to the acquisition team for further investigation.

6.1.9 Interferometric work

Acquisition

Interferometric sonar (IFMS) is a technology which provides significant advantages when sounding in shallow water. Unlike multibeam, IFMS systems are not beam-forming but measure depths through the use of exactly spaced phase differencing transducer elements which measure the phase offsets of acoustic returns. This is converted into the angles from which the return was received and is used in combination with range based on two way time travel to calculate the positions on the seafloor relative to the transducer. IFMS provides both high density bathymetry and side-scan imagery which enables advanced display and quality control capability with seafloor datasets.

The major advantage of IFMS is that in shallow water, it covers a much larger swath than a comparable multibeam system; for example, a typical IFMS swath could be 12 times the water depth as compared to 4 times for a typical MBES. This could significantly reduce the time survey crews spend in dangerous inshore waters which would considerably increase production. The disadvantages are limited sounding depth due to transducers being required to be mounted at an angle deflected from the vertical; typically by about 30°. IFMS systems have had issues in the past resulting in noisy data mostly attributed to ambient and internal noise, as well as difficulty resolving multiple angles of arrival. Recent improvements in electronics and algorithm advancements along with the use of increased numbers of elements have improved the precision of this technology.

Sounding with IFMS follows the same principles as multibeam in that depth data must be corrected for vessel attitude relative to the X, Y and Z platform coordinate system

Sounding lines shall be run parallel, as much as possible, to the natural bathymetric contours of the sea floor. The line spacing will depend on the required coverage (100%, 200% or other).

Field Survey Instructions require that the IFMS backscatter be logged and may be required to be rendered at the end of the survey.

Data Processing

Applicable regional Hydrographic Survey QMS procedures must be observed. An outline of the steps required in post processing IFMS work entails:

- review and correct attitude sensor data and navigation,
- apply draft corrections, dynamic draft,
- filter latent heave data (e.g. TrueHeave™),
- apply SVP corrections,
- attribute TPU values,
- apply water level reductions, and
- remove noise or other anomalies from the sounding data.

Sufficient coverage and sounding density should be ensured to meet the specified survey order. The soundings are to be attributed according to digital coding guides.

Check lines are to be compared against the regular sounding pattern and used to verify that the acquisition project is meeting the specified survey order. Check line patterns and spacing should also be reviewed for conformance with the values prescribed in the Standards. (See the Standards for Hydrographic Surveys § 7.4).

6.1.10 Airborne (LiDAR) work

Acquisition

Airborne system such as LiDAR (*Light Detection And Ranging*) is an optical remote sensing technology which measures properties of scattered light to find range and/or other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses. Like the similar radar technology, which uses radio waves instead of light, the range to an object is determined by measuring the time delay between transmission of a pulse and detection of the reflected signal. Depth range is dependent upon water clarity, and can vary from 0m to 40m. In the ocean, turbidity, breaking waves and kelp can render LiDAR measurements difficult to impossible. Low level (ground) fog and the presence of ice will also prevent LiDAR measurements. Poor depth ranges occur where there is abundant sediment or other suspended material (turbidity) in the water column. Typically 2-3X secchi dish readings are expected.

Low ceiling heights will restrict bathymetric coverage and often prevent flight operations. Attention must be given to planning Airborne LiDAR surveys around known seasons of inclement weather, the presence of ice and high sediment load (turbidity). Satellite remote sensing imagery such as MODIS provides an excellent means for pre-survey and in-situ analysis of turbidity conditions.

An area of overlap between acoustic surveys and the LiDAR survey is preferable.

To calibrate the depth measurements, ideally full bottom coverage groundtruthed patches should be surveyed in the LiDAR survey area. Such groundtruth must cover the depth range of the LiDAR survey at different locations. The positional accuracy of the system can also be checked in-situ against precisely positioned terrestrial features such as buildings.

Data Processing

The Canadian Hydrographic Service doesn't own such a system, and this type of survey is normally done under contract to the private sector. A CHS representative must be present during the acquisition to supervise the contract and optimize the operations in conjunction with the contracted company. The processing and verification process is normally done by the contracted company and CHS involvement is minimal. A final report should be submitted with the data and must include all pertinent information and metadata pertaining to the data.

Upon reception of the data, thorough quality controls of the data are necessary and consist of validating the survey methodology (positioning, calibration, etc.), comparing the resulting depths against the groundtruth and other data available in the survey area, and validating the water level values applied. Any anomalies should be reported to the contractor for revision.

6.1.11 Spot soundings

Acquisition

Spot soundings may be conducted with a graduated rod, a lead line, or with a single beam transducer sounding through ice.

When the depth of water is measured with a lead line or other type of graduated rod, the depth as well as the position, date and time at which the depth has been taken must be recorded. The results must be manually entered either in the logging system or in the main processing system.

Through-ice sounding entails clearing the ice of snow, lubricating the ice surface and transducer face, placing the face of the transducer on the ice surface and recording depths for the time required to obtain an adequate redundancy of depths. Generally, sonar frequencies of <50kHz will yield results.

Data Processing

The depth values obtained from a graduated rod or lead line should be corrected for tide.

Depths acquired with the through-ice technique are to be corrected for ice thickness, tide and sound speed. The difference in sound speed between ice and water mediums must be accounted for. Noise or other anomalies from the sounding data should be removed and one representative sounding must be selected for each spot.

All soundings are to be attributed according to the PSCG.

6.1.12 Shoal examination

Acquisition

A shoal is a distinct rise of the seabed, which could be a hazard to navigation. A 10% rise in the seabed depending on the depth of the surrounding area may indicate the existence of a shoal or some other serious hazard to surface navigation and should therefore be investigated. Consideration must be made for the type of vessel traffic expected. When taking into account the draft of some modern tankers, any isolated indication of shoaling of less than 50 meters may be of sufficient importance to warrant an examination for a possible shoal. In some instances, it may be necessary to further develop shoaling areas deeper than 50 meters.

Potential shoals are, for the most part, identified by analyzing the depths obtained from regular soundings or historic data. It is therefore imperative that the processing of the bathymetric data be kept up to date and be available for shoal identification. In other cases, information pertaining to shoals and other hazards may come from various reports and local knowledge.

Whenever there is any indication of a shoal, or if a shoal is suspected, additional investigation must be done to determine the position and the least depth.

If single beam systems are used, an adequate shoal examination shall be conducted to identify the least depth, then a series of short lines (a minimum of 3) shall be run in either a star or grid pattern over that least depth. Lead line depth verification may be required if weeds or kelp are present, making the sounder’s data non-conclusive. A bottom sample should be recorded and can be acquired with a bottom grab or an armed lead line.

When a multi-transducer or multibeam system is used to investigate shoals, the ping density and the vessel speed should be set such that the chances of missing the shoal is reduced and that there is sufficient overlapping soundings.

Data Processing

When post processing sounding data from a shoal exam: ensure that adequate coverage is obtained to meet survey specifications, the least depth is identified and the recorded bottom classification is assigned to that sounding. Any potential new shoals should be identified and forwarded to the acquisition team for further investigation. All soundings are to be attributed according to the PSCG.

6.1.13 Check lines

Acquisition

As a means to validate a hydrographic survey, check lines should be run perpendicular to the regular sounding lines. The check lines should be spaced according to the specifications stated in the *CHS Standards for Hydrographic surveys*.

The information obtained from these check lines will confirm the precision of the positioning system, the depth measurement and corrections applied to depths such as sound velocity, draft and tide adjustments. These lines should be run on a different day (when possible) than the regular sounding or LiDAR acquisition lines and if possible using a different survey vessel.

Data Processing

Verify that the check lines are spaced according to the specifications stated in the *CHS Standards for Hydrographic Surveys* (§ 7.4). The difference in the depths between the regular sounding lines and the check lines must fall within the depth accuracy limits (95% of the time) of the Survey Order as specified in the Field Survey Instructions (the various survey orders are found in Table 1 of the *CHS Standards for Hydrographic Surveys*).

The comparison of the check line soundings over a DTM generated from the regular lines on a relatively flat bottom is a good way to obtain difference values. Data processing software, such as CARIS HIPS and SIPS, offer automated tools to generate such statistics.

When discrepancies exceed the permissible amount, the soundings must be carefully examined to determine the possible sources of error: tide or water level, sea state, beam angle, position errors, calibration errors, corrections used etc. Once the sources of error have been determined, corrective action must be taken. This work should be done as soon as possible as the survey progresses. In some cases, it may be necessary to resurvey the portion of the area that is subject to disagreement with the check lines.

6.1.14 Track and reconnaissance survey

Acquisition

In some cases, it may be required to run sounding lines in uncharted waters in order to obtain valuable depth data in advance of regular surveys or provide additional soundings in sparsely sounded areas.

Depths obtained for these purposes should be obtained and processed in the same fashion as a standard survey.

Data Processing

Depths obtained for these purposes should be obtained and processed in the same fashion as a standard survey. (See § 6.1.5 – 6.1.7 inclusive.)

6.1.15 Reducing soundings to datum from water level survey

Acquisition

All soundings must be reduced to a sounding datum as specified in the survey project instructions (also see §5.2 Vertical Datum). The water levels used to reduce the soundings may be acquired by readings from a permanent water level gauge, a temporary water level gauge, a water level staff or by leveling to the waterline from known benchmarks. In some cases, it might be necessary to use tidal predictions to reduce the soundings to a known datum. In this situation, it is advisable to verify the local predictions by leveling to the waterline from benchmarks at the station used to produce the predictions.

All water level readings, whether they are obtained manually or telemetrically, should be measured with instruments capable of attaining the required accuracy as specified in the *CHS Standards for Hydrographic Surveys*.

The water level gauges should be checked daily against readings obtained from a stable water level staff or by leveling from known benchmarks.

Data Processing

Corrections to the water levels should be applied before using them to reduce soundings. Procedures as outlined in the *Canadian Tidal Manual* should be followed.

The final datasets must contain a note describing the method used to reduce the soundings and include a reference elevation to at least one benchmark, a reference port in the case of tidal predictions or the reference port and number of the co-tidal chart used.

A record of the water levels used to reduce the soundings should be included with the sounding notes.

6.1.15.1 Reducing soundings to datum from Kinematic) GPS Surveys

Acquisition

Kinematic GPS positioning is capable of yielding sub-decimeter accuracy on a moving survey platform – both horizontally and vertically. This technology can provide real-time or post-processed elevations of survey vessels, which can be related to the local chart datum surface. If adequate attitude compensation equipment is used, and an accurate water level datum model, such as separation table from ellipsoid to chart datum, have been developed, accurate real-time or post-processed water level reductions can be directly obtained without observing water levels.

High quality geodetic GPS receivers capable of processing the necessary information are required in order to use this method. The height from the GPS ship antenna to the water line, and consequently to the transducer draft set on the echo sounder, must be accurately measured. The height of the reference station antenna to the horizontal control point must also be accurately measured. The elevation of the horizontal control point above local sounding datum must also be accurately determined.

This method of obtaining reduced depths is usually applicable to a specific area where tidal information is accurate and has been recorded for long periods allowing the generation of accurate tidal models.

Specific Field Survey Instructions will be required before leaving for the field.

Data Processing

When the real time water levels are not applied directly to soundings it will be necessary, in post-processing, to run software equipped with algorithms capable of extracting, filtering and applying water level corrections to the soundings. See *CUBE Bathymetric data Processing and Analysis (CHS February 2012)*.

6.2 Navigational aids

Acquisition

If navigational aids (fixed or floating) have to be observed, the position and a detailed description must be taken. Note that this task is not required for aids entered in SIPA, unless requested by the Canadian Coast Guard (CCG).

Data Processing

Unless otherwise stated, it will be necessary to verify the position of all fixed and floating aids established and maintained by Federal Government (if requested by the CCG) or private agencies found in the area of work and report the positions obtained to the regional CCG offices for inclusion in the CCG database (SIPA). It is a good practice to submit coordinates to Provincial Geodetic Agencies for inclusion in their database.

Survey positions and heights (where applicable) of fixed or floating aids according to *CHS Standards for Hydrographic Surveys* and describe their characteristics. Information is to be tabulated according to a format sufficient for charting and CCG applications.

The position and characteristics of these fixed and floating aids must be compared with values published in SIPA and the List of Lights (if required). If they do not correspond with SIPA and the List of Lights and the differences are such that they may be considered hazardous for navigation, they must be reported to CCG - see § 9.1 Reporting Dangers. If the differences are not considered to be dangerous to navigation they must still be reported to the CHS Regional Director and to the Coast Guard offices.

6.2.1 Fixed aids

Acquisition

A fixed aid can be defined as any stationary man-made structure erected for navigational purposes (day beacon, lighthouse, light structure including range lights, sector light, etc.) and must be positioned to the accuracy mentioned in the *CHS Standards for Hydrographic Surveys*.

Private fixed aids of navigational significance should also be positioned whenever possible.

Fixed aids must be described using the CHS Fixed Aid Tabulation (FAT) form which will eventually be submitted to CCG for their records (see § 8 Data rendering and submission). The description shall include the geodetic position, the elevation, the height of the light structure to the ground, the height of the structure from the ground to the vane (focal height), sufficient to code mandatory attribution per PSCG. Color photographs (analogue or digital) of the fixed aid should be taken and filed.

The elevations of fixed aids must be obtained (see § 6.7 Elevations).

Data Processing

The processing entails to calculate the position of the fixed aid as per regional Hydrographic Survey QMS procedures. The CHS FAT form should be completed.

The light history should be investigated to determine if the light has been previously positioned, has moved or been altered since the previous survey, and whether the structure is the same type as shown in the List of Lights. Check if the light is in the same position, relative to the shoreline, as shown on the largest scale chart.

6.2.2 Floating aids

Acquisition

Private floating aids not included in SIPA should be positioned and described. The agencies or organizations responsible for the maintenance of the private floating aid should be noted.

Floating aids must be described (shape, colour, light characters, letters and numbers, etc.) and any significant feature noted (whistle, bell, horn, radar reflector, etc.) sufficient to code mandatory attribution per PSCG. Colour photographs (analogue or digital) should be taken.

Data Processing

The position of CCG and private floating aids (from the SIPA database) should be verified to the accuracy given for the specified survey order as found in Table 2 of the *CHS Standards for Hydrographic Surveys.*

The Color photographs (analogue or digital) taken should be filed.

6.2.3 Ranges

Acquisition

In addition to being positioned to the accuracy mentioned in the *CHS Standards for Hydrographic Surveys*, the true bearing (geodetic azimuth from seaward) of the range line must also be determined. This is done by drifting across the range line approximately at right angles and at several locations along the usable length of the range. Good fixes (positions) must be obtained when the beacons are exactly in line. The azimuth from seaward shall be determined by an average of the geodetic inverses computed between the visual "drift" fix positions and the position of the front beacon.

Survey the usable portion of the range line, i.e. visibility and depths. Detailed soundings must be taken along and adjacent to range lines in order to validate the depths available. This sounding coverage should be designed so as to ensure that all hazards within the navigable limits of the range line are detected, examined and verified. The anticipated draft, size and maneuvering ability of the largest vessel likely to navigate the range should be considered in determining the extent and detail of the survey.

Where possible, the soundings should be acquired using a multi-transducer or multibeam system according to standards prescribed in Exclusive or Special Order surveys (Table 1 of the *CHS Standards for Hydrographic Surveys*).

Less critical range lines can be surveyed using single beam echo sounders. A minimum of 3 sounding lines should be run, one along the center line of the range line and one on each side of the center line. Additional parallel lines and checklines must be sounded if the depths along the range are suspect or do not agree with charted depths. This may necessitate a full bottom search of the range.

Data Processing

In addition to surveying the position of the fixed light structures (see § 6.2.1 Fixed Aids) that make up a range line, the true bearing (geodetic azimuth from seaward) of the range line must be computed and checked against the published value.

Inverses computed from the various obtained positions and the Front Range light will yield a geodetic azimuth – statistical means can be used to determine the average azimuth, which should then be compared to the published value. The maximum allowable difference between the theoretical and drift azimuths is given in Table 2 of the *CHS Standards for Hydrographic Surveys*.

Verify the least depth available by processing the soundings taken along and adjacent to range lines. The anticipated draft, size and sea room required for the largest vessel likely to use the range should be considered when determining the extent along ranges to which the verification and examination of hazards and shallower depths are to be carried out.

To process multi-transducer or multibeam data, see § 6.1.6 and 6.1.7.

When single beam echo sounders are used, verify that a minimum of 3 sounding lines have been run, one along the centre line of the range line and one on each side of the centre line. Report to CCG and the Regional Director if the depths along the range are suspect or do not agree with charted depths. Additional parallel sounding lines may be required.

A comprehensive comparison with the charted depths must be made and all discrepancies (in azimuth or depths along the range line) shall be verified and reported. If any discrepancies are found, the procedure described in § 9.1 Reporting Dangers should be followed.

6.2.4 Sector lights

Acquisition

Sector lights separate zones where it is safe to navigate (usually a white light) from zones which are unsafe when the vessel has gone too far to starboard or port (red and green lights respectively). On a chart, the various navigation zones are separated by lines drawn according to the true bearing of each sector line limit.

The true bearing of the various sector lines must be determined and checked by drifting across the limit between two zones and obtaining a series of positions which can then be used to compute the bearing of the various limits (see § 6.2.3 Ranges).

Data Processing

In addition to surveying the position, the true bearing of the various sector lines must be determined and checked from the series of positions taken (see § 6.2.3 Ranges).

6.3 Wrecks and obstructions

It might be necessary to search for wrecks and obstructions using information, which may have been obtained through Mariner reports, local authorities or found on documents obtained through the Navigable Waters Protection Act or other sources.

In some circumstances, care should be taken not to disclose some wreck information to the public, as these sites may be protected by federal or provincial regulations in respect of marine heritage.

6.3.1 Position of wrecks and obstructions

Acquisition

All wrecks and other obstructions such as submerged cribs, piles, artificial islands, etc. are to be accurately positioned using applicable regional Hydrographic Survey QMS procedures. The obstruction should be sufficiently surveyed in order to determine its orientation and extents. Positions should also be acquired for the portions of the hull, superstructure or masts that may be visible above water.

If wrecks or other obstructions are located in areas where it is dangerous or impractical to approach by launch or ship, the position must be obtained by intersection or by helicopter equipped with GPS. Side scan sonar can be used as a reconnaissance tool to locate wrecks and obstructions.

Data Processing

Determine the orientation and limits of the obstruction as it exists above and below chart datum and/or high water. Verify positions obtained and the definition of the portions of the hull, superstructure or masts that may extend out of the water.

New wrecks or wrecks which have shifted position and are hazardous to navigation must immediately be reported to the Regional Director. Additional action may also be required (see § 9.1 Reporting dangers).

The photographs and pertaining documentation of the wrecks and obstructions are to be filed.

6.3.2 Least depth over wreck

Acquisition

The least depth over the wrecks and obstructions must be determined. In the simplest of cases when the obstruction is in shallow water, the depth can be verified by using a lead line or graduated pole. In certain situations, SCUBA divers could be used to ensure that the least depth is measured.

Least depths over wrecks and obstructions found in deeper water must be obtained using echo sounders. The use of multibeam or multi-transducer systems with precise positioning and increased coverage is recommended. Modern MBES's have the ability to record volume backscatter data throughout the water column which can be very useful in identifying least depth of wrecks, particularly their masts.

If located using side scans sonar, the least depth and its position should be confirmed by using another method.

Data Processing

The least depth over the wrecks and obstructions must be determined.

Depths acquired by lead line, or by echo sounders are to be processed as per § 6.1.5 – 6.1.7 inclusive. All depths are to be reduced to a sounding datum as specified in the Field Survey Instructions (also see § 5.2 Vertical Datum).

For wrecks that have been found during a hydrographic survey for which no previous information exists, a report containing least depth and position must be forwarded to a transport Canada "Receiver of Wreck"official or any other designated organizations.

6.4 Submerged cables and pipelines

Acquisition

The positions of submerged cables and pipelines should be acquired from existing as-built plans or by survey. The type of cable (e.g. telephone, power, ferry etc.) and pipeline (e.g. oil, gas, water intake and outfall) should also be noted. Structures such as manifolds, cribs or diffusers should also be surveyed. Side scan sonar can be used as a reconnaissance tool to locate cables, pipelines and structures related to these installations.

Warning signs, such as those prohibiting anchorage or warning buoys at the end of pipelines must also be positioned.

Data Processing

The positions of submerged cables and pipelines, and the position of the cables used to pull ferries from one shore to another should be extracted from the sounding lines. Soundings may be overlaid with any existing as-built plan, gridded multibeam imagery and/or a side scan sonar mosaic to verify the survey.

Validate cables and pipelines against existing nautical publications.

6.5 Clearances

Acquisition

Clearances under bridges, cables and other overhead structures are vital to safe navigation. The elevations must therefore be measured with care and precision to the accuracy specified for the various survey orders given in Table 2 of the *CHS Standards for hydrographic Surveys*. The elevation of the lowest point over the navigable channel should be obtained.

The elevations may be determined using an optical range finder, laser/reflectorless measurement system or or by using a trigonometric height measurement method. Furthermore, the observer should be at right angles (as close as possible) to the bridge, cable, etc. and be in a position to measure to the lowest point of least clearance over the water surface.

In some cases, the elevation of a bridge may be determined by using a measuring tape or by levelling to the waterline or to a benchmark. If a tape is used, the measurement should be taken at least twice for verification. When feasible, this method should be used to verify the results obtained by using a trigonometric height measurement method.

In situations where the accuracy requirements are lower, other devices such as range finders, hand levels, etc. may be used. At least three measurements must be taken and they must be within the accuracy specifications listed in Table 2 of the *CHS Standards for hydrographic Surveys*.

The elevation of cables and bridges will be affected by load whether vehicular or electrical, as well as by ice, snow, wind, etc. In addition to measuring elevations, the following information should also be recorded, as it will help determine the vertical elevation that will be charted:

- date, time temperature and barometric pressure

- elevation of observer above the water level at the time of the observations
- nature of the overhead cable
- sketch, or photograph (analogue or digital) and description of object measured

Cable owners, i.e. provincial hydroelectric authorities, telephone companies, etc. must be contacted to determine the maximum catenary for a cable considering temperature, ice, load, etc.

It is important to acquire the position of the support structures of bridges and overhead cables, especially if they are in the water area and/or areas where they are conspicuous and can be used for taking visual positioning, bearings.

Data Processing

Apply any tidal corrections and catenary load corrections relative to collection time of clearances obtained. Validate clearances against existing nautical publications and the authorities responsible for these installations.

6.6 Conspicuous objects

Acquisition

A conspicuous object can be described as any natural or artificial object which is distinctly and notably visible from seaward and may be used for navigational purposes (distinct topography such as bluffs, cliffs or rock pinnacles, church spire, chimney, cross, silo, water tank, communications tower, aeronautical beacon, etc.).

Conspicuous objects must be positioned and their elevation determined to the accuracy given for the different survey orders found in Table 2 of the *CHS Standards for Hydrographic Surveys*. The methods described in § 5.1 Horizontal Control should be followed.

Each conspicuous object must be given a unique identifying number and described as specified in QMS documentation (see § 5.1.2 Station Description). Colour photographs (analogue or digital) should be taken and filed.

Data Processing

Ensure that positions and elevations obtained meet the required survey order specified for the project.

Validate conspicuous objects against existing nautical publications.

Refer to the appropriate regional Hydrographic Survey QMS procedures and forms for processing elevations.

File colour photographs (analogue or digital) as applicable.

6.7 Elevations

Acquisition

The elevation above a vertical datum (HHWLT)) of all horizontal control points, fixed aids, major wharves and conspicuous objects positioned must be determined as accurately as possible and be within the limits set in Table 2 of the *CHS Standards for Hydrographic Surveys.*

The elevations can be obtained using GPS, laser/reflectorless measurement system, by physically measuring the height of the structure to the ground and levelling to a benchmark, by physically measuring the height to the water level and applying a water level reduction, or by using a trigonometric height measurement method from known horizontal points with accurate elevation values.

Data Processing

Ensure that elevations obtained meet the required survey order specified for the project.

Refer to the appropriate regional Hydrographic Survey QMS procedures and forms for processing elevations.

The elevations of all major wharves in the survey area should be reduced and shown above a vertical datum of HHWLT (tidal areas) or a reference datum (non-tidal areas).

6.8 Seafloor classification

Acquisition

The nature of the seabed must be acquired to indicate its suitability for vessels anchoring, trawling or taking ground. The specific requirements for bottom sampling are given in the chapter 5.3 of *CHS Standards for Hydrographic Surveys*. Sampling density could be increased in potential anchorage areas, in fishing grounds, and in areas which could be used to ground a vessel in emergencies. The sampling equipment generally used is a tallow-armed sounding lead. This method is not very efficient and will only retrieve relatively fine-grained samples. However, an experienced user will be able to tell the difference between rock, sand and mud. The use of a small bottom grab, scoop or dredge type sampler will yield more sample but will prove difficult in a bottom consisting of boulders. This method is also useful if the bottom samples are to be retained for later analysis by others. A small submersible camera can also be used.

Bottom characteristics can also be determined from the classification of acoustic information recorded from single beam, multibeam and multi-transducer systems. This method requires ground-truthing using the above mentioned methods. Correlation tables may also be used.

Bottom characteristics determined from samples shall be classified in accordance with CHS Chart Number 1.

The size criteria table listed below can serve as a General Guide:

- Mud
    - Clay less than 0.002 mm

        - Silt 0.002 to 0.0625 mm
- Sand
    - Fine 0.0625 to 0.25 mm
    - Medium 0.25 to 0.50 mm
    - Coarse 0.50 to 2.0 mm
- Gravel 2.0 to 4.0 mm
- Pebbles 4.0 to 64.0 mm
- Cobbles 64.0 to 256.0 mm
- Boulders greater than 256.0 mm
- Rock bedrock or compacted bottom

All seafloor classification information must be geo-referenced. This information (position and bottom characteristic) shall be captured by the acquisition system aboard the vessel or entered later in the main processing system.

Data Processing

Verify the position and bottom characteristics and verify that the sampling interval is maintained.

Bottom characteristics may be determined from the acoustic information recorded from single beam, multibeam and multi-transducer systems by analysing the backscatter strength. As a general rule hard surfaces such as rock and gravel provide high backscatter and sand or mud provide low backscatter. Areas attributed with similar backscatter strengths can be delineated. However, ground-truthing is required to assign seafloor classification. Correlation tables may also be used.

All seafloor classification information must be geo-referenced. This information (position and bottom characteristic) should be entered later in the main processing system, if not entered in the acquisition system in the vessel.

6.9 Shorelining

Acquisition

The shoreline shown on charts is referred to the Higher High Water Large Tides (HHWLT), which must be verified in the field. It is therefore necessary to delineate the HHWLT using remote sensing and land survey techniques. In some cases it will only be necessary to do spot checks, but in low-lying areas where the coastal gradient is gentle, where flooding occurs or where tidal ranges are great, more data points will be required to properly position the HHWLT line.

The nature of the foreshore should also be recorded, as this information can be very useful for navigation.

Topographical maps, air photos, satellite images or other tools used to generate the shoreline on charts should be checked in the field and discrepancies resolved using land survey techniques as described above. New construction, landfill, accretion or erosion not found on existing plans and photos must be surveyed using land survey techniques. Navigable Waters Protection Act records should be referenced for proposed works. In the case of facilities, installations, etc. under construction, the names of the companies carrying out the work should be obtained as well as copies of the proposed work.

The drying line (defined by LLWLT, Zero Depth contour, etc.) must also be well delineated. It is of the utmost importance that the drying line of the mainland, of islands and of all drying features, especially offshore features, is accurately surveyed. The limits of Canada's internal waters, territorial sea, fishing zones and exclusive economic zones established from points based on this. According to the rules defined by UNCLOS, the limits listed above may be extended seaward if a drying rock or rock awash exists within the twelve nautical mile territorial sea.

Both the high shoreline line and the drying line must be positioned to the accuracy specified for the various survey orders found in Table 2 of the *CHS Standards for Hydrographic Surveys* using the methods and procedures outlined in the regional Hydrographic Survey QMS procedures.

Foreshore should be classified and the various limits geo-referenced.

Areas with structures in ruin should be delineated. If structures are no longer visible, it may be necessary to acquire additional bathymetry in order to validate the existence or the absence of ruined structures. Colour photographs (analogue or digital) or historical data should be consulted to obtain more information on those ruins.

<u>Data Processing</u>

Refer to the appropriate regional Hydrographic Survey QMS procedures and forms.

When processing the positions for both the shoreline and the drying line, verify that the accuracy specified for the survey has been met.

When multiple positions have been logged for point data, calculate an average position for the feature.

It may be necessary to apply transformations to digitized topographical maps, aerial photography, and satellite imagery to geo-reference the information they contain.

Foreshore should be classified and the various limits geo-referenced.

6.10 Revisory survey

Before updating of nautical publications surveys are required to acquire data describing additions, deletions and other changes that have taken place in an area. A revisory survey must incorporate all changes that may affect the safety of navigation.

6.10.1 Revisory work during a standard hydrographic survey

Acquisition

During the course of a standard hydrographic survey, it is imperative to verify the source information for the area being surveyed. Care must be exercised to verify the positions of existing charted information such as wharves, piers, shoals, rocks, dolphins, cribs, etc. The charted depths, especially shoals, wrecks, hazards and reported dangers including "Doubtful dangers" labeled ED-"existence doubtful", PA-"position approximate", PD-"position doubtful", SD-"sounding doubtful", Rep "reported danger", etc., must be verified and their existence or non-existence confirmed.

If the new soundings do not agree with the charted depths within the tolerances indicated in the *CHS Standards for Hydrographic Surveys*, a thorough investigation will be required to confirm the discrepancies.

In critical areas such as harbours, berths, canals, dredged channels, etc., it may be necessary to make use of a multibeam or multi-transducer system (if not already used), assisted with a side scan sonar system in order to prove the existence or non-existence of the feature being investigated. Enough information must be obtained to confirm that the feature in question does not exist in its charted or reported position. If the feature is non-existent, a report should be made to the regional office, which may then provide additional information as to the source of the charted feature.

Conversely, all new dangers must be thoroughly checked using the steps outlined in these guidelines and reported to the regional office for immediate charting action. The navigation community must also be informed through Navigational Warning or Notice to Mariners (see § 9.1 Reporting Dangers to Navigation).

The shoreline must be verified and all changes (landfill, construction, etc.) must be surveyed using standard land survey techniques if the information is not available from the latest remote sensing information or topographical maps. Photographs should be taken whenever possible.

Data Processing

Data processing is conducted as per a standard survey using the appropriate regional Hydrographic Survey QMS procedures and forms.

In some cases, it may be necessary to provide a written report to explain the changes found while conducting the hydrographic survey, especially if features no longer exist. These may be included in a hard copy document or in a digital form. Photographs should be filed with the Revisory reports to support any changes found.

6.10.2 Revisory work for Nautical Publication

Acquisition

A survey team may be required to perform a revisory survey of a specific area as requested by the chart production unit. The work is performed as a standard hydrographic survey except that sounding operations may be limited to areas critical to navigation such as harbours, wharves, berths, entrance channels, ranges, reported shoals, etc. Revisory surveys will also verify existing hazardous shoals and other dangers to navigation. The line spacing and methodology shall be chosen to satisfy the required survey order (Table 1 of the *CHS Standards for Hydrographic Surveys*). Photographs should be taken whenever possible.

Prior to leaving for the field, it will be necessary to obtain information specifying where changes are known or suspected to have taken place in order to establish priorities to the work to be done. Related source information will have to be studied and taken into the field if necessary. Lists detailing additional hydrographic data to be obtained, inquiries, etc. will also have to be obtained in order to assess the work to be done in the field.

This type of survey is prepared and executed as a standard survey, using the *CHS Standards for Hydrographic Surveys*, these guidelines and the regional Hydrographic Survey QMS procedures. Consult § 3.0 Survey Planning.

Data Processing

Data processing is conducted as per a standard survey using the appropriate regional Hydrographic Survey QMS procedures and forms.

In some cases it may be necessary to provide written report to explain the changes found while conducting the hydrographic survey, especially if features no longer exist. These may be included in a hard copy document or in a digital form. Photographs should be filed with the Revisory reports to support any changes found.

6.11 Sailing Directions

Acquisition

During the course of a hydrographic survey, it is imperative to verify the information contained in the Sailing Directions as applicable to the area being surveyed. Landmarks may have been removed or conspicuous new construction, such as communications towers, churches and tall buildings, may have been erected; shoals may have been removed; beacons may have become obscured by trees or destroyed; new harbour regulations may have come into effect; limits may have been altered, etc.

Surveys may find that certain areas within the Sailing Directions may be poorly described and require additional detailed information. In such a case, the information required covers a wide variety of subjects, among which are: descriptions of the coasts, harbours, dangers, landmarks, etc. as well as directions for entering harbours and for coastal navigation.

Special instructions may be given by the person responsible for the regional Sailing Directions. These may include a requirement to acquire oblique aerial photographs of specific areas and approaches.

Data Processing

Refer to regional QMS instructions for the procedures for submitting data to the regional Sailing Directions representative.

Ensure that any special instructions given by the person responsible for the regional Sailing Directions have been followed.

If applicable, Marina Facility Information Forms are to be filed. The information gathered should be submitted to the regional Sailing Directions office as soon as possible after the close of the project.

6.12 Chart nomenclature

Acquisition

In remote areas, it may be necessary to obtain the local names of the features that are significant for charts and Sailing Directions. In such instances, the source reference (local authority, etc.) should be recorded in case additional information is required.

Data Processing

All geographical names to be included on CHS documents and publications must be checked against the Geographical Names Board of Canada database or other provincial organisations such as the database maintained by the "Commission de toponymie" of the Quebec government.

It is possible to suggest names for unnamed entities. The methods and procedures required to undertake such an action are outlined in the document entitled *Principles and Procedures for Geographical Naming 1999* published by the Canadian Permanent Committee on Geographical Names, Natural Resources Canada.

All suggestions are subject to approval by the Regional Director's Office.

6.13 Use of photographs

Descriptive photographs are very useful for reporting and can be used for many tasks such as training, technical reference, public relations, etc. The use of video may also provide valuable information.

The photographs and videos taken must properly be identified, coded and stored in the hydrographic data centre (HDC) according to the regional Hydrographic Survey QMS procedures in use.

6.13.1 General use

Acquisition

Photographs should be taken of all horizontal and vertical control points occupied or installed during the survey. At least two photographs should be taken: one with a view of the general area and one showing the control point or benchmark with its immediate surroundings. The photographs should be taken from a horizontal viewpoint or a low level oblique.

Photographs or videos may be necessary to better describe features such as:

- Navigation aids (single lights, range lights and markers, beacons, buoys, etc.),
- signs signalling directions or giving navigational information,
- conspicuous objects and special features such as wrecks, pilings, critical shoals, etc.,
- revisory work (new construction, new features, changes, modifications, etc.). These can be submitted with the revisory report,
- Installations of the positioning system, the tide gauge set-up etc.,
- equipment in use during the survey (launches, instruments, equipment, office and processing facilities, etc.).

Data Processing

The photographs and videos taken must properly be identified, coded and stored in the hydrographic data centre according to the regional Hydrographic Survey QMS procedures in use.

6.13.2 Coastal photographs for Sailing Directions

Acquisition

Coastal photographs included in the Sailing Directions provide the mariner with a visual means to identify land features referred to in the text. Photographs most suitable for reproduction in the Sailing Directions need to be taken with a camera capable of producing sharp black and white prints having good contrast. They are usually taken from a ship or aircraft. It may be necessary to employ the services of an experienced photographer and may require the need of a helicopter.

Photographs of the following features are particularly useful:

- salient points of the land, especially those which would be sighted first on approaching the coast, or which would be rounded on passage,
- islands that lie near the usual routes followed and that are valuable aids for fixing position,
- entrances to narrow straits and channels,
- harbour entrances,
- landing places, leading beacons, etc.,

- conspicuous natural and cultural features.

In taking coastal photographs, the following general rules should be observed:

- Photos should be taken from about the height of the bridge of ship, if possible, and looking forward or on the bow, in order to show the appearance of the land from the normal direction of approach. Photos taken on or abaft the beam (when a vessel is passing or has already passed the land) are seldom of much value. Care should be taken to avoid including parts of the ship's structure such as the foremast.
- If the land is low, say 60 meters or less above the water level, photos should be taken at a range of about 2 to 3 kilometres. At any greater distance, low land will not show up well.
- If the land is of medium height, say 70 to 250 meters above the water level, photos can be taken at ranges of about 5 to 7 kilometres. If the land is high, say 300 meters and upwards, the range may be 9 kilometres or more.
- In the case of entrances to straits, channels and harbours, it is always desirable to include both entrance points (both sides of the entrance) in the picture. If the angular distance between them is too great for inclusion in one photo, two or more photos, overlapping horizontally, should be taken from the same position so that the prints can subsequently be cut and joined to make a continuous panorama. Wide angle camera lens may be used.
- Helicopter photos can be valuable provided they are taken form a moderate height, e.g. 15 to 50 meters, taking into consideration the height of land in the area and that the position from which they are taken can be determined with fair accuracy.
- In all circumstances, the photos should be taken when weather is clear and that all features are optimally identifiable.

It is essential that the position from which each photo was taken and the direction in which the camera was pointed be known. This may be determined by taking a bearing and a distance to a distinctive object that must appear in the photo. The bearing to roughly one degree and the distance to about 0.5 kilometers (0.25 nm) should be adequate. However, depending upon the circumstances and the distance away, these rough tolerances may be exceeded. All the information should be recorded immediately after a photo is taken.

<u>Data Processing</u>

A brief report should accompany the photographs taken specifically for Sailing Directions. The report should include:

- the reference numbers of the photos (corresponding to those on the prints),
- dates and times when photos were taken,
- positions of photo stations relative to land features shown,

- indication of the area shown in each photo depicted on a chart or topographic map,
- name of the ship,
- other details, e.g. taken from helicopter, part of panorama, etc.

The photographs and videos taken must properly be identified, coded and stored in the hydrographic data centre according to the regional Hydrographic Survey QMS procedures in use.

6.14 Current measurements

Acquisition

Current information is required mainly as an aid to navigation especially in entrances to harbours, in narrow or shallow channels, in anchorage areas and in the vicinity of wharves, piers or other areas where the margin for navigational error is small and where current velocities appear to exceed 0.5 knots.

Specific and detailed Fields Survey Instructions should be obtained prior to leaving for the survey area. The instructions should give the location where measurements are required, the instruments to be used and the length of time that data should be recorded. The time required to perform this work must be taken into account when establishing timetables for the total tasks to be done during survey operations.

Whenever possible, the following guidelines should be followed for the collection of tidal stream and current information:

1. Current observations should be made using a recording device.
2. Observations should be measured at depths between 0 and 10 m below the surface.
3. Simultaneous observations of water level height and meteorological conditions should be made. In the case of non-tidal waters, simultaneous observations of river discharge should be obtained.
4. The period of observation in tidal waters should normally extend over a period of at least 29 days, at intervals not greater than 1 hour. In the case of non-tidal waters, the observations should extend over the range of factors causing the currents (i.e. river discharge, etc.).
5. The speed and direction of the tidal stream should be measured to 0.1 knot and the nearest 10° respectively, at 95% confidence level.
6. Where there is reason to believe that seasonal river discharge influences the tidal streams, measurements should be made to cover the entire period of variability.

In other cases, it may be enough to get instantaneous readings from a portable current meter or other methods to get an idea of the current, which might affect low powered vessels and other small craft.

Instructions for the measurement of tidal streams and currents are given in Chapter 8 - Current Measurement of the *Canadian Tidal Manual*.

It should be noted that it will not always be possible to follow all of these guidelines completely and survey parties are encouraged to collect any information possible on the direction and speed of tidal streams and currents.

Data Processing

The current data must be processed according to the regional Hydrographic Survey QMS procedures in use.

A brief report should accompany the current data. This report should detail the instruments and the methodology used to measure the currents, as well as the calibrations and precisions records. The position of every current measurement must be recorded precisely, as well as the date / time, depths, speed and direction of each measurement. The depths must be reduced to chart datum. Any pertinent information that may help in the interpretation of the data must be noted in that report.

6.15 Field checking (before leaving the field)

If processing cannot be conducted during the survey, certain steps should be taken to ensure that post processing may take place off site and that the survey coverage and the data quality respect the survey specifications as defined in the Field Survey Instructions.

6.15.1 Bathymetry

Ensure that all sensors aboard the sounding platform have been adequately calibrated to meet the survey's specifications.

Ensure that the sound speed measurements casts and bar checks are performed within the areas surveyed and correlate with the times of data acquisition. Positions of the sound speed measurements and bar check sites should be recorded and filed. Ensure that the recorded values are valuable and not corrupted.

Review sounding pattern for adequate coverage.

Verify that check lines have been run.

Verify that the shoals, obstacles or hazardous areas have been properly investigated.

Randomly select subsets of data while collecting to verify consistency and quality of data.

Ensure that water level and current information has been gathered and is available.

Create a DTM of sounding data if possible and monitor anomalies.

6.15.2 Other Data

Ensure position files (i.e. SBET trajectory files or other positioning data) may be read and contain the required datagrams.

Ensure good quality of all the data collected.

Ensure all data required for forms, such as FAT forms are available or have been collected.

Ensure adequate positioning has been done to geo-reference digitized sources.

Ensure that photographs taken for Sailing Directions meet the required needs as per § 6.13 Use of Photographs

6.16 Other computations

All computations must be done with care and attention by a qualified hydrographer. In some cases (newly established horizontal control points, new benchmarks, temporary water level gauge installation, etc.) the computations should be checked and approved before sounding operations begin.

All comments, annotations, explanations, etc. recorded while performing revisory survey work for charts or sailing directions should be reviewed as soon as the fieldwork is completed and while the information is still fresh in the mind of the hydrographers that did the work. All annotations, comments, etc. pertaining to changes concerning the chart being revised should be included in a separate report.

Descriptions of horizontal and vertical control points or any other sketches drawn during field operations should also be reviewed as soon as possible after the data have been collected. All photographs taken during such operations should be developed or downloaded, identified and labelled as soon as possible.

The results of the various calculations and the various original observation forms should be included in a computation file or notebook and be readily accessible for consultation. All pertinent information must be clearly documented and classified.

7 Quality control

For all aspects of a hydrographic survey, checking procedures (checklists, etc.) must be in place to monitor that the data is being recorded or calculated correctly and that the manual inputs (system configuration values, navigational system data changes, etc.) are entered correctly. The guidelines outlined in the *CHS Standards for Hydrographic Surveys*, § 7 - Quality Control must be followed. Checks and verifications should be done following the regional Hydrographic Survey QMS procedures in place.

All adjustments, changes or alterations made to the various recording instruments must be documented and approved.

Efforts should be made so that all survey parties use the same version of the software. During the course of a hydrographic survey, changes or modifications to the various software packages used to process field data must not be made without approval from the regional office.

7.1 *Bathymetry*

The validity of soundings should be verified by an independent qualified hydrographer other than the data processor. The HIC must approve the list of shoal to be examined and where additional hydrography is required. He/She will have the final decision regarding agreement between soundings obtained from regular sounding lines, check lines, shoal exams and other verifications. The depth accuracies for the various survey orders are found in Table 1 of the *CHS Standards for Hydrographic Surveys*.

The final digital files with its metadata must be thoroughly checked before being submitted.

7.1.1 Overlap of surveys

It is the responsibility of the HIC to compare the bathymetry obtained during the present survey against the bathymetry obtained from previous surveys. It is also the responsibility of the HIC to ensure that all contiguous datasets overlap in order to facilitate the verification of survey accuracies and ensure continuity of survey coverage.

A surveyed area can be divided into separate datasets. In most cases, the limits of the datasets to be completed are such that the limits of the new datasets are contiguous to the limits of previously completed datasets. In such a case, the datasets produced during the same field season, using the same methods and equipment, and by the same vessels and HIC, do not require any overlap. But datasets where one or more of the limits are the same as the limits of previously completed datasets must have sufficient overlap to verify the accuracy of the new data and ensure that it compares well with the previous survey.

In the digital world, the bathymetric data can be shown as a series of data sets, each having its own set of limits within one large data set, showing where the present survey data ends. The new limits may or may not coincide with the limits of a previously surveyed area. Either way, the new data coverage must be such that there is a certain overlap in order to verify the accuracy of the new data and ensure that it compares well with the previous survey.

As a general rule, the overlap with previous data sets shall be sufficient to ensure that the hydrography shown in the overlap area is in agreement with the previously obtained data. The amount of overlap will depend on the purposes (scale of historic fieldsheets and density) for which the current data and previous data were collected and may vary from as little as 50 metres to as much as 2 Kms. The overlap section should also show the shoreline and foreshore details as well as the contour lines if applicable.

The depths should be within the accuracies stated in the Table 1 of the CHS *Standards for Hydrographic Surveys*. If depths in the overlap area do not appear to agree with the depths of the previous surveys, the results obtained from the survey underway must be thoroughly checked. If the disagreement still cannot be resolved, then check lines must be run across the previous survey area to determine the extent of disagreement. Any discrepancies in the overlap areas must be fully resolved before the datasets are certified to be correct and approved for use in chart production.

7.2 Other computations

All computations should be independently verified by a qualified hydrographer. Once completed, there should be a clear indication that the computations have in fact been verified as correct and that the results are acceptable for use.

8 Data rendering and submission

Once the field survey is completed and the survey party has returned to the office, the steps and methods outlined in the regional Hydrographic Survey QMS procedures must be followed in order to complete the survey project. These could include the following:

- file numbers should be obtained from Hydrographic Data Center (HDC) / Data management in order to properly identify and store the various information collected and produced in the field (digital files, observation notes, computation notes, descriptions, etc.),
- all sources data such as observations, computations, forms, etc. should be assembled, grouped, labelled, submitted to the HDC and classified. Make sure that everything is verified and approved,
- the revisory report and Sailing Directions report should be completed including a list of the information which is to be replaced,
- all sounding notes should be assembled, sorted and properly identified including date, name of launch or vessel, survey party, etc.,
- all documents taken out of the HDC must be returned,
- tidal information, water level records (digital or analogue), levelling notes, bench mark descriptions, photographs, comparison forms, vertical datum determination, location of water level staffs and gauges, etc.) must be assembled, properly labelled and classified.

The various products and other information collected must be forwarded to the appropriate sections, groups or authorities, in order that the various databases, files, products, etc. may be updated. More specifically:

- all products requested by external clients should be completed and sent in the most expedient fashion possible once a copy has been retained in HDC/regional database,
- once verified, the data should be forwarded to the regional data manager,
- data in the datasets, should be coded according to the PSCG,
- all raw data should be properly labelled and archived,
- the revisory report including the list of charting actions should be forwarded to the regional data manager,
- the Sailing Directions report and marina information should be forwarded to the regional data manager,
- the horizontal control point data (descriptions and calculations) should be submitted to the federal, provincial or local authorities in charge of updating the horizontal control point databases. Copies must be sent to the regional data manager and/or Tide Officer,

- the Fixed Aid Tabulation forms, describing the fixed aid and listing the observed position should be sent to the appropriate regional Coast Guard office in order to update their database. Copies must be sent to the regional data manager,
- all field notes pertaining to the establishment of bench marks and water level gauges should be submitted to the regional Tides and Water Level unit,
- all bathymetric records must be archived and stored in a safe environment.

9 Reporting

Reports must be produced in order to:

- signal dangers found during the hydrographic survey,
- inform on the progress of the survey,
- detail how the survey was done,
- describe and evaluate new methods and processes employed, or new equipment used,
- provide management with information necessary to plan and execute future surveys,
- provide recommendations in support of continuous improvement.

Reports provide a complete and convenient index of the work carried out during the field survey period and are important for immediate action, when required. More importantly, they give invaluable information as reference documents for the planning and budgeting of future hydrographic surveys.

9.1 Reporting Dangers to Navigation

Uncharted dangers to navigation found during the course of a hydrographic survey must be reported immediately to the Regional Hydrographic Survey Manager. The navigation community will also have to be informed using CCG's Navigational Warnings or Notices to Mariners.

When evaluating the importance of dangers, the size, type and draft of ships frequenting the area, as well as the location of the danger in relation to shipping lanes, must be considered.

If the HIC considers that immediate action must be taken, he / she is to contact the nearest Coast Guard Radio Station and request that a broadcast Navigational Warning be issued immediately. This must be followed by an urgent transmission of the Regional Manager of Hydrographic Surveys advising of the action taken. The other agencies concerned (Transport Canada, Harbour Master, Pilot authorities, DND, etc.) should also be informed directly. All of these communications must be recorded, including the details of all the communications such as; date, time, persons contacted and signature of the HIC.

Further investigation may be required to fully define the hazards.

If the HIC, after evaluating the results of the examination of the hazard, considers that the feature is not sufficiently critical to originate a Navigational Warning, he / she shall inform the Regional Hydrographic Survey Manager by the most expeditious means available, so that a Notice to Mariners can be issued as quickly as possible. Where possible, existing Navigational Warnings shall be investigated by survey and the HIC shall submit a follow-up with a recommended Notice to Mariners (to cancel the NTS). If applicable, the other agencies concerned (Transport Canada, Harbour Master, Pilot authorities, DND, etc.) should also be notified.

All radio and telephone communication with the Regional Hydrographic Survey Manager must be logged and confirmed immediately by a written report, which is to include all details requisite for Navigational Warning action.

Fixed aids and buoys out of position, extinguished lights, different light characteristics, etc. should be reported immediately to the local Coast Guard office followed up by a report to the Regional Hydrographic Survey Manager.

9.2 Progress reports

If the survey is to extend over a long period, it may be of interest to have the HIC produce progress reports on a monthly basis or other suitable interval. The report may contain the following information:

- a title page,
- a list of contents,
- a list of participating staff, including hydrographers, electronic technicians, casuals, summer students, helicopter personnel, etc., listing their names, functions and dates of arrival and departure,
- a list of projects undertaken including project title and number and type,
- the percentage of completeness for each project,
- a chronology of significant events (not a day to day account),
- a brief account of the planning, the preparations and the operations for the reporting period,
- budget summary,
- general comments as to equipment performance, progress made, future plans,
- sketches to show work completed (sounding coverage and limits, control work, remaining work, etc.),
- statistics required by management,
- other pertinent information.

The progress reports are to be submitted to the Regional Hydrographic Survey Manager or the Manager of Field Surveys or Data Acquisition as soon as possible at the end of the specified interval.

9.3 *Project report*

Upon completion of the hydrographic field survey, a Final Field Report must be produced. The project report should give a record of the work completed by a hydrographic survey team during a particular field season. This report is circulated to all levels in the CHS as well as to people and agencies outside the Department of Fisheries and Oceans (DFO). The project report should be submitted to the Regional Hydrographic Survey Manager as soon as possible after the end of the field survey. Once approved, the final project report will be distributed to the following:

- Director General, CHS (mandatory hard-copy)
- Manager, Planning CHS-HQ (mandatory hard-copy)
- All Regional Directors, CHS
- Chair of each standing committee
- Manager, Hydrographic Survey, Newfoundland and Labrador

Optionally, or as regional policy or QMS procedures may dictate, these reports may also be distributed to the following:

- Regional Director, Science
- Regional Director General, DFO
- DFO regional library (hard-copy suggested)
- HDC (2 hard-copies – in case one is loaned out)
- Captain of survey vessel (hard-copy suggested)
- Digital copy for National CHS Intranet site (must be in both official languages)

The appropriate distribution format may be regionally specified or specified by the intended recipient. Digital versions may be distributed by E-mail, placed on a web page, placed in public folders or on a shared drive depending on regional policy or at the request of the intended recipient. The most important criteria being that those who wish a copy receive it in a form that suits them and by a delivery method that is the most effective.

The field survey team may have worked on more than one project during the course of the field season. If such is the case, all items common to the various projects worked on (list of participating staff, list of major craft and equipment used, chronology of significant events, etc.) should be identified only once in the final report whereas details specific to each project undertaken (planning, preparations, how work was done, what areas are completed and those not, etc.) should be detailed for each of the projects undertaken.

The project report should include the following information:

- a cover page listing the following information:
    - Name of establishment (i.e. Canadian Hydrographic Service)
    - Region
    - Title (i.e. Final Field Report)
    - Project number
    - Name of ships and Cruise number (if applicable)
    - Type of Survey (i.e. standard, control, tides and water levels, revisory, etc.)

    - Period of operation
    - General area of operations (geographic name)
- a list of contents
- a list of participating staff
- a list of major crafts and equipment
- the chronology of important events (routine events can be grouped e.g. June 1 to 15 – sounding work)
- planning, preparations
- operations undertaken to complete the work assigned
- a list of the projects undertaken, if more than one
- details pertaining to each of the separate locations (see below)
- conclusions and recommendations as they apply for the whole of the project
- statistics (grouped by location and then summed to give project's totals)
- photographs and images that illustrate any phase of the work, vessel and equipment used, accidents, etc.

The project report must also include details for each location. The following information is required for each location:

- location
- period of operation
- chronology of major events
- planning, preparations and operations
- how horizontal control was established (include sketches if necessary)
- how vertical control was recovered
- how shoreline –if any – was established
- how soundings were collected, processed and reduced
- a statement qualifying the order of precision of the data obtained
- a list of information submitted including titles, limits, numbers and scales (it may be advantageous to show this information in a sketch)
- project status (which areas are complete and which areas will require additional work - usually in sketch form)
- conclusions and recommendations as they apply to the specific location
- photographs pertaining specifically to the location may also be included

If only one project was undertaken (or if a separate project report is produced for each location), the project report should be more homogeneous and incorporate all the information required to detail the work for a specific location.

9.4 Technical and other special reports

It may be necessary to write other reports in order to satisfy national or regional administration requests. These can include mission reports, cruise reports, vehicle reports, launch or craft reports, equipment reports, etc. These reports should be done according to the regional Hydrographic Survey QMS procedures or other procedures put in place in other sections of the regional office.

It may be of interest to produce special or technical reports that will describe and/or evaluate new processes, new methods, new equipment, etc. used during the field season. Such reports can also be produced regarding test results arising from field trials of new equipment, processes or methods of work.

9.5 Reporting accidents

Injuries sustained by personnel or damages to vehicles, launches or survey equipment resulting from an accident must be reported as soon as possible to the Regional Hydrographic Survey Manager by telephone, facsimile or radio message. It is necessary to fill out the applicable form: a Hazardous Occurrence and Investigation Report (HOIR), an Employer's Report and Employee's Report and a Motor Vehicle Report.

Guidance can be found on which form to use, how to fill it out, by when, and who to send it to from the regional authorities.

The reports include information like:

- the nature of any injury sustained by personnel
- type of accident, what occurred, its location, date and time
- the extent of damage to the vehicle, the launch or equipment
- if another vessel is involved, its name, owner, registry number and port (or licence number and district), and extent of damage

In all cases, and especially those that might result in claims for damage, the initial report shall be followed immediately by a detained written report including sketches, and photographs if appropriate, and names of witnesses, etc. No acknowledgement of responsibility or liability should be made to the other party.

10 Abbreviations, Acronyms, Definitions, and Terms

Accuracy The extent to which a measured or enumerated value agrees with the true value.

Bathymetric surface A surface model of the seafloor as determined by creating an interpolated (or not) grid of depths from the observed depth samples (Also called seabed surface model, seafloor surface model, seafloor model).

Bench marks Stamped, fixed elevation tablets from which sounding and/or chart datum may be recovered, and against which the zero setting of tide gauges and tide staffs are checked.

Bottom search A method of exploring the seabed, which attempts to provide complete coverage of an area for the purpose of detecting all features, addressed in this publication.

CCG Canadian Coast Guard

CCG-DGPS A DGPS service provided by Canadian Coast Guard.

CEP Circular Error Probability

CGVD28 The Canadian Geodetic Vertical Datum 1928 (CGVD28): Official height reference system in Canada The reference frame for the CGVD28 is the mean sea level at six tide gauges in dates of 1928.

CHS Standard Station Markers (Two main types exist):

CHS Tablet commonly known as a rock post, it is a circular metal disk, 7.6-cm (3 inches) in diameter, with Hydrographic Service Canada inscribed around its periphery. This type of tablet is usually cemented into bedrock or a concrete block.

CHS Rectangular Aluminium and Steel Rod with Spread-Foot commonly known as a terminus or soil post. One side of the upper portion is usually stamped Hydrographic Service Canada. This type of marker is usually driven into the soil.

Confidence levels The probability that an error will not exceed the specified maximum value.

Conspicuous features Any conspicuous natural feature that may be used by a navigator for positioning purposes (mountain peaks, hills, islet, etc.). These features are usually positioned by intersection or resection.

Conspicuous objects Any conspicuous man-made object that may be used by a navigator for positioning purposes (aeronautical beacon, church spire, chimney, cross, silo, water tank, television tower, etc.). A check position is necessary and the positions must agree within one meter.

Control Network A network of permanently marked control points having their geographic positions established to firm third order accuracy or better.

Correction	A quantity, which applied to an observation or function thereof, will diminish or eliminate the effects of errors and give an improved value of the observation or function. The correction corresponding to a given error is of the same magnitude but of opposite sign. (IHO S32 ed.1994, #1079)
CTDS	Conductivity / Temperature / Depth / Salinity
CUBE	Combined Uncertainty and Bathymetric Estimator
DGPS	Differential Global Positioning System
DTM	Digital Terrain Model
Electrical centres	The exact location of the electrical centre at antennae sites of any GPS reference or integrity monitor stations.
Error	Is the difference between an observed or computed value of a quantity and the ideal or true value of that quantity. (IHO S32 ed.1994, #1671)
FAT form	Fixed Aids Tabulation from
Fixed aids	Any stationary man-made structure erected for navigational purposes (day beacon, lighthouse, ranges, range lights, etc.). These are surveyed to third order accuracy, and then described and recorded on the Fixed Aid Tabulation Form.
Geostatistics	The field of statistics, which deals with estimating the confidence of interpolated values, derived from measurements of geo-referenced data.
GPS	Global Positionning System (satellites)
GSD	Geodetic Survey Division of Natural Resources Canada
HDC	Hydrographic Data Center
HHWLT	Higher High Water Large Tide
HIC	Hydrographer in Charge
IFMS	InterFeroMetric Sonar
ISO 9001	A family of standards for quality management systems.
ISO	International Organization for Standardization
LLWLT	Lower Low Water Large Tide
LOP	Line of Position is a line indicating a series of possible positions of a craft, determined by observation or measurement. It is also called position line. (IHO S32 ed.1994, #2848)
MBES	MultiBeam Echo Sounder
Metadata	Is the information describing characteristics of data, e.g. the accuracy of survey data. ISO definition: Data (describing) about a data set and usage aspect of it.

Metadata is data implicitly attached to a collection of data. Examples of metadata include overall quality, data set title, source, positional accuracy and copyright.

MS (Semi-Permanently Marked CHS Stations)

CHS control points marked by a drill hole, iron rod, pipe, or ring of nails, etc., considered to be of semi-permanent nature, usually described, and recorded on the form "Description of Survey Station or Object."

MTES Multi-Transducer Echo Sounder

PDOP Position Dilution of Precision

PMS (Permanently Marked CHS Stations)

CHS control points that have been permanently marked by a rock-post or soil-post, described and recorded on the form "Description of Survey Station or Object."

Precision A statistical measure of repeatability of a value, usually expressed as variance or standard deviation of repeated measurements.

PSCG Product Specification and Coding Guide

QMS Quality Management System

Quality assurance All those planned and systematic actions necessary to provide adequate confidence that a product or a service will satisfy given requirements for quality.

Quality control All procedures which ensure that the product meets certain standards and specifications (IHO S32 ed.1994, #4115)

Reference marks Supplementary marks established to enable relocation of main control points, antennae locations for major positioning systems, fixed aids, etc. Normally three referenced marks are used to witness the position in question and are identified by inscribing Ref 1, Ref 2, etc., on standard station markers.

RTQA Real-Time Quality Assurance

RTK Real Time Kinematic GPS.

SBES Single Beam Echo Sounder

secondary control A network of control points or individual points of a localized nature utilized for shoreline plots, electronic tacheometer (total station) work, etc., whose geographic positions may be established to a slightly lower order of accuracy than main control points.

SIPA Aids Program Information System

SSP Sound Speed Profile

STW Speed Through the Water

SVP Sound Velocity Profile

TPU Total Propagated Uncertainty

Unmarked CHS stations

Normally refers to secondary control points not marked and primary control stations that were not marked due to land usage e.g. area under construction, agricultural purposes, etc.

WADGPS Wide Area Differential Global Positioning System

WGS84 A World Geodetic System that is currently the reference ellipsoid being used by the Global Positioning System

XBT Expendable Bathythermograph

XSV Expendable Sound Velocimeter