NATIONAL HYDROGRAPHIC CENTRE

MALAYSIA
HYDROGRAPHIC SURVEYS
STANDARD

PREFACE

Malaysia Hydrographic Surveys Standard (MHSS) for charting is published to provide information on compliance with standards by The International Hydrographic Organization (lHO) Standards For Hydrographic Surveys (S44) for the publication of Nautical Charts and ENCs of Malaysia nautical publications. The IHO regularly updates its standards to align with emerging technology, this standard must be comprehended not only by individuals directly engaged in hydrographic surveys but also by the broader hydrographic communities in Malaysia.

The National Hydrographic Centre (NHC) is the national authority that publishes nautical and electronic navigational charts (ENC) that are crucial for ensuring the safety of navigation in Malaysian waters. It is important to highlight the precision of hydrographic surveys in achieving this goal. The MHSS aims to establish specific requirements for accurately acquiring hydrographic data. Additionally, it aims to ensure that the uncertainty of the data is properly quantified.

The standard does not encompass procedures covered in other related documents. It must be used in conjunction with the hydrographic survey project, which includes the Hydrographic Instruction (HI) from NHC and other contractual hydrographic survey work scopes. This standard will assist surveyors and contractors in meeting the NHC's quality control requirements.

The content of this standard is dynamic and will be updated regularly in compliance with S44 and emerging technologies. Proposed amendments to improve the content should be forwarded to the sponsor of this standard.

Director General of Hydrography

May 2024

RECORD OF AMENDMENT

Proposals for the amendment of this publication are to be forwarded to:

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No	Chapter/Paragraph	Description	Note
(a)	(b)	(c)	(d)

CONTENT

ABBREVIATIONS

A		
ALB	-	Airborne LIDAR Bathymetry
C		
CATZOC	-	Categories of Zone Of Confidence
E		
ENC	-	Electronic Navigational Chart
G		
GNSS	-	Global Navigation Satellite System
H		
HAT	-	Highest Astronomical Tide
I		
IHO	-	International Hydrographic Organisation
IMO	-	International Maritime Organisation
L		
LAT	-	Lowest Astronomical Tide
M		
MBES	-	Multibeam Echo Sounder
MHSS	-	Malaysia Hydrographic Surveys Standard
N		
NHC	-	National Hydrographic Centre
R		
RMN	-	Royal Malaysian Navy
S		
SBES	-	Singlebeam Echo Sounder
SSS	-	Side Scan Sonar
T		
THU	-	Total Horizontal Uncertainty
TPU	-	Total Propagated Uncertainty
TVU	-	Total Vertical Uncertainty
U		
UN	-	United Nation
W		
WGS84	-	World Geodetic System 1984

INTRODUCTION

1. The hydrographic services of the Royal Malaysia Navy (RMN) have played a significant role since 1960 for Malaysia in duties and responsibilities as a member state of the United Nations (UN), International Maritime Organization (IMO) and International Hydrographic Organization (IHO). Malaysia is required by the accepted conditions and agreements to establish hydrographic services to ensure the safety of navigation and meet the technical criteria for determining maritime boundaries. This obligation was then entrusted to the RMN through Cabinet Decision No. 443/887/72 dated 31 October 1972. Through this decision, the RMN was essentially appointed as a qualified and responsible entity to perform hydrographic services in Malaysian waters. These duties and responsibilities were carried out by the RMN Hydrographic Branch, which was established. In 2005, in response to increased demand for duties and responsibilities, the RMN Hydrographic Branch was transformed into a national entity, namely the National Hydrographic Centre (NHC).

2. Hydrographic surveying has advanced significantly in terms of technology. Satellite positioning systems, integrated multibeam systems and multi-tools systems, and advanced data processing systems have enhanced hydrographic surveying capacity. Due to these technological advances, hydrographic surveyors can now acquire data with greater precision and accuracy. As a result, standards must be updated to reflect these technological developments. It is essential to ensure the survey meets the standard to align with IHO objectives ‘Survey once use many times’ and hydrography data is much more than the nautical chart.

3. In past surveys, the required positioning accuracy was mostly determined by the practical limitations of draftsmanship at a given scale. Automated data management allows data to be presented at any scale. Therefore, the accuracy requirements for positions in this standard are somewhat determined by the errors introduced by positioning and sounding systems but mostly by the user's perceived accuracy requirements.

4. This standard is based on IHO requirements. The NHC adopted the latest resolution of the S44 working group on the evaluation of measurement equipment technologies for hydrographic surveys in ensuring the safety of navigation. Standards for surveys conducted for purposes other than safety of navigation (e.g. geophysical, oil and gas, dredging, and geotechnical) are not currently defined in this document. However, the range of accuracies presented in the Matrix of S44 edition 6.1.0 dated October 2022 was designed to accommodate other surveys and to provide a common framework for tasking and assessing hydrographic surveys in general. Although the Matrix is available for other hydrographic survey purposes, its usage must not reduce the minimum standards defined for the safety of navigation survey orders. For other hydrographic survey standard requirements, it will be published as annexes in this MHSS.

5. This standard establishes distinct requirements for different locations based on their relative importance for the safety of navigation when specifying

depth accuracy. The requirements have been eased for places that are less crucial for navigation. Additionally, this standard establishes a new obligation for surveyors to strive for all new data with a statistical estimate of its probable error.

Engagement of Hydrographic Surveyor

6. All survey work must be performed by qualified personnel. The Surveyor shall be certified by an institution that offers a Category ‘A/B’ programme recognised by the International Board on Standards of Competence for Hydrographic Surveyors and Nautical Cartographers (IBSC), International Hydrographic Organization (IHO), International Federation of Surveyors (FIG), International Cartographic Association (ICA) or as approved by the Director General of Hydrography. The Surveyor shall produce documented proof of such certification or registration with NHC.

7. The conduct of hydrographic surveys shall be carried out by a Category ‘A/B’ certified Surveyor and the survey plans and data shall be endorsed by Category ‘A’ certified Surveyor. The Surveyor shall be responsible for all survey works carried out including the submission of plans and reports to the Director General of Hydrography or his representative. The surveyor shall ensure that all survey works are carried out following this publication.

8. The Surveyor shall ensure that all survey works are carried out following the MHSS and technical terms will be used as defined both in the IHO Hydrographic Dictionary S-32 and IHO Special Publication 44, 6th Edition.

CLASSIFICATION OF BATHYMETRY

9. To accommodate different accuracy requirements for areas to be surveyed and to classify old surveys, five (5) orders of the survey are defined. These are described below and in Table 1 and summarise the overall accuracy requirements.

10. For surveys lower than Order 1A, the 100% feature search is not compulsory. However, it is strongly recommended to carry out feature searches in the areas in which significant features are deemed to exist.

11. MHSS for Total Vertical Uncertainty (TVU) in hydrographic surveys apply to general water depths and least depths over wrecks and obstructions. By extension, they also apply to the elevations of rocks or other features which uncover at low water and to the measurement of overhead clearances. These standards apply regardless of the method of determination; whether by single beam echo sounder, multibeam echo sounder, lidar, lead line or other method.

12. The table and formula below shall be used to compute the maximum allowable TVU for all depth estimates included in bathymetric data products or feature attribution after the application of correctors for all systematic and system-

specific errors. At least 95% of geographically distributed grid nodes shall meet this specification.

Criteria	Order 2	Order 1b	Order 1a	Special Order	Exclusive Order
Area description (Generally)	Areas where a general description of the sea floor is considered adequate.	Areas where under keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas where underkeel clearance is considered not to be critical but features of concern to surface shipping may exist.	Areas where under keel clearance is critical	Areas where there is a strict minimum under keel clearance and manoeuvrability criteria
Depth THU [m] + [% of Depth]	20 m + 10% of depth	5 m + 5% of depth	5 m + 5% of depth	2 m	1 m
Depth TVU (a) [m] and (b)	a = 1.0 m b = 0.023	a = 0.5 m b = 0.013	a = 0.5 m b = 0.013	a = 0.25 m b = 0.0075	a = 0.15 m b = 0.0075
Feature Detection [m] or [% of Depth]	Not Specified	Not Specified	Cubic features > 2 m, in depths down to 40 m; 10% of depth beyond 40 m	Cubic features > 1 m	Cubic features > 0.5 m
Feature Search [%]	Recommended but Not Mandatory	Recommended but Not Mandatory	100%	100%	200%
Bathymetric Coverage [%]	≥ 20%	≥ 20%	≤ 100%	100%	200%

Table 1: Standards for Hydrographic Surveys

(1) To calculate the error limits for depth accuracy, the corresponding values of a and b listed in Table 1 have to be introduced into the formula

$$\pm = \sqrt{[\mathbf{a}^2 + (\mathbf{b} \times \mathbf{d})^2]}$$

Where $\mathbf{a}$……… constant depth error, i.e. the sum of all constant errors in metre

$\mathbf{b}$ x $\mathbf{d}$.... depth-dependent error, i.e. the sum of all depth-dependent errors

$\mathbf{b}$……… factor of depth-dependent error

$\mathbf{d}$……… depth in metres

(2) The value of 40 m has been chosen considering the maximum expected draught of vessels.

13. The rows of **Table 1** are explained as follows:

Row 1 "Areas Description", gives examples of areas to which an order of survey might typically be applied.

Row 2 "Depth THU", lists the maximum allowable uncertainty values for positioning of each depth sounding to meet each order of survey.

Row 3 "Depth TVU", specifies maximum allowable vertical measurement uncertainty for reduced depths to meet each order of survey.

Row 4 "Feature Detection", specifies the detection capabilities of a system to detect features of a defined size.

Row 5 "Feature Search", extends to which an area has been surveyed using a systematic method of identifying features.

Row 6 "Bathymetric Coverage", specifies the seafloor coverage based on a systematic method of measuring the depth, the combination of the survey pattern and the theoretical area of detection of the survey instrumentation.

14. Feature detection implies that the seafloor will be completely ensonified for the width of the multibeam or the multi-transducer array and that there will be no gaps (areas of no ensonification) between sounding lines. When the feature to be detected is smaller, 200% coverage is recommended. It implies that the surface ensonified by the multibeam or multi-transducer will be covered at least twice from a minimum of two separate passes or swaths.

15. Even though an echo sounding system may be capable of detecting target features as defined in Table 1 Feature Detection, efforts will have to be taken such as priori estimate of survey order based on survey equipment used to ensure that all the cubic features are found when conducting a feature search.

Exclusive Order

16. Exclusive Order hydrographic surveys are based on the IHO Special Order with higher accuracy, and their use is intended to be restricted to shallow water areas (harbours, berthing areas, and critical channels) where there is optimal use of the water column and where specific critical areas with minimum under-keel clearance and bottom characteristics are potentially hazardous to vessels.

17. This order also applies to high-precision engineering surveys. All uncertain sources must be minimised. Exclusive Order requires very precise positioning systems, closely spaced lines (when target detection is required), and rigorous control of all aspects of the surveys. For this order, a 200% feature search and a 200% bathymetric coverage are required. The size of features to be detected is deliberately more demanding than for Special Order.

Special Order

18. Special Order hydrographic surveys are intended to be restricted to specific critical areas with minimum under-keel clearance and where bottom characteristics are potentially hazardous to vessels. These areas have to be explicitly designated by the agency responsible for survey quality (harbours, berthing areas, and associated critical channels. All uncertain sources must be minimized. Special Order requires the use of closely spaced lines (when target detection is required).

19. Therefore, 100% feature search and 100% bathymetric coverage are required and the size of the features to be detected by this search is deliberately more demanding than for Order 1a.

Order 1a.

20. Hydrographic surveys of Order 1a are intended for harbours, harbour approach channels, recommended tracks, inland navigation channels, and coastal areas of high commercial traffic density where under-keel clearance is less critical and the properties of the seafloor are less hazardous to vessels (e.g. soft silt or sand bottom). Order 1a surveys should be applicable but not limited to areas with less than 100 m water depth. Although seafloor search requirements are less stringent than for Exclusive Orders and Special Orders, full seafloor search may be required in selected areas where the bottom characteristics and the risk of obstructions are potentially hazardous to vessels. In required areas, appropriate sounding equipment and methodologies must be employed to ensure that all features greater than 2m cubed in water depths up to 40m, or features representing 10% or more of the depth in areas deeper than 40m are detected.

Order 1b.

21. Order 1b surveys should be applicable but not limited to areas with less than 200 m water depth and not covered by Exclusive Order, Special Order, and Order 1a. These are areas where a general description of the bathymetry is sufficient to ensure no obstructions on the seafloor will endanger the type of vessel expected to transit or work the area. As a minimum, an evenly distributed bathymetric coverage of 20% is required for the survey area. A full bottom search

may be required in selected areas where the bottom characteristics and obstructions risk may be hazardous to vessels.

Order 2.

22. Hydrographic surveys of Order 2 are intended for all areas not covered by Exclusive Order, Special Order, and Orders 1a and 1b in water depths more than 200 m. This is the least stringent order and is intended for areas where the depth of water is such that a general depiction of the bottom is considered adequate. As a minimum, an evenly distributed bathymetric coverage of 20% is required for the survey area.

POSITION

23. The term "position" in hydrographic surveying refers to the precise location of a point or feature on the surface or bottom of a body of water. This can include the location of shorelines, depths of the water, the shape of the seafloor, and any other important features. If the accuracy of a position is affected by different parameters, the contributions of all parameters to the total position error must be accounted for.

24. A statistical method combining different error sources for determining positioning accuracy must be adopted. The position error, at a 95% confidence level, must be recorded together with the survey data (see Data Attribution). World Geodetic System 1984 (WGS84) will be used for positioning as its reference coordinate system. Standard quality assurance checks techniques shall be completed prior to, during, and after the acquisition of data. Satellite systems shall be capable of tracking at least five satellites simultaneously, and integrity monitoring for Exclusive Order, Special Order, and Order 1a surveys is recommended.

Horizontal Control

25. If horizontal positions are referenced to a local datum, the name and epoch of the datum should be specified and the datum should be tied to World Geodetic System 1984. Recorded horizontal position must maintain a precision of at least decimeters, including in survey records and deliverables: i.e., for positions records in:

a. Decimal degrees: 6 decimal places.

b. Degrees and decimal minutes: 4 to 5 decimal places.

c. Degree, minutes, and decimal seconds: 2 to 3 decimal places.

Soundings

26. The position of soundings, dangers, and all other significant submerged features shall be determined such that the horizontal accuracy is as specified in Table 1. The accuracy of a sounding's position is the accuracy at the position of the sounding on the bottom, located within WGS 84.

Navigation Aids and Other Features

27. The horizontal positions and/or elevations of navigation aids and other conspicuous features shall be determined to the accuracy stated in Table 2, at a 95% confidence level.

The order to use for the positioning of navigation aids and other features such as bridge piers, walls, clearances, etc. should be determined in accordance with the importance of the safety of navigation in the surveyed area. As an example, bridge piers located along a critical channel have a higher significance than those located in an intertidal area and should therefore be positioned with higher accuracy. The examples of typical areas stated in Table 1 can be used as a guideline.

	Exclusive Order		**Special Order**		**Order 1a**		**Order 1b**		**Order 2**	
	HOR	VER	HOR	VER	HOR	VER	HOR	VER	HOR	VER
Fixed aids to navigation and features significant to navigation	0.2m	0.25m	0.5m	0.5m	1m	1m	2m	2m	5m	2m
Mean position of floating aids to navigation.*(See Note)	5m	N/A	10m	N/A	10m	N/A	10m	N/A	20m	N/A
Natural Coastline (high and low water lines)	2m	N/A	5m	N/A	10m	N/A	10m	N/A	10m	N/A
Topographical features (not significant for navigation)	5m	0.3m	10m	0.5m	15m	1m	20m	2m	20m	3m
Overhead clearances	1m	0.3m	2m	0.5m	5m	1m	10m	2m	10m	3m
Range line and sector lights limits azimuths	All range lines and sector lights limits must be drifted to confirm the theoretical azimuth. The maximum difference between the theoretical and drift azimuths is: 0.5°									
Water flow direction	10°									
Water flow speed	0.1 knots									

*Note: The accuracy of the position of a floating aid to navigation is the accuracy of the positioning including parameters like: the buoy movement; how close the vessel (antenna) was from the buoy, etc

Table 2: Standards for Positioning of Navigations Aids and Important Features

VERTICAL DATUM

Sounding Datum

28. All depths must be reduced to the Lowest Astronomical Tide (LAT) datum, which can be expected to occur under average meteorological conditions and under any combination of astrological conditions. It can be determined by inspecting predicted sea levels over 19 years from the properly maintained and calibrated gauges.

29. All soundings are reduced to LAT using verified water level observation data. Sounding datum must be referred to a minimum of 2 benchmarks established or verified by NHC.

30. If real-time water level cannot be observed due to the absence of land or permanent structures for tidal observation and the depth is more than 50m, then soundings may be reduced to LAT or Mean Sea Level (MSL) using predicted tide generated from constituent near the survey area or reduced to Mean Sea Surface using logged GNSS tide.

Datum for Elevations.

31. All elevations and clearances must be referenced to a specific datum. In semi-diurnal tidal regions, elevations are referenced to Mean High Water Spring (MHWS), whereas in the diurnal regions, elevations are referenced to Mean Higher High Water (MHHW). All clearances are referenced to the Highest Astronomical Tide (HAT).

Water Level Observations

32. Water level observations shall be carried out for the purposes as follows:

a. Providing water level throughout a survey for sounding reductions to a datum.

b. Providing data for tidal analysis, tidal constituent determination and prediction, or vertical datum (Tidal Level) establishment. Any observations should extend over the longest possible period and shall not be less than 30 days.

33. Water level heights should be observed so that the total measurement error at the gauging station, including timing and filtering errors, shall not exceed +/- 10cm at a 95% confidence level for Exclusive Order and Special Order surveys, for tidal analysis and the determination of vertical datum. For other orders +/- 20cm at 95% confidence level should not be exceeded.

34. The density and distribution of tide gauges depend on the changes in water level (usually tidal) characteristics of the survey area. The measurement of tide is generally planned to identify every 10 cm change in range for areas with 3 m or less range and every 20 cm change in range for areas with more than 3 m of range.

35. For the bathymetric data to be fully exploited in the future using advanced satellite observation techniques, water level observations and consequently sounding datum should be related to the Lowest Astronomical Tide (Chart Datum) and also to a geocentric reference system, preferably the World Geodetic System 84 (WGS 84).

DEPTH MEASUREMENT

36. Depth measurement is a crucial aspect of hydrographic surveys, as it provides essential information on the seafloor's topography and underwater features. The accuracy and reliability of depth measurements are critical for the safety of navigation, defense and security, maritime boundary management,

maritime commerce, marine resources exploration, and environmental management.

37. Hydrographic surveys use different techniques for measuring depths, depending on the water depth, seabed conditions, equipment availability, and survey objectives. The method for measuring water depths is primarily using acoustic signals. Acoustic sound waves are emitted from the survey vessel, and the echo returns from the seabed are recorded and analyzed to determine the water depth. This technique requires sophisticated instruments such as single-beam, multi-beam, or interferometric sonar, which provide accurate and detailed depth measurements.

38. Depth measurements can also be taken using a range of other techniques, including satellite altimetry, LiDAR, and GNSS positioning. Each of these methods has advantages and disadvantages in terms of accuracy, resolution, and cost. Therefore, the choice of the most suitable method depends on the survey requirements, environmental conditions, and budget.

Sensor Calibration

39. **MBES**. Field procedures before any survey must be undertaken to determine any residual biases and the corrections that will be used to fine-tune the calibration of the MBES. These field procedures are commonly referred to as a “Patch Test” and involve logging data while the survey vessel is run over specific lines over different types of bathymetric relief at differing speeds, reciprocal directions, and offset to identifiable targets. The patch test aims to determine any residual roll angle, pitch angle, azimuth angle, and time offset of the MBES concerning the motion reference unit. The patch test is also conducted at the end of the survey to confirm that the system has not changed during the survey. A patch test must also be conducted whenever there is a change of significant mechanical, hardware, or software components of the system.

40. **SBES**. The 'Bar Check' is one of the common field procedures for calibrating the SBES. It involves lowering a metal cone or plate device to the maximum depth of the survey area or a maximum depth of 60 meters, recording the true depth versus the measured depth, and compiling a depth correction table for later use in correcting the measured depths. If the size and shape of the vessel permit, the bar check may also be used to determine the correct draft entry in a MBES. This methodology should be performed at least three times a day during the morning, afternoon, and evening or in areas where sound velocity changes are significant.

41. **Sound Velocity Profile Sensors**. These sensors are to be factory-calibrated according to the manufacturer's schedule and specifications or sooner if the data has become suspect.

Sound Speed Measurement.

42. The speed of sound in the water column shall be measured either directly, using a sound speed sensor, or indirectly calculated from conductivity, temperature, and pressure measurements. In planning the measurement of

sound speed profiles, the type of acoustic survey instrumentation as well as other potential uses for the sound speed data must be considered.

43. **SBES Survey**. The measurement of sound speed profiles for the use of a SBES is desired to correct for the sound speed propagation differences caused by changes in sound speed through the water column. This results in a vertical correction only. Sound speed profiles are to be taken at an interval dictated by the variability of conditions in the survey area. Where possible, the entire sound speed profile shall be applied directly by the echo sounder. If only a single value is accepted by the echo sounder in use, a calculated harmonic sound speed shall be used. Bar checks shall be done at a frequency sufficient to validate the sound speed being used.

44. **MBES Survey**. The measurement of sound speed profiles for a multibeam survey is required to correct for the sound speed propagation and ray path variability through the water column. This results in a vertical and across-track correction. Sound speed profiles shall be measured at a sufficient frequency to ensure that the horizontal and depth accuracies for the order of the survey as defined in Table 1 are met. If a continuous profiling system is available, sound speed profiles shall be measured at the maximum rate that logistics and vessel traffic allow.

45. Continuous monitoring is required to determine the changes in sound velocity profile. Monitoring is done in two distinct means, the data and observable water conditions. Data monitoring consists of watching for refraction effects in the data. These will include a mismatch in the overlap of survey lines and a trend towards an arcuate ping profile. Observable water conditions consist of effects that indicate a change in the sound speed profile. These include but are not limited to, observation of a change in measured surface sound speed, an inflow of freshwater or a sediment plume, wind/wave action causing surface mixing, significant rainfall, traversing of currents, surface water temperature change, etc. Any such indications shall result in a new sound speed profile being measured.

46. The surface speed of sound shall always be measured and applied in real-time for a multi-beam sounder whether it is an arcuate array (e.g. barrel array) or a flat, electronically steered array.

47. **Oceanographic Purposes**. Sound speed profile measurements shall be recorded with the sensor details, UTC/ local time, and geographic position of measurement. When sound speed is measured directly, it is desirable to measure temperature as well to enable the calculation of salinity for oceanographic purposes. When sound speed is calculated from conductivity, temperature, and pressure, these values shall be retained along with the calculated sound speeds.

Sounding Density.

48. In planning the density of soundings, both the nature of the seabed in the area and the requirements of the users have to be taken into account to ensure 100% coverage and adequate bottom search for MBES survey and at the given scale of the survey for SBES survey. It should be noted that no method (not even 100% search, although desirable) guarantees the reliability of a survey by itself.

49. Furthermore, it cannot disprove the existence of hazards to navigation with certainty; in particular, the existence or non-existence of isolated natural hazards or man-made objects such as wrecks between survey lines if conducting a SBES survey, or in the absence of redundant overlap in the case of MBES surveys. If 100% seafloor search is required, it is recommended to use MBES or SBES combined with accurate side scan sonar to achieve your results.

a. **Line Spacing**

(1) For MBES, line spacing is replaced with the percentage of coverage or density of soundings per square grid cell. To ensure adequate sounding density in shallow waters (<40m water depth), which are deemed critical to navigation, it is recommended that surveys use 200% coverage or 100% overlap. The sounding density should be at least 5 pings per cell to achieve the desired resolutions.

(2) For SBES surveys, appropriate line spacing for the various orders of the survey is proposed in Table 1. The results of a survey have to be assessed using procedures developed by the Surveyor responsible for the survey quality. Based on these procedures, it has to be decided whether the extent of the bottom search is adequate and whether the line spacing shall be reduced or extended. These procedures may include an appropriate statistical error analysis that shall consider interpolation errors and depth and positioning errors of the measured depths.

b. **Shoal Examination**

(1) A shoal is a distinct rise of the seabed, which could be a hazard to navigation. Considering the draught of some modern ships, any isolated indication of shoaling of less than 50m may be of sufficient importance to warrant an examination for a possible shoal. A 10% rise in the seabed depending on the depth, the relative character, and the navigation type (maximum draught, etc.) of the surrounding area may indicate the existence of a shoal or some other serious hazard to surface navigation and therefore be investigated.

(2) For MBES surveys, ensure that there has been sufficient redundant data over the peak of the shoal to ensure the least depth has been accurately determined.

(3) When operating an SBES, a detailed pattern of sounding lines over the shoal area shall be run. The line pattern and density are determined by the surrounding bathymetry, the system used, and the navigational characteristics of the area. Another method is to sweep an area for 100% bottom coverage using either a mechanical or Side Scan Sonar.

(4) Depending on the bottom characteristics, systems used, and the client's needs, the Surveyor will determine if the shallowest depth at each shoal examination shall be verified and the bottom sample obtained (mechanical or inference method).

c. **Depth Measurement Over Hazards**

(1) Determination of the general seabed topography, tidal reduction, detection, classification, and measurement of seabed hazards are fundamental hydrographic surveying tasks. The depths above hazards need to be determined with, at a minimum, the depth accuracy as specified in Table 1.

(2) For wrecks and obstructions that may have less than 50 m clearance above them and may be dangerous to normal surface navigation, the least depth over them shall be determined either by high-definition sonar examination or physical examination (diving). Mechanical sweeping may be used when guaranteeing a minimum safe clearance depth.

(3) All anomalous features previously reported in the survey area and those detected during the survey shall be examined in greater detail, and, if confirmed, their least depth is to be determined. The Surveyor responsible for survey quality may define a depth limit beyond which a detailed seafloor investigation, and thus an examination of anomalous features, is not required.

VARIOUS OTHER MEASUREMENTS

Aids to Navigation (AtoN)

50. All aids to navigation (fixed and floating) and conspicuous objects significant to navigation shall be determined according to the accuracies given in Table 2. To confirm the theoretical azimuth, all range lines and sector light limits must be drifted. The maximum difference between a theoretical and a drifted azimuth is given in Table 2.

51. The surveyor shall investigate all AtoN located within the survey area limits. If the surveyor determines that an AtoN is located off station, damaged to the extent that it does not serve its intended purpose or its characteristics are incorrectly charted and found the uncharted AtoN, the surveyor shall obtain position specifications on the aid and immediately report the information through hydrographic note form or https://hydro.gov.my/index.php/perkhidmatan/hydro-note and shall include a report in the Report of Survey.

Elevations and Clearances

52. All elevations and clearances shall be determined to the accuracies given in Table 2.

Acoustic Backscatter

53. Surveys conducted with multibeam or interferometric echo sounders require that the acoustic backscatter be logged, processed, and to be rendered at the end of the survey.

Bottom Sampling

54. The nature of the seabed shall be determined by sampling or may be inferred from other sensors (e.g. single beam echo sounders, side scan sonar, sub-bottom profiler, video, etc.) up to the depth required by local anchoring or trawling conditions; under normal circumstances, sampling is not required in depths greater than 200 m. Samples have to be spaced according to the seabed geology. The spacing of samples shall typically be 10 times that of the selected line spacing. In areas intended for anchorage, the density of sampling shall be increased. Any inference technique (e.g. Acoustic Seafloor Classification from single-beam echo sounder, multibeam echo sounder, or side scan sonar) must be ground-truthed by physical sampling.

Natural Coastline

55. The high and low water lines shall be determined according to the accuracies given in Table 2.

Current Observations

56. The speed and direction of tidal streams and currents, which may be of sufficient strength to affect surface navigation (typically more than 0.5 knots), should be observed at the entrances to harbors and channels, at any change in the direction of a channel, in anchorage and adjacent to harbors. Survey parties should verify all current information portrayed on Charts of the survey area during their surveys. Survey parties are encouraged to make note of channels and harbours that exhibit negligible current as this information can be provided to mariners through Sailing Directions. It is also desirable to measure coastal and offshore currents when they are of sufficient strength to affect surface navigation.

Passage Sounding

57. The minimum acceptable horizontal accuracy for the passage sounding shall be achieved through the use of stand-alone GNSS. However, to submit the passage sounding to NHC, the precise survey standard referred to in Order 2 in Table 1 shall be conducted.

DATA PROCESSING

Correction

58. The determination and application of corrections to echo soundings must be accomplished and documented systematically. In addition, all corrections should be applied in such a way that the online values may be removed and replaced with a revised set of correctors during the field survey or post-

processing. Corrections to echo soundings are divided into five categories, and listed below in the sequence in which they are applied:

a. Instrument error corrections account for sources of error related to the sounding equipment itself.

b. Draft corrections shall be added to the observed soundings to account for the depth of the echo sounder transducer below the water surface.

c. Dynamic draft corrections shall be applied to soundings to correct the vertical displacement of the transducer, relative to its position at rest, when a vessel is underway.

d. Sound speed corrections shall be applied to soundings to compensate for the fact that echo sounders may only display depths based on an assumed sound speed profile while the true speed may vary in time and space.

e. Attitude corrections shall be applied to multibeam soundings to correct the effect of vessel motion caused by waves and swells (heave, roll, pitch) and the error in the vessel's heading.

59. Once calibration data have been processed and final system biases determined, the new corrections shall be used in a performance check to ensure that the new system biases are adequate. The surveyor shall discuss procedures and results of Quality Control of the project Data Acquisition and Processing in the Report of Survey.

Processing Method.

60. The Swath Angle and Combined Uncertainty and Bathymetry Estimation (CUBE) are acceptable as a processing method that has been provided in the post-processing software.

Surface Gridded Bathymetry Resolution.

61. The surveyor is required to create and manage individual grids for each required depth/resolution band. The surveyor will adjust the extent and number of grids based on the bathymetry of the survey area, feature detection requirements, the type of echo sounder used, and other factors (Refer to Table 1). However, adjacent grids shall always overlap in depth to ensure no gaps in coverage exist at the transition from one depth grid to another.

Resolution Surfaces	
Depth Range (m)	**Resolution (m)**
0-20	0.5
20-40	1
40-60	3

60-100	5
100-200	7
200-500	10

Table 3: Surface Gridded Bathymetry Resolution

Note: The grid resolution for water depths greater than 500 m shall be 5% of the water depth, not to exceed 30 m resolution.

Grid Coverage.

62. For single-resolution surfaces, the application of depth range thresholds to bathymetric surfaces shall only occur during the finalization stage and all final submitted grids shall include only the grid coverage within the specified depth ranges listed above. In cases of steep slopes, the overlap between grids of different resolutions may need to be increased to prevent gaps in their junction. In these cases, the coarser resolution grid should have its shoaler extent modified to prevent this coverage gap. For variable resolution surfaces, 95% of all surface nodes shall have a resolution equal to or smaller than the coarsest allowable resolution for the node depth. For both single and variable-resolution surfaces, at least 95% of all nodes on the surface shall be populated, with at least 5 soundings.

Gridding Methods.

63. The surveyor is responsible for determining the appropriate method for the intended purpose of the resulting grid dataset is to display the shallowest depth. This determination should consider the implementation of binding methods or algorithms in selected software packages. The Shoalest Depth method examines depth estimates within a specific area of influence and assigns the shoalest value to the nodal position. The resulting surface represents the shallowest depths across a survey area. The use of shoal depth values is often used for the safety of navigation purposes.

Uncertainties.

64. This standard addresses total propagated uncertainty (TPU) by the two components; total horizontal uncertainty (THU) and total vertical uncertainty (TVU). The TVU and THU values must be understood as an interval of ± the stated value. Depth values shall be recorded in meters. The precision shall be maintained throughout the bathymetry processing and all digital data products. A statistical method, combining all uncertainty sources for determining both the horizontal and the vertical positioning uncertainty should be adopted to obtain THU and TVU respectively. The uncertainties at the 95% confidence level must be recorded with the survey data.

65. Uncertainty estimates for depth values and ancillary measurements shall be recorded with sufficient precision to support the Total Propagated Uncertainty (TPU) estimated according to **Table 1**. Bathymetry data quality depends on management uncertainty that needs to be determined before and after the hydrographic survey work is carried out. This is because achieving the minimum standard order specified requires, the use of equipment that can provide the

minimum value of uncertainty. Therefore the calculation of Total Horizontal Uncertainty (THU) and Total Vertical Uncertainty (TVU) to ensure the apriori and priori of uncertainty management. Proof of the TPU calculation to achieve the minimum standard of hydrographic survey (Table 1) for the entire survey data that has been processed must be included in the Report of Survey.

Data Processing Output

66. Any hydrographic survey data that affects the safety of navigation due to changes in depth or new survey data that require updating nautical charts, the survey data must be sent to NHC. The overall data requirements must meet the standard format and type of data required (Annex A).

QUALITY CONTROL

67. To ensure that the required accuracy is achieved it is necessary to check and monitor performance. Establishing quality control procedures shall be a high priority. All related pertinent documentation should be preserved for further consultation.

Depths.

68. A standard quality control procedure shall be to check the validity of soundings by conducting additional depth measurements. Differences shall be statistically tested to ensure compliance of the bathymetric data with the standards given in Table 1. Anomalous differences shall be further examined with a systematic analysis of contributing error sources. All discrepancies shall either be resolved by analysis or re-survey during the progression of the survey task.

Check Lines.

69. The line crossing the regular lines shall always be done to confirm the accuracy of the positioning, the depth measurement, and other depth corrections. They shall be run as close to perpendicular to the principal lines as possible. The differences between principal lines and check lines shall fall within the limits of the survey order. If possible, check lines shall be collected using an independent system, different survey vessels, and or time and on a rough bottom.

70. Check lines crossing the principal sounding lines shall always be run to confirm the accuracy of positioning, sounding, and depth corrections. Check lines shall be spaced so that an efficient and comprehensive control of the principal sounding lines can be done. As a guide, it may be assumed that the interval between check lines shall normally be no more than 15 times that of the principal sounding lines.

Multibeam Sonar Calibration.

71. Before commencing survey operations, the surveyor shall conduct a system accuracy test (i.e., patch test) to quantify the accuracy, precision, and alignment of the multibeam system. Testing shall include the determination of residual biases in roll, pitch, heading, and navigation timing errors in acquisitions and the uncertainty of these values. These values will be used to correct the initial

alignment, calibrate the multibeam system, and used to compute the Total Propagated Uncertainty (TPU) for each sounding. System accuracy testing should be conducted in an area similar in bottom profile and composition to the survey area, and during relatively calm seas to limit excessive motions and ensure suitable bottom detection. In addition, system accuracy tests should be conducted in depths equivalent to the deepest depths in the survey area. Static transducer draft, dynamic draft corrections, sound speed corrections, and tide corrections shall be determined and applied to the survey data. The surveyor should determine the biases in the following order: navigation timing error, pitch, roll, and heading (yaw). Deviations from this order or other variations on the accepted calibration methods shall be explained in the Report of Survey.

Data Analysis.

72. Two possible methods of conducting the independent analysis are beam-by-beam statistical analysis and surface difference. Other methods may be used. The chosen method must be described in the Report of Survey. Regardless of the method, the comparison shall be performed at the same resolution as the final survey product as required in Table 3.

73. The surveyor shall evaluate each area of overlapping crossline and main scheme coverage to ensure that the depth values from the two data sets do not differ more than the maximum allowable TVU for the depth of the comparison area (Table 1). Any deviations from this standard shall be investigated, and the source of error identified and corrected. If unexplained or excessive discrepancies persist, additional crosslines shall be re-acquired to assist in the resolution of the issue.

74. The surveyor shall evaluate the crossline to the entire coverage of the survey data, and discuss the method and results in the Report of Survey. If the magnitude of any discrepancies varies widely over the survey, the surveyor shall make a quantitative evaluation of the disagreements area by area. If differences were found to be within the allowable maximum TVU, the surveyor shall note this. Conversely, any errors identified through crossline analysis and the means by which they were corrected shall be discussed.

Sonar Quality Control Checks

75. The patch test involves collecting data over certain types of bottom terrain and processing the data through a set of patch test tools. There are two primary methods of processing the data that are currently used: an interactive graphical approach and an automatic, iterative surface match. Each of these techniques has strengths and weaknesses and the preferred approach is dependent on the types of terrain features available to the surveyor. The full report of the patch test must be generated from the survey acquisition system and be included in the Report of the Survey.

Sounding Density Requirements

76. **SBES**. Depending on the characteristics of the seafloor the line spacing from Table 1 may have to be reduced or, if circumstances permit, expanded. Check lines shall be run at discrete intervals.

77. **SSS**. Where SSS is being used in conjunction with SBES or MBES, the line spacing from Table 1 may be increased, whilst ensuring adequate coverage of the area directly beneath the towfish.

78. **MBES**. MBES has great potential for accurate seafloor coverage if used with proper survey and calibration procedures. An appropriate assessment of the accuracy of measurement with each beam is compulsory when full bottom coverage is required for use in areas surveyed to Exclusive Order, Special Order, and Order 1a standards. If any of the outer beams have unacceptable errors, the related data are to be excluded or weighted accordingly. If not hampered by geographical constraints, all lines shall be crossed, at least once, by a check line to confirm the accuracy of positioning, depth measurement, and depth corrections – squat, draft, tide, and sound speed. Accuracies can also be confirmed by redundant measurement on a small seafloor target.

79. **Airborne Systems**. Airborne laser systems are capable of measuring depths to 50 m or more provided the water is clear. Hazards to navigation detected by airborne laser shall be examined using an independent method. A check line to confirm the accuracy of positioning, depth measurement, and depth corrections shall cross all lines, at least once.

80. **Multispectral Image Derived Bathymetry**. The chosen algorithm to derive the bathymetry was developed by Stumpf (2003). This algorithm uses a two-band ratio equation where the different absorption of the bands in water is exploited to derive the water depth. The Stumpf algorithm requires some control point to scale the ratio to depth. Due to the different seabed morphology, it has been decided to split the model into two parts: an open sea area in the middle of the bay and an area near the reef where the seabed features are clearly visible. Any imprecise depth or dynamic depth from high technology (still undergoing research) such as imagery from satellite or UAV or drone may be used for charting but not for the safety of navigation. The chart can be used for general purposes only.

Categories of Zone Of Confidence (CATZOC).

81. MHSS details the accuracy of raw data acquisition in hydrographic survey, while CATZOC characterizes the accuracy of the ENC data display. The ZOC system only applies to the bathymetry related features and does not apply to the accuracy of charting the high water line, wharves, navigation aids, pipelines, and so on.

82. CATZOC is designed to indicate the reliability and accuracy of the survey data. Divided into 6 different categories: A1, A2, B, C, D, and U. Each category has a defined accuracy. The definition for the various categories stipulates whether all bottom features have been detected, how likely it is that depth inaccuracies will exist, and a value for the accuracy of all depths (both horizontal and vertical). Some product liability will accrue and navigators may make decisions based on the CATZOC which affects the safety of their ship.

83. The survey order achieved of survey data collected based on Table 1, the surveyor should propose the appropriate ZOC upon rendering of survey data in the Report of Survey. NHC then further assesses and decides the proposed ZOC value based on the quality of data rendered.

ZOC	Position Accuracy	Depth Accuracy		Seafloor Coverage	Typical Survey Characteristics	Recommendation by Survey Order Achieved
		Depth (m)	Accuracy (m)			
A1	± 5 m + 5% depth	=0.50 + 1%d 10 30 100 1000	 ± 0.6 ± 0.8 ± 1.5 ± 10.5	Full area search undertaken. Significant seafloor features detected, and depths measured.	Controlled, systematic survey high position and depth accuracy achieved using DGPS or a minimum three high quality lines of position (LOP) and a multibeam, channel or mechanical sweep system.	**Exclusive Order Special Order Order 1a (≥95%)**
A2	± 20 m	= 1.00 + 2%d 10 30 100 1000	 ± 1.2 ± 1.6 ± 3.0 ± 21.0	Full area search undertaken. Significant seafloor features detected, and depths measured.	Controlled, systematic survey achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder and a sonar or mechanical sweep system.	**Order 1a (≤95%)**
B	± 50 m	= 1.00 + 2%d 10 30 100 1000	 ± 1.2 ± 1.6 ± 3.0 ± 21.0	Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.	Controlled, systematic survey achieving similar depth but lesser position accuracies than ZOC A2, using a modern survey echosounder, but no sonar or mechanical sweep system.	**Order 1b**
C	± 500 m	= 2.00 + 5%d 10 30 100 1000	 ± 2.5 ± 3.5 ± 7.0 ± 52.0	Full area search not achieved; depth anomalies may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage.	**Order 2**
D	*Worse than ZOC C*	Worse than ZOC C		Full search not achieved; large depth anomalies expected.	Poor quality data or data that cannot be quality assessed due to lack of information.	
U	Unassessed - The quality of the bathymetric data has yet to be assessed					

Table 4: The position accuracy and seafloor coverage for each Zone of Confidence (ZOC)

DATA ATTRIBUTION

84. To allow a comprehensive assessment of the quality of survey data it is necessary to record or document certain information together with the survey data. Such information is important to allow the exploitation of survey data by various users with different requirements, especially as requirements may not be known when survey data is collected.

85. The process of documenting the data quality is called data attribution; the information on the data quality is called metadata. Metadata should be comprehensive, but should include, as a minimum, information on:

Category or Group	Description
Survey Type	e.g. safety of navigation, passage, reconnaissance/sketch, examination
Technique of vertical / depth measurement	e.g. echo-sounder, side scan sonar, multi-beam, diver, lead-line, wire-drag, photogrammetry, satellite-derived bathymetry, lidar
Auxiliary Equipment	e.g Tide Gauge, Sound Speed Profiler, Surface Velocity Sensor, Current Meter, ADCP
Order of survey achieved	In accordance with MHSS
Horizontal and vertical datum and separation models used	Including ties to a geodetic reference frame based on WGS84 and epoch information, if a local datum or realization is used
Uncertainties achieved (at 95% Confidence Level)	For both horizontal and vertical components: THU and TVU
Feature detection ability	In metres
Feature Search	% of survey areas searched
Bathymetric coverage	% of survey area covered
Survey date range	Survey’s start and end dates
Survey was undertaken by	Officer In Charge (OIC), Surveyor, survey company, survey authority
Data Ownership	e.g. funding body, government,
Grid attributes	Where a grid is the deliverable (i.e. resolution, method, underlying data density, uncertainty)

Category or Group	Description
Data density	Description of average or range of density of source data (e.g. number of accepted points per surface unit)
Usage constraints	e.g. none, classified, not for navigation, or restricted

Table 5: Metadata Description

86. Metadata shall preferably be in digital form (metadata file) and an integral part of the survey record. If this is not feasible, similar information shall be included in the documentation of a survey such as the Report of Survey.

DATA MANAGEMENT

Data Security and Archiving.

87. The hydrographic surveyor responsible for all survey data shall ensure that original sensor datagrams are secured on a suitable media and stored in a safe location promptly after acquisition. Processed data shall be backed up on a daily basis on a suitable media and stored in a safe location.

88. Digital data shall be submitted on a compatible hard drive following the data directory structure in Annex A. Survey data shall be accompanied by NHC Form Letter Transmitting Data in digital and hard copy format. The surveyor is also responsible for ensuring all files are present and not corrupted during transfer. The Naming Convention of every type of data shall refer to Annex A.

89. All data submissions shall be sent to the National Hydrographic Centre as follows:

Director General
National Hydrographic Centre
Bandar Armada Putra, Pulau Indah
42009 PORT KLANG
Selangor Darul Ehsan
(Attention: Department Head Of Marine Geospatial,
National Hydrographic Centre)

REPORTING

Reporting of Navigational Hazards

90. Upon discovery of any depth or obstruction that may be considered a hazard to navigation, the Project Manager shall inform the Director General of the National Hydrographic Center, Malaysia, and have a Navigational Warning issued. All actions shall be documented and a copy sent to the Charting Branch, National Hydrographic Center, Malaysia which will initiate appropriate actions. The charged person of the survey shall issue a Hydrographic Note and inform NHC via nhc@navy.mil.my.

Annex A

HYDROGRAPHIC SURVEY SUBMISSION AND DATA FORMAT

Ser	Subject	Survey Information	Format	Naming Convention Format
(a)	**(b)**	**(c)**	**(d)**	**(e)**
1.	Report of Survey	Full Report	*.pdf	ROS_ProjectID_VesselID_equipment_YYYYMMDD
2.	Multibeam Calibration	Patch Test Calibration Report	*.pdf	PTCR_ProjectID_VesselID_equipment_YYYYMMDD
		Performance Test Report	*.pdf	PTR_ProjectID_VesselID_equipment_YYYYMMDD
3.	Tide	Tidal Observation Data	*.xlsx, .tid, .txt	TideStation_ YYYYMMDD
		Tidal level reference	*.pdf	ProjectID_ Tidal level reference
		Levelling and diagram report	*.pdf	ProjectID_Levelling Diagram
		Benchmark Description	*.pdf	ProjectID_BM
		Datum Transferring Report	*.pdf	ProjectID_ DatumTransfer_Tide Station_YYYMMDD
		GNSS Height Transferring	*.pdf	ProjectID_ HeightTransfer _Tide Station_YYYMMDD
4.	Data coverage of survey plot on the satellite image or MAL chart	MAL Chart Satellite Image	*Tiff	ProjectID_SatImage
5.	Positioning	DGNSS verification report	*.pdf	Reportxx_ProjectID_DGNSS

Ser	Subject	Survey Information	Format	Naming Convention Format
		Equipment calibration report	*.pdf	Reportxx_ProjectID_DGNSS
6.	Survey System Offset (i.e. DGPS, Multibeam / Singlebeam Transducer, Motion Sensor to COG)	Vessel offset diagram and measurement	*.pdf	ProjectID_VesselID_YYYYMMDD
7.	SVP casting	Daily Sound Velocity Profile (SVP) apply in the acquisition	*.csv *.txt *.svp	ProjectArea_ YYYYMMDD_HHMM
8.	Bathymetry Survey: Project file - Acquisition software in bathymetry data collection (QINSy, PDS 2000, HYPACK, SIS, EIVA) ** Only include data for software - related formats	Atlas ASD Atlas Hydrosweep Atlas SURF	*.sda, *.asd, *.acf, *.six	VesselID_SequenceNumber_YYYYMMDD_HHMMSS.
		CMAX	*.cmx, *.cm2, *.cmp	
		EIVA	*.sbd *.xse	
		ELAC	*.*, *.mb41	
		FURUNO LOG	*.*	
		Generic Sensor Format GSF	*.gsf, *.*	

Ser	Subject	Survey Information	Format	Naming Convention Format
	used during data collection and data processing	GeoAcoustics RDF GeoAcoustics RFF	*.rdf,*.rff	
		Hypack HS2 Hypack RAW, HSX	*.hs2, *.hs2x, *,hsx, *.raw, *.*	
		Klein SDF	*.sdf	
		Kongsberg ALL Kongsberg EA600 RAW, DEPTH	*.all, *.out, *.raw *. depth *. mb57	
		Kraken TIL	*.til	
		PDS 2000	*.pds/ S7K	
		PROSAS	*.img	
		QINSy	*.db *.qpd	
		XTF (Extended Triton Format)	*.XTF	

Ser	Subject	Survey Information	Format	Naming Convention Format
9.	Backscatter: Project file - Acquisition software in backscatter data collection (QINSy, PDS 2000, HYPACK, SIS, EIVA)	Raw Data and Processed Backscatter Image	*.S7K *.RAW *.hsx *.7K *.all, kmall *.BAG *.csar	VesselID_SequenceNumber_YYYYMMDD_HHMMSS.
10.	Bathymetry Processing - The final data that has been processed is forwarded in the form of a gridded surface of the entire bathymetry data from the processing software (Qimera, Qinsy, Fledemaus, Caris, Hypack, etc	Gridded Surface Extension Format	*.BAG *.csar *.Ascii *.Pts *.xyz *.txt	ProjectID_VesselID_CellSize_Area/ BlockID
11.	Coastlining	GNSS Positioning LIDAR Topo Survey	*.xyz *.Ascii *.TIFF *.LAS	Reportxx_ProjectID_Coastlining