S-67

Mariners' Guide to Accuracy of Depth Information in Electronic Navigational Charts (ENC)

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Preface

IHO publication S-67 "Mariners Guide to Accuracy of Depth Information in ENC" is a guide to navigators, and navigator training organizations, on the degree of confidence they should have in the adequacy and accuracy of charted depths and their positions in an Electronic Navigational Chart.

This document is laid out, as far as possible, along the lines of the IHO Publications S-4 – "Regulations of the IHO for International (INT) Charts and Chart Specifications of the IHO"; S-57 – "IHO Transfer Standard for Digital Hydrographic Data"; and S-52 – "Specifications for Chart Content and Display Aspects of ECDIS".

The intended readers for this document are navigators on coastal or international voyages; and organizations training navigators for these voyages.

This document is supplementary to IHO Publication S-66 – "Facts about Electronic Charts and Carriage Requirements"; and the already existing IHO Standards mentioned above, so as to provide a more in-depth knowledge as to how a navigator should interpret the depth information presented to them by an Electronic Chart Display and Information System (ECDIS). Readers of this document should also consult guidance regarding national policies on the depiction of depth accuracy information in ENCs, such as Mariners' Handbook and national hydrographic authority web sites, where they exists.

The IHO acknowledges the valuable contribution to the development of this document by various stakeholders, in particular Intertanko and CSmart/Carnival.

1 Introduction

The primary purpose of nautical charts is to provide the information required to enable the mariner to plan and execute safe navigation.[1] The mariner has a need for appropriate, relevant, accurate and unambiguous information.

Most Hydrographic Offices have an obligation to provide nautical chart cover of their national waters to such an extent, and on such scales, as to permit safe navigation for all classes of vessel, from the smallest to the largest, throughout coastal waters, including major ports visited by the largest vessels and minor arms of the sea of purely local interest. In this, the best-known sense, nautical charts are navigational tools.[2]

National nautical chart series are usually the largest scale publications available showing the detailed configuration of the seabed offshore. In this respect, Hydrographic Offices have a de facto responsibility for their national waters similar to that of topographic mapping agencies for land areas. Such information about the shape of the seabed is required by a variety of national users other than navigators. For example, construction engineers concerned with offshore developments; dredging contractors; oceanographers; defence departments; and coastal zone managers.[3]

The combined effect of the two requirements has caused national chart series to cover national waters in great detail, reflected by small and medium scale charts to provide an overview, general picture and coastal image; and large scale charts to provide information for harbour approach, harbour and berthing. Hydrographic Offices supply Electronic Navigational Charts (ENCs) with the intended usage of the Chart aligned to so-called Usage Bands (or Navigational Purposes). Their values are:

1. Overview
2. General
3. Coastal
4. Approach
5. Harbour
6. Berthing

The mariner requires ENCs to be consistent throughout the Usage Bands, at least for essential data content; this is called 'vertical consistency'. At smaller scales, details must be generalized, with only a selection of the available source data (including soundings) being portrayed, so that the information which is included in the ENC is presented clearly. Any sounding on the smallest scale chart will also be present on the largest scale.[4]

A chart presents an image of the real world to the mariner. The depth information in a chart is compiled from various sources, each having their own adequacy and accuracy. Given this, an obvious question arises: How can the mariner distinguish, when using an ECDIS, what the adequacy and accuracy of the depth information is for the planning and executing of a voyage?

1.1 Abbreviations

CATZOC Category of Zone of Confidence in Data[5]

ECDIS Electronic Chart Display and Information System

ENC Electronic Navigational Chart

HO Hydrographic Office

m Metre

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[1] Adapted from S-4 clause B-100.4
[2] Adapted from S-4 clause A-102.1
[3] Adapted from S-4 clause A-102.1B
[4] Adapted from S-4 clause B-100.5
[5] S-57 Appendix A, Chapter 2 – page 2.106

NM Nautical Mile

ZOC Zone of Confidence

2 Executive summary and recommendations

Accuracy of depth Information in an ENC can be visualized by showing the Zones of Confidence (ZOC) areas. A ZOC area is a generalized picture of the quality of charted depth information for that area. The quality of the hydrographic source data is assessed according to six categories (CATZOC): Five quality categories for assessed data (A1, A2, B, C and D); and a sixth category (U) for data which has not been assessed. The assessment of hydrographic data quality and classification into zones by Hydrographic Offices is based on a combination of:

- Depth accuracy;
- Position accuracy; and
- Seafloor coverage.

For ease of reading, this can be interpreted as follows:

1. High accuracy depth information (ZOC A1 and A2), shown as 5 stars or more.
2. Medium accuracy depth information (ZOC B), shown as 4 stars.
3. Poor accuracy depth information (ZOC C, D and U), shown as 3 stars or less; or letter U.

ZOC can be visualized in an ECDIS by activating the ECDIS "Accuracy" selector. The following recommendations are made to the mariner:

- When planning a new voyage, ZOCs should be visualized as an overall check of the quality of the area the vessel is going to transit.
- When changing the planned route whilst en-route, the ZOCs should be visualized as an overall check of the quality of the area the vessel is going to transit.
- When route planning in areas with ZOC A1 and A2, the mariner should consider that isolated dangers and shallow soundings could be up to 20 metres from their charted position and at least 0.5-1 metre shoaler/deeper than their charted depth.
- When route planning in areas with ZOC B, the mariner should consider that isolated dangers and shallow soundings could be up to 50 metres from their charted position and at least 1 metre shoaler/deeper than their charted depth.
- When route planning in areas with ZOC C, D and U, the mariner should consider that isolated dangers and shallow soundings could be up to 500 metres from their charted position and at least 2 metres shoaler/deeper than their charted depth.
- The mariner should take note of the accuracy of the depth areas the vessel is planning to transit and take appropriate caution by applying appropriate safety margins, especially in situations where under keel clearance is critical and/or in areas of continual and rapid change.
- The mariner should take the horizontal accuracy as defined by the CATZOC for the area into consideration when setting cross track distance for the automatic route check function performed during the voyage planning.
- In ZOC C, D and U the mariner is advised to take caution as charted depths may in reality be significantly shallower. It is very likely that some significant seafloor features dangerous to the safety of navigation (rocks, coral reefs, wrecks, submerged obstructions) have not been identified, and do not appear in the chart.
- By using a Pick Report in ECDIS, the mariner can read additional quality information on isolated dangers to the safety of navigation and/or survey reliability, if these have been included in the ENC. Otherwise the mariner should assume that the isolated danger may in reality be out of position and/or be shallower as indicated by the CATZOC.
- The mariner must ensure to have the full portfolio of ENCs available at the appropriate chart scales suitable for the voyage being undertaken, as ECDIS in-built safety functions use the data encoded in the largest scale product available in the system (irrespective of it being displayed

or not) to trigger alarms. ECDIS does allow the mariner to over-scale, however this will give a false sense of security of the accuracy of isolated dangers if CATZOCs are not checked; and their extent (see Annex B). Over-scaling the ECDIS display is not recommended under normal circumstances; as a consequence the over-scale indicator in the ECDIS should be heeded.

- Areas of continual and rapid change occur in many tidal rivers and estuaries; over bars in the approaches to some ports; and over some off-lying banks. A limitation of the CATZOC system is the lack of information about when a survey was conducted, or whether the seabed is stable; noting however that the date that a survey was conducted in an area may be available in the ENC through an ECDIS Pick Report. It is therefore considered important for mariners to note areas of sand-waves; dates within dredged channels; and any other notes advising that channels may have changed or are subject to change.

Put in simple terms, mariners should be able to navigate with confidence in areas with ZOC A1 and A2 classifications. It is also unlikely that uncharted dangers affecting surface navigation exist in ZOC B areas. In ZOC C areas mariners should exercise caution since hazardous uncharted features may be expected, particularly in or near reef and rocky areas, or areas of mobile seabed. A very high degree of caution is required for areas assessed as ZOC D, as these contain either very sparse data or may not have been surveyed at all. Finally, it is good practice for mariners to treat ZOC U areas with the same degree of caution as ZOC D areas.

Within ports, the Pilot or Harbour Master may advise that higher accuracy surveys have been conducted that allow for smaller under-keel clearances (subject to tides, weather, speed, and manoeuvring margins). In the absence of this advice, smaller under-keel safety margins should not be assumed.

In coastal shipping areas the most common assessments likely to be encountered are:

- ZOC B – around 40% of the world's coastal waters;
- ZOC C – around 30% of the world's coastal waters;
- ZOC D – around 10% of the world's coastal waters; and
- ZOC U – around 15% of the world's coastal waters.

While these percentages may vary from place to place, the key point to note is that the standards of surveying in ports are only very rarely encountered outside those ports. Ships may therefore be at greater risk away from ports, even though depths may be deeper. The risk will decrease with increasing under keel clearance (depths greater than 100 metres); and depth areas deeper than 200 meters are generally considered safe for surface navigation. An understanding of how much confidence can be placed in the depth information in an ENC is therefore most important.

3 Accuracy of depth information in paper charts

Charts provide information to guide navigators, and those planning 'navigational operations' (including the planning of new routes and official routeing measures), on the degree of confidence they should have in the adequacy and accuracy of charted depths and their positions. This is portrayed on paper charts as a graphic with accompanying text in what is known as a Source Diagram. This diagram provides information about source surveys from which the mariner can deduce the degree of confidence in charted depth information. The diagram provides an indication of:

- The adequacy of the equipment used;
- The thoroughness of examinations of dangers at particular depths (based on the maximum draught of vessels afloat at that date); and
- The likelihood of changes in depths, particularly in areas of mobile or unstable seabed or coral growth.

The date of the edition of a published paper chart can be misleading (as the source data may be much older) but may have some value.[6]

The type of survey should be stated on conventional paper chart Source Diagrams (the terms being translated as necessary):

- 'Survey' implies a regular, controlled or systematic hydrographic survey of any date.
- 'Sketch survey' or 'Reconnaissance survey' implies that there is a significant risk of undetected dangers, even if the 'survey' is of recent date.
- 'Passage soundings' implies soundings acquired on an uncoordinated basis over a period of years.
- Qualifying comments, for example: '(leadline)'; '(no sonar)'; and '(multibeam)', may be added after the type of survey where the date does not give sufficient indication of the survey methods.
- Where a charted survey is supplemented by occasional soundings from older or later sources, only the main survey should normally be listed.[7]

Areas of continual and rapid change occur in many tidal rivers and estuaries; over bars in the approaches to some ports; and over some off-lying banks.[8]

In most areas which have not been wire-swept or full seafloor search has not been achieved, there is a possibility that depths somewhat shoaler than those charted may exist. Navigators allow for this and other uncertainties by applying safety margins. Inadequately surveyed areas may be defined as those where bathymetry is based on older leadline surveys or other surveys which are either open in nature (for example reconnaissance surveys), or are not hydrographic surveys (for example seismic surveys). These types of surveys are inadequate for identifying all shoals that may exist between lines of soundings, or may not be 'shoal-biased' in their selection of recorded depths.[9]

The details and interpretations of published Source Diagrams often vary widely between nations. The variations in method, detail and interpretation render this type of quality information unsuitable for use in an electronic navigation system such as ECDIS, as it prevents use of automated checking routines to look along a planned route to confirm suitability.

When making the transition from paper chart to the ENC, the International Hydrographic Organization developed and published the concept of Zones of Confidence areas in their Publication S-57 – "IHO Transfer Standard for Digital Hydrographic Data". It should be noted that some Hydrographic Offices have replaced paper chart Source Diagrams with "Zone of Confidence (ZOC)" diagrams to be consistent with their ENC portfolio.

4 Accuracy of depth information in Electronic Navigational Charts

Depth accuracy in ENCs may be described in three ways:

1. Generalized information through a Zone of Confidence (ZOC) indication (mandatory);
2. Quality descriptions of individual objects dangerous to safe navigation (similar to labelling of individual features as "*PA*" or "*PD*" on paper charts) (optional); and
3. Reliability of a survey (optional).

NOTE: The optional methods listed in (2) and (3) are generally only viewable in ECDIS by utilizing the ECDIS Pick Report functionality (see clauses 4.2 and 4.3).

[6] Adapted from S-4 clause B-294.1
[7] Adapted from S-4 clause B-295.2
[8] Adapted from S-4 clause B-416
[9] Adapted from S-4 clause B-417

4.1 Generalized information

The quality of the bathymetric data charted on the ENC is assessed according to six categories (CATZOC or ZOC): five quality categories for assessed data (A1, A2, B, C and D) and a sixth category (U) for data which has not been assessed[10] (see Table 4-1 below). The CATZOC is an attribute included in the S-57 object class M_QUAL (Quality of Data). CATZOC indication covers all areas of the ENC that contain bathymetry; never overlap; and have no gaps between them. The assessment of bathymetric data quality and classification into zones is based on a combination of:

- Position accuracy;
- Depth accuracy; and
- Seafloor coverage.

Table 4-1 –ZOC Categories

ZOC	Position accuracy	Depth accuracy	Seafloor coverage
A1	± 5 m + 5% depth	0.50 m + 1% depth	Full area search undertaken. Significant seafloor features detected and depths measured.
A2	± 20 m	1.00 m + 2% depth	Full area search undertaken. Significant seafloor features detected and depths measured.
B	± 50 m	1.00 m + 2% depth	Full area search not achieved; uncharted features hazardous surface navigation are not expected but may exist.
C	± 500 m	2.00 m + 5% depth	Full area search not achieved, depth anomalies may be expected.
D	Worse than ZOC C	Worse than ZOC C	Full area search not achieved, large depth anomalies may be expected.
U	Unassessed – The quality of the depth data has yet to be assessed.		

The full version of this table, including the explanatory notes relating to each category, can be found in Annex A.

The position accuracy is the cumulative error and includes in general survey; geodetic transformation; and digitizing and compilation errors. The higher CATZOC categories, A1 and A2, are categorized by full seafloor search or sweep and very high accuracy standards only achievable with technology that has been available since about 1980. Therefore many sea lanes which have hitherto been regarded as adequately surveyed may carry a ZOC B classification. Modern surveys of critical areas can be expected to carry ZOC A2 classification whilst ZOC A1 will cover only those areas surveyed under exceptionally stringent conditions.[11]

Figure 4-1 below provides a graphical representation of the impact of the position accuracy and depth accuracy on a charted feature; in the graphic, the actual real-world location of the charted 5 metre obstruction may be anywhere within the cylinder, the volume of which is defined by the assigned CATZOC values as defined in Table 4-1 above.

[10] Adapted from S-4 clause B-297.4
[11] Adapted from S-4 clause B-297.6

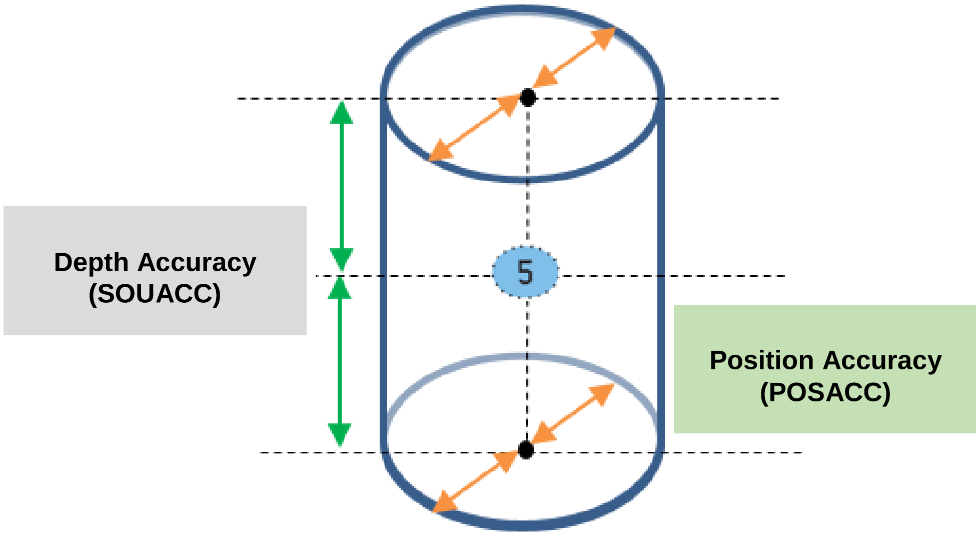
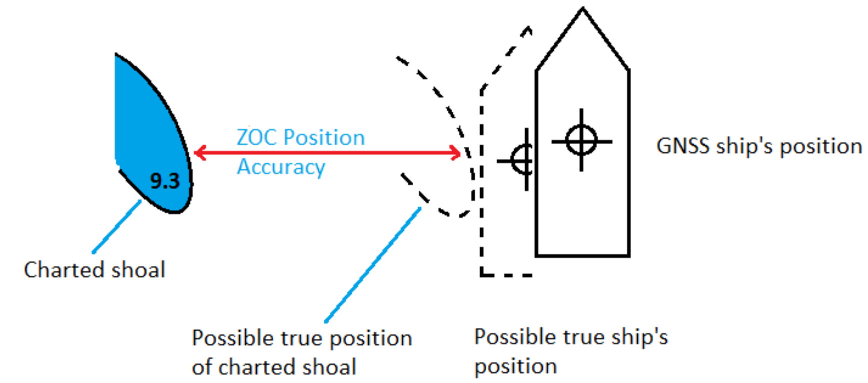


Figure 4-1 – Charted feature depth and position accuracies accounting for ZOCs

One limitation of the CATZOC system is the lack of information about when a survey was conducted, or whether the seabed is stable. While the date can be provided in an additional data field within an ENC, this is rarely done; and can only be viewed by the mariner using the ECDIS Pick Report function. In areas where the seabed is subject to change, ENC encoding guidance recommends the inclusion of the date of the survey(s) and/or downgrading of the assigned ZOC category, restoring it only once a replacement survey is incorporated in the ENC. However, this isn't always done, so it is wise to note areas of sand-waves; dates within dredged channels; and any other notes advising that channels may have changed or are subject to change.

Figure 4-2 below depicts where a charted shoal may be out of position. The difference between the charted and true position of a shoal may be much greater than the difference between the GNSS measured ship's position and the ship's true position. Mariners are advised to take appropriate caution.



- *A planned route should allow for both chart accuracy and ship's positioning accuracy, as well as other factors. The dashed lines indicate the possible worst-case scenario for the mariner.*

Figure 4-2 – Horizontal position accuracy accounting for ZOCs and ship's GNSS position

For ease of reading, Table 4-1 can be interpreted as follows:

1. High accuracy depth information (ZOC A1 and A2)
2. Medium accuracy depth information (ZOC B)
3. Poor accuracy depth information (ZOC C, D and U)

4.1.1 High accuracy depth information

The depth of this area has been measured by a collection of regular, controlled or systematic hydrographic surveys. Significant seafloor features dangerous to the safety of navigation (rocks, coral reefs, wrecks, submerged obstructions) have been identified, accurately positioned and their least depth value has been accurately determined. Therefore, when route planning in areas with ZOC A1 and A2, the mariner should consider that isolated dangers and shallow soundings could be up to **20 metres** from their charted position; and at least **0.5 to 1 metre** shoaler/deeper than their charted depth (refer to Table 4-4).

4.1.2 Medium accuracy depth information

There is a risk that significant seafloor features dangerous to the safety of navigation (rocks, coral reefs, wrecks, submerged obstructions) have not been identified, and do not appear in the chart. Those features that are present in the chart have a horizontal accuracy of ± 50 metres and a depth accuracy of at least ± 1 metre (refer to Table 4-1). Therefore, when route planning in areas with ZOC B, the mariner should consider that isolated dangers and shallow soundings could be up to **50 metres** from their charted position; and at least **1 metre** shoaler/deeper than their charted depth (refer to Table 4-4).

4.1.3 Poor accuracy depth information

The mariner should take appropriate caution when navigating through this area. Charted depths may in reality be significantly shallower. It is very likely that some significant seafloor features dangerous to the safety of navigation (rocks, coral reefs, wrecks, submerged obstructions) have not been identified, and do not appear in the chart. Those features that are present in the chart have a horizontal accuracy of ± 500 metres and a depth accuracy of at least ± 2 metres (refer to Table 4-1). Therefore, when route planning in areas with ZOC C, D and U, the mariner should consider that isolated dangers and shallow soundings could be up to **500 metres** from their charted position; and at least **2 metres** shoaler/deeper than their charted depth (refer to Table 4-4).

4.2 Quality descriptions of individual objects dangerous to safe navigation

In S-57 – "IHO Transfer Standard for Digital Hydrographic Data", the following (subsurface) items are considered to be hazardous to safe navigation:

- Obstructions
- Rocks and reefs
- Wrecks

The individual encoding of these items, as well as soundings, may contain additional quality information only applicable to the item. The structure of the ENC allows Hydrographic Offices to add this information, however it is not mandatory for them to do so.

Individual obstructions, rocks, reefs, wrecks and soundings may have the following additional quality information:

Table 4-2 – Additional quality information for obstructions, rocks, reefs, wrecks and soundings

Object	Additional information	Options
Obstruction (OBSTRN) Rock (UWTROC) Wreck (WRECKS) Sounding (SOUNDG)	Exposition of sounding (EXPSOU) (Some types of obstructions may have a different least depth to the depth range assigned to the surrounding area, such as a 10 metre wreck lying in a 15 to 20 metre depth area)	1. within the range of depth of surrounding depth area
		2. shoaler than the range of depth of surrounding depth area
		3. deeper than the range of depth of surrounding depth area
	Quality of sounding (QUASOU) (Values 3, 4, 6, 8, 9 and 11 have essentially the same practical meaning – that the true depth may	1. depth known
		2. depth unknown
		3. doubtful sounding

Object	Additional information	Options
	differ from the charted depth)	4. unreliable sounding
		5. no bottom found at value shown
		6. least depth unknown
		7. least depth unknown, safe clearance at value shown
		8. value reported, not surveyed
		9. value reported, not confirmed
		10. maintained depth
		11. not regularly maintained
	Sounding Accuracy (SOUACC) (May be populated only if different from the depth accuracy as indicated by the CATZOC value)	Value in meters
	Technique of sounding measurement (TECSOU) (While some Hydrographic Offices may state the equipment used to determine the position and depth of a feature, mariners should primarily focus on the CATZOC value and other specific quality attributes, rather than the equipment used)	1. found by echosounder
		2. found by side-scan sonar
		3. found by multi-beam
		4. found by diver
		5. found by lead-line
		6. swept by wire drag
		7. found by laser
		8. swept by vertical acoustic system
		9. found by electromagnetic sensor
		10. photogrammetry
		11. satellite imagery
		12. found by levelling (not applicable)
		13. swept by side-scan sonar
		14. computer generated

The mariner can execute a "Pick Report" in the ECDIS to show the underlying information of an obstruction, rock, reef, wreck or sounding.

The value of the overlaying CATZOC applies to the horizontal accuracies of individual obstructions, rocks, reefs, wrecks and soundings. However, note that the horizontal position accuracy for individual objects may be encoded using the attributes POSACC and QUAPOS on the associated spatial objects where these individual objects have a different positional accuracy than the overlaying CATZOC indicates.

4.2.1 Obstructions

The following items are considered to be an obstruction[12]:

- Snags
- Stumps
- Wellheads
- Diffusers
- Cribs

[12] S-57 Appendix B.1, Annex A – Use of the Object Catalogue for ENC, clause 6.2.2

- Fish havens
- Foul areas
- Foul ground
- Booms
- Ice booms
- Sites of cleared platforms
- Ground tackle

For obstructions, note the difference between a foul area and a foul ground. A foul area is defined as an area of numerous uncharted dangers to navigation. If the Hydrographic Office creates a foul area in an ENC, it will show in an ECDIS "base display" as an obstruction to navigation, with all associated alarms to indicate that it is unsafe for vessels to enter or transit the area.

Foul ground is defined as an area over which it is safe to navigate but which should be avoided for anchoring, taking the ground or fishing. Foul ground included in an ENC will only show in ECDIS "other display", with no associated alarms or indications. NOTE: Booms, ice booms and ground tackle included in ENC as point objects perform the same in ECDIS as foul ground.

4.3 Survey reliability

The Hydrographic Office may provide additional quality information on individual surveys used in compiling the ENC, using the M_SREL (Survey Reliability) object class. The information, when included in the ENC, can be viewed by executing a pick report on the area. The components of the information are[13]:

Table 4-3 – Components of survey reliability

Attribute	Allowable values	Definitions
Quality of Position (QUAPOS)	1: surveyed	The position(s) was(were) determined by the operation of making measurements for determining the relative position of points on, above or beneath the earth's surface. Survey implies a regular, controlled survey of any date.
	2: unsurveyed	Survey data is does not exist or is very poor.
	3: inadequately surveyed	Position data is of a very poor quality.
	4: approximate	A position that is considered to be within 30.5 meters of its correct geographic location. Also may apply to an object whose position does not remain fixed.
	5: position doubtful	An object whose position has been reported but which is considered to be doubtful.
	6: unreliable	An object's position obtained from questionable or unreliable data.
	7: reported (not surveyed)	An object whose position has been reported and its position confirmed by some means other than a formal survey such as an independent report of the same object.
	8: reported (not confirmed)	An object whose position has been reported and its position has not been confirmed.
	9: estimated	The most probable position of an object determined from incomplete data or data of questionable accuracy.
	10: precisely known	A position that is of a known value, such as the position of an anchor berth or other defined object.
	11: calculated	A position that is computed from data.
Quality of sounding measurement (QUASOU)	1: depth known	The depth from chart datum to the bottom is a known value.
	2: depth unknown	The depth from chart datum to the bottom is unknown.

[13] Adapted from S-57 Appendix A, Chapter 2 – Attributes

Attribute	Allowable values	Definitions
	3: doubtful sounding	A depth that may be less than indicated.
	4: unreliable sounding	A depth that is considered to be an unreliable value.
	5: no bottom found at value shown	Upon investigation the bottom was not found at this depth.
	6: least depth known	The shoalest depth over a feature is of known value.
	7: least depth unknown, safe clearance at value shown	The least depth over a feature is unknown, but there is considered to be safe clearance at this depth.
	8: value reported (not surveyed)	Depth value obtained from a report, but not fully surveyed.
	9: value reported (not confirmed)	Depth value obtained from a report, which it has not been possible to confirm.
	10: maintained depth	The depth at which a channel is kept by human influence, usually by dredging.
	11: not regularly maintained	Depths may be altered by human influence, but will not be routinely maintained.
Scale value one (SCVAL1)	numerical value (25000 -> scale 1:25 000)	The largest scale for the range of survey scale as used in source diagram information.
Scale value two (SCVAL2)	Numerical value (250000 -> scale 1:250 000)	The smallest scale for the range of survey scale as used in source diagram information.
Sounding distance – minimum (SDISMN)	numerical value (50 for 50 meters or feet)	The minimum spacing of the principal sounding lines of a survey.
Sounding distance – maximum (SDISMX)	numerical value (150 for 150 meters or feet)	The maximum spacing of the principal sounding lines of a survey.
Survey authority (SURATH)	name of the source survey authority	The authority which was responsible for the survey.
Survey end date (SUREND)	CCYYMMDD CCYYMM CCYY	The 'survey date, end' should be encoded using 4 digits for the calendar year (CCYY), 2 digits for the month (MM) (e.g. April = 04) and 2 digits for the day (DD). When no specific month and/or day is required/known, indication of the month and/or the day is omitted. This conforms to ISO 8601: 1988.
Survey start date (SURSTA)	CCYYMMDD CCYYMM CCYY	As for Survey end date above.
Survey type (SURTYP)	1: reconnaissance/sketch survey	A survey made to a lower degree of accuracy and detail than the chosen scale would normally indicate.
	2: controlled survey	A thorough survey usually conducted with reference to guidelines.
	4: examination survey	A survey principally aimed at the investigation of underwater obstructions and dangers.
	5: passage survey	A survey where soundings are acquired by vessels on passage
	6: remotely sensed	A survey where features have been positioned and delimited using remote sensing techniques.
Information (INFORM)	text	Textual information about the object.
Information in national language (NINFOM)	text	Textual information in national language characters.

It should be noted that, as with CATZOC indication, survey reliability information does not provide any indication regarding the stability of the seabed and the possible difference over time between charted bathymetry and actual depths due to a mobile seabed.

4.4 Depth accuracy in relation to charted depth

CATZOC provides a general impression of the quality of the source data that is used to create depth areas bounded by depth contours. A depth area is an area where the charted depths are bounded by a minimum and (possibly) maximum depth value. A depth contour by default is displayed as a solid line; a boundary between deeper and shallower water. The Hydrographic Office may have provided additional information that the contour line is approximate; it will then be displayed as a dashed line.

Several different depth areas may have the same CATZOC value. On the other hand, more than one CATZOC value may be present within a single depth area.

The mariner should take note of the vertical accuracy of the charted depth information (soundings, depth contours, depth areas, dredged areas and underwater hazards) in the areas the vessel is planning to transit and take appropriate caution. Table 4-4 below provides depth accuracy for a range of depths, based on the depth accuracies for the ZOC categories as defined in Table 4-1.

Table 4-4 – Depth accuracy based on CATZOC value

	CATZOC					
depth	**A1**	**A2**	**B**	**C**	**D**	**U**
0	0.5m	1.0m	1.0m	2.0m	>2.0m	unknown
10	0.6m	1.2m	1.2m	2.5m	>2.5m	unknown
20	0.7m	1.4m	1.4m	3.0m	>3.0m	unknown
30	0.8m	1.6m	1.6m	3.5m	>3.5m	unknown
40	0.9m	1.8m	1.8m	4.0m	>4.0m	unknown
50	1.0m	2.0m	2.0m	4.5m	>4.5m	unknown
75	1.3m	2.5m	2.5m	5.8m	>5.8m	unknown
100	1.5m	3.0m	3.0m	7.0m	>7.0m	unknown

However, mariners should note that in ZOC C, D and U, and even possibly ZOC B, undetected (and therefore uncharted) hazards may exist, and these may exceed the depth accuracy of the charted depths.

4.4.1 Safety contour

In an ECDIS the default setting for a safety contour is the 30 metre depth contour. When using the default settings of an ECDIS, depth areas deeper than 30 meters will be presented in white (safe water) and areas shallower than 30 meters will be presented in blue (unsafe water). When a safety contour value is entered into the ECDIS, the system will search for the equal or nearest deeper depth contour (if no contour equal to the value entered are included in the ENC) and assign this as the safety contour to be used. White and blue colours will be adjusted accordingly.

In an ENC, the following standard contour lines are generally available:

0, 2m, 5m, 10m, 20m, 30m, 50m, 100m, 200m, 300m, 400m, 500m, 1000m, 2000m, 3000m, 4000m.

The ENC may also contain additional depth contours, for example:

3m, 8m, 15m, 25m, 40m, 75m, 600m, 700m, 800m, 900m.[14]

In addition to the above contours, some Hydrographic Offices are now producing "High Density (HD) ENCs", which may have a contour interval as small as 0.1 metres covering the depth ranges suitable for the draughts of vessels for which the ENC is intended.

[14] Adapted from S-4 clause B-411

5 Zones of Confidence symbols in ENCs

There are two validations of Zones of Confidence:

- Assessed
- Unassessed

Areas that have been assessed are symbolized by the number of stars. Areas which have not been assessed are symbolized by the letter U.

The number of stars is an indication of the CATZOC value:

6 stars = A1 (in a triangle)
5 stars = A2 (in a triangle)
4 stars = B (in a triangle)
3 stars = C (in a horizontal bar)
2 stars = D (in a horizontal bar)

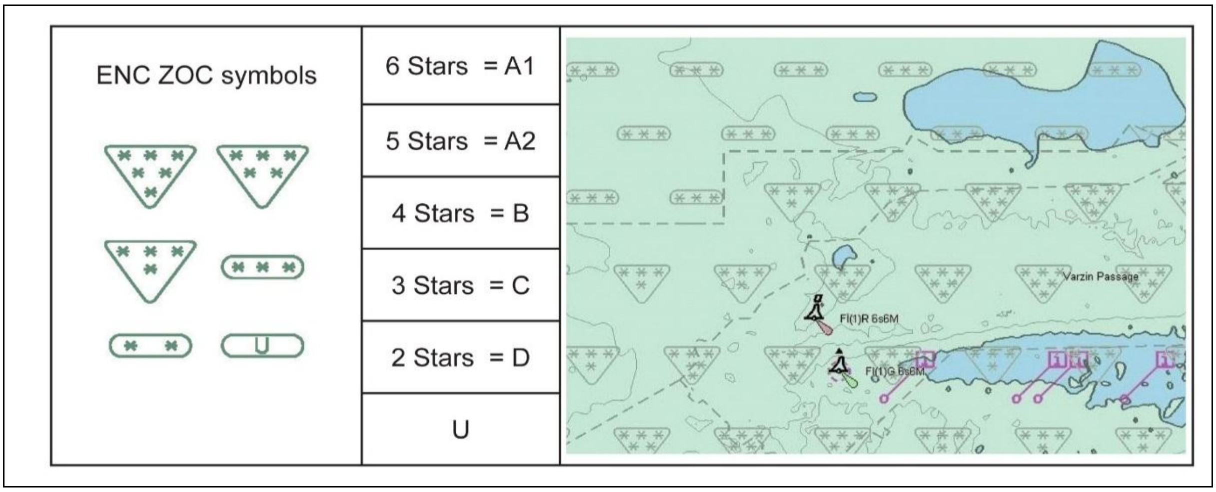


Figure 5-1 – Zones of Confidence symbols, categories and depiction on an ENC

To view the Zones of Confidence symbology, the mariner is required to activate the "information on chart display layer" (or a similar setting, depending on the type of ECDIS used).

The ZOC symbols are placed horizontally across the screen in a regular gridded pattern. The boundary of the CATZOC areas is defined by a dashed line. The ZOC symbol displayed is based on the area defined for each different CATZOC. This means that occasionally only a partial symbol indicating the CATZOC may be depicted, with the symbol being "cut" at the border of adjacent CATZOC areas (thus creating an invalid "composite" symbol, which may be confusing) or at the edge of the ENC cell. This can be seen in Figure 5-1 above, particularly along the boundary separating the ZOC A1 and B areas.

This kind of symbology tends to clutter the screen, therefore during execution of a voyage mariners will most likely de-activate this setting. However, when planning a new route or changing an existing route whilst en-route, mariners are recommended to activate the CATZOC display and use the information provided to support their decision making process before accepting the new route in the ECDIS system.

Quick Reference:

- 5 stars or more = high accuracy depth information area.
- 4 stars = medium accuracy depth information area.
- 3 stars or less = poor accuracy depth information area.
- U = unassessed, take appropriate caution.

5.1 Impact of ZOC categories upon mariners

Put in simple terms, mariners should be able to navigate with confidence in areas with ZOC A1 and A2 classifications. It is possible, but unlikely, that an uncharted danger affecting surface navigation exists in ZOC B areas. In ZOC C areas mariners should exercise caution since hazardous uncharted features may be expected, particularly in or near reef and rocky areas. A very high degree of caution is required for areas assessed as ZOC D, as these contain either very sparse data or may not have been surveyed at all. Finally, it is good practice to treat ZOC U areas with the same degree of caution as ZOC D areas.

To put this in perspective, Table 5-1 below is an overall analysis of over 14 million square kilometres of coastal ENC[15] from 32 nations:

Table 5-1 – Coverage by ZOC category - analysis

ZOC category	% area of English Channel	% area of Singapore & Malacca Straits	% area of world's coastal ENC (32 nations)	Confidence
A1 (6 stars)	12.4%	1.4%	2.5%	Good
A2 (5 stars)	7.1%	0.2%	3.0%	Good
B (4 stars)	43.5%	2.5%	38.5%	Medium
C (3 stars)	21.6%	76.2%	27.8%	Poor
D (2 stars)	12.4%	1.1%	12.5%	Poor
Unassessed (U)	3.0%	18.5%	15.7%	Poor

5.1.1 Effect of over-scaling

The display scales available to mariners in an ECDIS are not standardized and they vary between different ECDIS. Hydrographic Offices on the other hand are recommended by the IHO to compile their ENCs using one of the predefined scale values shown in Table 5-2 below. These scale values, although developed to align as close as possible with standard radar ranges, do not always match the display scale step values available to mariners in ECDIS. Consequently, mariners are strongly recommended, especially during route monitoring, to use the 1:1 ECDIS display setting where available. This setting will display the ENC at the intended viewing scale for the position of the vessel. Mariners will then benefit from the maximum level of detail available in the ENC without the risk of over-scaling.

Table 5-2 – Recommended standard ENC compilation scales

Selectable range	Standard scale (rounded)
200 NM	1:3.000.000
96 NM	1:1.500.000
48 NM	1:700.000
24 NM	1:350.000
12 NM	1:180.000
6 NM	1:90.000
3 NM	1:45000
1.5 NM	1:22.000
0.75 NM	1:12.000
0.5 NM	1:8000

[15] From Navigation Purpose 3 and 4 ENC, covering 14,218,244 SQ KM. World and English Channel figures are from 2020; Singapore and Malacca Straits figures are from 2015. The analysis did not include ports.

0.25 NM	1:4000

There is also a general relationship between the scale of an ENC and its intended purpose. ENCs intended for coastal navigation or approaching a port will generally be compiled at a smaller scale than ENCs intended for more precise navigation and manoeuvring within a port. For instance, on a coastal navigation ENC there is generally no intention by the Hydrographic Office to present the charted information such that mariners can navigate within close proximity of isolated dangers (for example hazards covering an area may be depicted as point features); if this was the intent the ENC would be compiled at a much larger scale. Over-scaling an ENC effectively breaks this relationship between the scale at which the charted information is being displayed and the intended usage of this information.

A large scale chart covers a small area with high level of details. The associated Zones of Confidence therefore also are provided to a high level of detail. When transitioning to a smaller scale chart, at some point two adjacent CATZOC areas will merge into one. At that point only the lesser value of the two CATZOCs will be available for safety reasons. Shipping accidents have occurred when mariners did not have the largest scale chart in their ECDIS available; they over-scaled using a medium scale chart, and ran aground by passing too close to isolated underwater dangers.

Accidents have also occurred due to over-scaling in areas where area obstructions have been generalized to point features due to the scale at which the data has been compiled. Further details and examples are provided in Annex B.

6 Assessment of the quality of a survey into a Zone of Confidence by the Hydrographic Office

ENCs contain different kinds of data collected with different technologies. Some data may be more than 50 years old whereas other data is collected with the latest technology. Some data may be collected using a leadline from a ship, other data may be measured by satellite from space. All this data is compiled to provide an image of the seabed and objects above the seabed. Some data is collected by the Hydrographic Office; other data may come from port authorities, scientific research institutes and through private ship-owners. The Hydrographic Office has the task to evaluate the quality of the data received and decide if and how this data should be made available to update the ENC. This is generally achieved in accordance with the criteria described in Annex A.

As a general guideline, the following choices are made by the Hydrographic Office:

- Data from ports are generally assigned ZOC A1, A2 or B.
- Satellite data are assigned ZOC C.
- Laser data by plane are assigned ZOC B, sometimes A2.
- Private ship-owner data are assigned ZOC D.
- Data before 1980 are assigned ZOC B, C or D. In general, the older the data, the lower the value.

On a case-by-case basis, the Hydrographic Office may deviate from these general guidelines as they see fit, taking into account local knowledge of the area, intended shipping routes etc.

6.1 Assessment examples

Typical survey characteristics are the first considerations when making an assessment of seafloor coverage, depth accuracy and position accuracy. Next, the systematic/non-systematic nature of the survey; does the survey comprise planned survey lines on a known geodetic datum that can be accurately transformed to WGS 84? How accurate are the transformation parameters when converting an old survey (before 1980) to the WGS84 datum used in the ENC? The Hydrographic Office will generally take this into consideration and downgrade the CATZOC areas appropriately.

In this example, a single beam survey conducted in 1963 is very complete. Developments (more survey lines) were made around the shoal areas and crosslines were conducted to see if any shoals existed between survey lines. Due to the completeness of this survey no uncharted features hazardous to surface navigation are expected. The resulting charted depth data would be given CATZOC of B. The area could not be given a CATZOC of A1 or A2 because full seafloor coverage was not achieved. The dynamics of the area could also influence the quality of the data.

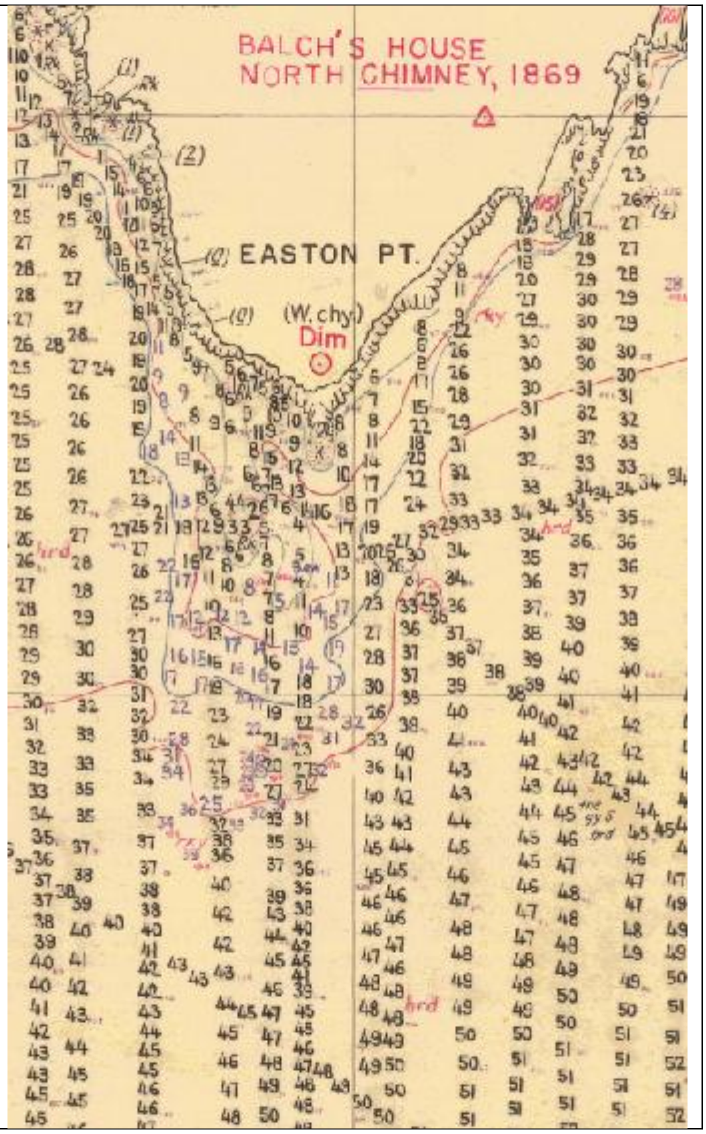


Figure 6-1 – Example: Systematic single beam survey from 1963

In this example, the older hand-drawn survey was completed in 1899. It was done by leadline measurements (recorded in fathoms). These measurements are actually quite accurate. However, they are only isolated measurements, with no guarantee of finding any hazard between one leadline depth and the next. This old survey only includes hazards seen by the surveyors at or above the sea surface. It was assessed as ZOC C – depth anomalies may be expected.*

In contrast, depths taken from the modern metric survey shows a significant 2.1 metre shoal not found during the original survey. It proves that the 1899 survey, if it was the only survey in this area, could not be trusted; and that precautions should be taken.

NOTE: The CATZOC value shown on the ENC would be based on the value assigned to the modern metric survey, however soundings from both surveys may be used.

(1 fathom equals 1.8 meters.)*

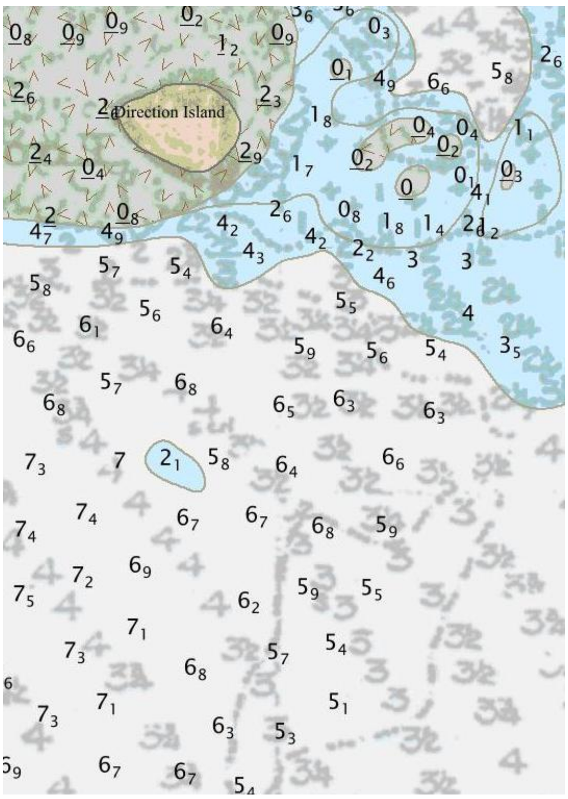


Figure 6-2 – Example: Leadline survey from 1899

6.2 Position accuracy of a survey

Position accuracy of a survey is typically determined by the positioning systems used during the hydrographic survey. The ability to accurately position a ship anywhere on the globe has significantly improved over the last 100 years.

Since 1978 the US government has provided a space-based radio navigation system, operated by US Air Force. This service, the Global Positioning System (GPS), is available to an unlimited number of users with a GPS receiver. The user can determine accurate time and location, in any weather, day or night, anywhere around the globe. Other countries have provided a similar service, GLONASS (Russian); Beidou (Chinese); and Galileo (EU). A user with a Global Navigation Satellite System (GNSS) receiver can now use all these services at the same time, thus improving the horizontal and vertical accuracy of their position.

The accuracy of a GPS receiver in the 1980s was approximately 30 meters. For hydrographic surveys, a land-based correction signal was supplied to correct for errors introduced by the US Air Force for military purposes; and for signal loss between satellites and receiver. The initial accuracy of 30 meters was initially brought down to 2 meters and eventually to 0.10 meters. The accuracy for a standard GNSS receiver is nowadays in the range of 5 meters, however accuracy of positions in the Arctic can be less due to the fact that the satellites do not pass directly overhead. With the full service of Galileo, the accuracy of a standalone GNSS receiver will become 0.20 meters. This means that the position of the ship will become (far) more accurate than the surveys previously collected and charted.

From the late 1940s to the 1990s survey ships depended upon shore-based electronic positioning systems transmitting their signal over short or medium ranges, giving accuracy of around 20 to 100 meters. In coastal areas, this means that true position of an object could be up to 100 meters from where it was thought to be. Much of this depended upon how accurately the transmitter ashore was positioned, as well as the accuracy of the transmitted ranges to generate the 'fix'.

Prior to this, survey ships used sextants to measure angles between a system of prominent marks, or flag poles built on towers established ashore, with surveyors 'angling' for hours at a time. A second row of towers could be built in shallow water or on reefs to extend the network further offshore, but with a further reduction in accuracy. Depending upon how accurately the towers were placed, accuracy of 50 to 500 meters was possible for the survey ship. So again, particularly offshore, the true position of an object could quite easily be up to 500 meters from where it was thought to be.

	
Up to early 1940s: Survey flag on an offshore reef to extend horizontal sextant control further offshore could achieve accuracy typically between 50 – 500 meters of actual position.	*Late 1940s to mid-1990s: Shore based electronic position fixing systems could achieve accuracy typically between 20 – 100 meters of actual position.*

Figure 6-3 – Position fixing – pre-1940s; late 1940s to 1990s

Further offshore, where information was collected by ships relying entirely upon celestial navigation, positions could be considerably less accurate, typically no better than 1 to 2NM, and frequently worse.

While modern satellite imagery can be used to correct the position of many isolated visible offshore features, such as islands, reefs or perhaps shoals breaking in rough weather, anything more than a few meters below the surface is likely to remain unseen, and therefore possibly charted well out of its true position.

Annex A Zones of Confidence Categories

Table A-1 – Zones of Confidence categories

<table>
<tr><th>ZOC Category (note 1)</th><th>Position Accuracy (note 2)</th><th colspan="2">Depth Accuracy (note 3)</th><th>Seafloor Coverage</th><th>Typical Survey Characteristics (note 5)</th></tr>
<tr><td rowspan="2">A1</td><td rowspan="2">± 5 m + 5% depth</td><td colspan="2">=0.50 + 1%d</td><td rowspan="2">Full area search undertaken. Significant seafloor features detected (note 4) and depths measured.</td><td rowspan="2">Controlled, systematic survey (note 6) high position and depth accuracy achieved using DGPS and a multi-beam, channel or mechanical sweep system.</td></tr>
<tr><td>Depth (m)
10
30
100
1000</td><td>Accuracy (m)
± 0.6
± 0.8
± 1.5
± 10.5</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="2">A2</td><td rowspan="2">± 20 m</td><td colspan="2">= 1.00 + 2%d</td><td rowspan="2">Full area search undertaken. Significant seafloor features detected (note 4) and depths measured.</td><td rowspan="2">Controlled, systematic survey (note 6) achieving position and depth accuracy less than ZOC A1 and using a modern survey echo-sounder (note 7) and a sonar or mechanical sweep system.</td></tr>
<tr><td>Depth (m)
10
30
100
1000</td><td>Accuracy (m)
± 1.2
± 1.6
± 3.0
± 21.0</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="2">B</td><td rowspan="2">± 50 m</td><td colspan="2">= 1.00 + 2%d</td><td rowspan="2">Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.</td><td rowspan="2">Controlled, systematic survey (note 6) achieving similar depth but lesser position accuracies than ZOC A2, using a modern survey echo-sounder (note 7), but no sonar or mechanical sweep system.</td></tr>
<tr><td>Depth (m)
10
30
100
1000</td><td>Accuracy (m)
± 1.2
± 1.6
± 3.0
± 21.0</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td rowspan="2">C</td><td rowspan="2">± 500 m</td><td colspan="2">= 2.00 + 5%d</td><td rowspan="2">Full area search not achieved, depth anomalies may be expected.</td><td rowspan="2">Low accuracy survey or data collected on an opportunity basis such as soundings on passage.</td></tr>
<tr><td>Depth (m)
10
30
100
1000</td><td>Accuracy (m)
± 2.5
± 3.5
± 7.0
± 52.0</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>D</td><td>Worse than ZOC C</td><td colspan="2">Worse than ZOC C</td><td>Full area search not achieved, large depth anomalies may be expected.</td><td>Poor quality data or data that cannot be quality assessed due to lack of information.</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>U</td><td colspan="5">Unassessed - The quality of the bathymetric data has yet to be assessed</td></tr>
<tr><td>Column: 1</td><td>2</td><td colspan="2">3</td><td>4</td><td>5</td></tr>
<tr><td colspan="6">Source: IHO S-57 Ed3.1 Supp 3 (Jun 2014), pp 13-14</td></tr>
</table>

<u>Remarks:</u>

To decide on a ZOC Category, all conditions outlined in columns 2 to 4 of the table must be met.

Explanatory notes quoted in the table:

<u>Note 1.</u> The allocation of a ZOC indicates that particular data meets minimum criteria for position and depth accuracy and seafloor coverage defined in this Table. ZOC categories reflect a charting standard and not just a hydrographic survey standard. Depth and position accuracies specified for each ZOC

category refer to the errors of the final depicted soundings and include not only survey errors but also other errors introduced in the chart production process.

Note 2. Position accuracy of depicted soundings at 95% CI (2.45 sigma) with respect to the given datum. It is the cumulative error and includes survey, transformation and digitizing errors etc. Position accuracy need not be rigorously computed for ZOCs B, C and D but may be estimated based on type of equipment, calibration regime, historical accuracy etc.

Note 3. Depth accuracy of depicted soundings = a + (b*d)/100 at 95% CI (2.00 sigma), where d = depth in meters at the critical depth. Depth accuracy need not be rigorously computed for ZOCs B, C and D but may be estimated based on type of equipment, calibration regime, historical accuracy etc.

Note 4. Significant seafloor features are defined as those rising above depicted depths by more than:

Depth Significant Feature

a. <40m: 2 m

b. >40m: 10% depth

A full seafloor search indicates that a systematic survey was conducted using detection systems, depth measurement systems, procedures, and trained personnel designed to detect and measure depths on significant seafloor features. Significant features are included on the chart as scale allows. It is impossible to guarantee that no significant feature could remain undetected, and significant features may have become present in the area since the time of the survey.

Note 5. Typical Survey Characteristics - These descriptions should be seen as indicative examples only.

Note 6. Controlled, systematic surveys (ZOC A1, A2 and B) - surveys comprising planned survey lines, on a geodetic datum that can be transformed to WGS 84.

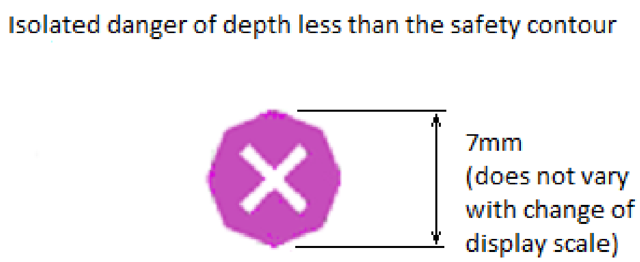
Note 7. Modern survey echo-sounder - a high precision single beam depth measuring equipment, generally including all survey echo-sounders designed post 1970.

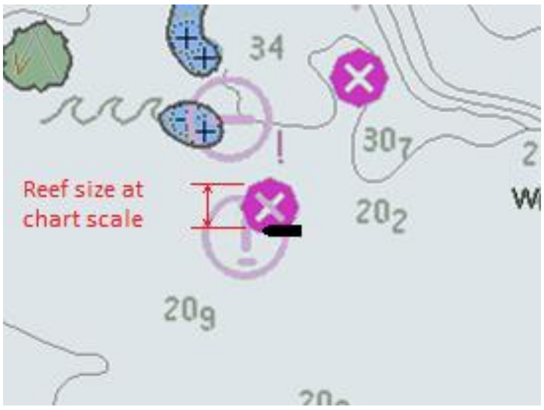
Annex B Dangerous effects of over-scale ECDIS display near 'isolated dangers'

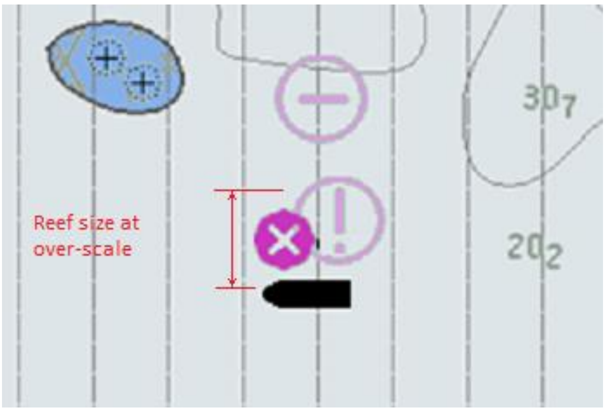
Use of over-scale display of an ENC may be dangerous in certain circumstances. There is a mistaken belief that zooming in allows for greater accuracy; however, this is not the case. In reality, zooming in beyond the compilation scale of the ENC may be misleading and dangerous, particularly for *'Isolated dangers of depth less than the safety depth'*; as any positional errors included in the data are magnified. The over-scale indicator in the ECDIS should therefore be heeded as a measure to prevent over-scaling the chart.

Every ENC is compiled at an intended maximum viewing scale, known as the compilation scale. At this scale the maximum level of detail is revealed, while zooming out will progressively reduce the level of detail. None of this affects the accuracy of the chart. Zooming in may reveal a new, larger scale ENC, but this too has limits, and a point will be reached where there is no point zooming in further.

At the ENC compilation scale, area details which are too small to chart, but which still present a hazard to navigation, are typically replaced by a point symbol larger than the charted size of the feature (such as a very small reef). Zooming in to over-scale negatively impacts the relationship between the scaled size of the (now larger) real-world area hazard and the size of the symbol.







When the ENC is displayed correctly (that is, at compilation scale), the danger to a ship close to an isolated danger is clear.	*However, when displayed at over-scale, a ship positioned the same unsafe distance from the isolated danger incorrectly appears to be safe, because the isolated danger symbol is still the same size on the screen.* *This is not more accurate, and is definitely not safe.*

Figure B-1 – Effect of over-scaling on relationship between point symbol and real-world feature

Remember, the positioning accuracy of the isolated danger may be worse than 500 meters. Routes should be planned to clear these dangers by at least as far as the ZOC category immediately around the danger dictates.

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