What is Hydrography?

WOCE Section A14

Potential Temperature [°C] for A14 5°W

CTD Salinity for A14 5°W
What is Hydrography?

- **Hydrography** is the branch of applied sciences which deals with the measurement and description of the physical features of oceans, seas, coastal areas, lakes and rivers, as well as with the prediction of their change over time, for the primary purpose of safety of navigation and in support of all other marine activities, including economic development, security and defense, scientific research, and environmental protection. -IHO
International Hydrographic Organization*

- Established in 1921
- The intergovernmental consultative and technical organization to support safety of navigation and protection of marine environment
- UN observer status
- Recognized as the UN competent technical authority for hydrography and nautical charting.

* IHO Publication M-2
A principal Aim of the IHO is to ensure that all the world’s seas, oceans and navigable waters are surveyed and charted.

The Mission of the IHO is to create a global environment in which States provide adequate and timely hydrographic data, products and services and ensure their widest possible use.

The Vision of the IHO is to be the authoritative worldwide hydrographic body which actively engages all coastal and interested States to advance maritime safety and efficiency and which supports the protection and sustainable use of the marine environment.

**VIDEO CLIPS ABOUT HYDROGRAPHY AVAILABLE HERE**
IHO Water Level Requirements
Reference S-44 IHO Standards for Hydrographic Surveys
IHO Categories of Surveys

- Special Order
- Order 1a
- Order 1b
- Order 2

More stringent requirements
# IHO Standards for Hydrographic Surveys

## Table 1

Minimum Standards for Hydrographic Surveys

*(To be read in conjunction with the full text set out in this document.)*

<table>
<thead>
<tr>
<th>Reference</th>
<th>Order</th>
<th>Special</th>
<th>1a</th>
<th>1b</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chapter 1</strong></td>
<td>Description of areas.</td>
<td>Areas where under-keel clearance is critical</td>
<td>Areas shallower than 100 metres where under-keel clearance is less critical but features of concern to surface shipping may exist</td>
<td>Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area</td>
<td>Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate</td>
</tr>
<tr>
<td><strong>Chapter 2</strong></td>
<td>Maximum allowable THU 95% Confidence level</td>
<td>2 metres</td>
<td>5 metres + 5% of depth</td>
<td>5 metres + 5% of depth</td>
<td>20 metres + 10% of depth</td>
</tr>
</tbody>
</table>
| Para 3.2 and note 1 | Maximum allowable TVU 95% Confidence level | a = 0.25 metre  
 b = 0.0075 | a = 0.5 metre  
 b = 0.013 | a = 0.5 metre  
 b = 0.013 | a = 1.0 metre  
 b = 0.023 |
| Glossary and note 2 | Full Sea floor Search | Required | Required | Not required | Not required |
| **Para 2.1, Para 3.4 and note 3** | Feature Detection | Cubic features ≥ 1 metre | Cubic features ≥ 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres | Not Applicable | Not Applicable |
| Para 3.6 and note 4 | Recommended maximum Line Spacing | Not defined as full sea floor search | Not defined as full sea floor search | 3 x average depth or 25 metres, whichever is greater  
For bathymetric lidar a spot spacing of 5 x 5 metres | 4 x average depth |
| **Chapter 2 and note 5** | Positioning of fixed aids to navigation and topography significant to navigation 95% Confidence level | 2 metres | 2 metres | 2 metres | 5 metres |
| **Chapter 2 and note 5** | Positioning of the Coastline and topography less significant to navigation 95% Confidence level | 10 metres | 20 metres | 20 metres | 20 metres |
| **Chapter 2 and note 5** | Mean position of floating aids to navigation 95% Confidence level | 10 metres | 10 metres | 10 metres | 20 metres |
The Importance of Hydrography

- Nautical Charting and supporting safe and efficient navigation of ships
- Development & Maintenance of the Marine Transportation System
- Resource Exploitation
- Maritime Boundary Delimitation
- Coastal Zone Management
- Tsunami flood and inundation modelling
- Maritime Defense and Security
- National Marine Spatial Data Infrastructures
- Environmental Protection
- Recreational Boating
- Tourism
- Habitat Mapping
- Marine science
Cargo and container ships rely on accurate charts.

These ships move 95% of all international goods.
Increasing Drafts of Large Container Ships

Each inch of draft can mean an extra $5M of cargo can be loaded (NOAA/NOS)
Uncharted waters: Mega cruise ships sail the Arctic
Crystal Serenity Cruise Ship Completes Historic Northwest Passage Arctic Journey – Sep 2016

Viewed online 10/27/16
www.cruisecritic.com
Resource Exploitation Oil/Gas

Average monthly active offshore rig count in the U.S. Gulf of Mexico and rest of world total rigs

- Africa
- Middle East
- Europe
- Latin America
- Asia Pacific
- U.S. GOM
- U.S. non-GOM

GOM share (%)
Resource Exploitation
Offshore Wind Farms
Global Warming Triggers an International Race for the Arctic

As the ice melts, national rivalries heat up over oil and gas deposits and shipping routes.

At the Top of the World
This summer saw the first-ever recorded opening of both potential Arctic Ocean routes—the Northwest Passage and the Northern Sea Route. The historic melting of the Arctic sea ice is likely to launch a new era of oil and gas exploration, shipping, tourism, and—perhaps—geopolitical rivalries.

By Thomas Omestad Oct. 9, 2008
Basics of What is in a Chart

• A mathematical model of the earth as an ellipsoid of revolution (dimensions and orientation), also known as a horizontal datum onto which we prescribe latitude and longitude
• Positions of the coastline in the horizontal datum
• Positions of Aids to Navigation and Dangers to Navigation in the horizontal datum
• Heights of overhead obstructions with respect to a high tidal water level, and their positions with respect to the horizontal datum
• Depths of water with respect to a low water level ("chart datum"), and their positions with respect to the horizontal datum
• Cartographic rules for depicting the data on the horizontal datum in 2-D (either paper or electronically)
Horizontal/3-D Datums: Geodetic Datums


Geodetic Datum:
• Size (e.g., semi-major axis and semi-minor axis lengths)
• Orientation to the Earth
• Modern way to navigate in this system is the GNSS
Different Geodetic Datums, Different Latitude and Longitude

Two recent chart editions, two different datums: European Datum (ED 1950) and WGS84.

Coastline, Aids to Navigation (ATONs) and Dangers to Navigation (DTONs)

- Coastline
  - Photogrammetry
  - Satellite imagery
  - LIDAR (Laser Land Surveying)

- ATONs
  - GNSS (GPS)

- DTONs
  - Acoustic mapping and techniques and precise positioning of vessel (coordinates relative to horizontal datum and chart datum)
    - Single beam echo sounder
    - Multibeam echo sounder
    - Sidescan sonar
Chart Datums/Water Level Datums
Different Types

- Tidal
- Lakes
- Rivers
Tidal Datums

At each location there are many different tidal datums. Some examples are:

- **Mean Sea Level**: arithmetic mean of hourly heights observed over the NTDE.
- **Mean High Water**: average of all high water heights observed over the National Tidal Datum Epoch (NTDE).
- **Mean Low Water**: average of all low water heights observed over the NTDE.
- **Mean Lower Low Water**: average of the lower low water height of each tidal day observed over the NTDE.
- **Lowest Astronomic Tide**: Lowest tide level from harmonic analysis.
Tidal Datums

• Tidal forcing is well understood and occurs due to the orbital characteristics of the sun, earth and moon, and the diurnal spin of the earth.
• The longest period of practical concern for hydrography is the lunar nodal period of 18.6 years.
• All of the tidal forcing up to this period can be written as a linear combination of 5 periods, e.g.:
  1. A mean solar day (MSD)
  2. Lunar month, 27.3216 MSD
  3. Mean solar year, 365.2422 MSD
  4. Lunar perigee period, 3231.4818 MSD (8.85 year)
  5. Lunar nodal period, 6798.3661 MSD (18.61 yr)
Tidal Datums Require Tide Gauges

• In the US and some other countries there is a national network of long-term tide gauges that serve as primary gauges for hydrographic surveying.

• If more tide gauges are required for a hydrographic survey then secondary stations are installed for the length of the survey, but not less than 30 days. A technique known as a datum transfer, from a primary gauge is used to obtain equivalent long term datums at the secondary gauge.

• In some cases known tidal harmonic constituents and/or modeling are used to obtain chart datum.
LONG TERM SEA LEVEL TRENDS FOR THE UNITED STATES

(Accepted Global Sea Level Rise is 2mm/yr)
Secondary Gauge Installation
Mapping the Seafloor
From Leadline to Multibeam

https://www.nauticalcharts.noaa.gov/hsd/images/SW_History_lead2mb.jpg
Multibeam Surveying
Mapping of Seafloor & Sounding Reduction

Water depth = sounding depth (sd) + transducer depth (td)

Chart Datum (e.g., MLLW)

Water Level relative to Chart Datum

Water Level
Operational Scenario

**Bathymetry**
- Diameter of laser spot = 2.5 meters
- Diameter of largest void = 0.54 meters

**Topography**
- Diameter of laser segment spot = 0.83 meters
- Diameter of largest segment void = 0.7 meters
Mapping of Seafloor
When Vessel is Not Right Next to Tide Gauge
Co-Range, Co-Phase Chart

Source: Canadian Tidal Manual
Other Complicating Factors

• Vessel Heave
  – mitigate with low pass filter
• Vessel Pitch and Roll
  – Measure and remove if necessary
• Vessel Squat
  – Measure and remove if necessary
• Vessel Dynamic Draft
  – Measure and remove if necessary
• Sound speed variations and refraction
  – Measure sound speed profiles periodically
Vessel Configuration Survey

Determine a Vessel Frame of Reference for Instruments (GNSS Antennae, Sonar, etc, to Geolocate Soundings
Ellipsoidally Referenced Survey
Decoupling Tides from Hydrographic Surveying

- Water depths are measured to the reference ellipsoid
- The separation between the ellipsoid and chart datum ("separation model") is determined by others (e.g., NOAA in the United States)
- The separation model is used to convert, or reduce, the water depths to chart datum.
Product Examples
Bathymetric Surface & Targets

USM Hydrographic Science
Class 2015, Rigolets Team
USM Student made ENC Chart
Class 2015, Rigolets Team
Satellite Altimetry and Bathymetry

Space radar can sense ocean surface slopes, manifestations of gravity anomalies in the form of deflections of the vertical. These may be correlated with sea floor structure.

Figure from Smith (2003)
World oceans altimetry-mapped – 5 km resolution
Moon radar-mapped -100m
Mars radar-mapped – 20m
Venus radar-mapped – 100m
San Francisco Grounding Location Survey

SFO Grounding Survey Polygon

SFO Grounding

New feature

Vertical exaggerated
Maritime Defense and Security

Bathymetric Model from Satellite Altimetry

Smith and Sandwell Altimetry Model used to establish potential hazards to Navigation
Resources

- IHO [www.iho.int](https://www.iho.int)
  - Publications [https://www.iho.int/iho_pubs/IHO_Download.htm](https://www.iho.int/iho_pubs/IHO_Download.htm)

- NOAA Office of Coast Survey [https://www.nauticalcharts.noaa.gov/index.html](https://www.nauticalcharts.noaa.gov/index.html)
  - Hydrography pubs [https://www.nauticalcharts.noaa.gov/hsd/hydrog.htm](https://www.nauticalcharts.noaa.gov/hsd/hydrog.htm)