Implementation of River Information Services in Europe

Title of Report

Recommended accuracy and update requirements for depth data

Sub-Activity

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1 Introduction

1.1 Users and usage of depth data

Measured and processed depth data provides information about the contour of the river bottom. Especially in a muddy waterway the measured depth very much depends on the frequency that is used by the echo sounder.

Fairway users, especially fleet operators and skippers, are very much interested in the available water depth. This information is relevant to locate river banks for horizontal navigation purposes. Furthermore the available water depth is an important criterion for the amount of the cargo that can be loaded on the vessels (draught of the vessels). Providing exact water levels coming from gauges at certain locations along the fairway is only one important part towards the provision of the exact water depth. The other important information is the depth data of the fairway itself, the contour of the river bed. Only when having available this contour, the exact available water depth a any specific point along the fairway can be provided, especially when the exact water levels between the gauges is calculated by means of sophisticated water level models as well.

1.2 Process towards provision of depth data

Several steps have to be run through before the depth data can be provided to the fairway users:

- Measurement of the depth
- Data processing
- Integration of the depth data into the IENCs
- Publication of the IENCs and integration into the Inland ECDIS viewers

1.3 Technologies and their (dis-)advantages

For the measurement of the depth data along the fairway there are basically two different technologies, each with advantages and disadvantages:

- Single beam
    - Short description
        - Only measures one single depth value at a time. Normally a depth value directly under the equipment.
        - Single beam is generally used to measure a cross-section profile.
        - The vessel navigates along a line (cross-section profile).
    - Advantages
        - Less effort due to low amount of measurement data
        - Low cost equipment
    - Disadvantages
        - Due to the fact that one only has available the cross sections of certain locations, the depth soundings between these locations have to be interpolated.
        - Measurements are very time consuming if one wants to cover an area, not only a cross section.

- Multi beam
    - Short description
        - Multi beam equipment measures a lot of-depth values at a time.
        - Multi beam is generally used to measure larger areas. The vessel navigates along the waterway. Depending on coverage of multi beam and waterway

dimensions the vessel needs to navigate a waterway several times to cover the entire waterway.

- Advantages
  - An exact morphological model of the river bed (depth data) is provided by multi beam technology, so the interpolation between cross section profiles is not necessary which results in higher accuracy and higher reliability of the depth data. Hence, multi-beam data are much more reliable and needs less effort for data preparation because no interpolation between cross section profiles is necessary.
  - Fast measurement of areas
- Disadvantages
  - High effort for data processing due to the high amount of measurement data
  - High cost equipment
  - Coverage on the bottom depends on the current water level, i.e. the shallow the water level, the more time-consuming is the measurement.

For the sake of accurate and reliable depth data, multi beam is certainly the technology to be preferred.

1.4 Purpose of this document

More and more countries provide depth data of their national fairways within their national IENCs. In the past it was identified that the quality, mainly the actuality and accuracy of the depth data, is different per country and partly below the minimum requirements.

There are no specific standards for hydrographic surveying for inland navigation waterways. What is available are the international recommendations defined in the “S44 Standards for Hydrographic Surveys” by the “International Hydrographic Organisation” as a guideline. The specifications of “Special Order” are applicable for critical sections.

ORDER	Special	1a	1b	2
Description of areas	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under keel clearance is less critical but features of concern to surface shipping may exist	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	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
Maximum allowable THU (95% Confidence Level)	2 m	5 m + 5% of depth	5 m + 5% of depth	20 m + 10% of depth
Maximum allowable TVU for reduced depths (95% Confidence Level)	a = 0.25 m b = 0.0075	a = 0.5m b = 0.013	a = 0.5m b = 0.013	a =1.0 m b = 0.023
Full sea floor search	Required	Required	Not required	Not required
Feature dedection	Cubic features > 1 m	Cubic features > 2 m in depths up to 40 m; 10% of depth beyond 40 m	Not applicable	Not applicable
Recommanded maximum Line Spacing	Not defined as full sea floor search is required	Not defined as full sea floor search is required	3 x average depth or 25 m, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth

THU……total horizontal uncertainty
TVU……total vertical uncertainty

Table 1: IHO standards for hydrographic surveys, special publication no. 44 (5th edition, 2008)

As the minimum requirements towards the provision of depth data for inland navigation purposes are not clearly defined so far, this document is a first step by providing recommendations and proposals for minimum requirements towards accuracy and update intervals of depth data for inland navigation purposes as an input for Inland ECDIS Standard.

2 Minimum accuracy requirements towards depth data

2.1 Dependencies

The main dependency for the accuracy of depth data is:

- The depth itself
  - The shallower the area, the more critical is the accuracy and the higher it should be or vice versa the deeper the area, the less critical is the accuracy and the lower it could be.
    - More precise the range of the relevant under-keel-clearance determines whether the area is shallow or deep. The relevant under-keel-clearance most likely differs from river to river and from region to region depending on the characteristics of inland navigation in the area (e.g. inland navigation convoys vs. seagoing vessels).
  - The steeper a river bank the less critical the accuracy or vice versa the more gradual a river bank is the more critical the accuracy is.
- Consistency of river bottom
  - The harder the river bottom (e.g. rocks), the more critical is the accuracy.

2.2 Recommended accuracy

In practice a vertical accuracy of +/- 5 cm and a horizontal accuracy by using RTK-GPS of +/- 20 cm could be reached by the measurement equipment. The achievable vertical accuracy of soundings depends on the operational frequency of the echo sounder. Transducers with a high frequency have a higher resolution, than transducers with a low frequency.
After post processing of surveyed data (this is data thinning at multi-beam data and computation of Digital Terrain Model and further the interpolation between single-beam profile data) the horizontal and vertical accuracy decreases to approximately +/- 15-20 cm.
To reduce the data volume of Inland ENCs the number of isobaths has to be reduced and therefore the horizontal and vertical accuracy decreases even more due to the calculation of depth contours and depth areas.

The following table contains the recommended vertical- and horizontal accuracy (maximum acceptable deviation of presented depth data within Inland ENCs from the real world at the time of measurement) as well as the recommended spacing between the isobaths[1] based on the depth at reference low water level (RLW):

The Depth (in m) refers to the "relevant water depth range" (RWDR) which might be different from waterway section to waterway section and from region to region. The RWDR for a waterway section is determined by the range of draughts of the vessels navigating in that section as well as by the range of occurring water levels in that section. Each national authority should determine the RWDR based on these parameters for its waterways / sections. Furthermore each national authority is responsible for setting a definition of the waterway bottom (e.g. different density of mud) and which frequency for the sonar measurements is used (different frequencies lead to different measured depths due to different diffusion of the mud).

[1] To reduce the data volume within the IENCs, the ISO bath which shall be displayed are recommended to be reduced to the ones as proposed in the table.

Depth (in m)	**Maximum acceptable vertical deviation* (in cm)**	**Maximum acceptable horizontal deviation** (in cm)**	**Minimal ISO spacing (in cm)**
0m to 1m	-	-	no isobaths
1m to (RWDR – 1m)	+/- 50 cm	+/- 100 cm	50
(RWDR – 1m) to RWDR	+/- 20 cm	+/- 50 cm	20
RWDR	+/- 15 cm	+/- 40 cm	10
RWDR to (RWDR + 1m)	+/- 20 cm	+/- 50 cm	20
(RWDR + 1m) to (RWDR + 2m)	+/- 50 cm	+/- 100 cm	50
(RWDR + 2m) to (RWDR + 3m)	+/- 50 cm	+/- 100 cm	100
> (RWDR + 3m)	+/- 50 cm	+/- 100 cm	500

* … maximum acceptable deviation (95 % confidence level) of vertical spacing of depth contours/areas (isobath) displayed in the IENCs
** … maximum acceptable deviation (95 % confidence level) of horizontal accuracy of the depth contours/areas (isobath) perpendicular to the general direction of the traffic displayed in the IENCs

3 Minimum update requirements towards depth data

3.1 Dependencies

The main dependencies for necessary updates of depth data are:

- The main reason for updating depth data is because the actual accuracy of the depth data is not within the maximum acceptable deviations (as described in paragraph 2.2). Actuality requirements are therefore directly connected to the accuracy requirements.

- Critical areas, unstable river bed with dynamic changes
  - Depending on the material forming the river bed (rock, gravel, clay, silt, sand), the contour may be stable or change dynamically.
  - Based on experiences from measurements over the past years, the experts can identify areas with low and high rate of change in the river bed.
  - For areas with high rate of change, the actuality of the depth data is more critical; thus a higher update frequency is required.
  - For areas with no changes or low rate of change, the actuality of the depth data is less critical; thus a lower update frequency might be sufficient.

- High water and flood events
  - Especially high water and flood events have the potential to change the contour of the river bed enormously, which might require an unscheduled update of the depth data after such an event.

3.2 Recommended update intervals

The following table contains the recommended update intervals based on the identified dependencies:

Changes of the river bed	Update interval between 2 surveys
Critical sections (depth within RWDR and unstable river bed with dynamic changes)	New survey when verification soundings indicate a depth that is more than 20% outside the accuracy requirement as defined in chapter 2.2.
Non-critical sections (depth outside RWDR)	Regular verification soundings, Update on demand
After high water and flood events which (might) have an impact on the contour of the river bed.	It is recommended to make a complete measurement of the affected area as soon as possible. In most cases the authority knows from experience that a complete measurement is necessary. Alternatively verification soundings could be done if it is not certain that a complete measurement is necessary.

4 Recommendations

It is recommended to use multi beam technology at least in navigation critical areas to ensure reliable and exact geological model of the river bed with accurate depth data along the whole waterway (especially inside the navigable fairway).

It is recommended to execute regular verification soundings to identify changes in depth.

Depth data shall be also available for the approach areas to berths/ports and at the berth itself.