DQWG8-06A

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Information Paper for consideration by TSMAD, DIPWG, CSPCWG, TWLWG

New ways of representing data quality for surface navigation

Submitted by: DQWG 'HICUP' Sub-WG

Executive Summary:

The DQWG HICUP Sub-WG has developed usage case scenarios for a revised way of displaying data quality in a more intuitive manner than the current 'star' system displayed within current generation ENC. The envisaged display methodology is a three-tiered traffic light scheme which takes into account depth, data quality and the user-defined Safety Depth of a vessel. In this paper the three tiers are nominally referred to as Red, Amber and Green, representing three levels of risk.

The scenarios use the uncertainty attributes inherent in most modern surveys currently used to determine and assign a ZOC category. For ENC producer-nations who have only assigned an overall ZOC assessment for various areas, without maintaining an accessible record of the individual uncertainty components, mapping from each existing ZOC assessment is included in order to impose no additional work upon producer-nations.

However, this paper also includes proposals for a number of optional additional parameters permitting producer-nations to enter more refined and informative values beyond existing ZOC default values in order to better meet emerging requirements, particularly in areas of special order surveys and minimal under-keel clearance.

This draft paper has yet to undergo final DQWG review.

Related Documents: DQWG Work Plan 2013-14, Task E

Related Projects: S-100, S-101

Commentaire [KC1]: I see the term 'uncertainty attributes" referred to throughout the document…does this meant to include the time varying uncertainty as well or just in position and depth?

Background

The IHO Data Quality Working Group has been tasked to 'investigate ways of ensuring that ECDIS displays provide a clear warning or indication to the mariner on the quality of the underlying survey data, through appropriate use of the attribute CATZOC and/or improvement of the existing display capabilities (IHO Task 2.5.2 refers)'. This paper presents a number of usage case scenarios intended to address all reasonably conceivable circumstances and detail the expected display outcomes for each combination of those circumstances. It includes a number of considerations on how those indicators should be displayed.

Situation

Most nations are limited in their capacity to radically alter the manner in which hydrographic surveys are categorised with regard to data quality, while some have yet to apply meaningful Zones Of Confidence (ZOC / CATZOC) to their ENC. The preferred option is to present information which already exists, or to which producer nations are already working, in a more intuitive manner, rather than developing an entirely new data quality system. It is considered ~~absolutely critical~~important that any new scheme does not force new requirements upon chart producers although, if the investigations indicate that a new requirement is needed to usefully portray data quality, it is recognised that this is included.

However, where possible, any new scheme should be able to cater for future requirements and user expectations. It should therefore provide non-mandatory options to provide greater clarity to mariners, as well as cater for the very much smaller under-keel clearances being used in some ports since 'S-44 – IHO Standard for Hydrographic Surveyors' was first published, and which are not adequately represented within the current range of fixed ZOC attribute combinations.

Alignment to S-44 – IHO Standard for Hydrographic Surveyors

While there is no intentional direct alignment between S-44 and the various ZOC categories, achievement of a certain ZOC is frequently quoted in specifications for surveys, particularly contract surveys for areas where ZOCs are already charted. This habit is likely to increase as use of ENC (with CATZOC embedded) becomes more widespread. Typically, the person contracting the survey is not a surveyor, but is more likely to be a Harbour Master or member of a port's operational or infrastructure support staff. The required final ZOC rating is therefore increasingly used because that is what those with a mariner background are becoming familiar with – in contrast, port operational staff have rarely heard of S-44.

In seeking a greater degree of alignment between S-44 and ZOC, a number of shortfalls are apparent:

- ZOC does not cater for Special Order surveys (ZOC A1 only approximates S-44 Order 1a)
- S-44 only generally covers surveys which will be classified as ZOC B or better.
- The threshold for applicability of S-44 is based upon depth, whereas cessation of use of ZOC on charts is driven by the scale of the chart, irrespective of depth.

The scenarios in this paper therefore include a greater degree of flexibility for chart producers to use optional parameters enabling more direct alignment to the various S-44 uncertainties, as well as scenarios directly aligned to the more rigid 'maximum' parameters defined for each existing ZOC category. For example, there should be scope to optionally enter a vertical uncertainty for a Special Order survey in a port of 0.25m, even though the default value for ZOC A1 is 0.5m.

Apart from the lack of adequate representation of Special Order areas, ZOC categories of A1, A2 have all the necessary information to support sound decision making by a mariner, and in

Commentaire [h2]: Non-mandatory is OK but the use cases must identify what action is to be taken when a non-mandatory attribute is not filled in. E.g. the ECDIS will need to take action on a populated non-mandatory field but will also need to take heed of an unpopulated field. These will need to be in the use cases.

Commentaire [KC3]: As we move forward with this document it will have to be made more specific what is meant by this with a list of suggested non-mandatory attributes or make a reference to the S-101 document where these attributes will be defined.

Commentaire [h4]: S-44 is a survey standard. ZOC (or more importantly, the new data quality indicator) should be an indication of how well the sea floor matches the depiction of the seafloor in the ENC. This matching (or mis-matching0 can be a function of survey quality (e.g. S-44 linkage or age of survey) and a function of how mobile the seafloor is. The mariner can expect there to be a good match (e.g ZOC A1/A2 where the survey is good and the seafloor is stable. A poor match would result from a poor survey or a good survey in a mobile area. This is not covered by ZOC (although it could be!) but should be covered by the new system.

Commentaire [h5]: A greater degree of alignment would be good – allow S-44 survey orders to enable ZOCs or the new categories to be created – providing other matters do not intervene (mobile se floor etc). However, the current DQWG thinking is that indicators in the ENC are individual items not the composite such as CATZOC so I am not sure what ZOC or ZOC equivalent we can match up to!

particular include quite rigorous feature detection attributes (Seafloor coverage). However, this Seafloor Coverage attribute becomes increasingly ambiguous through categories B, C and D. Additionally, ZOC includes two quite different choices for typical survey characteristics, namely 'low accuracy survey' and 'opportunity passage soundings'. The breadth of ZOC C has lead some producer nations to differentiate between the two using either upright or sloped sounding text, or use of 'Inadequately Surveyed', or both.

Therefore, while the component attributes for horizontal and vertical uncertainty, and feature detection, have been carried over from the existing ZOC system to ensure compatibility with existing ENC and attributions, a number of additional producer defined, non-mandatory parameters are proposed. These are intended to offer a possible solution to adequate representation of Special Order surveys, the ambiguities present in ZOC B, C and D, as well as cater for time-variable data quality. In the absence of producer defined parameters, defaults associated with the existing ZOC system will be used.

Commentaire [h6]: The mapping of S-57 attributes to the new attributs has been done and could be appended to this document. It breaks down the CATZOC into its various components and uses these unless more accurate values have been inserted outside of CATZOC.

The three risk tiers

The three tiers considered in this paper are intended to be very simple for mariners to understand. The three tiers are:

- Green – 95% confidence that a vessel with a correctly set Safety Depth can operate in the depicted area. The 95% confidence level is aligned to S-44 survey standards.

- Amber – a vessel's correctly set Safety Depth may extend deeper than the least possible depth resulting from the combined uncertainties of measured depth plus the possible height of any undetected seafloor feature. Cautious navigational practices are required. Height of tide or prudent navigational practices may reduce risks.

- Red - a vessel's correctly set Safety Depth may extend deeper than the uncertainty associated with the measured depth; the vessel may run aground in general seabed areas and is highly likely to encounter an undetected seafloor feature. Vessels should not enter the area.

How deep should data quality indicators for surface navigation extend?

Noting that ZOC are intended to support surface navigation, there is both limited value in extending the system into deep water, significant difficulty in generating a meaningful assessment in areas charted with ocean passage sounding data only and some potential practical display issues. In relatively well surveyed areas, it is considered that the proposed data quality indicators for surveyed areas should extend to a the 100m depth contour to align with S-44 Order 1, but may extend to the 200m depth contour where abrupt changes in seabed are probable. Despite this discretion for surveyed areas, it is considered that all unsurveyed areas touching or enclosed by a 200m depth contour should be included in the scheme. Extension of the scheme to greater depths is considered unwise - the very great variation in data density available in mid ocean areas suggests that application beyond 200m would make most oceans appear to be un-navigable.

Presentation

Only limited considerations have been made regarding presentation. These are:

- **Colours** – Red, Amber and Green are used in this paper to represent the areas of high, medium and low risk, however DIPWG may determine other colour palettes to be more suitable within the finished data quality indicator system. There may be some merit in interpreting Red in this paper as Magenta in the finished system, as there would be synergies in showing areas of high risk in the same colour as an obstruction considered dangerous to surface shipping.

- **Colours outside shallow risk zones** – In deep water, beyond 100 / 200m for surveyed areas and 200m for areas specifically charted as 'unsurveyed', where no assessment is made, it is assumed that the existing White (day-bright) or Black (night), and shades in between will be used. The same White / Black shades should be used in areas where data quality is unassessed (currently ZOC U).

- **Colours in areas shoaler than the nominated Safety Depth** – In areas where depths are too shallow for a vessel to enter (as is currently defined by the Safety Depth contour), it is recommended that while the data quality indicators are displayed, shoal areas be shaded the same colour as other deeper high risk areas, such as Red / Magenta, so that this colour is used consistently for all areas where a ship cannot or should not go. However, when the data quality layer is not displayed it is assumed that areas shoaler than the Safety Depth contour will revert to use of existing colour palettes such as Blue (day-bright) to minimise any requirement to change the existing colour palettes for other cartographic symbols.

- **Application of colours to depth areas and surfaces -** Application of colours to depth bands within any individual ZOC area would result in a visually simple presentation for the mariner. However, this may result in the colour assigned to an entire depth area within a ZOC area being based upon the shoalest depth within that band. This may unnecessarily extend areas of apparent higher risk into deeper water. While not ideal, this conservative approach minimises risk to both the mariner and ENC producer. For example, an 11m draft vessel may be at risk in 12m of water, but not at risk in 14m depths. However, application of a single risk colour throughout the entirety of that 10 to 15m depth band would appear to force the vessel to stay outside the 15m contour. Adoption and consistent application of narrower depth bands down to a nominated depth of (say) 30m, or use of a navigation surface, would result in a visually better presentation, but may be unachievable for some ENC producers.

- **Application of colours to depth surfaces** - Application of colours to a depth 'surface', instead of defined depth areas, would require use of navigation surface. A simple tinned surface based upon charted depths may meet minimum requirements for displaying the extent of any data quality indicator area, even in areas outside areas of high density bathymetry. This 'charted' tinned surface is likely to be shoaler than the true navigation surface, so still represents a moderately conservative view (but is less conservative than the 'depth area' solution). The relevance of the proposed data quality indicator system would reach its full potential through input of predicted or observed tides. Both these capabilities should be explored.

- **Application of colours to charted soundings** – Application as a coloured circle or disk centred on each sounding, or colour-coding of the actual sounding value, is not considered viable. While it caters for the known uncertainties associated with the depth measurement at that point, it fails to adequately address the feature detection considerations that exist between charted soundings.

- **Application of colours to 'Inadequately Surveyed' and 'Unsurveyed' areas** - Again noting that certain nations already have identified that ZOC C is too broad, and have resorted to or continued use of 'Inadequately Surveyed' in some parts, it is recommended that 'Inadequately Surveyed' be recognised as area-based data quality choice within the attributes available for defining typical survey characteristics. Recommended depth display thresholds are:

    - **Inadequately Surveyed –** 30m or less – Red

    - **Inadequately Surveyed –** 100 / 200m to 30m – Amber

- As this scheme would result in 'Inadequately Surveyed' areas being more strongly highlighted than 'Unsurveyed' areas, 'Unsurveyed' areas should be included within this scheme as follows:

    - **Unsurveyed – 200m or less** (enclosed by or touching a depth area 200m or less) – Red

Translating Zones Of Confidence to a three colour data quality indicator system

The existing full ZOC Table is attached as Table 1. In charting use it can become ambiguous as it is invariably shown in abridged form and without the accompanying notes shown in Table 2. The absence of Table 2 leads mariners to question "How big is a significant seafloor feature?" The answer is most important, as for ZOC A1 and A2, it is larger than the uncertainty associated with measured depths, while from ZOC B onward the size of any undetected features is currently ambiguous. However, the size can also be interpreted as the same in ZOC B and C as it is in A2, as there is no reference to 'large' seafloor features until ZOC D is assigned, even though the 'likelihood' of encountering a feature increases. From a risk-averse mariner's perspective, this ambiguity is quite unhelpful, while from a producer nation's perspective, it makes development of a useful rules-based data quality indicator particularly difficult.

Commentaire [h7]: I agree. Indeed if the sounding is from a point system (e.g. lead line) the presentation of a circle within which the measured sounding should fall based on the horizontal uncertainty is completely meaningless. It simply states that somewhere within the circle there is a 10m depth. It does not imply that everywhere within the circle it is 10m or that 10m is the shoalest depth. Indeed if the circle is large there is absolutely no guarantee that where the chart states 10m it is not actually 5m and the 10m is off to one side!

Commentaire [KC8]: I like the emphasis in the document on moving to a more explicit and stringent rules based system that will be easier for all (mariners and chart makers alike) to understand

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[1] detected and depths measured.	Controlled, systematic survey[2] 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[1] detected and depths measured.	Controlled, systematic survey[2] achieving position and depth accuracy less than ZOC A1 and using a modern survey echosounder[3] 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[2] achieving similar depth but lesser position accuracies than ZOCA2, using a modern survey echosounder[3], 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

Where the seafloor is mobile the ZOC should be able to indicate this unreliability even if the survey was done to a very high standard. I suggest that the words of this table are modified so that Seafloor Coverage and Typical Survey Characteristics allow this:
CATZOC B: Seafloor Coverage: Full area search not achieved or seafloor is mobile; uncharted....Typical Survey Characteristics: ...or full multibeam survey over a mobile seafloor.
CATZOC C: Seafloor Coverage: Full area search not achieved or seafloor is highly mobile; uncharted... Typical Survey Characteristics; .....or full multibeam survey over a highly mobile seafloor.
The words for Typical Survey Characteristics will need to be refined to cater for all survey types over mobile seafloors.

Notes:	
1.	Significant seafloor features are defined as those rising above depicted depths by more than: Depth — Significant Feature less than 40 m — 2 m greater than 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.
2.	Controlled, systematic surveys (ZOC A1, A2 and B) - surveys comprising planned survey lines, on a geodetic datum that can be transformed to WGS 84.
3.	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

Usage case scenarios

12 usage case scenarios have been developed. Of these, scenarios 3, 4, 5, 7, 9 and 12 represent a direct carry-over of the existing parameters associated with ZOC categories A1, A2, B, C, D and U.

All remaining scenarios are based upon combinations of circumstances which are already encountered in the real-world and which have proved challenging to clearly and accurately depict in a cartographic sense using the existing ZOC parameters. These include:

- Scenario 1: A declared safe depth, such as one confirmed by bar sweep, or which represents a known safe level at some distance above the seabed, and which effectively removes any possibility of an undetected feature protruding above the declared safe depth. This scenario can be met through use of two data quality indicator (CATZOC) layers applicable to two distinct depth bands.

- Scenario 2: An area surveyed to Special Order, as defined in IHO publication S-44, which has the vertical uncertainty of measured depths, and the height of any remaining undetected seafloor features, both considerably better than for ZOC A1. This scenario can be met through use of specific vertical uncertainty values, entered by the chart producer, rather than the default generic maximum value associated with ZOC A1.

- Scenario 6: An area surveyed to standards which meet requirements for ZOC B (including what would normally be an undefined height for undetected seafloor features which may affect surface navigation), but which, due to the nature and volume of shipping within a defined corridor, is considered safe for surface navigation to a certain depth (such as within the defined limits of the Great Barrier Reef Two Way Route). This scenario can be met through use of two data quality indicator (currently CATZOC) layers. Rules would be required regarding depths associated with each layer.

Commentaire [h9]: An interesting one. When using the draft of shipping to determine the safe swept depth we will need to also take account of the tidal height when they transitted or assume they went through at high tide. However, this need have no rules in ECDIS since this is a HO thing to decide then enter the depth of the lower and deeper 'CATZOC' layer.

- Scenario 8: An area surveyed to standards which meet requirements for ZOC C (including what would normally be an undefined height for undetected seafloor features which may be expected to affect surface navigation), but which, due to the nature of the area or an existing charting assessment, has been specifically identified as 'Inadequately Surveyed'. This scenario can be met through a greater range of choices for 'typical survey characteristics'.

Other points to note are:

- In the various scenarios, references to 'Safety Depth' refer to the total of the vessel's static draft plus the under-keel manoeuvring margin, as entered by a vessel's Master or Navigating Officer. The under-keel margin is the allowance made for squat, settlement, roll, pitch and manoeuvrability (water-flow under the hull and around rudders). It does not refer to the safety depth contour as displayed on the ECDIS.

- In S-101 ENC it will be possible to have two depth layers for CATZOC in any given area. This additional feature will be essential for both Scenario 1 covering certain swept areas within ports, as well as Scenario 6 covering certain offshore areas surveyed using Lidar (with its associated limitation of an 'extinction depth') with underlying data of a lower classification, or where certain shipping routes are known beyond reasonable doubt to be safe down to a certain depth based on the volume of shipping traffic within a defined corridor.

- Certain nations already have identified that ZOC C is too broad, particularly as it covers two definitions of survey characteristics (controlled low accuracy survey or uncontrolled opportunity soundings). They have therefore resorted to use of 'Inadequately Surveyed' as a means of further classifying within ZOC C areas. Additionally, some nations yet to fully adopt ZOCs have already used the term 'Inadequately Surveyed' for many years – both chart producers and mariners are therefore familiar with the term.

In all these scenarios, the difference between the depth accuracy and the 'height' of any residual undetected significant seafloor features provides the defining difference between the Red, Amber, Green data quality depiction bands for any user selected safety depth. In this regard the 'height' of any residual undetected significant seafloor feature includes the uncertainty of the surrounding depth measurements (eg. A 2.0 metre undetected object may be lying on a seabed 0.5m shoaler than charted, giving a total 'height' of 2.5m). Considerations of horizontal uncertainty have been omitted for clarity, but will be discussed separately in a later addition to this paper.

Commentaire [h10]: I am proposing a third – high accuracy survey in an area of mibile seafloor. Possibly, where the mobile features are known to move horizontally but do not gain height the two layer ZOC can be used. Good quality above the least expected depth and a low quality below this depth.

Commentaire [h11]: This is like. However it raises my never resolved bone of contention re object detection size and vertical uncertainty in areas designated as having full seafloor coverage. If we state full seafloor coverage then I feel the vertical uncertainty and the object detection need to be the same. If we say we have gathered depths everywhere with a vertical uncertainty of 0.5m yet also say we may have missed 2m high objects surely the vertical uncertainty under the undetected object is 2m which breaks the 0.5m requirement?

Scenario 1: Declared safe depth (Bar swept depth, Maintained Depth, Declared Depth or equivalent)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: displayed for any vessel with Safety Depth (SD) less than the declared safe clearance depth. Amber or Red: displayed for any vessel with SD =/greater than the declared clearance depth, based upon the assessment applied to the data quality layer below (which will probably be A1 or A2).
Vertical Uncertainty *(Mandatory)*	Producer defined value.	*Measured depths deeper than the declared safe depth must be defined by a separate ZOC (probably A1 or A2).*	
Significant Feature Height *(Mandatory)*	Producer defined value. *= 0 in this scenario*	*Under-keel clearance is defined by the port or pilot. All risk resides with the authority claiming the defined depth exists.*	
Typical survey Characteristics *(Mandatory)*	Controlled high accuracy survey. *Default value based on current ZOC A1/A2 category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*While depths may change below the declared safe clearance depth, the declared depth remains in force (but Producer-nations may also change the declared depth by ENC update.)*	
Depth bands to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Values within range 1 to 100m.*	*Typical values likely to be within range 5 to 20m in this scenario*	

Scenario 2: Special order area (better than ZOC A1)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: displayed for any vessel with Safety Depth (SD) 1.25m (vertical uncertainty + significant feature height) less than the measured depth. Amber: displayed for any vessel with SD greater than above, and with SD less than the measured depth minus (depth uncertainty +significant feature height). Amber: displayed for any area where the seabed is subject to significant change within the repeat survey cycle, irrespective of depth, down to the maximum depth for the depth band to which the data quality assessment applies. Red: displayed for any vessel with SD =/greater than the measured depth minus depth uncertainty.
Vertical Uncertainty *(Mandatory)*	+/- 0.25m. *Producer defined value based on S-44 and achieved survey vertical uncertainty.*	*Current ZOC A1 maximum value is not representative of survey standards maintained does not meet requirements within many ports.*	
Significant Feature Height *(Mandatory)*	1m. *Producer defined value based on S-44 and achieved survey vertical uncertainty.*	*S-44 Special Order requires detection of 95% of features $1m^3$ or larger*	
Typical survey Characteristics *(Mandatory)*	Controlled high accuracy survey. *Default value based on current ZOC A1/A2 category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.* *This scenario could also be used for the layer deeper than a safer upper depth layer (such as Scenario 1).*	
Depth bands to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Values within range 1 to 100m.*		

Commentaire [h12]: We should allow the entry of tidal height here to alter the red/amber/green colours. This will then allow user entered tide or maybe broadcast tide to be automatically entered. The tide height should have an uncertainty as well. This applies to all scenarios!

Commentaire [h13]: Need to define how an unpopulated optional field is handled – it should not be ignored otherwise it will act like one of the populated options and give a false result. I am also keen that the 'Extreme Event' field is used. This could be here as a part of the Temporal Change or elsewhere since I se extreme event as being an overriding flag that effectively turns everything red regardless of any other data.

Scenario 3: Default ZOC A1 values (ZOC A1)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: displayed for any vessel with Safety Depth (SD) 2.5m (vertical uncertainty + significant feature height) less than the measured depth. Amber: displayed for any vessel with SD greater than above, and with SD less than the measured depth minus (depth uncertainty +significant feature height). Amber: displayed for any area where the seabed is subject to significant change within the repeat survey cycle, irrespective of depth, down to the maximum depth for the depth band to which the data quality assessment applies. Red: displayed for any vessel with SD =/greater than the measured depth minus depth uncertainty.
Vertical Uncertainty *(Mandatory)*	+/- 0.5m + 1% depth. *Default value based on current ZOC A1.*		
Significant Feature Height *(Mandatory)*	2m (down to 40m) then 10% of depth. *Default value based on current ZOC A1.*	*S-44 Special Order requires detection of 95% of features 2m^3 or larger (down to 40m) then 10% of depth*	
Typical survey Characteristics *(Mandatory)*	Controlled high accuracy survey. *Default value based on current ZOC A1/A2 category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.* *This scenario could also be used for the layer deeper than a safer upper depth layer (such as Scenario 1).*	
Depth bands to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Values within range 1 to 100m.*		

Scenario 4: Default ZOC A2 values (ZOC A2)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: displayed for any vessel with Safety Depth (SD) 3.0m (vertical uncertainty + significant feature height) less than the measured depth. Amber: displayed for any vessel with SD greater than above, and with SD less than the measured depth minus (vertical uncertainty + significant feature height). Amber: displayed for any area where the seabed is subject to significant change within the repeat survey cycle, irrespective of depth, down to the maximum depth for the depth band to which the data quality assessment applies. Red: displayed for any vessel with SD =/greater than the measured depth minus depth uncertainty.
Vertical Uncertainty *(Mandatory)*	+/- 1m + 2% depth. *Default value based on current ZOC system.*	a producer defined value should be an option.	
Significant Feature Height *(Mandatory)*	2m (down to 40m) then 10% of depth. *Default value based on current ZOC system.*	*S-44 Special Order requires detection of 95% of features 2m^3 or larger (down to 40m) then 10% of depth*	
Typical survey Characteristics *(Mandatory)*	Controlled high accuracy survey. *Default value based on current ZOC A1/A2 category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.* *This scenario could also be used for the layer deeper than a safer upper depth layer (such as Scenario 1).*	
Depth bands to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Values within range 1 to 100m.*		

Scenario 5: Default ZOC B values (ZOC B)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: cannot be displayed as Significant Feature height is undefined. Amber: displayed for any vessel with Safety Depth (SD) less than the measured depth minus (ZOC B vertical uncertainty + ZOC A2 significant feature height) #. Red: displayed for any vessel with SD =/greater than the measured depth minus depth uncertainty. *# Within the existing ZOC categories, no specific distinction is made for the height of a significant seafloor feature in areas of A2, B or C.*
Vertical Uncertainty *(Mandatory)*	+/- 1m + 2% depth. *Default value based on current ZOC system.*		
Significant Feature Height *(Mandatory)*	Height Undefined. *Default value based on current ZOC system.* # Note: ZOC A2 values are 2m (down to 40m) then 10% of depth.	*Existing ZOC descriptor is "Full area search not achieved, uncharted features hazardous to surface navigation are not expected but may exist". S-44 has no specific requirements.*	
Typical survey Characteristics *(Mandatory)*	Controlled survey. *Default value based on current ZOC B category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.* *This scenario could also be used for the layer deeper than a safer upper depth layer.*	
Depth bands to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Values within range 1 to 200m.*		

Scenario 6: Area considered safe to a defined depth due to historic heavy use (ZOC B), existing above a lower ZOC area			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: displayed for any vessel with Safety Depth (SD) less than the defined maximum depth for upper CATZOC layer. Amber: displayed for any vessel with Safety Depth (SD) greater than the maximum depth of the upper CATZOC layer, but less than the measured depth minus depth uncertainty. Red: displayed for any vessel with SD =/greater than the measured depth minus depth uncertainty.
Vertical Uncertainty *(Mandatory)*	+/- 1m + 2% depth. *Default value based on current ZOC system.*		
Significant Feature Height *(Mandatory)*	Height Undefined. *Default value based on current ZOC system.*	*Existing ZOC B descriptor is "Full area search not achieved, uncharted features hazardous to surface navigation are not expected but may exist". S-44 has no specific requirements.*	
Typical survey Characteristics *(Mandatory)*	Controlled survey. *Default value based on current ZOC B category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.*	
Depth bands to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Values within range 1 to 200m.*		

Scenario 7: ZOC C (default ZOC C values)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: cannot be displayed as Significant Feature height is undefined. Amber: displayed for any vessel with Safety Depth (SD) less than the measured depth minus depth uncertainty. Red: displayed for any vessel with draft greater than above, and with SD =/greater than the measured depth minus depth uncertainty.
Vertical Uncertainty *(Mandatory)*	+/- 2m + 5% depth. *Default value based on current ZOC C.*		
Significant Feature Height *(Mandatory)*	Height Undefined. *Default value based on current ZOC C.*	*Existing ZOC C descriptor: "Full area search not achieved, depth anomalies may be expected". S-44 has no specific requirements.*	
Typical survey Characteristics *(Mandatory)*	Controlled low accuracy survey. *Default value based on current ZOC C category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.* *This scenario could also be used for the layer deeper than a safer upper depth layer.*	
Depth bands to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Values within range 1 to 200m.*		

Scenario 8: Area subject to change (ZOC C or ZOC D)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*	+/- 500m or worse. *'Worse' requires a Producer defined value.*		*Consider that any horizontal uncertainty greater than 50m should block a 'Green' display when combined with use of 'Seabed subject to change=Yes'.* Green: displayed for any vessel with Safety Depth (SD) less than the defined maximum depth for upper CATZOC layer. Amber: displayed for any vessel with Safety Depth (SD) greater than the maximum depth of the upper CATZOC layer, but less than the measured depth minus depth uncertainty. Red: displayed for any vessel with SD =/greater than the measured depth minus depth uncertainty.
Vertical Uncertainty *(Mandatory)*	+/- 2m + 5% depth *Default value based on current ZOC C.*		
Significant Feature Height *(Mandatory)*	Height Undefined. *Default value based on current ZOC C.*	*Existing ZOC C descriptor: "Full area search not achieved, depth anomalies may be expected". S-44 has no specific requirements.*	
Typical survey Characteristics *(Mandatory)*	Controlled low accuracy survey. *Default value based on current ZOC C category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.* *This scenario could also be used for the layer deeper than a safer upper depth layer.*	
Depth bands to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Values within range 1 to 200m.*		

Scenario 9: Inadequately surveyed (ZOC C)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: cannot be displayed as Typical Survey Characteristic does not = "Controlled survey". Amber: can be displayed as Typical Survey Characteristic = "Low Accuracy survey" if depth is also greater than 40m. Red: displayed for area where Typical Survey Characteristic = "Low Accuracy survey" if depth is also 40m or less.
Vertical Uncertainty *(Mandatory)*	Worse than +/- 0.5m +1% depth *Default value based on current ZOC system.*		
Significant Feature Height *(Mandatory)*	Worse than 2m (down to 40m) *Default value based on current ZOC D system.*	Existing ZOC descriptor: "Full area search not achieved, large depth anomalies may be expected"	
Typical survey Characteristics *(Mandatory)*	Inadequate survey / uncontrolled passage soundings. *Default value based on lower end of range for current ZOC C category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.*	
Depth band to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Value within range 1 to 100m.*		

Scenario 10: Inadequately surveyed (ZOC D)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: cannot be displayed as Typical Survey Characteristic does not = "Controlled survey". Amber: can be displayed as Typical Survey Characteristic = "Low Accuracy survey" if depth is also greater than 50m. Red: displayed for area where Typical Survey Characteristic = "Low Accuracy survey" if depth is also 50m or less.
Vertical Uncertainty	Worse than +/- 0.5m +1% depth *Default value based on current ZOC system.*		
Significant Feature Height *(Mandatory)*	Worse than 2m (down to 40m) *Default value based on current ZOC D system.*	Existing ZOC descriptor: "Full area search not achieved, large depth anomalies may be expected"	
Typical survey Characteristics *(Mandatory)*	Inadequate survey / uncontrolled passage soundings. *Default value based on lower end of range for current ZOC C category.*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.*	
Depth band to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Value within range 1 to 100m.*		

Scenario 11: ZOC D (unsurveyed)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: cannot be displayed as Typical Survey Characteristic does not = "Controlled survey". Amber: cannot be displayed as Typical Survey Characteristic = "Unsurveyed". Red: displayed for all unsurveyed areas estimated to contain depths 200m or less.
Vertical Uncertainty *(Mandatory)*	Worse than +/- 0.5m +1% depth *Default value based on current ZOC system.*		
Significant Feature Height *(Mandatory)*	Worse than 2m (down to 40m) *Default value based on current ZOC system.*		
Typical survey Characteristics *(Mandatory)*	Unsurveyed / Very sparse uncontrolled data. *Default value based on current ZOC D category*		
Seabed subject to significant change within repeat survey cycle (Optional)	Producer defined value. *If a producer chooses to use this parameter and set a value of Yes, the ability to display a Green quality indicator is blocked, with only Amber or Red available.*	*A Producer-nation may alternatively choose to periodically amend CATZOC by ENC update.*	
Depth band to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Value within range 1 to 100m.*		

Scenario 12: Unassessed (ZOC U)			
Data Quality parameter	Value	Comment	Display
Horizontal Uncertainty *(Mandatory)*			Green: cannot be displayed as Typical Survey Characteristic = "Unassessed". Amber: displayed in depths less than 100 / 200m as Typical Survey Characteristic = "Unassessed". Red: displayed in depths less than Safety Depth Contour as Typical Survey Characteristic = "Unassessed". White / standard colour palette: displayed as Typical Survey Characteristic = "Unassessed".
Vertical Uncertainty *(Mandatory)*	'Not Applicable'.		
Significant Feature Height *(Mandatory)*	'Not Applicable'.		
Typical survey Characteristics *(Mandatory)*	'Unassessed'. *Default value based on current ZOC U category*		
Seabed subject to significant change within repeat survey cycle (Optional)	'Not Applicable'.		
Depth band to which this Data Quality assessment applies (see 'Parameters and values')	Producer defined values. *Value within range 1 to 100m.*		

Parameters and 'values'

To achieve the desired display outcomes listed in these scenarios, the following parameters and 'values' are considered to be required.

No specific attempt has been made to identify parameters which already exist in S-57 or S-101 as the intention is to specify what should be included. It is envisaged that, within the ENC, the values for horizontal and vertical uncertainty will be numeric values. However, to aid compilation or mapping from existing ZOC to a numeric system, any drop-down menu

will specifically list the various ZOC, selection of any one of which will then populate the correct default numeric value. This should be in addition to a field allowing the producer to directly enter any other appropriate value.

Input	Options				Comments
Total Horizontal Uncertainty *Mandatory (unless ZOC U)*	Producer defined values for HU and %D. *Must include option for %D = 0*	Special Order. Use of Special Order results in a value of	ZOC A1 *Use of ZOC A1 results in a value of* 5 metres + 5% of depth	ZOC A2 *Use of ZOC A2 results in a value of* 20 metres	*Most common use of a producer defined value will be for Special Order surveys or ZOC D surveys.*
	ZOC B *Use of ZOC B results in a value of* 50 metres	ZOC C *Use of ZOC C results in a value of* 500 metres	ZOD D *Use of ZOC D requires a producer defined value of* 500m or greater		

Input	Options				Comments
Total Vertical Uncertainty *Mandatory (unless ZOC U)*	Producer defined values for VU and %D. *Must include option for %D = 0*	Special Order. Use of Special Order results in a value of	ZOC A1 *Use of ZOC A1 results in a value of* 5 metres + 5% of depth	ZOC A2 *Use of ZOC A2 results in a value of* 20 metres	*Most common use of a producer defined value will be for Special Order surveys or ZOC D surveys.*
	ZOC B *Use of ZOC B results in a value of* 50 metres	ZOC C *Use of ZOC C results in a value of* 500 metres	ZOD D *Use of ZOC D requires a producer defined value 500m or greater*		

Input	Options				Comments
Significant Feature Height (Feature Detection to 95% confidence) *Mandatory (unless ZOC U)*	Producer defined values for FD and %D. *Must include option for FD or %D = 0*	Special Order. Use of Special Order results in a value of	ZOC A1 *Use of ZOC A1 results in a value of* 5 metres + 5% of depth	ZOC A2 *Use of ZOC A2 results in a value of* 20 metres	*Most common use of a producer defined value will be for Special Order surveys (1metre cube).*
	ZOC B *Use of ZOC B results in a value of* 50 metres	ZOC C *Use of ZOC C results in a value of* 500 metres	ZOD D *Use of ZOC D requires a producer defined value 500m or greater*		

Input	Options			Comments
Typical survey characteristics *Mandatory*	Controlled high accuracy survey. *Default value based on current ZOC A1/A2 category.*	Controlled survey. *Default value based on current ZOC B category.*	Controlled low accuracy survey. *Default value based on current ZOC C category.*	*Drop-down list of standardised attribute choices.*
	Inadequate survey / uncontrolled passage soundings. *Default value based on lower end of range for current ZOC C category.*	Unsurveyed / Very sparse uncontrolled data. *Default value based on current ZOC D category*	Unassessed. *ZOC U*	

Input	Options			Comments
Date of survey *Optional*	Producer defined value			*SURSTA, SUREND may be appropriate.*

Input	Options			Comments
Seabed subject to significant change within repeat survey cycle	Yes.	No.	Unknown. (= Yes)	*Drop-down list of standardised attribute choices.*

Input	Options			Comments
Depth range to which this assessment applies *Optional*	Depth value 1	Depth value 2		*If not populated, the category assessment applies to the full water column.*

Input	Options			Comments
Depth range to which this assessment applies *Mandatory <u>if</u> two data quality depth layers are used.*	Depth value 1	Depth value 2		*No gap or overlap between depth ranges in the same area if there are two differing data quality layers.*

Input	Options			Comments
Safety Depth (Draft plus Manoeuvring Margin) *User input*	User defined value			

Input	Options			Comments
Height of tide *Awaiting development*	'Predicted Tides applied'	'Observed Tides applied'	'No tidal input available'	*The data quality indicator will have significantly greater applicability if either predicted or observed tides are available.*

Further actions

The nominated technical working groups are reminded to note the draft status of this paper.

However, successful development of '*ways of ensuring that ECDIS displays provide a clear warning or indication to the mariner on the quality of the underlying survey data, through appropriate use of the attribute CATZOC and/or improvement of the existing display capabilities (IHO Task 2.5.2)*' will require the coordinated contribution of several working groups and cannot be achieved in isolation.

TSMAD is therefore invited to note the potential parameters and values required to drive a revised data quality indicator system, and comment where appropriate.

DIPWG is invited to note the potential requirements to develop area-based colour bands providing three risk tiers which would be displayed as 'temporary overlays' which can be switched on or off as necessary by the ECDIS operator, particularly noting that use of a solid colour overlay may unnecessarily and inappropriately hide other important detail.

CSPCWG are invited to note the proposed scheme and comment upon any aspect, as well as consider any desirable parallels with paper charts (but also noting that paper charts and ENC already differ significantly with regard to quality indicators and paper charts will have no ability to relate risk to vessel draft).

TWLWG are invited to note the desirability of applying predicted or real-time tides to the overall ECDIS / ENC display.

DQWG will consider any comments received and revise this paper where appropriate. Constructive comment upon this draft paper is therefore invited.