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CIRCULAR LETTER 45/2001
5 October 2001

GUIDELINES FOR THE PROCESSING OF HIGH VOLUME BATHYMETRIC DATA

Reference: CL 1/2001 dated 11 January 2001.

Dear Sir,

Under cover of CL 1/2001 the Bureau disseminated the final draft of the "Guidelines for the Processing of High Volume Bathymetric Data", which was developed by correspondence in cooperation with the IHO Working Group on S-44.

Member States were invited to send their comments on this draft to the Bureau. The Bureau is grateful to the 15 Member States who responded. A summary of the comments provided by some Member States is provided in Annex A to this Circular Letter.

In Annex B you will find the refined final draft for your perusal. You are kindly requested to send your **final** comments to the Bureau by **31 January 2002**.

Afterwards and as indicated in CL 1/2001, the Bureau plans to incorporate the Guidelines as an Annex into a future edition of S-44. It should be noted that the annexed Guidelines are not to be considered part of the Standard (see also the last sentence of the Introduction).

On behalf of the Directing Committee
Yours sincerely,

Rear Admiral Giuseppe ANGRISANO
President

Annex A – Summary of Comments
Annex B – Refined Draft Guidelines

Summary of Comments made by Member States
(in response to CL 1/2001)

Argentina
Has not yet started using MBES. Removing anomalous values it should be ascertained that dangers to navigation are not suppressed inadvertently. Paragraph 3.4 should be more detailed. The Guidelines could also be included in the Manual on Hydrography instead of including them in S-44 .

Chile
Agrees in general. Points out that doubtful data (2.3) should be checked using data from other sensors. There should be uniform criteria for data reduction (2.4) based on the importance of the area and the bottom configuration.

IHB: Thinks that individual HOs have to develop their criteria; the Guidelines aim at specifying only minimum requirements.

Emphasizes that operators must know processing procedures very well, that position gaps caused by signal loss required particular attention, and that several sound velocity profiles should be determined in environmentally complex areas.

Cuba
Although Cuba does not yet use MBES, the Guidelines are considered useful; no amendment necessary.

Finland
Proposes that the Guidelines are published as a separate document and not as an Annex to S-44. Finland has implemented similar principles for its own work. The Guidelines contain mainly high level minimum requirements; more detail is needed for practical processes.

Proposes that also some guidelines for data cleaning should be included. To avoid the Guidelines being used against HOs in liability cases, it should be pointed out in the Introduction that the purpose of the Guidelines is to provide guidance to HOs.

IHB: If "data cleaning" is to be understood as "data reduction", this is dealt with under 2.4; if not, the entire document deals with checking and correcting data. Will amend the Introduction as proposed.

France
Proposes modifications to 3rd paragraph of 3.4 (operator rules should be documented; explicit operator action should only be required if flags set during the automatic stage are related to depths shallower than the surrounding area) and the addition of a paragraph on metadata.

IHB: Comments will be taken into consideration in the refined draft.

Monaco
Although Monaco is not directly involved in surveys, we believe that the Guidelines will help to ascertain a high quality level and to standardize survey results.

Netherlands
Proposes to add the following paragraph to 1. Introduction: "Modern hard- and software capabilities enable to execute processing stages during real-time data acquisition. This tendency does not replace the requirements for raw data logging and full post-processing capabilities."

IHB: Thinks that paragraph 2.1 suffices, keeping in mind that the aim is to specify minimum requirements.

Suggests adding the following paragraph to 2.2 Statistics: "Systematic errors should be eliminated by means of calibration prior to execution or by procedure during execution of the survey."

IHB: Agrees that calibration should take place prior to or during the survey. But these guidelines are dealing with processing, not surveying.

Proposes to add to the 2nd paragraph under 2.2: "Fault-detection, fault-identification and -adaptation mechanisms may be added." and "Each individual measured position and depth should be tested w.r.t. the precision criteria set in S-44."

IHB: Regarding the first part of this proposal, the IHB thinks that this goes beyond minimum requirements as "may be added" indicates an option. Regarding the second part, a short sentence has been added to the guidelines.

Proposes to add "Errors introduced in the data-reduction (thinning) process should be included in the total propagated error budget" under 2.4.

IHB: Again, minimum requirements.

Suggests adding a new paragraph :
"2.5 Audit trail
All automatic and manual processing steps should be logged in an audit trail to be able to reconstruct the executed processing steps."

IHB: For manual processing, the requirement for an audit trail has been specified under 3.4. For automatic processing only flags may be set.

In paragraph 3.1, it is proposed to replace "files" by "ancillary data" in several places.

IHB: Cannot see the benefit of these replacements; seems mainly semantic.

Several deletions are suggested in the sub-paragraphs of 3.2.

IHB: Cannot see the benefit of this suggestion, as the introduction under 3.2 clearly indicates that the steps are to be considered as an indication and that adaptations may be required.

Suggests adding to 3.2.3 "Validation and correction of the applied SV-profiles should be executed in a temporal and spatial framework."

IHB: See 3.1.

Proposes replacing 3.2.5 by "A representation of the time series of the returning acoustic signal should be available for assessment of the quality of soundings."

IHB: The new text seems to make this a more compulsory requirement which might be better avoided when aiming at minimum requirements.

Suggests adding a reference to a paper in 3.3.

IHB: Reference added.

Proposes deleting "editing of data should be possible in all modes and include an audit trail" from the first sub-paragraph of 3.4.

IHB: Editing of data must be possible. The NL proposed an audit trail themselves as new paragraph 2.5.

New Zealand
Suggests inserting a paragraph between 3.2.2 and 3.2.3 to take the integrity of logged attitude sensor data into consideration.

IHB: Will do.

Suggests inserting a paragraph between 3.2.3 and 3.2.4 saying that it should be possible to re-process data if tidal data has been applied in real-time or at an early processing stage. Furthermore "water level changes" should be deleted from 3.2.2.

IHB: Will add a sentence about re-processing to 3.2.2. But "water level changes" should stay as this term covers tidal and non-tidal waters.

Suggests adding 2 sentences to paragraph 4 saying that validation should, at least, include the inspection of depth differences between overlapping data and also the use of sun-illuminated images from orthogonal directions so that MBES artefacts become apparent.

IHB: Thinks that this should be included in more detailed national instructions and not in Guidelines trying to define minimum requirements.

Together with its answer, New Zealand provided copies of standards used in conjunction with contract surveys, i.e. Hydrographic Survey Digital Data Formats, Hydrographic MBES Survey Standards, and Technical Specifications for Hydrographic Surveys (HYspec). These Standards, which might be of interest to Member States contracting out surveys, can be downloaded from http://www.linz.govt.nz/services; scroll down to Hydrographic Surveying.

Norway
Proposes adding in 2.1 "from the different sensors" to the text in parenthesis.

IHB: Will do.

Proposes adding "Calibration is recommended as part of quality assurance of the sensors, and the result of the calibration should be kept and archived" to the last paragraph in 3.1.

IHB: Thinks that calibration is part of the survey (cf., for example, S-44, p.12). Having added the proposed text to 2.1, calibration data are comprised.

Portugal
Proposes changing 3.2.3 to read "….. in real-time, it is desirable to be able to override them ….".

IHB: The present text ("…in real-time, it should be possible to override ....") should stay unchanged as the proposed new wording is not an improvement.

Suggests removing the 2nd paragraph of 3.3 as robust estimation techniques are not yet generally used and have not yet been fully proven; such methods should not be promoted.

IHB: This paragraph is meant as a hint to take robust estimation techniques into consideration when selecting an algorithm. Automated object detection tools are cited as well in this paragraph.

The term "audit trail" used in 3.4 (end of 1st paragraph) should be clarified.

IHB: The audit trail is a record of all changes made by an operator.

The last paragraph under 3.4 should be deleted as the connection with S-44 does not seem to be straightforward.

IHB: Agrees.

Sweden
Thinks that the Guidelines interfere to some extent with S-44 and suggests that the Guidelines should be considered and finalized in conjunction with an updated version of S-44. The new edition of S-44 should then consist of a part containing mandatory requirements and another part containing non-mandatory requirements as e.g. these Guidelines.

Refined Final Draft (October 2001)
GUIDELINES FOR THE
PROCESSING OF HIGH VOLUME BATHYMETRIC DATA

N.B.: Modifications are indicated in italics and additionally by strikethrough for deletions.

1. Introduction

With the advent of multibeam echosounders (MBES) and laser airborne systems, hydrographers and oceanographers are nowadays confronted with the task of processing high data volumes collected during surveys. The main advantages of MBES and laser airborne systems are increased bottom coverage and potentially wider spacing of track lines, due to the greater swath, when compared to single beam echosounder (SBES) surveys which may result in a reduction of time required for a survey.

However, processing procedures used prior to the introduction of MBES and laser airborne systems are inefficient, in terms of both manpower and time required to process the high volume of data gathered by these systems. Therefore, new processing procedures are needed to allow the reduction, processing and production of the final data set within acceptable manpower and time constraints while maintaining data integrity.

As hydrographic offices continue to be responsible (liable) for their products, these processing procedures should be well documented and fulfil, at least, certain requirements. The following processing guidelines concentrate on principles and describe **minimum requirements**; they do not specify details as, for example, computer hardware, operating system, use of screen colours etc. *The principle purpose of these guidelines is to provide guidance to hydrographic offices and not to set standards.*

2. General Principles

2.1 Conservation of Data

It is strongly recommended that the original survey data (raw data *from the different sensors*) be conserved adequately before commencing with the processing of data. The final processed data set should also be conserved.

2.2 Statistics

Statistical algorithms employed for detecting erroneous and/or doubtful data should be adequately tested to prove their suitability.

For the control of positions, a Kalman filter or comparable mechanism is deemed adequate. *Compliance with the criteria specified in IHO Publication S-44 (4th edition) has to be ascertained.*

The minimum control of depths should consist of defining areas where the number of, and distance between, depths allow the calculation of meaningful statistics to ensure compliance with the standards specified in IHO Publication S-44 (4th edition). Furthermore, cross checklines have to be used for the quality control of depths.

In addition to statistics, threshold values for survey data can be used to facilitate the detection of blunders.

2.3 Treatment of Doubtful Data

Data considered erroneous and/or doubtful, either by the statistical algorithms employed or by an operator, shall be flagged (marked) accordingly and shall not be deleted. To classify errors in accordance with their magnitude, use of error classes is recommended.

2.4 Data Reduction

The rules and mechanisms employed for data reduction have to be documented. When reducing the data density, the selection of shoal biased depths must be possible.

3. Processing Stages

The processing of high volume bathymetric data can be divided into the following stages:

- Data Preparation
- Data Processing
- Automatic (Non-interactive) quality control
- Manual (Interactive) quality control

3.1 Data Preparation

Data preparation files contain either fixed values, e.g. system calibration factors and sensor offsets, or variable values such as sound velocity profiles and tide values for the reduction of soundings. Data files are either prepared by direct operator interaction or automatically. The data in these files are needed for processing raw survey data.

All of these files should be subject to automatic or manual plausibility checks to avoid contamination of the survey data during processing. If, for example, the athwartship offset between the positioning antenna and the transducer is incorrect, a systematic error will be introduced in the positions of all depths.

Files prepared manually by direct operator interaction should be subject to an independent check by a second operator.

3.2 Data Processing

The processing steps outlined below are only to be interpreted as an indication, also with regard to their sequence, and are not necessarily exhaustive. Adaptations may be required due to the configuration of the survey as well as the processing system actually used. In general, processing should strive to use all available sources of information to confirm the presence of navigationally significant soundings.

3.2.1 Position

This step should comprise merging of positioning data from different sensors (if necessary), qualifying positioning data, and eliminating position jumps. Doubtful data should be flagged and not be deleted.

3.2.2 Depth corrections

Corrections should be applied for water level changes, measurements of attitude sensors, and changes of the draught of the survey vessel (e. g. squat changing with speed; change over time caused by fuel consumption). *It should be possible to re-process data for which corrections were applied in real-time.*

3.2.3 Attitude corrections

Attitude data (heading, pitch, roll) should be qualified and data jumps be eliminated. Doubtful data should be flagged and not be deleted.

3.2.4 Sound velocity

Corrections due to refraction should be calculated and applied during this step. If these corrections have already been applied in real-time during the survey, it should be possible to override them by using another sound velocity profile.

3.2.5 Merging positions and depths

For this operation the time offset (latency) and the geometric offset between sensors have to be taken into consideration.

3.2.6 Analysis of Returning Acoustic signal

When a representation of the time series of the returning acoustic signal is available, the processing methods should attempt to use this information to qualify soundings.

3.3 Automatic (Non-interactive) Quality Control

During this stage, the coordinates (i.e. positions and depths) obtained should be controlled automatically by a programme using suitable statistical algorithms which have been documented, tested and demonstrated to produce repeatable and accurate results.

Selecting an algorithm, robust estimation techniques should be taken into consideration as their adequacy has been confirmed by extensive and independent research conducted by –inter alia- China[1], France[2], *Denmark*, Germany, and *the NATO*[3]. Employing automated object detection tools using angle-independent time-sampled backscatter from the acoustic signal might be considered as well as a check on automated processing algorithms.

All blunders and erroneous and doubtful data should be flagged for subsequent operator control. The type of flag used should indicate that it was set during the automatic stage.

3.4 Manual (Interactive) Quality Control

For this stage the use of 3-D visualisation tools is strongly recommended. These tools should allow viewing the data using a zoom facility. The interactive processing system should also offer different display modes for visualisation, e.g. depth plot, error plot, single profile, single beam, backscatter imagery etc. and should allow for the visualisation of the survey data in conjunction with other useful information as e.g. shoreline, wrecks, aids to navigation etc.; editing of data should be possible in all modes and include an audit trail. If feasible, data displays should be geo-referenced.

If feasible, these tools should include the reconciliation of normalised backscatter imagery with bathymetry and, provided that automated object detection tools were used, display of flagged data for both data modes should be possible.

The rules to be observed by operators during this stage should be documented.

The flags set during the automatic stage, *which correspond to depths shallower than the surrounding area*, should require explicit operator action, *at least, for Special Order and Order 1 surveys (cf. S-44, Table 1)*. If the operator overrules flags set during the automatic stage, this should be documented. If a flag is set by the operator, the type of flag used should indicate this.

~~*It may be possible to exclude areas where depths are not relevant for the safety of navigation (cf. IHO Publication S-44, Table 1).*~~

4. Metadata

Metadata should be associated with each processed dataset. Chapter 5 of S-44 contains recommendations on the scope of metadata.

5. Validation Procedures

The final data should be subject to independent in-house validation employing documented quality control procedures.

[1] Huang Motao et al. "Robust Method for the Detection of Abnormal Data in Hydrography" in International Hydrographic Review, Monaco, LXXVI(2), September 1999, pp. 93-102

[2] N. Debese, H. Bisquay "Automatic Detection of Punctual Errors in Multibeam Data Using a Robust Estimator" in International Hydrographic Review, Monaco, LXXVI(1), March 1999, pp. 49-63

[3] *G. Canepa, O. Bergen "An approach to robust map generation from multibeam bathymetric data" in SACLANTCEN Report Nr. SR-285*