

## Paper for consideration by DQWG

### Proposal to refine and clarify the existing S-57 Zones Of Confidence system for cartographers

**Submitted by:** Australia

**Executive Summary:** A study undertaken in 2012 and previously presented to DQWG identified that, while 75% of responding mariners claimed to understand data quality indicators on papers charts, an equal number claimed not to understand the Zones Of Confidence rating system used within ENC. To address this, guides for both mariners and hydrographic offices were identified as being desirable.

This paper proposes changes to the S-57 Zones of Confidence tables included within the existing S-57 standard. It is intended to address a number of inconsistencies between the specified parameters and the associated guidance provided for hydrographic offices contained within the "survey characteristics" part of the table. It also proposes one revision regarding the potential size of undetected features within the ZOC A1 category to remove the most obvious contradiction between S-44 and S-57.

If accepted, or accepted in modified form, these revisions to the S-57 table should be passed to NCWG for inclusion in the S-57 standard. It is considered the changes should also be publicised by circular letter.

A separate paper has proposed a draft guide for mariners for consideration at DQWG12.

This paper does not specifically propose revisions to the levels of uncertainty associated with the existing ZOC categories. However, in developing this paper it was noted that there are some significant inconsistencies between S-44 and S-57 (where they overlap), that contribute to confusion for both mariners and cartographers when attempting to determine the reliability of information within ports and similar waterways.

**Related Documents:** Draft publication S-67 "Mariners' Guide To Accuracy And Reliability Of Electronic Navigational Charts (ENC)".

**Related Projects:** DQWG Work Plan 2016-17, Task C: Maintain and extend as needed existing quality indicators in S-57 "IHO Transfer Standard for Digital Hydrographic Data", including the education of both the mariner and the cartographer, and the development of documentation (IHO Task 2.5.2)

## Background

While a study undertaken in 2012 and previously presented to DQWG identified that understanding of the existing Zones Of Confidence rating system used within ENC is (or was) poor, it was also identified that understanding by cartographers has room for improvement. To address this, guides for both mariners and hydrographic offices were identified as being desirable.

In looking in detail at the second of these two issues, it was noted that there are a number of logical inconsistencies within the existing S-57 Zones of Confidence table. These are identified within this paper. Most are contained within the descriptions of Seafloor Coverage and Survey Characteristics. In addressing these issues it should be simpler for hydrographic offices to categorise bathymetric data consistently.

If accepted, or accepted in modified form, these revisions to the S-57 table should be passed to NCWG for inclusion in the S-57 standard. It is considered the changes should also be publicised by circular letter.

A separate paper has proposed a draft guide for mariners for consideration at DQWG12.

This paper does not specifically propose revisions to the levels of uncertainty associated with the existing ZOC categories. However, in developing this paper it was noted that there are some significant inconsistencies between S-44 and S-57 (where they overlap), that contribute to confusion for both mariners and cartographers when attempting to determine the reliability of information within ports and similar waterways.

## **Discussion**

### **High quality data...ZOC A1**

Over the course of 15 years of lecturing to marine pilots it has become most apparent that the categories A1 and A2, and their fundamental mismatch to the survey standards applicable to ports where these ZOC ratings are typically charted, creates considerable confusion at best, and leaves the ZOC system without any credibility at worst.

### **ZOC A1**

As an example, data used within the approaches to many major ports is categorised on the chart as S-57 ZOC A1, having a vertical uncertainty of better than 0.7m (for a 20m depth) and suggests an allowance of 2m should be made for the possibility of undetected features, yet when the same dataset is used in the corresponding dynamic under-keel clearance system it has an S-44 attributed vertical uncertainty better than 0.3m, and only requires a 1m<sup>3</sup> maximum size for undetected features. While there are ways to work around this difference through additional attributions, they are exactly that – work arounds.

Consequently, when laden vessels are entering or leaving a port, it is invariably the Port surveyor's and Harbour Master's advice which is followed in the interests of maximising a ship's draft, and the chart's advice is ignored. Regretably, not only does this create confusion, when the ZOC rating in the ENC is rightly ignored in one area, it soon becomes wrongly ignored in other areas. Ignoring the ZOC assessment becomes a learned response in these areas – in the absence of any other advice the ZOC system is then easily dismissed but inappropriately dismissed in other areas.

As a means of addressing much of this anomaly, the fundamental difference in quoted feature detection is both a most obvious and unjustified difference, and one that can be easily addressed by amending the feature detection size associated with ZOC A1 from 2m to 1m<sup>3</sup> maximum size for undetected features.

## ZOC A1 and A2

Within both ZOC A1 and A2 there is currently a step change in feature size at 40m depth. In depths less than 40m this is specified as features less than 2m, changing to 10% depth at 40m (4m feature). Revising the change point to 10% at 20m provides a continuous progression and removes the step change in feature size, without increasing survey system requirements.

As a separate issue, an assessment of relevant and appropriate horizontal and vertical uncertainties should be considered by the newly formed HSPT, including the effects of processing, sampling and modelling of large datasets to make them chart-ready - until then the differences between the total horizontal and vertical uncertainties associated with S-44 Special Order and Order 1a should remain unchanged (but revisions are a strong possibility).

## Very low quality data / no data...

At the opposite end of the bathymetric data quality spectrum, the survey characteristics for ZOC C are ambiguous. The ZOC C description currently states:

“Low accuracy survey or data collected on an opportunity basis such as soundings on passage.”

Noting that ‘soundings on passage’ is not a specific measure of data density, uncertainty or feature detection’ some additional clarification is required.

Similarly, the survey characteristics associated with ZOC D are ambiguous and incomplete. Firstly, both ZOC D and ZOC U refer to unassessed data. ZOC D is described as including:

“...data that cannot be quality assessed”,

while ZOC U is described as:

‘Unassessed. The quality of the bathymetric data has yet to be assessed’.

Secondly, ZOC D does not include unsurveyed areas, leading to the common belief that ‘U’ stands for ‘unsurveyed’.

Finally, there is inconsistent use of the terms ‘significant seafloor features’, ‘features’ and ‘depth anomalies’ within the seafloor coverage descriptions. There is an excessive reliance upon notes in a separate accompanying table, making comprehension more difficult than necessary.

## Proposed actions

It is therefore proposed that:

- the ZOC A1 category “Seafloor Coverage” attribute be revised from 2m to 1m<sup>3</sup> maximum size for undetected features (but leaving ZOC A2 unchanged); to cater for Special Order areas within the S-57 ZOC system,
- a correction be made to the way in which 2m objects are described to remove the ambiguity between a to 2m<sup>3</sup> and 2m high object rising from the seafloor;

- a correction be made to the descriptions of ZOC C and D within the S-57 ZOC system, and,
- other clarifications be incorporated as shown; and
- HSSC be recommended to consider the scope of HSPT to include the effects of processing of hydrographic surveys in making datasets chart-ready, such that the manner in which data is described on the chart does not artificially and arbitrarily degrade the quality of bathymetric data, and that any changes should be reflected in both a new edition of S-44 and in the Quality of Bathymetric Data proposed for S-101 ENC where the quality of datasets overlaps.

### **Actions**

DQWG members are requested to:

- note this paper and the key factors within it;
- provide any suggested revisions;
- propose agreed changes to HSSC;
- propose a method / methods of publication, promulgation and 'advertising'; and
- propose scoping changes to HSSC for HSPT.

## Proposed revisions to S-57 Zones Of Confidence

ZOC Category (note 1)	Position Accuracy (note 2)	Depth Accuracy (note 3)		Seafloor Coverage	Typical Survey Characteristics (note 5)
A1	± 5 m + 5% depth	=0.50 + 1%d		Full area search undertaken. Significant seafloor features detected (note 4) and depths measured. Full seafloor search undertaken. Full area search undertaken. Undetected seafloor features larger than 1m <sup>3</sup> (or 5% depth beyond 20m) are unlikely to exist.	Controlled, systematic survey (note 6) high position and depth accuracy achieved using DGPS and a multi-beam, channel or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10	± 0.6		
		30	± 0.8		
		100	± 1.5		
		1000	± 10.5		
A2	± 20 m	= 1.00 + 2%d		Full area search undertaken. Significant seafloor features detected (note 4) and depths measured. Full seafloor search undertaken. Undetected seafloor features larger than 2m above the general seabed (or 10% depth beyond 40m) are unlikely to exist.	Controlled, systematic survey (note 6) achieving position and depth accuracy less than ZOC A1 and using a modern survey echo-sounder bathymetric survey system including full seabed ensonification or illumination (note 7) and a sonar or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10	± 1.2		
		30	± 1.6		
		100	± 3.0		
		1000	± 21.0		
B	± 50 m	= 1.00 + 2%d		Full area search not achieved; uncharted seafloor features, hazardous to surface navigation drawing less than 30m draft are not expected but may exist.	Controlled, systematic survey (note 6) achieving similar depth but lesser position accuracies than ZOCA2, using a modern survey system (note 7), but no sonar or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10	± 1.2		
		30	± 1.6		
		100	± 3.0		
		1000	± 21.0		
C	± 500 m	= 2.00 + 5%d		Full area search not achieved, uncharted seafloor features and depth differences may be expected.	Low accuracy survey or data collected on an opportunity basis such as soundings on passage, such that the area is considered inadequately surveyed for the depth of water and likelihood of undetected features.
		Depth (m)	Accuracy (m)		
		10	± 2.5		
		30	± 3.5		
		100	± 7.0		
		1000	± 52.0		
D	worse than ZOC C	Worse Than ZOC C		Full area search not achieved, large uncharted seafloor features and large depth differences hazardous to surface navigation may be expected. Area may be unsurveyed.	Poor quality data or data that cannot be quality assessed due to lack of information that is so sparse as to be considered unsurveyed.
U	Unassessed - The quality of the bathymetric data has yet to be assessed				
Column: 1	2	3	4	5	

Source: IHO S-57 Ed3.1 Supp 3 (Jun 2014), pp 13-14

### Remarks:

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:

Note 1. 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 metres 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:

ZOC A1	Depth	Significant Feature
a.	<20m:	1m <sup>3</sup>
b.	>20m:	5% depth

ZOC A2	Depth	Significant Feature
a.	<40m:	2m <sup>3</sup> (S-44 Order 1a feature detection)
b.	>40m:	10% depth (S-44 Order 1a feature detection)

ZOC B	Depth	Significant Feature
a.	<40m:	Not specified (generally aligned to S-44 Order 1b feature detection)
b.	>40m:	Not specified (generally aligned to S-44 Order 1b feature detection)

ZOC C	Depth	Significant Feature
a.	<40m:	Not specified (generally no better than S-44 Order 2 feature detection)
b.	>40m:	Not specified (generally no better than S-44 Order 2 feature detection)

ZOC D	Depth	Significant Feature
a.	<40m:	Not specified (generally worse than S-44 Order 2 feature detection)
b.	>40m:	Not specified (generally worse than S-44 Order 2 feature detection)

~~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 ~~system echo-sounder~~ - a high precision single beam ~~echo-sounder~~ **in conjunction with side scan sonar**, generally including all **systems** designed post 1970, **or multibeam echo-sounder, or lidar with full illumination.**

**Enclosures:****Existing Zones Of Confidence Categories**

ZOC	Position Accuracy	Depth Accuracy		Seafloor Coverage	Typical Survey Characteristics
A1	± 5 m + 5% depth	=0.50 + 1% depth		Full area search undertaken. Significant seafloor features <sup>1</sup> detected and depths measured.	Controlled, systematic survey <sup>2</sup> 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.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 0.6 ± 0.8 ± 1.5 ± 10.5		
A2	± 20 m	= 1.00 + 2% depth		Full area search undertaken. Significant seafloor features <sup>1</sup> detected and depths measured.	Controlled, systematic survey <sup>2</sup> achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder <sup>3</sup> and a sonar or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 1.2 ± 1.6 ± 3.0 ± 21.0		
B	± 50 m	= 1.00 + 2% depth		Full area search not achieved; uncharted features, hazardous to surface navigation are not expected but may exist.	Controlled, systematic survey <sup>2</sup> achieving similar depth but lesser position accuracies than ZOCA2, using a modern survey echosounder <sup>3</sup> , but no sonar or mechanical sweep system.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 1.2 ± 1.6 ± 3.0 ± 21.0		
C	± 500 m	= 2.00 + 5% depth		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.
		Depth (m)	Accuracy (m)		
		10 30 100 1000	± 2.5 ± 3.5 ± 7.0 ± 52.0		
D	worse than ZOC C	Worse Than ZOC C		Full area search not achieved, large depth anomalies may be 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 1 – Zones Of Confidence Full Table

## Existing Zones Of Confidence Notes

Explanatory notes quoted in the table:

Note 1. 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. Data may be further qualified by Object Class 'Quality of Data' (M\_QUAL) sub-attributes as follows:

a) Positional Accuracy (POSACC) and Sounding Accuracy (SOUACC) may be used to indicate that a higher position or depth accuracy has been achieved than defined in this Table (e.g. a survey where full seafloor coverage was not achieved could not be classified higher than ZOC B; however, if the position accuracy was, for instance,  $\pm 15$  metres, the sub-attribute POSACC could be used to indicate this).

b) Swept areas where the clearance depth is accurately known but the actual seabed depth is not accurately known may be accorded a 'higher' ZOC (i.e. A1 or A2) providing positional and depth accuracies of the swept depth meets the criteria in this Table. In this instance, Depth Range Value 1 (DRVAL1) may be used to specify the swept depth. The position accuracy criteria apply to the boundaries of swept areas.

c) SURSTA, SUREND and TECSOU may be used to indicate the start and end dates of the survey and the technique of sounding measurement.

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 metres 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. <40 m 2 m
- b. >40 m 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.

Table 2 – Zones Of Confidence Notes

## Existing S-44 Survey Orders

IHO STANDARDS FOR HYDROGRAPHIC SURVEYS (S-44)  
5<sup>th</sup> Edition February 2008

**TABLE 1**  
Minimum Standards for Hydrographic Surveys  
(To be read in conjunction with the full text set out in this document.)

Reference	Order	Special	1a	1b	2
<a href="#">Chapter 1</a>	Description of areas.	Areas where under-keel clearance is critical	Areas shallower than 100 metres where under-keel clearance is less critical but <i>features</i> of concern to surface shipping may exist.	Areas shallower than 100 metres where under-keel clearance is not considered to be an issue for the type of surface shipping expected to transit the area.	Areas generally deeper than 100 metres where a general description of the sea floor is considered adequate.
<a href="#">Chapter 2</a>	Maximum allowable THU 95% <i>Confidence level</i>	2 metres	5 metres + 5% of depth	5 metres + 5% of depth	20 metres + 10% of depth
<a href="#">Para 3.2 and note 1</a> <a href="#">Glossary and note 2</a>	Maximum allowable TVU 95% <i>Confidence level</i> <i>Full Sea floor Search</i>	a = 0.25 metre b = 0.0075	a = 0.5 metre b = 0.013	a = 0.5 metre b = 0.013	a = 1.0 metre b = 0.023
<a href="#">Para 2.1</a> <a href="#">Para 3.4</a> <a href="#">Para 3.5</a> and <a href="#">note 3</a>	<i>Feature Detection</i>	Cubic <i>features</i> > 1 metre	Cubic <i>features</i> > 2 metres, in depths up to 40 metres; 10% of depth beyond 40 metres	Not Applicable	Not Applicable
<a href="#">Para 3.6</a> and <a href="#">note 4</a>	Recommended maximum Line Spacing	Not defined as <i>full sea floor search</i> is required	Not defined as <i>full sea floor search</i> is required	3 x average depth or 25 metres, whichever is greater For bathymetric lidar a spot spacing of 5 x 5 metres	4 x average depth
<a href="#">Chapter 2</a> and <a href="#">note 5</a>	Positioning of fixed aids to navigation and topography significant to navigation. (95% <i>Confidence level</i> )	2 metres	2 metres	2 metres	5 metres
<a href="#">Chapter 2</a> and <a href="#">note 5</a>	Positioning of the Coastline and topography less significant to navigation (95% <i>Confidence level</i> )	10 metres	20 metres	20 metres	20 metres
<a href="#">Chapter 2</a> and <a href="#">note 5</a>	Mean position of floating aids to navigation (95% <i>Confidence level</i> )	10 metres	10 metres	10 metres	20 metres