ACCURACY AND RELIABILITY OF CHARTS

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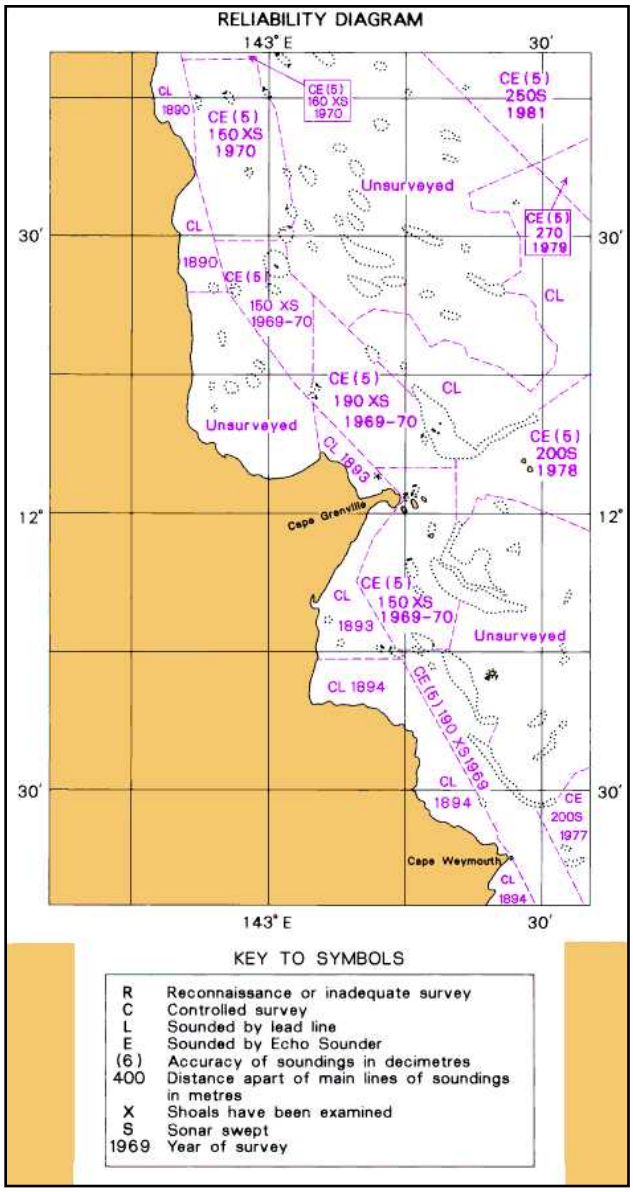
How accurate are nautical charts? How much faith can be placed in them? Unfortunately, the answer is quite complex – far more complex than simply saying one chart is accurate whilst another is not. However, having the necessary skills should be essential for any mariner venturing into unfamiliar waters.

Reliability versus Confidence

All charts, whether paper or electronic, contain data which varies in quality due to the age and accuracy of individual surveys. In general, remote areas away from shipping routes tend to be less well surveyed, and less frequently, while areas of high commercial traffic are re-surveyed frequently to very high levels of accuracy, particularly where under-keel clearances are small. It is quite accurate to consider a chart as a jigsaw of individual surveys pieced together to form a single image. This is quite apparent in the Reliability Diagrams, also known as Source Diagrams, which were used on charts until recently.



In this Reliability Diagram, taken from the 1992 edition of Aus 835, the details of each individual survey are readily apparent. Most notable are the differing dates of the various surveys over a period of almost 90 years. What are less obvious are the technological limitations of these surveys and how much confidence should be placed in them today.

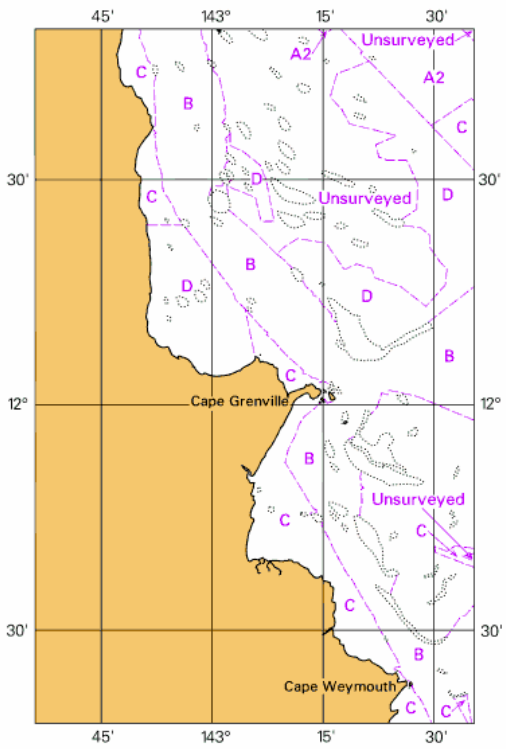
The level of confidence in an area shown as 'Unsurveyed' should be self evident. However, in this example, how much 'trust' should be placed in surveys of differing age and quality, such as those conducted in the 1890s compared to the 1970s?

In 1893-94 the position of the survey ship or boat was determined by measuring angles with a sextant between large flags erected on the shore, combined with a lead-line (a marked and tagged rope with a lead weight) to measure depth beneath the ship. The limitations mean that positions may be out by up to 500 metres, even when shifted to fit a modern coastline, while it is quite possible that the lead-line may have been lowered between two shoals that consequently remained undetected. However, the observation and recording of features rising to or near the sea surface was usually very good.

In contrast, those surveys dating from 1969-70 are significantly more reliable.

By then, use of electronic positioning systems had improved horizontal accuracies to 50 metres or better, while the use of echo sounders and sonar provided a significantly greater level of confidence that features between the individual lines of sounding were detected and did not remain unexamined.

Unfortunately, the information presented in a Reliability Diagram requires knowledge of past and present hydrographic surveying practices – something most mariners neither have nor should need. To address this, the Australian Hydrographic Service developed a system known as Zones of Confidence that has since been adopted internationally.



ZOC CATEGORIES
(For details see Australian Seafarers Handbook AHP 20)

ZOC	POSITION ACCURACY	DEPTH ACCURACY	SEAFLOOR COVERAGE
A1	±5m	=0·50m + 1%d	All significant seafloor features detected.
A2	±20m	=1·00m + 2%d	All significant seafloor features detected.
B	±50m	=1·00m + 2%d	Uncharted features hazardous to surface navigation are not expected but may exist.
C	±500m	=2·00m + 5%d	Depth anomalies may be expected.
D	Worse than ZOC C	Worse than ZOC C	Large depth anomalies may be expected.
U	Unassessed - The quality of the bathymetric data has yet to be assessed.		

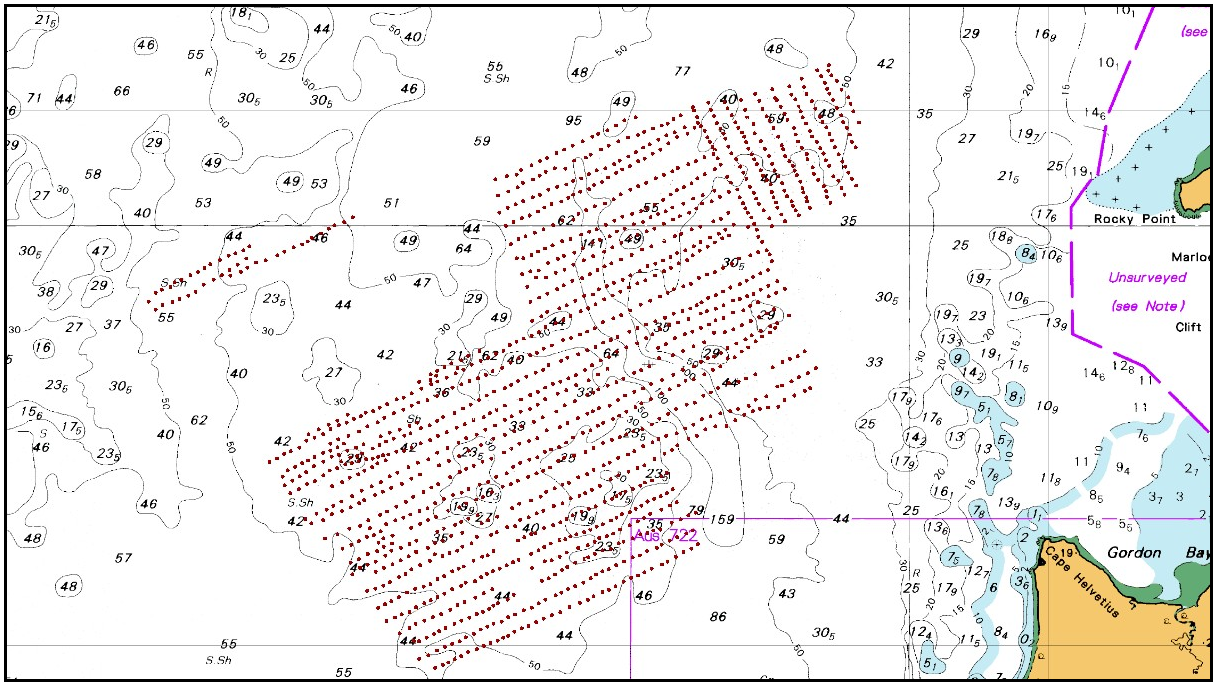
On each nautical chart, such as the 2006 edition of Aus 835, the accuracy and reliability of the information used to compile the chart is shown on a Zones of Confidence (ZOC) Diagram. Within official Electronic Navigational Charts (ENCs), the same information is shown as a layer which can be switched on and off by the mariner.

ZOC categories warn mariners which parts of the chart are based on good or poor information and which areas should be navigated with caution. The ZOC system consists of five quality categories for assessed data, with a sixth category for data which has not been assessed. The table accompanying the ZOC diagram on each chart summarises the meaning of the ZOC categories.

Position Accuracy refers to the horizontal accuracy of a depth or feature. Depth Accuracy refers to the vertical accuracy of individual recorded depths, of which those shown on the chart are a subset designed to best represent the sea floor as it is known or best estimated.

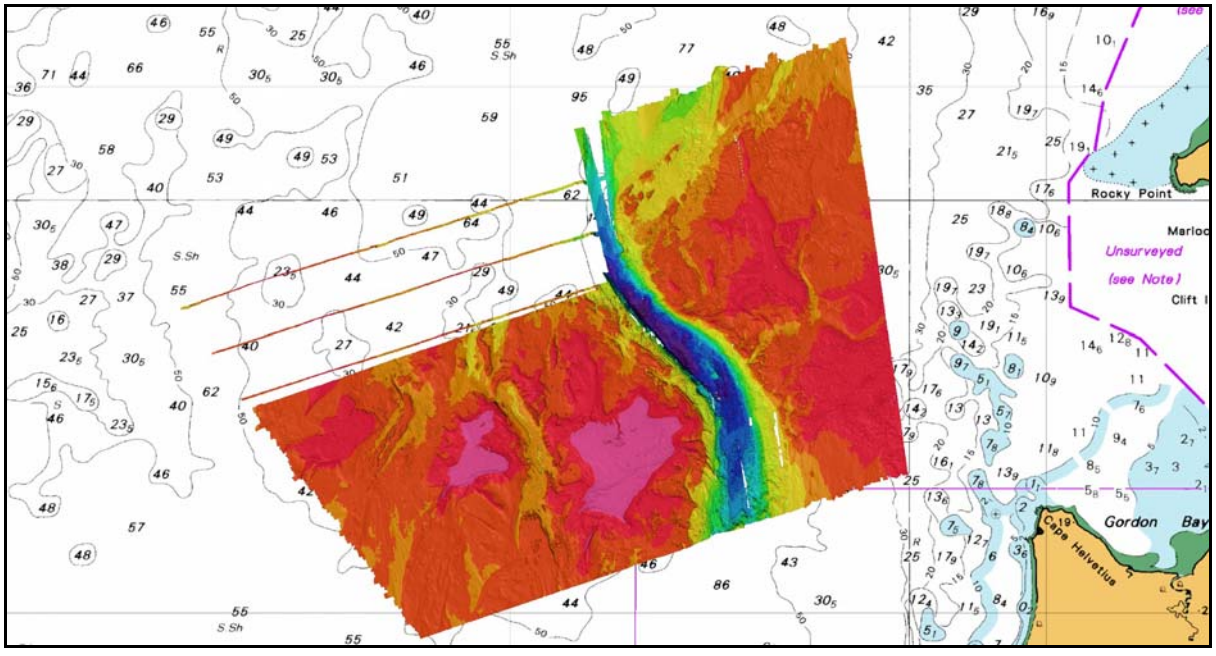
However, the most important factor is Seafloor Coverage. This is the level of confidence that the hydrographic surveyor and hydrographic office has that the soundings that were collected as the survey ship steamed back and forth actually represent the remainder of the sea floor between the adjacent lines of sounding. Typically, these adjacent lines may be between 60 and 250 metres apart based upon the depth of water and nature of the area, occasionally extending to as close as 10 metres or as wide as one kilometre.

In older surveys such as the 1945 survey below, the ship measured a series of individual depths as it steamed along each line of soundings. Confidence that these separate soundings did not miss anything between the lines was typically achieved using a sonar, though the technology of the day was not always perfect. These surveys are typically assessed as ZOC C which states that *'depth anomalies may be expected'*.



1945 single beam survey, approaches to Darwin

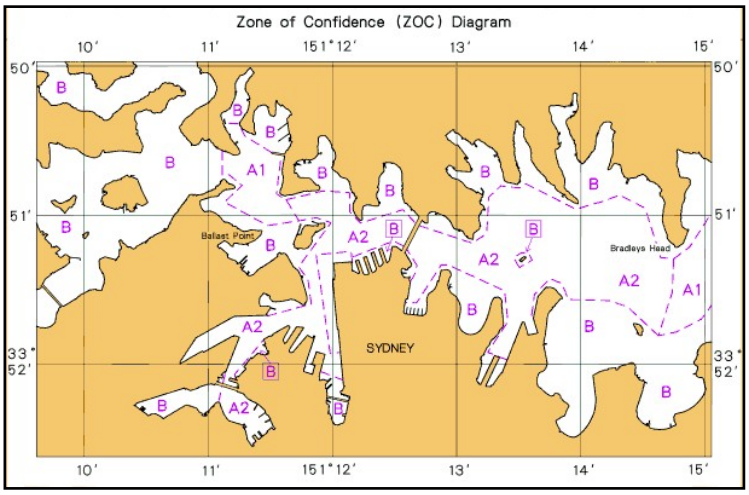
However, modern surveys are quite different. Equipment performance has improved allowing most surveys from the 1970s and later to be assessed as ZOC B *'Uncharted features hazardous to surface navigation are not expected…'*, while current systems can achieve 100% coverage using multi-beam echo-sounders. The beams from these echo-sounders spread like a fan beneath the ship and completely sweep the seabed both directly below the ship and to either side. Aircraft using lasers can achieve similar results. Multi-beam systems lay down thousands of soundings every minute as close as 30 centimetres apart. This level of detail is necessary for an assessment of ZOC A1 or A2 *'All significant seafloor features detected'*. In these areas an object the size of a 200 litre oil drum is considered significant.

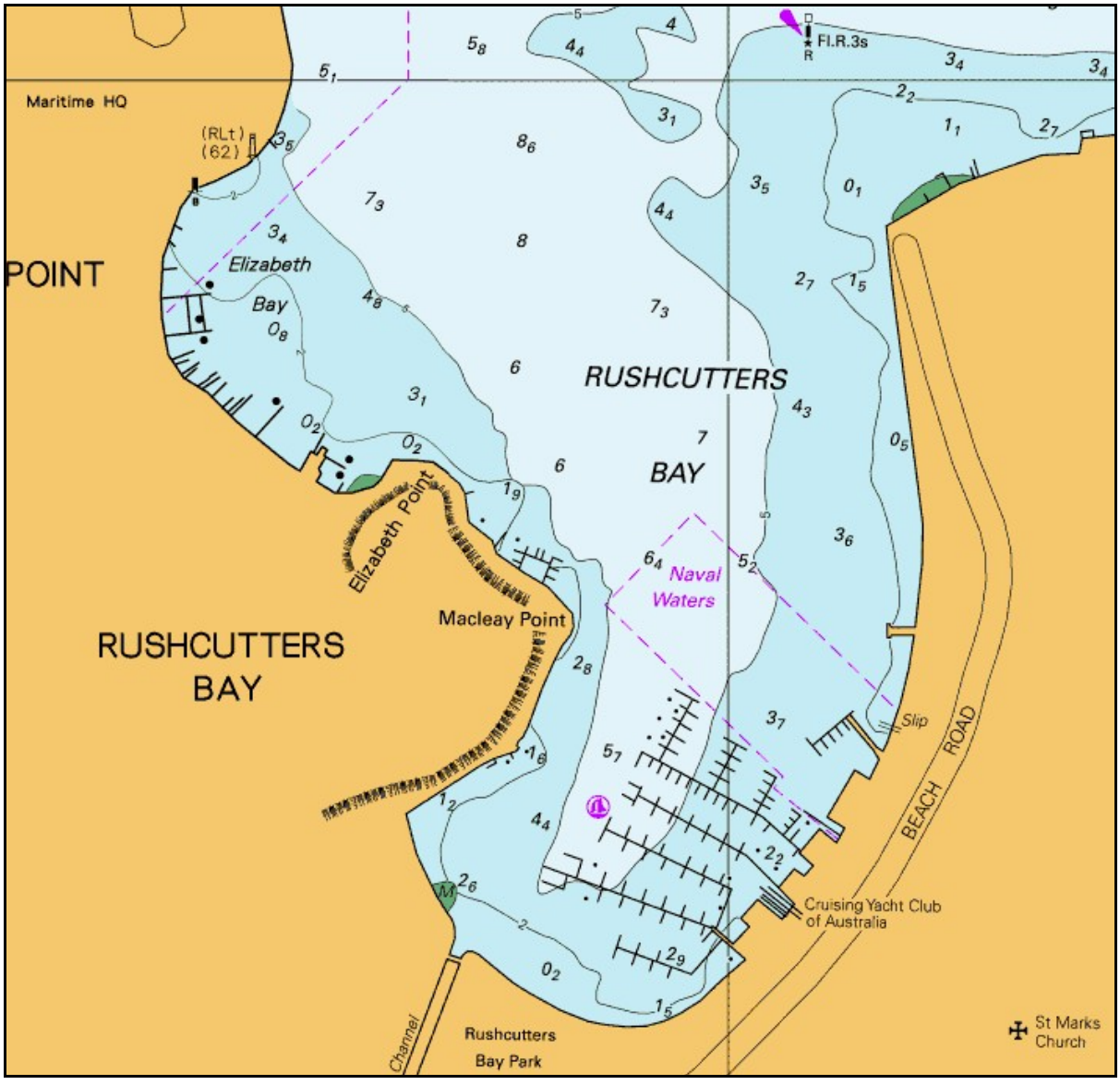


Modern multi-beam survey, approaches to Darwin

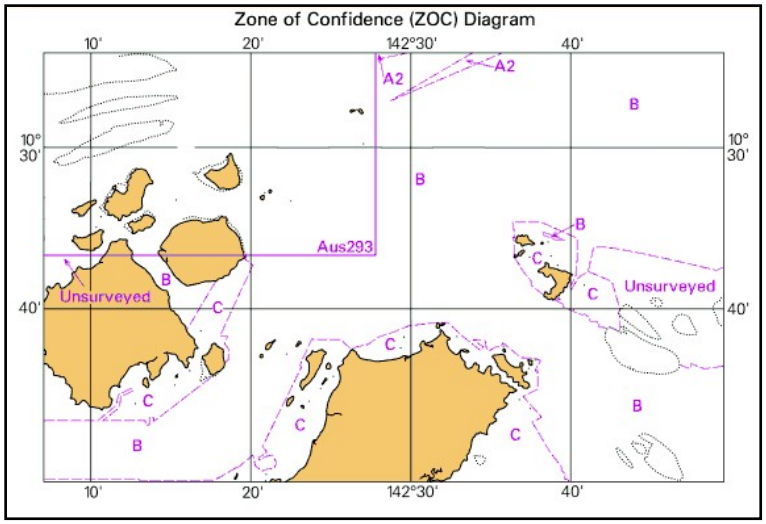
Interpreting a traditional nautical chart

On picking up a chart, an early step in planning should be a look at the Zone of Confidence Diagram. Total confidence can be placed in ZOC A1 and A2 areas, and very high confidence placed in ZOC B areas. These typically show all soundings in bold italics (sloped), soundings are evenly spread and the depth contours are unbroken.

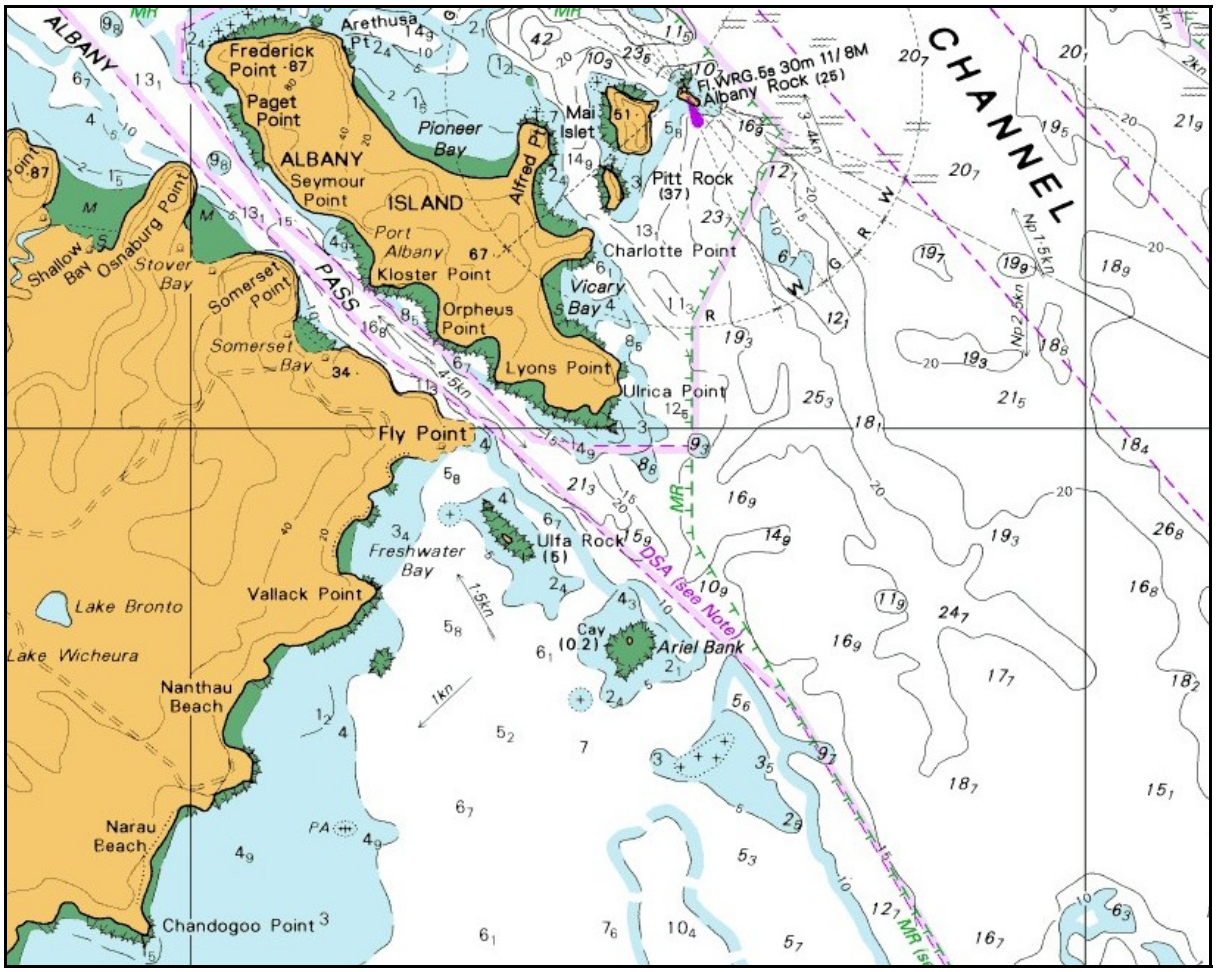




Extract – Aus 202, Rushcutters Bay, Sydney (ZOC B)

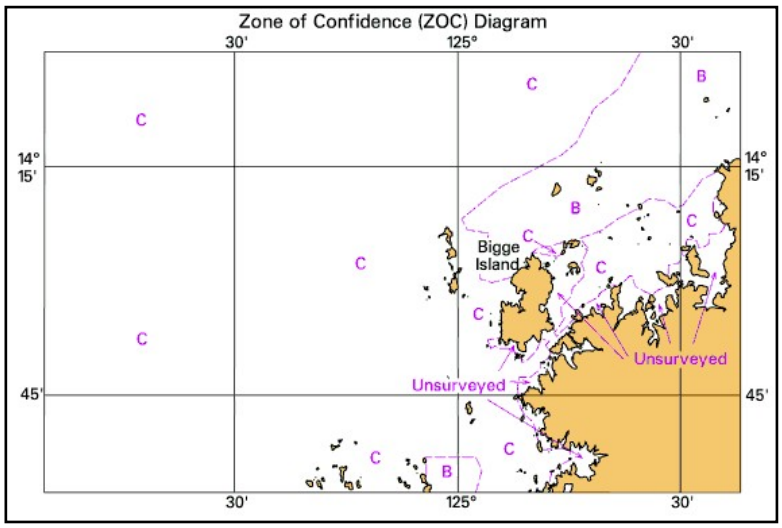


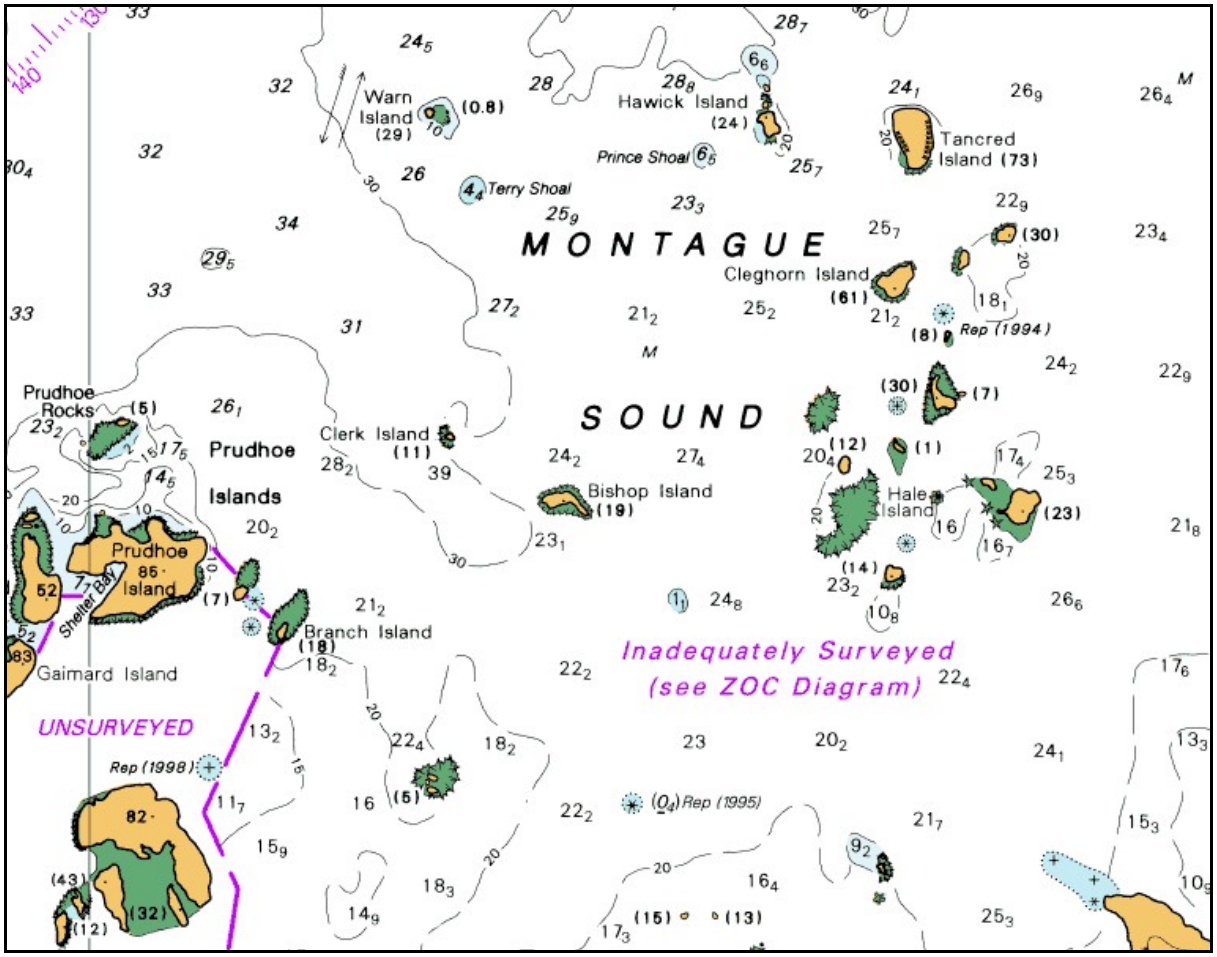
ZOC C is a broad category encompassing generally older surveys ranging from those that do not quite meet modern standards, through to colonial surveys and those not specifically conducted for navigation safety (such as a geophysical survey). Where reasonable confidence remains, the ZOC diagram will be the primary source of information to show where this lower area of confidence exists, as the face of the chart will show little difference between the ZOC B and C areas. However, as confidence decreases, additional indicators are shown on the charts. These include the soundings changing from bold italics to a faint (hairline) and upright style to indicate they are 'approximate', while contours change from continuous to broken or dashed lines. In ZOC C areas, *'depth anomalies may be expected'*.



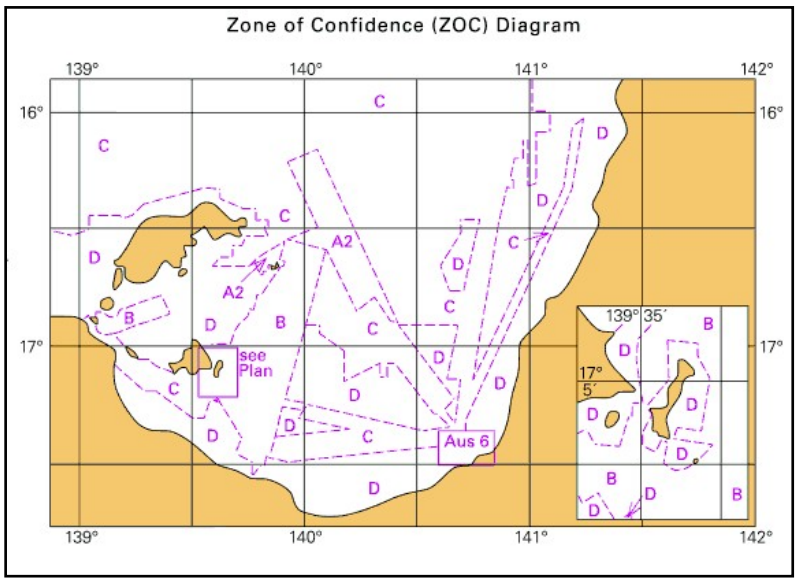
Extract – Aus 292, Albany Island, Cape York (ZOC B to north-east, ZOC C to south-west)

This is particularly the case where the seabed is known to be broken in nature, such as in Montague Sound in northern WA, as well as the Bonaparte Archipelago and Kimberley area in general. Other similar areas exist elsewhere. The extract from Aus 729 again contains both ZOC B and ZOC C data, the latter highlighted by upright soundings, broken contours and, in this instance, a specific warning. The presence of several isolated pinnacles charted in the area should lead to the reasonable expectation that others are highly likely to exist – again, *'depth anomalies may be expected'*. Entry into areas such as these should not be undertaken lightly – as a minimum, the sun should be high in the sky and not obscured by cloud, with a good lookout maintained while underway.

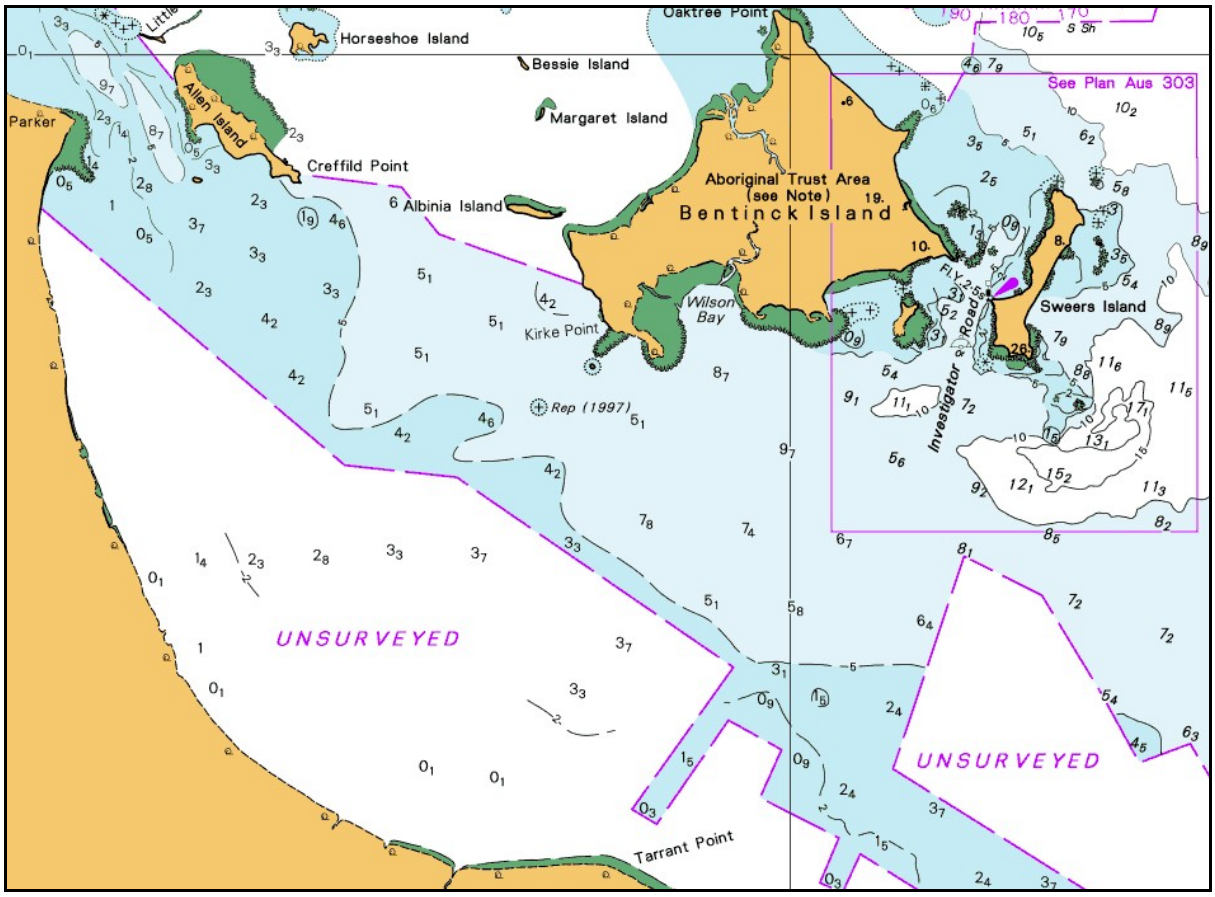




Extract – Aus 729, Montague Sound, northern WA (ZOC B to north-west, ZOC C to south-east)



Finally, ZOC D represents a very low level of confidence. Areas such as these typically consist of sparse lines of sounding, where the track of each individual ship is still apparent. They have not been systematically surveyed. Soundings are very widely dispersed with contours only present in the very near vicinity of soundings. Unsurveyed areas are also classed as ZOC D. In ZOC D areas *'large depth anomalies may be expected'*.



Extract – Aus 303, Bentinck Island, Gulf of Carpentaria, QLD (ZOC B to north-east, ZOC C to north-west, ZOC D to north and south)

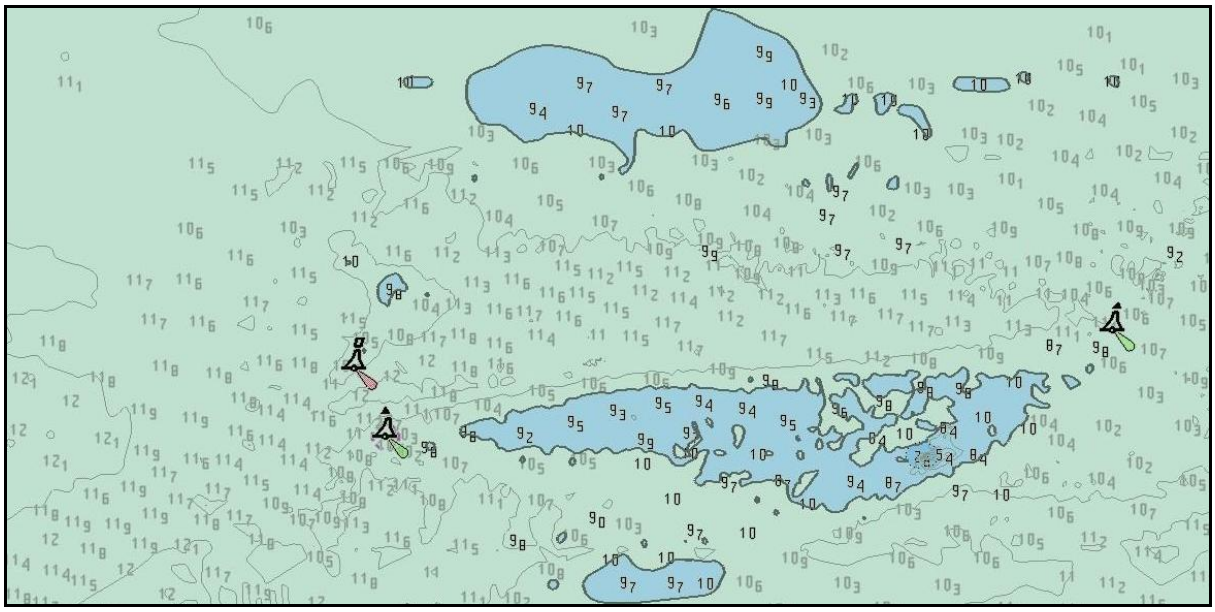
Interpreting an Electronic Navigational Chart

There are two basic types of electronic charts – raster and vector. Raster Nautical Charts (RNCs) are facsimile copies of the paper chart. They look identical to the paper charts, have the same content, but are essentially 'dumb' images. For example an RNC chart,

connected to GPS, will happily plot and display your position both at sea and as the boat goes up the ramp at the end of the day, or as you inadvertently run aground. Information in the chart can't be interrogated or changed. In contrast, a vector chart contains 'smart' data – use it correctly and it will provide an audible warning before you enter an area considered too shallow. Official vector charts are published by national hydrographic offices and are known as Electronic Navigational Charts (ENCs).

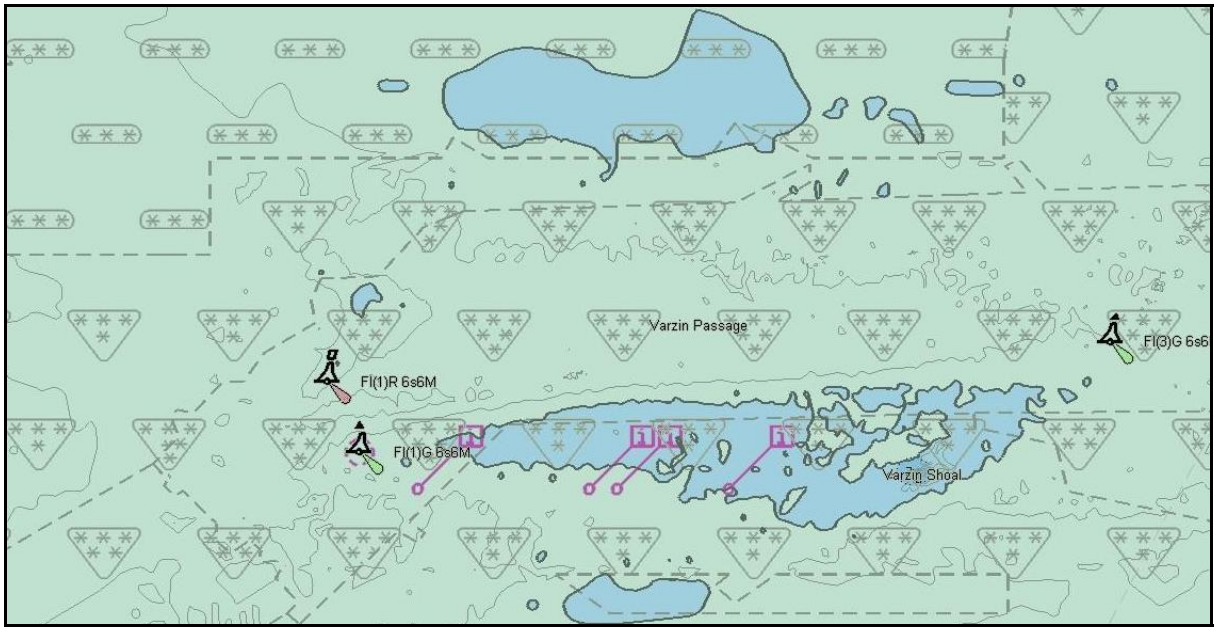
The Australian Hydrographic Service publishes a raster chart series known as *Seafarer RNC*. These display ZOC information, including the ZOC diagram, in exactly the same manner as the paper chart.

In contrast, the official ENCs published by the Australian Hydrographic Service have the same or greater content as the paper charts, including ZOCs, but look a little different. They adhere to a series of international standards frequently (but inaccurately) referred to as S-57. While there is a base level of information always displayed, many of the other features exist on separate layers that can be switched on and off. Why, for example, does a mariner need to know how often a light buoy flashes during the day? They don't, so the option exists to turn this information off until needed.



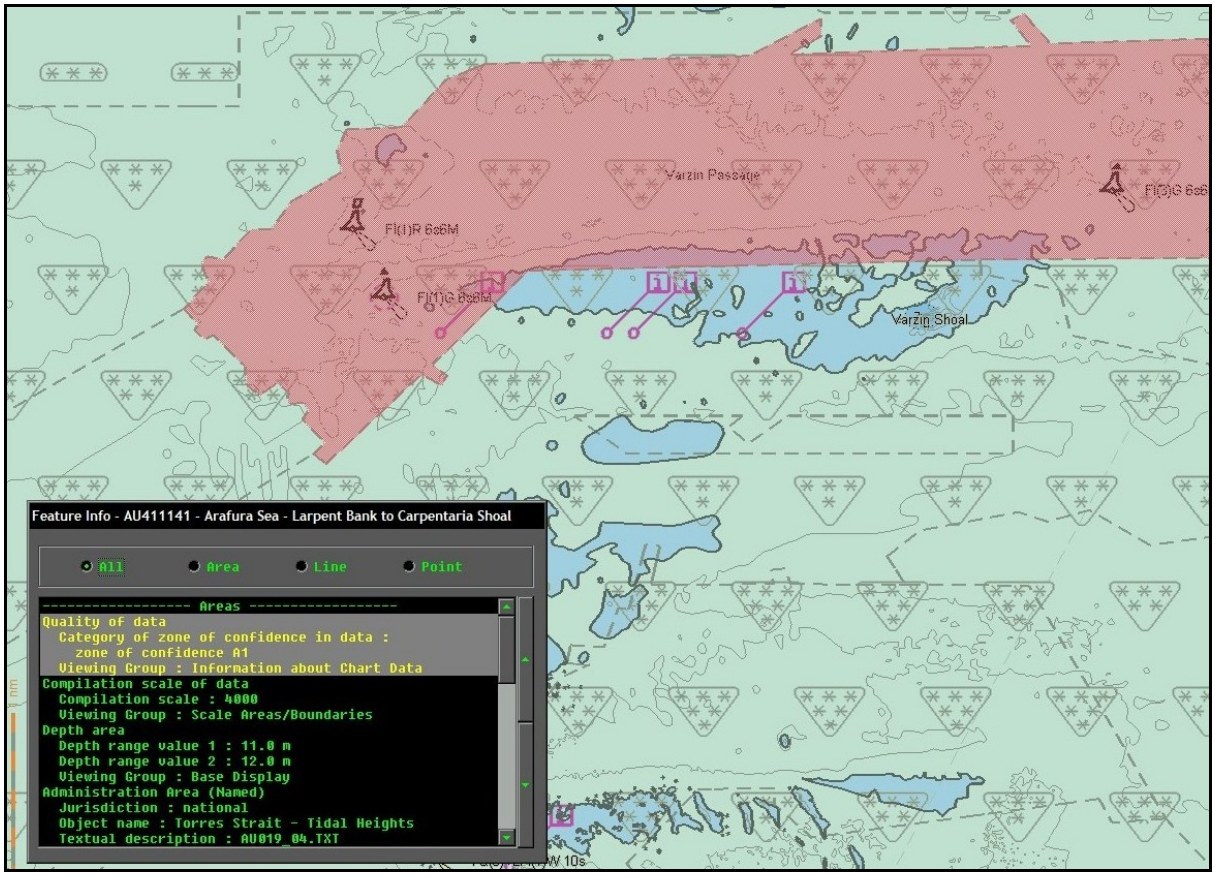
Extract – ENC AU4 11141, Varzin Passage, western Torres Strait

Similarly, zones of confidence exist as a separate layer that can be viewed when planning a route then switched off until needed again. Mariners don't need to search the face of the chart to find the ZOC diagram as, when switched on, the information is visible throughout the entire ENC. The various ratings are shown using a system of stars – the higher the ZOC rating, the greater the number of stars. Unlike paper charts which use both bold italic and upright hairline soundings as further confidence indicators, ENCs only use upright characters. Instead, those 'approximate' soundings shown as upright hairline characters on the paper chart are shown circled on the ENC. This is the international method for showing 'approximate' soundings in ENCs. However, the use of continuous or broken contours has been carried over from the traditional paper charts.

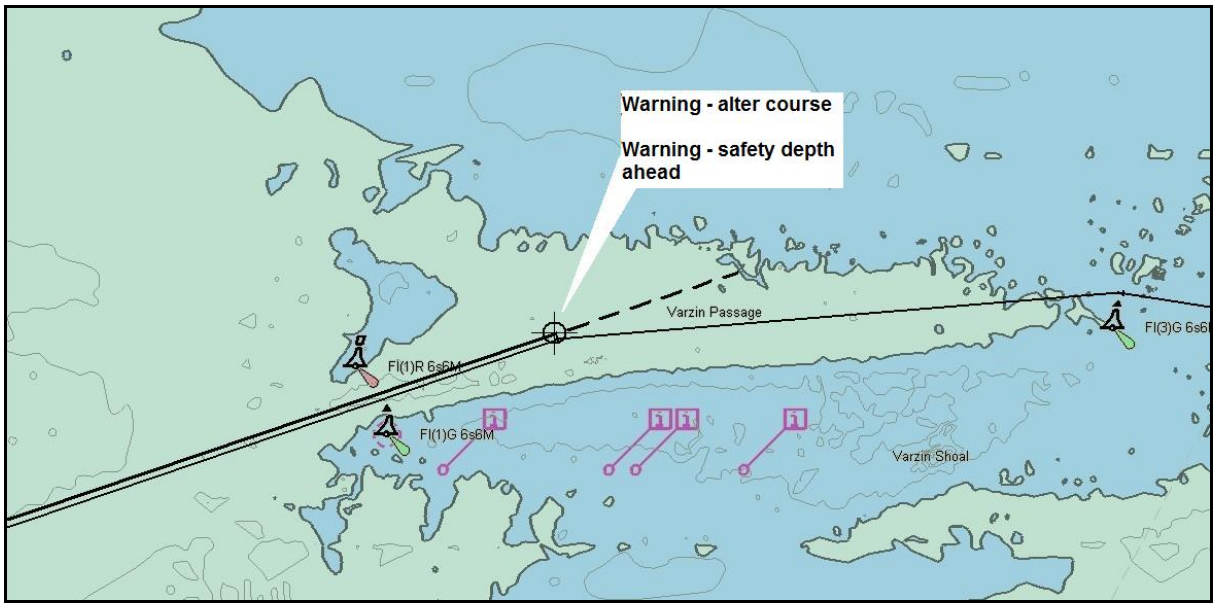


Extract – ENC AU4 11141, Varzin Passage, western Torres Strait (with ZOC layer switched on, soundings layer switched off)

Additionally, every single feature and area in an ENC can also be interrogated to obtain additional information.



Extract – ENC AU4 11141, Varzin Passage, western Torres Strait (with ZOC A1 area being interrogated)



Extract – ENC AU4 11141, Varzin Passage, western Torres Strait (safety depth increased to 11 metres)

Summary

All charts consist of a jigsaw of separate surveys which are combined to form the final chart. These surveys vary in age and quality, particularly due to changes in technology. However, one fundamental truth remains – a hydrographic surveyor can typically only physically see a very small percentage of their survey area – the parts which rise above the sea surface; for the remainder they must have confidence in their systems and long-standing practices to accurately and confidently chart the seabed. Because priority for surveying is given to the major shipping routes, an essential skill for mariners venturing into unfamiliar waters away from these routes is the ability to interpret the various quality indicators that are, or should be, on every chart. These are the best guides available to mariners, whether on commercial vessels or cruising yachts, to help them decide how much confidence should be had in past and current surveyors and the technology available to them when surveying the different areas of each chart. Indeed, a prudent mariner should be wary of any chart that does not show these indicators, irrespective of whether it is a traditional paper chart, a Raster Nautical Chart or one of the new Electronic Navigational Charts. Finally, if in doubt, post a lookout, make your approach in daylight and good conditions, or go somewhere else – there is no such thing as a good grounding.

Mike Prince is the Director of Charting within the Australian Hydrographic Service. He is a hydrographic surveyor by profession, as well as a former naval officer with experience as a Commanding Officer and Navigating Officer. He still sails when time permits.