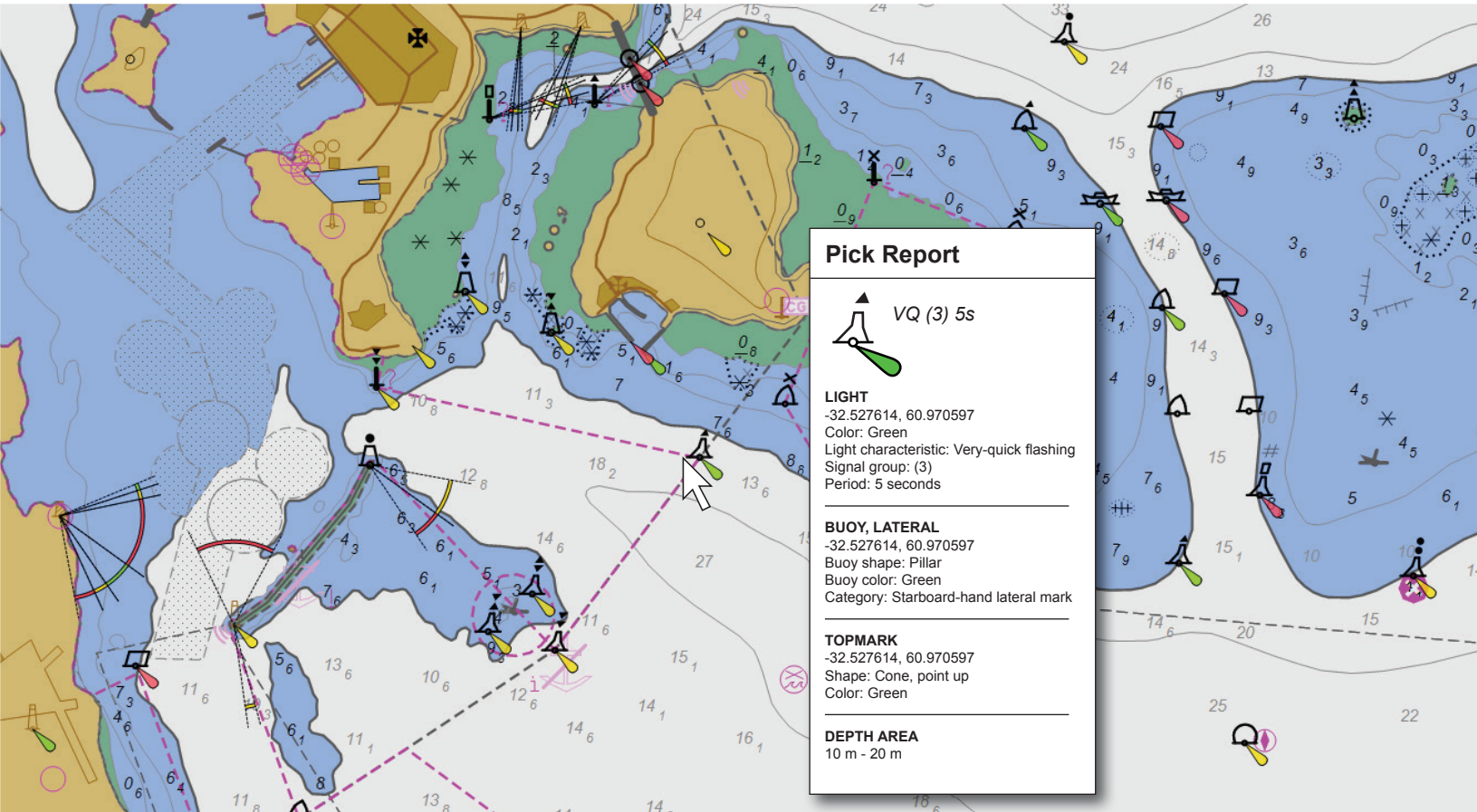


Introduction to

Electronic Chart Navigation

With an Annotated ECDIS Chart No. 1, Second Edition



David Burch

Support and resources for this book are at
www.starpath.com/ENC



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ISBN 978-0-914025-76-4

Published by

Starpath Publications

3050 NW 63rd Street, Seattle, WA 98107

Manufactured in the United States of America

www.starpathpublications.com

10 9 8 7 6 5 4 3 2 1

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Forward to the Second Edition

In November, 2019 (two years after the first edition of this book), NOAA announced the initiation of a 5-year program to discontinue all production of paper charts and the RNC counterparts to them. This process is well underway; more and more charts are being canceled monthly. Sometime in 2024 the only navigation charts available will be in the ENC format. The National Geospatial Agency (NGA), responsible for the US production of international charts for US Navy and NATO partners, will also be transitioning from their special vector format they presently use, called Digital Navigational Charts (DNC), to all ENC on approximately this same timetable, according to NGA public announcement No. 19-878 (July, 2019). Thus civilian and governmental charts will all be ENC by the end of 2024. The essential call for the content of this book is now ratified!

Two primary factors have taken place since the first edition that affect the content of this book. Foremost was the initialization, now well underway, of NOAA's program to redesign the layout of all US electronic navigational charts (ENC) to make them more consistent amongst themselves and with the ENC from other nations. This is a major improvement. The process is called *rescheming*. The most apparent changes are the shapes and coverages of the individual charts, which, when reschemed, become regular and consistent. Chart scales and depth contour conventions are also improved, plus we get a larger (more detailed) compilation scale for many areas.

NOAA was a pioneer in the production of ENC and as such had to work with what was available at the time, both with regard to what paper charts were available to base them upon, as well as the technology at hand for producing and distributing them. Now we are at a time when ENC have met the nautical chart carriage requirements for commercial shipping for many years, and as noted NOAA has announced the discontinuation of traditional paper charts. Paper charts, however, will not be gone from the navigator's table; they are just, in a sense, getting "reschemed" as well. Mariners can already create their own paper charts in a new format called NOAA Custom Charts (NCC), which is a promising development.

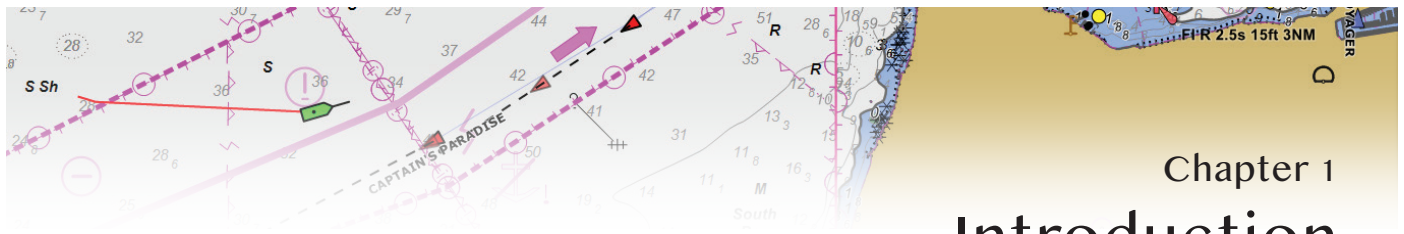
On top of these changes, the USCG has just completed a call for comments on the proposed new ruling that vessels must have some electronic chart viewer on board to effectively read the official ENC. In other words, we are at the moment when ENC have gone from an optional substitute for paper charts to being a required method of navigation. With all of this going on, we can see why NOAA decided it was time to take on the daunting task of rescheming all of the US ENC.

We have added an appendix on rescheming to cover the details of the changes and how we recognize them in conjunction with what we now call the *legacy ENC* that exist before rescheming. The full conversion will take some years to complete, so we will be using the legacy ENC layouts for quite a while to come. The interpretation and basic use of ENC does not change with the reschemed charts. When a topic comes up in the book that is affected by rescheming, we make note of the changes with a reference to the appendix.

There is also a short new appendix on the NCC program; another on Inland ENC, the US Army Corps of Engineers charts for the Western Rivers; and one emphasizing a recommended vessel icon set up for navigation in strong wind or current. An overview of the next generation ENC called S-100 has also been added as an appendix.

The second primary factor that has led to updates in this edition was the preparation for and first experiences we have had with our new training course on Electronic Chart Navigation. Many sections throughout the book have been enhanced to reflect the practical experience we gained. Interactions with students first learning a new subject is an invaluable resource we are lucky to have.

Beyond minor updates throughout the book, topics with more extensive updates include: coverage of the Quality of data object and Zone of Confidence attributes; treatment of magnetic variation; the use of safety contour and safety depth; and we added a new section on the use of encrypted S-63 charts with a specific example using the newly free ENC from New Zealand.



Chapter 1

Introduction

Our goal with this publication is to help mariners make the transition from traditional navigation using paper charts and associated printed publications to the use of an electronic charting system (ECS) that relies on some digital form of nautical charts.

An ECS is a software program that incorporates GPS signals and other sensor data so as to display a vessel's moving position on a digital chart, along with crucial derived parameters such as course over ground (COG) and speed over ground (SOG), among others. In its simplest form, it can be a handheld GPS with a rudimentary base map; in its most sophisticated form it can be a complex system that meets the highest international standards of safe, efficient ship navigation. The type of ECS in use plays a key role in how we read and interact with digital charts.

There are two broad categories of digital charts, both of which are widely used internationally. They are distinguished by the nature of the digital files that represent the charts. The two chart file types are *raster charts* and *vector charts*.

1.1 Raster Charts

A raster chart is a graphic image of a region of the earth. They are photographic images that have been georeferenced, meaning each pixel location on the image has associated with it the corresponding latitude and longitude of the point shown in the image.

A raster chart can be made from an image of a street map, topographic map, or satellite image. A cellphone app following your position across a satellite image is an ECS using raster charts. For the discussion at hand, the most important type of raster chart is one made from a photographic image of an official paper nautical chart. Electronic charts made from official paper charts are called *raster navigational charts* (RNC).

On the display screen of an ECS, an RNC looks just like the paper chart it was made from, except that in this digital format the image can be zoomed, panned, rotated, and digitally annotated to carry out traditional navigation plotting. Thus a key point in the use of RNC is that the chart

symbols, labels, and chart notes are identical to those of traditional paper charts, because they are indeed just georeferenced pictures of the paper charts.

When using only RNC, the navigator's transition from using paper charts to using digital charts is wholly a matter of learning the use of the navigation software that displays the charts, which is generically referred to here as the ECS. For example, how do we download and install the electronic charts; input our GPS signals to follow our vessel across the chart; how to use electronic range and bearing tools; how to set up waypoints and routes; and how to monitor our progress along that route using the electronic tools in the software.

Another factor that remains the same when going from paper charts to RNC is our dependence on related navigation publications, such as the *U.S. Coast Pilot* and *Light List*. These documents contain crucial navigation information that is not shown on paper charts, and consequently not included in the RNC.

Since digital versions of these crucial navigation publications are readily available, some ECS programs have incorporated access to this supplemental data from within the software. This is one of the virtues of using electronic navigation in the first place, regardless of the chart type in use.

For example, place names in the *U.S. Coast Pilot* often include the Lat-Lon of the location, so an ECS program can include *U.S. Coast Pilot* data in such a way that a user could search on a place name, or mouse-click a specific place on the chart, and *U.S. Coast Pilot* information for that region will show up on a supplemental screen. This type of functionality is an asset to that ECS product, but it is not related to the chart in use. This extra information has been included by the ECS software manufacturer; it is not part of the RNC itself. Likewise, many ECS programs include tide and current overlays that can be displayed on the chart. These are a great asset to navigation, both when planning and when underway.

Of the many types of raster charts we might use, it is good policy to reserve the name "RNC" to those made specifically from the official paper charts issued by a national

Official charts vs. third party charts

But just as there are different types of raster charts, there are different types of vector charts as well. Several commercial companies create their own proprietary vector charts. These are all based on official government charts to some level, but it is largely market competition that dictates how thorough, accurate, and up-to-date they are. The manufacturers of these charts are aware of their limitations and warn mariners very specifically of this in their end user license agreements (EULA) as shown in Figure 1.2-2.

In this book, however, we are only addressing official vector nautical charts produced by national hydrographic offices. Official vector charts all adhere to the same standard of content prescribed by the IHO called *S-57, IHO Transfer Standard for Digital Hydrographic Data*. Vector nautical charts produced to this standard are called *electronic navigational charts* (ENC). The name “ENC” applies only to S-57 adherent charts.

1.3 RNC versus ENC

In a sense, the use of RNC is a traditional approach to electronic chart navigation, whereas ENC are the future of electronic chart navigation. The many advantages of ENC are not limited only to those already mentioned (more information and user customization). Since the software knows where you are, and it knows what is on the chart in front of your vessel icon, you can define anti-grounding zones in the direction of your COG (course over ground) to warn you of approaching hazards or shallow water. You can also highlight the visible arc of navigation lights in the vicinity to aid your visual navigation. There are numerous

Section of Navionics-Garmin EULA (6/18/22)

3. Additional Restrictions for Certain Licensed Materials. You acknowledge that the Licensed Materials should be used only for general information purposes and you should not rely on the Licensed Materials for any life-or-death situation. Licensed Materials containing marine and lake cartography are designed to provide ancillary aid to navigation by facilitating the use of authorized government charts, not to replace such charts. **Only official government charts and notices to mariners contain all information needed for safe navigation.** You are responsible for the prudent use of Licensed Materials and shall act in such a way as not to harm or endanger or hinder or create inconvenience to any other person. **Any track generated by electronic charts, autorouting software, or similar tools are basic suggestions for route planning only and must not be used for direct navigation.** Licensor encourages users to comply with all applicable rules, including speed limits, and recommends them safe, prudent, and vigilant behaviors.

Section of C-Map EULA (6/18/22)

5. WARNINGS. YOU ACKNOWLEDGE, SHALL COMPLY WITH, AND TAKE INTO CONSIDERATION THE FOLLOWING WARNINGS FROM C-MAP: NAUTICAL NAVIGATION IS AN INHERENTLY DANGEROUS ACTIVITY AND SHOULD ONLY BE ENGAGED IN BY PERSONS WITH ADEQUATE TRAINING AND EXPERIENCE. **ONLY UP-TO-DATE OFFICIAL GOVERNMENT CHARTS AND NOTICES TO MARINERS CONTAIN ALL INFORMATION NEEDED FOR THE SAFETY OF NAVIGATION** AND, AS ALWAYS, THE CAPTAIN IS RESPONSIBLE FOR THEIR PROPER USE AND AWARENESS OF CURRENT CONDITIONS. UNLESS OTHERWISE SPECIFIED BY NATIONAL MARITIME AUTHORITIES, **THE DATA LICENSED HEREUNDER IS INADEQUATE AS A PRIMARY MEANS OF NAVIGATION, AND SHOULD BE USED ONLY AS A SUPPLEMENT TO OFFICIAL GOVERNMENT CHARTS AND TRADITIONAL NAVIGATION METHODS.** NEW CHARTS OR NOTICE TO MARINERS CORRECTIONS WILL RENDER THE DATA OBSOLETE AND INACCURATE. UPDATES MAY BE AVAILABLE FROM C-MAP. THE DATA MAY NOT CONTAIN ALL NAUTICAL NAVIGATION DATA EXISTING WORLDWIDE AND YOU SHOULD MAKE NO ASSUMPTION OTHERWISE.

Figure 1.2-2. Notices from the three most popular third party chart sources that they are intended to be used in conjunction with official electronic charts. Color added for emphasis.

safety and efficiency features available to the navigator using an ENC.

Beyond that, because an ENC is a database, it is much easier and more economical to update and distribute than the graphic or paper products are. An ENC can be updated in seconds. The more mariners rely on this form of chart-

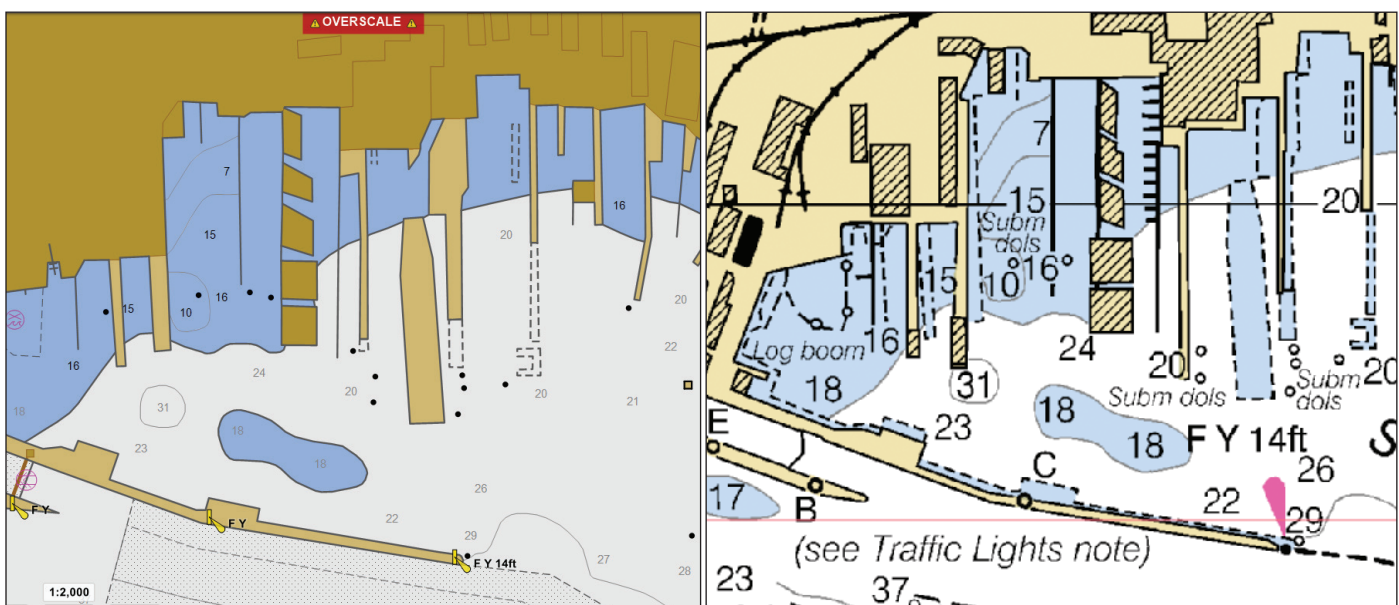


Figure 1.3-1. ENC (left) and RNC (right) of the same docks area. Note breakwater lights shown on the ENC are relegated to a chart note in the RNC—an advantage of the ENC that also applies to some bridge lights.

1.9 New Zealand ENC — Practice with S-63

New Zealand (NZ) is unique amongst advanced maritime nations in that they are the only nation other than the US that provide their official ENC and RNC free of charge to the maritime community. The only difference is they provide these in the encrypted S-63 format, not the open S-57 format used by the US. That might seem less attractive, but for commercial mariners who use ECDIS this is actually an advantage, because many must use S-63 charts. In fact, to use the free US S-57 charts they must be first encrypted to S-63 by third parties that in turn sell them to ECDIS users.

All navigators, however, using ECDIS or ECS who plan to sail in international waters will eventually want to use official international charts, which will be in the S-63 format. So the unique NZ system offers all mariners an excellent way to learn about the process of using S-63 charts as well as the chance to study their excellent ENC products.

For this you will need an ECS that is compatible with S-63 charts, and essentially all popular programs, commercial and free, qualify, which means somewhere in the program there will be a file called IHO.PUB.

Then you will need from the ECS maker a *User Permit* that is needed to purchase the S-63 from any source. This is alpha-numeric number, 28 characters long. It insures the source of the S-63 charts that they will only open on a specific ECS, being run on a specific computer.

Most commercial ECS are limited to just one computer, but free ones, such as qtVlm and OpenCPN, can be loaded onto any number of computers, so to protect the charts using those two, each computer in use will generate a unique hardware ID number, and then that number and your User Permit must be submitted to the ECS maker for an Activation Key. Any number of S-63 charts from any number of sources can be installed with the User Permit. Commercial ECS do not have an extra charge for this. Some include a User Permit; others require users to request one.

Once you have a User Permit loaded into your ECS, you are ready to purchase S-63 charts, or download the free ones from NZ. For the NZ ENC, start at encservice.linz.govt.nz, where you can read about the program and apply for a free account. Once the account is set up you can log in and go to the Systems and Subscriptions tab, click the + sign on the System line and download the files *PERMIT.txt*, *ENC.pmt*, and *NZ ENC Chart Service Certificate.pdf*. The *PERMIT.txt* file links your User Permit to the NZ ENC; *ENC.pmt* is a list of all the ENC, and the PDF Certificate documents your User Permit and the expiration date (one year from download date) of the charts. *PERMIT.txt* is a file of data, different from your User Permit, which is just a number.

Then from the Downloads tab of your NZ account, download the Base charts zip file (~85MB) and the Cumulative updates zip file (~20kB). Once unzipped, these resulting folders need to be loaded into your charts folder in

a specific order, usually in a separate S63 folder—confirm this with your ECS manual. See Figure 1.9-1.

You can view the charts after they expire, but cannot update them until you download a new Base set. For other nations you would have to buy them again, but for these just download again.

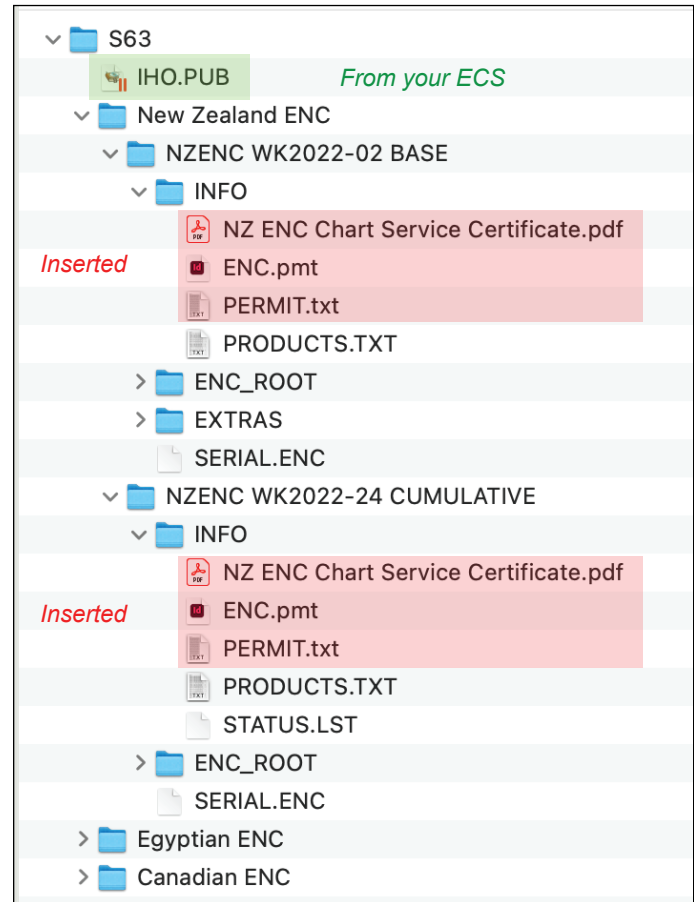


Figure 1.9-1. Folder structure for S-63 charts. Make or find the S63 folder, and add the IHO.PUB file that comes with your ECS. Make a folder called (e.g.) New Zealand ENC, and add the unzipped Base and Cumulative folders. In the INFO sub folders, add the ENC, Permit, and Certificate files as shown. The ENC_ROOT includes numerous folders containing the actual ENC and related files. In this example, we also have charts from Egypt and Canada, which include the same internal structures.

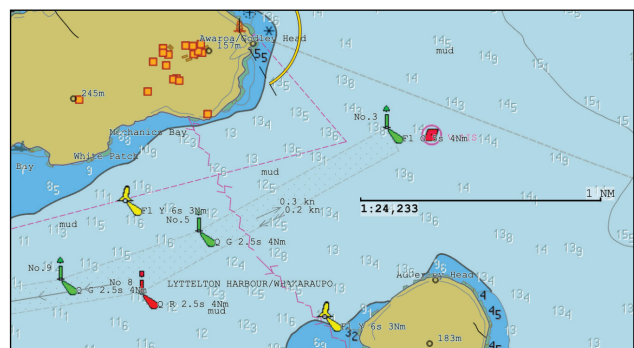
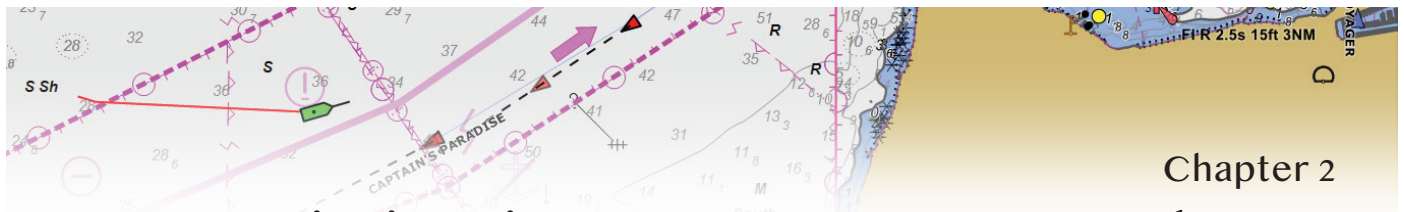


Figure 1.9-2. Entrance to Lyttelton Harbour, NZ.



Key Distinctions Between ENC and RNC

2.1 Introduction

We have already covered several generic differences between raster navigational charts (RNC) and the corresponding electronic navigational charts (ENC), such as file sizes, nomenclature and boundaries, obtaining crucial content by cursor pick, and their respective places in nautical chart evolution. In this chapter we look into details that affect our usage of ENC, focusing on the changes RNC users face when transitioning to ENC usage.

of RNC. They pretty much look the same from one to the other, and any one of them never changes as we use it. This has been the policy in nautical charting for a hundred years. ENC, on the other hand, purport the virtue of user customization of the chart display, and we look at these options in following sections.

The most conspicuous content difference between RNC and ENC is absence of terrain detail on an ENC, which (at

One notable difference is when ENC are zoomed, only the land and water areas change size. Individual chart symbols stay the same size, specified in the S-52 standard (see Figure 2.1-1). This can appear counterintuitive to RNC users at first, but it becomes more understandable with practice. This feature leads to a cleaner display of a congested region of a chart when zoomed, but it remains the user's obligation to keep in mind the limitations of overzooming discussed later.

The primary philosophical difference between RNC and ENC is the variability of ENC appearance. That they are notably different looking charts to begin with is not so much a challenge as the fact that the appearance of any one ENC can change. We are accustomed to the invariance

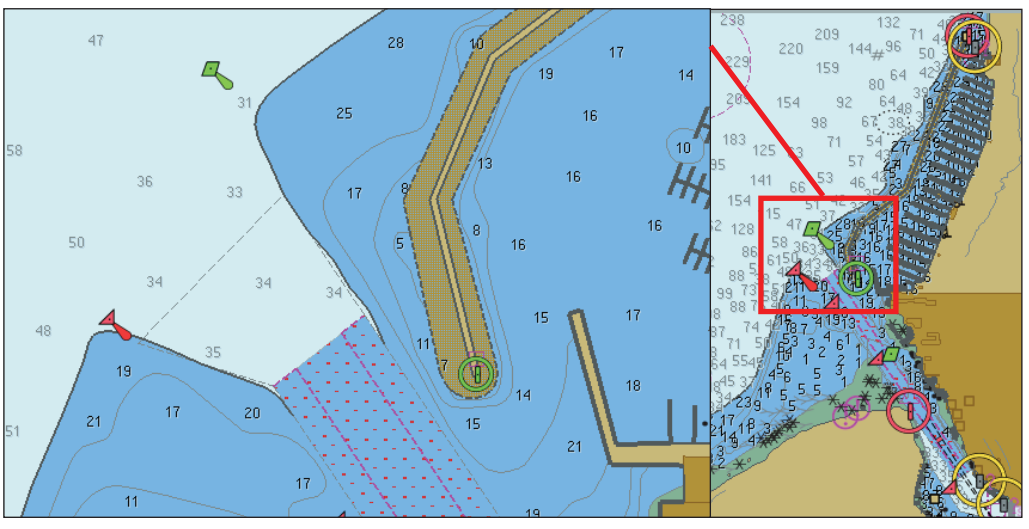
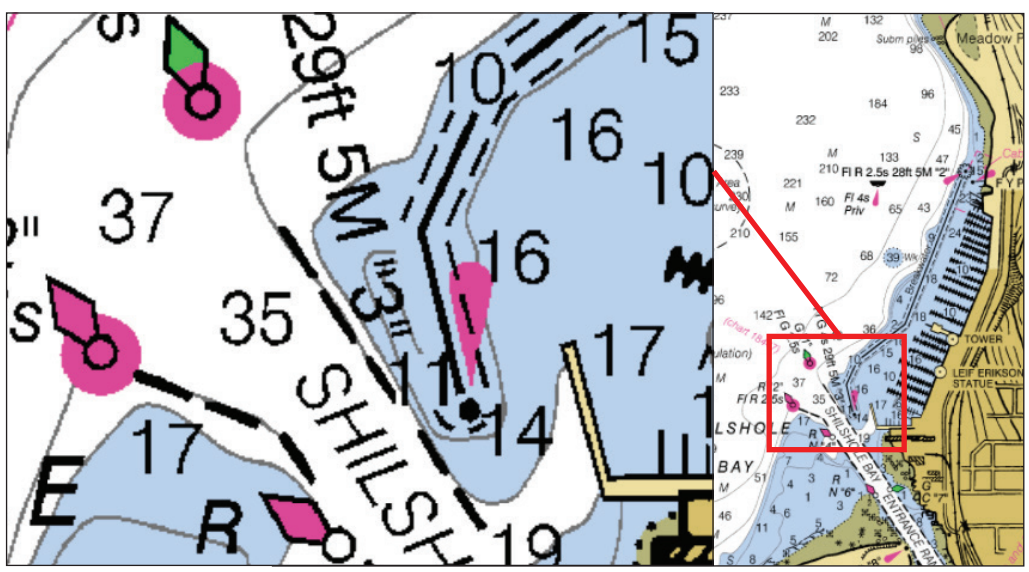


Figure 2.1-1. Right side shows 1:25,000 chart segments viewed at x1; on the left, each is zoomed to x6. Top is an RNC; bottom is the same chart as ENC. Symbol and text sizes do not change in the ENC.

of all charts in view—they are all rendered to match that scale—but a screen note such as “x2.5” has to apply to a specific chart on the screen. When these scale factors are employed, which are often useful, we need to learn how to identify which chart on the screen they refer to. Keep in mind, too, that the same object can have different SCAMIN values on charts with different compilation scales.

Chart Display Summary

First, the extent of chart reading challenges illustrated in Figure 2.3-3 represent an especially difficult case with an important navigation light located right at the convergence of four ENC with varying SCAMIN values. Nevertheless, elements of these issues occur in more typical cases, so it is important to understand how this behaves.

It is also important to know that essentially all of the challenges illustrated there go away completely when the charts are reschemed, as discussed in Appendix 5, so we have that improvement to look forward to over the next few years. For the time being, a working protocol on chart display would involve:

- Be sure to have all available charts loaded for a planned route.
- Plan your ENC chart usage much as we did in selecting and laying out paper charts ahead of time. Namely go over all of the charts along the route, noting the small and large scales available. This can require zooming in and out to see them load. Some ECS offer a one click view to a list of all charts available at a given point.
- Showing chart outlines is a universal display feature, which can be turned on and off as needed.
- It might be valuable to shut SCAMIN off until clear cases arise for its value.
- Consider the value of choosing to show only one chart, which then prevents chart changes without you choosing them—equivalent to shutting of chart quilting.

- Remember what we see also depends on display mode selected. Depth contours, for example, are not part of the Standard display option and have to be added.
- Remember that important features might be shut off individually in the ECS configuration setup.

2.4 Soundings, Depth Areas, and Contours

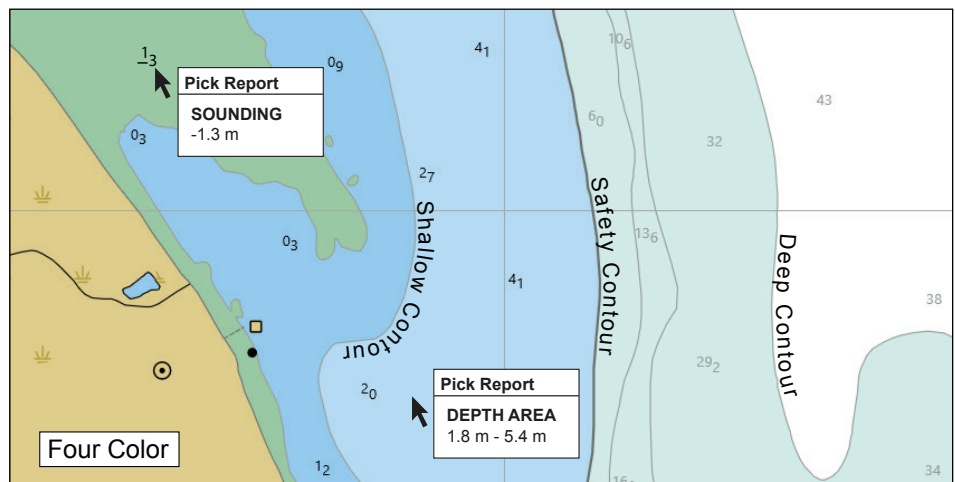
In traditional navigation training we push the topic of water depth to the front of the course, because there is nothing more fundamental to a vessel. Chart scales are a secondary factor with paper charts, in the sense that we have no control over them and we are, after all, looking at the charts when we buy them, and they never change. As shown earlier, however, chart scales play a more crucial role with ENC use, so we just now get to the water itself.

Soundings retain their same meaning in ENC, i.e., they are not just water depths, they are water depths that have actually been measured—it could have been a long time ago, but they were measured. This accounts for some charts having more soundings than others, because they are charts with better hydrographic surveys. The first key point is, soundings on an ENC are one-to-one the same as those on the RNC it was based upon—but we do have new soundings-related options in ENC.

Using ENC, we are no longer restricted to the sounding units on the paper chart or RNC, which is an issue for the use of NOAA charts, since other nations use meters to begin with. The inherent units of all ENC are meters, but this is easily changed in any ECS to display feet and sometimes fathoms if desired.

ENC soundings also have the same reference level as on RNC; they are measured from the depth of the water when the tide is zero. Technically, the soundings are indeed ENC objects (SOUNDG) with attributes (discussed further at the end of this section), but only a few of the ECS we know offer cursor pick information, unless (rarely) they are circled, meaning they are uncertain. A line of con-

Figure 2.4-1. Four-color and two-color water displays. The four colors are standardized, but they vary from one ECS to the next, sometimes notably. Also shown are several cursor pick reports. The areas can be interrogated anywhere between the contours, but the cursor pick must be precisely on the contour line. The values shown will be the next deeper ones to the numerical values entered. To highlight a specific one, click it to learn its value, then enter one slightly below that. Some ECS can show contour labels; others do not. Only a few ECS can cursor pick a sounding.



Electronic Chart Navigation Underway

3.1 Basic Features and Operations

This chapter discusses basic procedures that can contribute to safe, efficient navigation using electronic charts. Details and important background are left to other navigation texts and courses listed in the References. Our focus is on small-craft navigators who are new to electronic charting, but the fundamental procedures are much the same for any vessel. And even though this book is primarily devoted to use of ENC, for those new to *all* electronic charting it could be best to start with RNC when first learning to use your chosen ECS. Doing so allows you to concentrate on the tools of the navigation program while using familiar charts. Then later you can take advantage of the benefits ENC can add to the navigation.

We start with a list of basic features and operations that most ECS programs include, and then discuss how these are used in planning and underway.

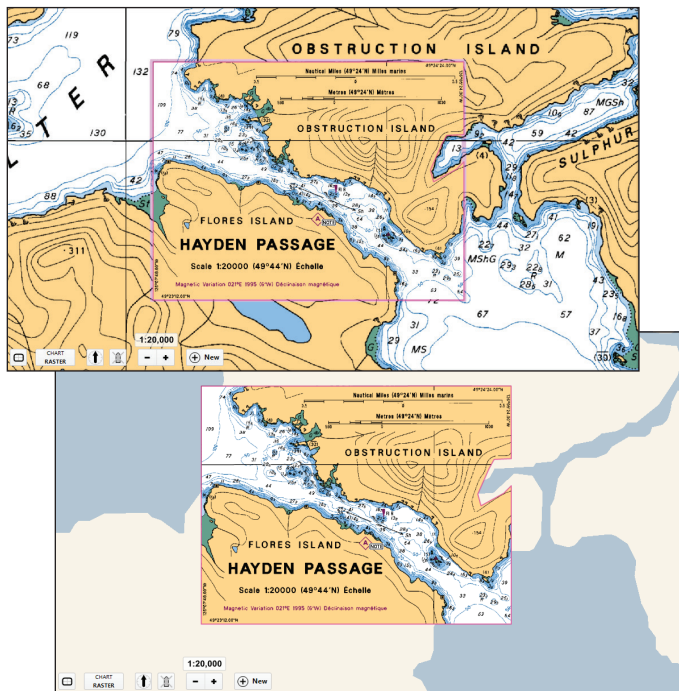


Figure 3.1-1. Top: Section of Canadian chart 3674 (1:40,000) with a quilted insert of 1:20,000 and chart outlines turned on. Bottom: The single chart display of the insert.

- It is crucial to master the loading of new charts into your ECS. Study and practice the process, including auto-update procedures if included, and recall that the auto-update function on some ECS programs only applies to full regions and not individually installed charts.

- Practice changing between RNC and ENC.

- Practice with quilted versus not-quilted chart display. The behavior can differ in RNC and ENC. A not-quilted chart shows only one full chart at a time. Some single chart displays show paper chart border notes; others show the single chart clipped at the chart area as in Figure 3.1-1. The quilted display shows adjacent charts matched at the boundaries as best can be done. Quilted generally works best, but there are exceptions (see Chart display options in Section 2.3). Note how displays can change at the border of two quilted charts. Check for options on how adjacent quilted charts with different scales are presented. Both behaviors to change with rescheming.

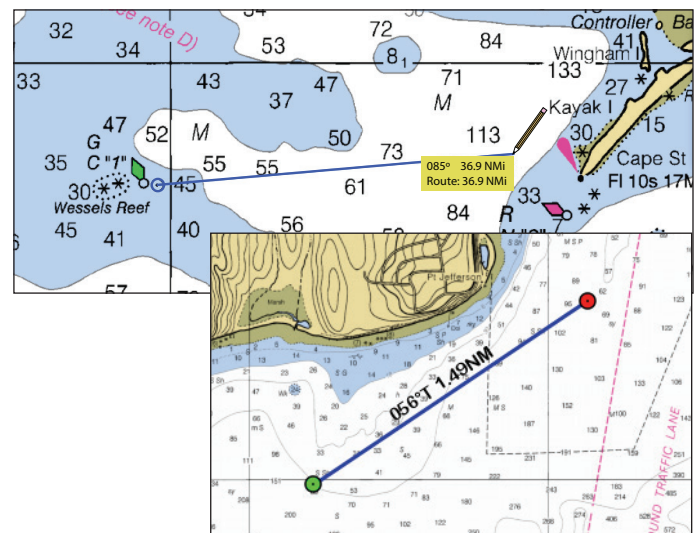


Figure 3.1-2. Measuring or Range and Bearing tool. Top example is activated by the M key. When an ECS does not offer a specific range and bearing tool, we can always use the new-route or pathway tool, which in some cases is preferred as it leaves the data on the screen. Bottom is an example using the route tool for this type of measurement.

lected time interval or after some distance run. That is, plot a point every 5 seconds, or every 5 minutes; every 100 yards, or every mile, etc. How we set this best depends on what we are doing at the time. If we set these track points more frequently than needed, we can end up with very large files of stored tracks. On the other hand, if the steps are too far apart, we miss details that could be crucial to safe navigation. Transiting a narrows of strong, swirling currents, we want as detailed a track as possible. Crossing the ocean we do not need such small increments.

One of the steps in learning a specific ECS is learning how the tracks are configured and how to change this. If you choose to save a track, you may have the option, once again, to select how it should be configured. Tracks can then be converted to routes for use in the future, or you can just load and display the saved track, and set a new route with the past track in view. When under sail, you will thus recall what tacking or jibing angles you had when you were there before. For racing sailors, a history of past tracks will remind you of persistent lifts or headers in specific regions, and thus accelerate your accumulation of local knowledge.

Sailors can also use the lay of the track lines on opposite tacks to predict the layline to the next waypoint, taking into account current and leeway, as shown in Figure 3.8-1. How you actually make the parallel-rulers-style move of the line depends on the ECS. In some systems you can draw a range and bearing line, then just grab it and move it; without that option, you would read the bearing along the line, then draw another one emanating from the target waypoint.

3.9 Vessel Icon Range Rings to Aid Radar Watch

Beside putting range rings on charted marks as piloting aids, or on waypoints as arrival markers, or on our anchor location to warn of dragging, we can also add range rings to the vessel icon itself. The vessel icon rings can be used for monitoring minimum distance off in piloting, or you can match the rings on the vessel icon with those on the present radar display for an effective way to interpret the radar screen. This is most useful for vessels that have a radar but not a radar interface to the ECS. Many ECS systems offer a full radar overlay option that plots the actual radar image right on the chart in use, but this in turn calls for a compatible radar and associated connections or ECS enhancements.

A display of the vessel rings alone might even be preferred in cases when the overlay of actual signals might

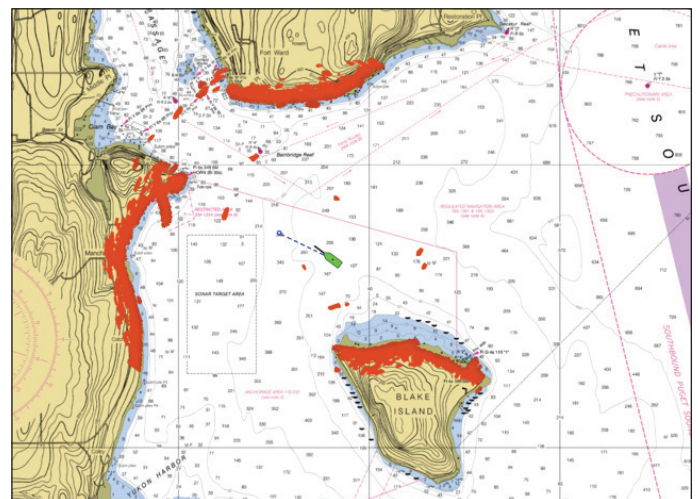
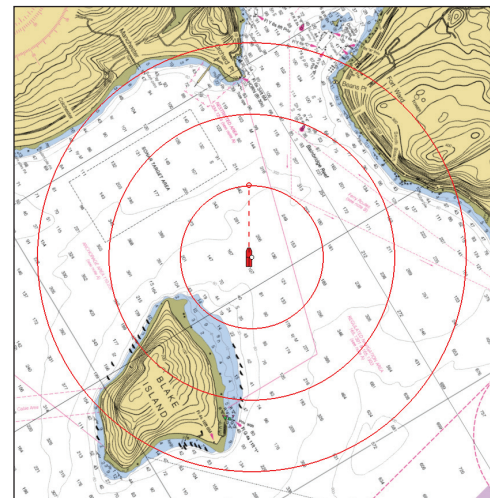
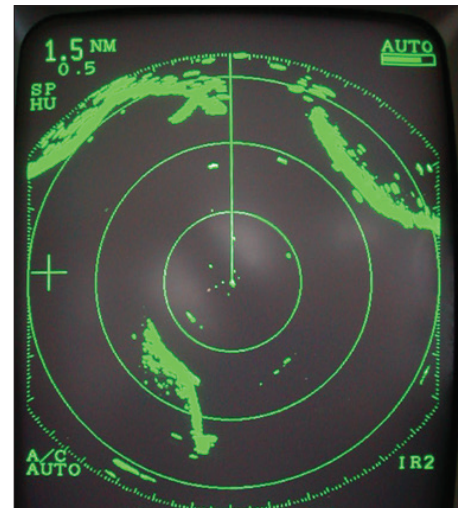


Figure 3.9-1. Top is a radar image in head-up mode with range rings at 0.5 nmi. To help interpret the radar image, we can set matching range rings on the vessel icon in the ECS (set to course-up display) as shown in the middle view. This display is possible in the most basic ECS, and from the overlap of the rings we learn what we are seeing on the radar, independent of visual identification. The steep terrain of the targets limits the radar images to the front face of the targets. This is effectively a low-budget alternative to a more sophisticated system that overlays the radar image on the chart within the ECS, as shown in the bottom panel. In a busy radar image, the middle option can sometimes be preferable to the full overlay, which can obscure the chart.

Introduction to Electronic Chart Navigation

program, we can often learn crucial matters of route selection over long routes that we might have missed without these tools.

Furthermore, even though individually we might not have access to the state of the art analysis program, nor the best possible performance data for our vessel, we all still have access to essentially the same environmental data as those with the best possible analysis tools. Global ocean wind, current, and sea state data are readily available, as are high resolution inland and coastal wind data in many locations. Ocean current data are generally less reliable

than wind data on a global basis, but the data are readily available to all mariners. Part of the “not plug and play” aspect is that we must train ourselves to best evaluate the data that go into the routing. Figures 3.15-1 to 3.15-3 show examples of Ocean data that can be loaded into an ECS to assist in route planning. See *Modern Marine Weather* for discussion of the wind and ocean models presented in the figures.

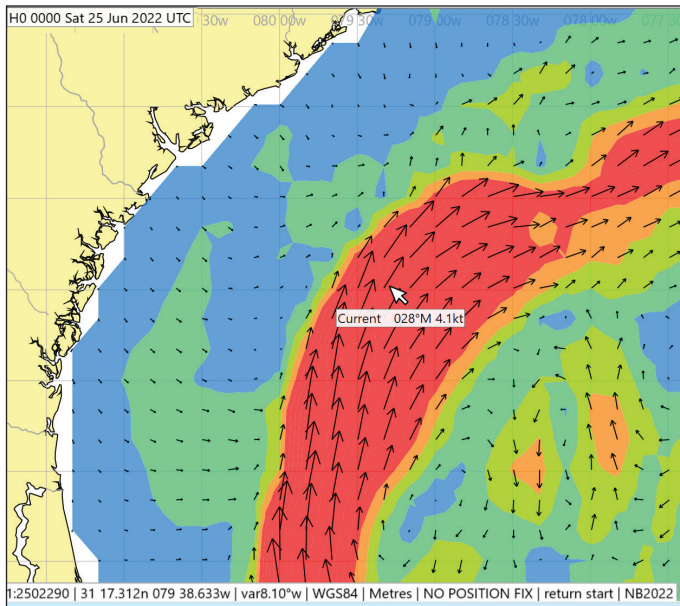


Figure 3.15-1. Section of the Gulf Stream current predicted from the NCOM ocean model overlaid onto an ECS base map in GRIB format. These data are crucial to efficient routing. Colors represent speed bands.

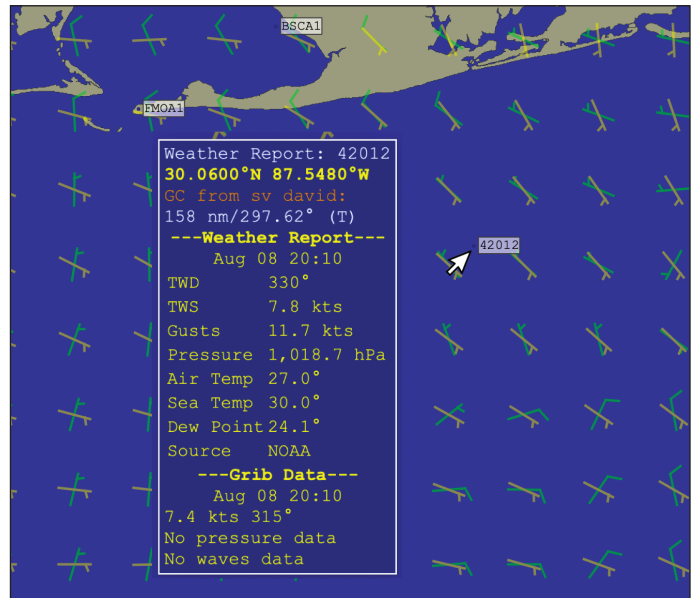


Figure 3.15-3. Wind data in GRIB format overlaid in an ECS. Here we see two different wind models, the global GFS and the regional HRRR. The model data are automatically interpolated to the time of the 42012 buoy report, which shows that the green regional forecast (HRRR) was much better than the GFS at this time and place. This is a larger discrepancy than usual.

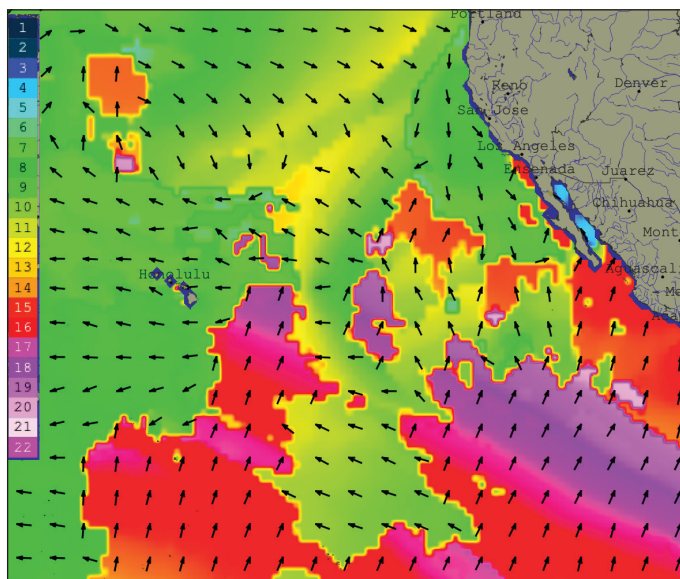
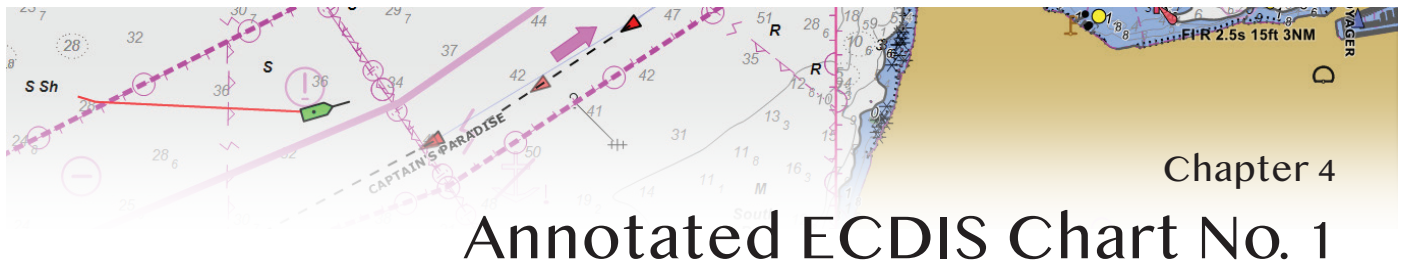


Figure 3.15-2. Left. Primary wave period (sec) and direction from GFS model. This color bar code in the ECS matches that used by the NWS. Below 9 or 10 sec are wind waves; longer than that are swells.




Chapter 4

Annotated ECDIS Chart No. 1

Introduction




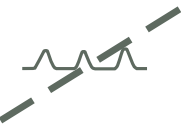

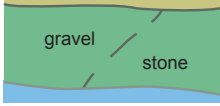
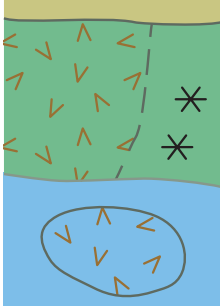
This chapter of the book is essentially a reproduction of the ECDIS part of *U.S. Chart No. 1*, which we have abbreviated in some cases and reformatted. We have then added annotations to clarify some symbols and provided cross references to sections in the text where appropriate. To distinguish what we have added from the original text of *U.S. Chart No. 1*, our annotations appear in *[square brackets, using blue italic font]*.

Columns in the body of the Chapter have this format:

Category and symbol	Short description	Paper Chart Equivalent
●	Land as a point at small scale	K 10
	Land as an area, with an elevation or control point	K 10
✳	Rock which covers and uncovers or is awash at low water	K 11, K 12





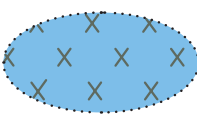












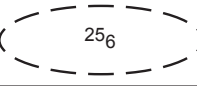


The paper chart equivalents refer to the International Symbols (INT 1) listed in *U.S. Chart No. 1*. When there are multiple references given it means the ECDIS symbol has multiple meanings, as many do. As stressed throughout, a cursor pick is the key to learning the meaning of individual symbols, lines, and areas. Click everything! The main reference for our annotations is IHO S-52 Presentation Library, version 3.4, with awareness of proposed changes in version 4.0 planned to be in effect Sept 1, 2017.

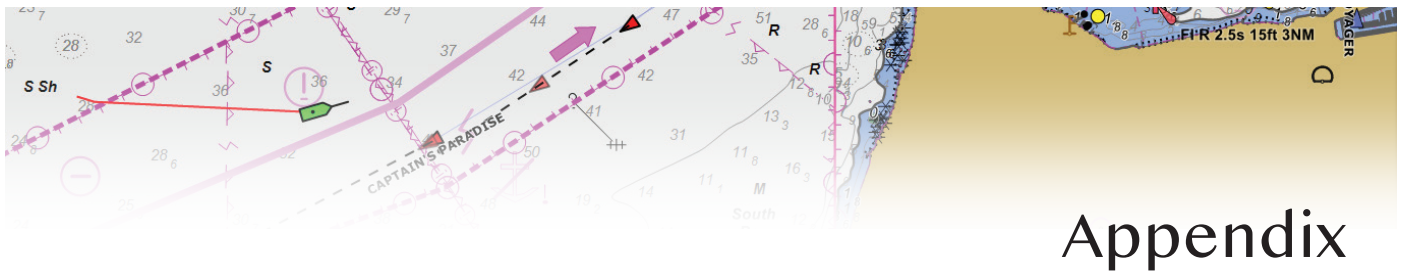
J. Nature of the Seabed

Types of Seabed		Paper Chart Equivalent
S	Sand [0.06 mm to 2 mm]	J 1
M	Mud	J 2
Cy	Clay	J 3
Si	Silt	J 4
St	Stones	J 5
G	Gravel [2 mm to 4 mm (buckshot to marbles)]	J 6
P	Pebbles [4 mm to 64 mm (marbles to golf balls)]	J 7
Cb	Cobbles [64 mm to 256 mm (golf balls to soccer balls)]	J 8
R	Rock	J 9.1
R	Boulder [bigger than cobbles]	J 9.2
R	Lava	J 9.2
Co	Coral	J 10
Sh	Shells	J 11
	Weed, kelp	J 13.1
	Weed, kelp as an area	J 13.2
	Sand waves as a point	J 14
	Sand waves as a line	J 14
	Sand waves as an area	J 14
T	Spring	J 15
Types of Seabed, Intertidal Areas		
	Areas of gravel and stone [See Types of Seabed.]	J 20
	Rocky ledges or coral reef [See also I 15.]	J 21, J 22

K. Rocks, Wrecks, Obstructions, Aquaculture

[Key attributes of rocks and wrecks and obstructions are: water level effect and value of sounding.]

General [See Section 2.5.]		Paper Chart Equivalent
	Obstruction, depth not stated	K 1, K 16, K 40, K 43
	Obstruction which covers and uncovers	K 1
	Underwater hazard with depth of 20 meters or less	K 1, K 14, K 26, K 41, K 43, K 46.1
	Isolated danger of depth less than the safety contour [This is activated by safety contour, not safety depth.]	K 1, K 11, K 12-14, K 16, K 26-28, K 30, K 40-43, K 46
	Foul area, not safe for navigation	K 1
	Swept sounding, less than or equal to safety depth	K 2
	Swept sounding, greater than safety depth	K 2
Rocks [See Section 2.6.]		
	Land as a point at small scale	K 10
	Land as an area, with an elevation or control point	K 10
	Rock which covers and uncovers or is awash at low water	K 11, K 12
	Underwater hazard which covers and uncovers with drying height	K 11, K 12
	Underwater hazard which covers and uncovers	K 12
	Dangerous underwater rock of uncertain depth	K 13, K 16
	Underwater hazard with depth greater than 20 meters	K 14, K 15, K 26, K 30, K 41, K 46.2
	Underwater hazard with a depth of 20 meters or less	K 15,
	Safe clearance shoaler than safety contour	K 16, K 40, K 46.1, K 46.2
	Safe clearance deeper than safety contour	K 16
	Safe clearance deeper than 20 meters	K 16, K 46.2
	Overfalls, tide rips; eddies; breakwaters as a point	K 17
	Overfalls, tide rips; eddies; breakwaters as a line	K 17



Appendix

Appendix 1. Chart Accuracy and Overscaling

Chart accuracy is discussed in Section 2.4 and overscale (also called overzoomed) is discussed in Section 2.3. This section illustrates these points. This is not an exact cartographic analysis, but just a way to get a feeling for the issue at hand, namely, overscaling can present a chart that appears more accurate than it is. We start by looking at a case where we know something is wrong.

Figure A1-1 shows the two adjacent ENC cells that are the only charts of the coastline shown. The Zone of confidence (ZOC) for both charts is level B (4 stars), which means a position accuracy of $\pm 50m$. The discrepancies we see in Figure A1-2 are consistent with this, noting that the ZOC applies to the contours only, not to the coastline. The mismatch could be even larger on other legacy ENC, but these issues should be rectified with rescheming (Appendix 5).

The point here is, overzooming on these chart boundaries can illustrate this discrepancy in accuracy, whereas in other places it would not at all be obvious. Figure A1-3 shows an example where we would want to take care in heeding the stated charting uncertainties that we can read

from an ENC, but not an RNC. When in doubt, switch to an All-objects display mode to reveal the ZOC symbols.

Remember, however, that just because chart data has a stated uncertainty of some amount does not mean it is wrong by that amount. Indeed, position measurements in early surveys (that led to B and higher uncertainties) were made by horizontal sextant piloting, which can be more accurate than what we might dependably assign to standard GPS ($\pm 20 m$). In fact, we will be amazed much more often by NOAA chart accuracy than by a lack of accuracy.

GPS is often better than noted above; that “standard” value accounts for situations with no differential corrections (DGPS) and considers the often unaccounted for location of the GPS antenna on the vessel, not to mention that high nearby terrain can limit fix quality. For a practical look at this, when tied up at the dock, turn on your GPS, set the tracking to plot your position every 30 sec-

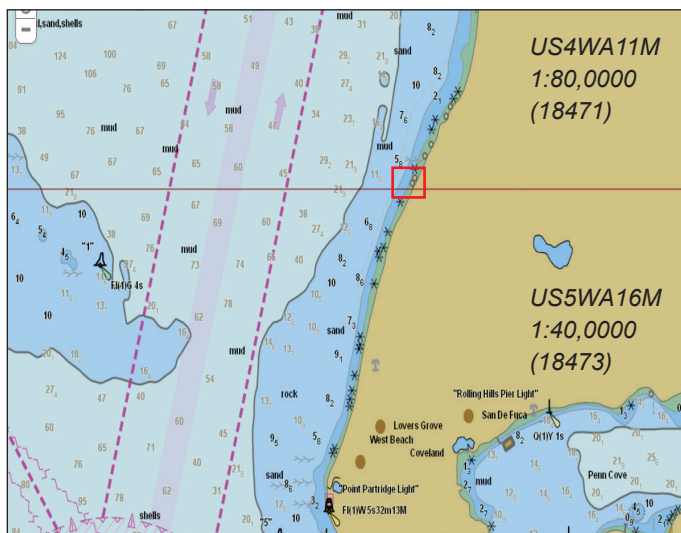


Figure A1-1. Two adjacent ENC cells. The red box marks the area shown in Figure A1-2.

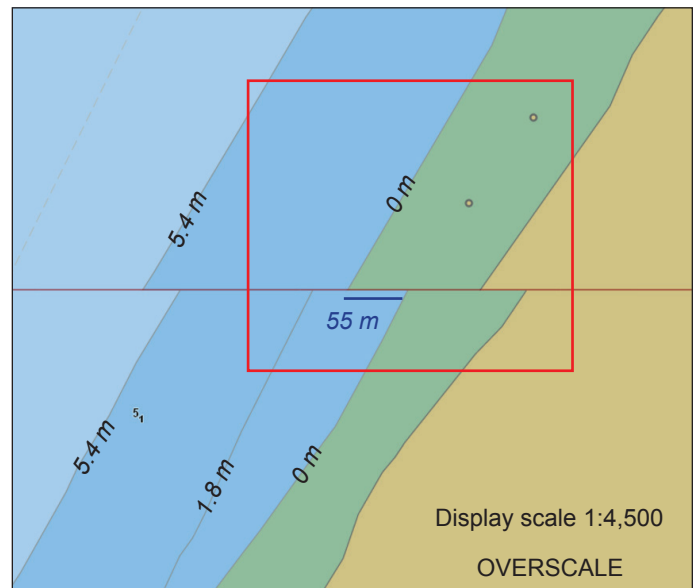


Figure A1-2. A much overscaled view showing discontinuity at the boundary. The 55 m shown is consistent with ZOC value of $B = \pm 50m$. The top ENC does not include a 1.8 m contour, so that one just ends at the boundary..

ATTRIBUTE	ACRONYM
Value of annual change in magnetic variation	VALACM
Value of depth contour	VALDCO
Value of local magnetic anomaly	VALLMA
Value of magnetic variation	VALMAG
Value of maximum range	VALMXR
Value of nominal range	VALNMR
Value of sounding	VALSOU
Vertical accuracy	VERACC
Vertical clearance	VERCLR
Vertical clearance, closed	VERCCL
Vertical clearance, open	VERCOP

ATTRIBUTE	ACRONYM
Vertical clearance, safe	VERCSA
Vertical datum	VERDAT
Vertical length	VERLEN
Water level effect	WATLEV
Information in national language	NINFOM
Object name in national language	NOBJNM
Pilot district in national language	NPLDST
Text string in national language	\$NTXST
Textual description in national language	NTXTDS
Horizontal datum	HORDAT
Positional Accuracy	POSACC
Quality of position	QUAPOS

Appendix 5. NOAA ENC Rescheming Plan

The US was one of the first nations to create ENC from existing paper chart data in the early 1990s. Because of the varying sizes and regions covered by paper charts (dating back to 1807), along with the then new set of international standards on the structure of ENC (in particular that none could overlap and all cells had to be less than 5 MB), this led to over 1200 ENC cells of irregular shapes, compiled in over 100 scales. We are still using updated versions of most of these early products in what we now call the legacy ENC, but this is in the process of changing.

The goal at hand in the *NOAA ENC Rescheming Plan* (announced in the 2017 National Charting Plan) is to modernize the ENC by doing away with the irregular shapes, sizes, and scales, as well as improving the continuity of depth contours on adjacent charts. The troublesome consequences of these early limitations mentioned in the book

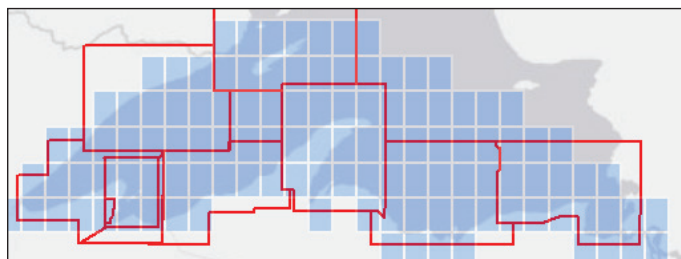


Figure A5-1. Reschemed charts of Lake Superior (blue) overlaid with red outlines showing the legacy ENC that were replaced. The span of the region shown is 320 nmi. Each of the reschemed charts are 1:80,000. There are a few larger scale charts planned but not yet completed (See Figure A5-3).

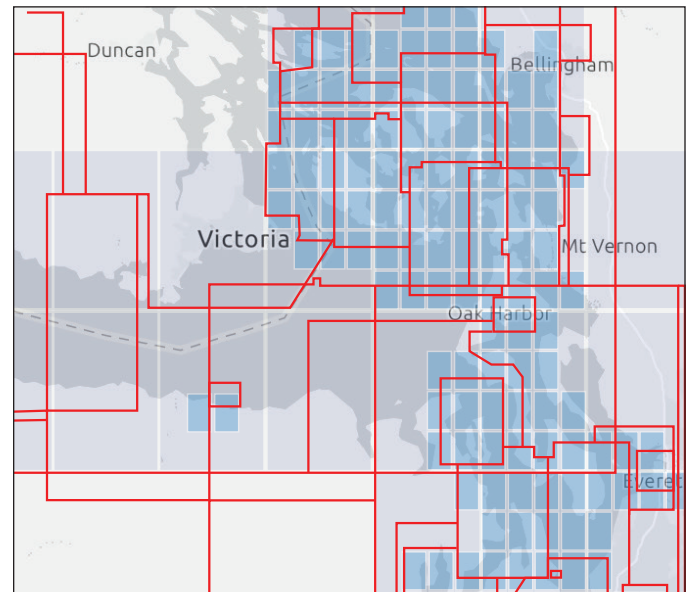


Figure A5-2. Rescheming plan for part of the Salish Sea in Washington and British Columbia, a 65 nmi span, showing the outlines of the existing legacy ENC, discussed earlier in Figure 1.5-1. This region will be covered by a regular set of 1:80,000 charts (faint magenta) with the indicated blue charts at 1:10,000—legacy ENC in this region span six different scales. This is a big improvement on detail. With two small exceptions, the best detail now is 1:25,000. The 1:80,000 are planned for 2023; the 1:10,000 production dates have not been announced.

Appendix 7. Heading Line and COG Predictor

One of the most powerful navigation aids we have in electronic charting is the ability display both a heading line showing which way the vessel is headed and a COG predictor line that shows which way the boat is actually moving, as discussed in Section 3.7.

The difference between these two directions as viewed from these two lines is usually the fastest way we have to learn that they may not be the same, which is always a key alert to the navigator. Viewing these two values (heading and COG) digitally on meters does tell us they are different and indeed more precisely numerically, but with some expected jitter in the readouts as well as the required mental arithmetic, the lines themselves are usually the most effective alert to a divergence. It is even better to view both, the lines and the meters.

This is a dynamic, interactive set up. We can usually change the length and color of each of these, and the best choice depends on the circumstances. And this will change

as the speed changes or the waterway changes. Generally they are best at comparable lengths, which can mean setting the length of the heading line to match your choice of COG predictor time. The best look ahead time changes often during navigation. You might want the heading line to be longer; it's personal preference. The COG predictor line typically has a small dot on the end, which the heading line does not.

It is also important to check the dampening settings you may have active. Most ECS let users apply an averaging factor to almost all of the parameters that show in meters. Thus you may be showing a heading sensor output that is averaged over 10 seconds or longer. This has to be tested in present conditions. In some cases you need fastest possible response; in others the jitter or natural oscillations in the values may be distracting. For sensitive navigation, the first try would be raw data without a filter.

Figure A7-1 shows an annotated screen capture from a video that illustrates the value of this setup in a situation where prompt accurate navigation was crucial.



Figure A7-1. Screen capture of a video reenactment of the [grounding of the Ever Given in the Suez Canal](#) based on AIS data that include both heading (CTW, black line) and COG (green line). The look ahead time (green dot) was 2 minutes. A strong southerly wind pushed the boat to the left (green line left of the black line). The meters tell us the drift was 7° at this time, 0508. The correction to the right was not adequate to keep the vessel off the left bank, and 11 min later, about 1.5 nmi to the north, it came close enough to the bank that hydrodynamic effects almost certainly affected its motion (insert). The center section is dredged to 25m; from the dotted line to the buoys the bottom slopes from 25 m to 11m; the draft of the ship is 16m. The reenactment, showing these navigation data as the vessel progressed to the point of grounding, can be seen at [starpath.com/evergiven](#), which includes several background videos. The grounding took place on the right bank at 0543 after a close encounter on the right, then again on the left.

Appendix 9. Looking ahead to S-100

The present IHO standard for ENC production and content is called S-57. It was essentially frozen in time at Edition 3.1 in 2010. Ever since then, the IHO, and many government agencies and private companies related to marine navigation around the world have been working on the next generation of this standard, called S-100. It has far-reaching and promising aspirations, but we do not have to worry that our study of the existing system is in vain. It will be some years down the line before the methods we now use are replaced by S-100 components. In the IHO standard itself (*S-100 Universal Hydrographic Data Model, Ed 4.0.0*) we read: “S-57 will continue to exist as the designated format for ENC data for the foreseeable future.” The IHO goal for now is to encourage developers of next generation resources to use the S-100 standards.

S-100 is actually much more than just the replacement of S-57. It also effectively replaces S-52, because the presentation of charted information on the display screen is included in S-100. But there is still much more: S-100 is a data model or framework of standards for an open-ended set of essentially all matters related to safe navigation. Table A9-1 lists the products included, keeping in mind each has a layer of administration, validation, and delivery to be standardized. Updating the ENC themselves, called product S-101, is only one part of the new standard, although a fundamental one.

The information we care about is usually tied to a time and place, generically called GIS (geographic information system) data. The backbone of S-100 comes from GIS data standards set by the International Organization for Standardization (ISO). These standards for each of the products are compiled into the S-100 Geospatial Information Registry that S-100 product producers and distributors access to insure that all functions as intended. It is a bit like the Windows registry on a PC that stores all the information needed for an app or service to function properly.

It can also be thought of as the cookbook needed to explain how to make a recipe for, say, a vector overlay of the tidal currents of Chesapeake Bay, or the dynamic plot of all the AIS targets in the Bay at the moment. Thus we can end up with vast array of GIS data that can be overlaid onto the ENC. Interactions with an ENC will become a bit like interacting with a Google Map on our phone screen; we not only see where we are and which way we are going, but we can tap to ask for the nearest Italian restaurant or a good parking space, or we can choose to show this on a satellite image rather than a map. That is the type of technology we will have in an S-100 navigation system.

With a mature S-100, we can overlay the surface current flow and let it correct our route’s ETAs, or show wind vectors, or click and ask for all the latest ship and buoy reports of wind, current, and waves. Or we can draw the equivalent of a radiofax weather map, georeferenced right

on the chart; or learn which AIS targets we see are participating in a traffic separation scheme; display an updated route plan; be alerted at the next radio check in; and much more. In short, we would have automated, standardized access to all the products of Table A9-1, much through cursor pick interaction with ENC or associated ECDIS or ECS controls.

It is not clear yet how S-412 (Table A9-1) weather data will appear. The elements of a weather map could be expressed as ENC objects and attributes in which case we could draw an isobar much as we draw a depth contour. Figure A9-1 shows what it might look like.

Experienced mariners know that they already have access to the vast majority of the S-100 products in Table A9-1, but it is not button-click access, nor plug and play. The information comes from different instruments, in different formats. Ships get much of it by text, voice, or radiofax communications. This standardization of format and sourcing for such a wealth of data will be a welcome upgrade to many professional mariners.

This much expanded functionality will certainly require enhanced training. At present, ECDIS users are required to take a generic 5-day course on the basics to meet STCW requirements, and many shipping companies require additional brand specific training—there are some 30 different ECDIS brands on the market. This training might have to double if not increase more to cover all the new tools, even in light of some traditional data being easier to access in S-100. Training for vessel officers, like many other professions, is evolving toward more and more sophisticated computer applications.

With that said, many of the goals of the S-100 program for professional mariners have in fact been in productive use by recreational mariners for many years. An import-

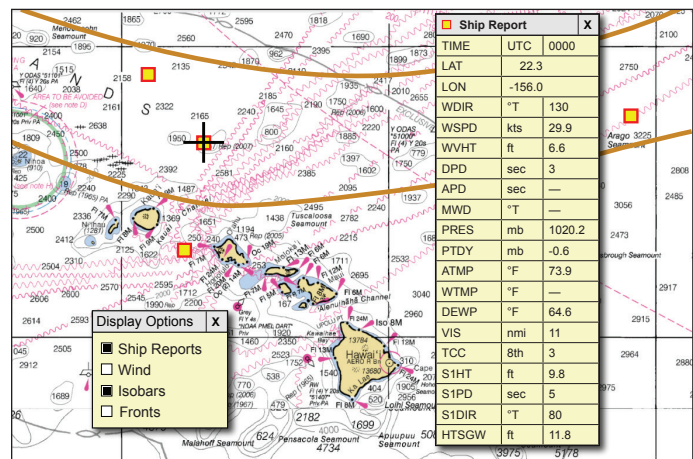


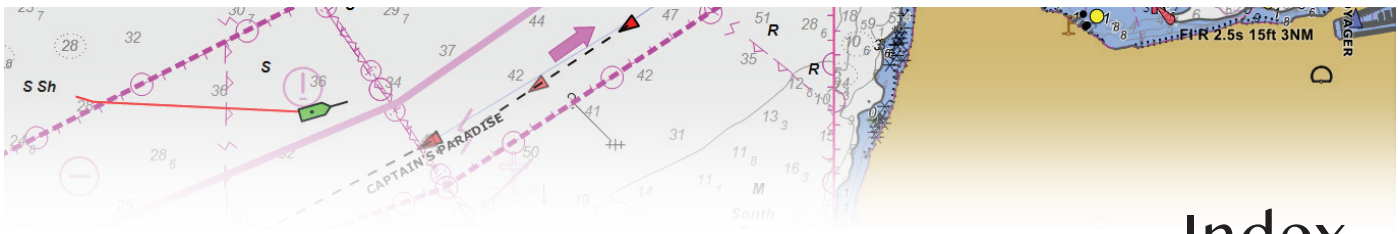
Figure A9-1. A hypothetical look at how we might one day read S-412 ship reports and other weather data on echart displays using a cursor pick. From Modern Marine Weather. This 2016 example used an RNC, but by the time S-100 is active we will be using all ENC.

Table A9-1 IHO S-100 Data Products*	
<i>IHO Products</i>	<i>Paraphrased, unofficial description</i>
S-101 Electronic Navigational Chart (ENC)	The nautical chart content and format updated from S-57 with associated presentation updated from S-52. Several of the products below make new overriding changes to both content and presentation.
S-102 Bathymetric Surface	Means a digital depth at every position, not just depth areas, contours, and soundings. Will include uncertainties. Important for precision inland navigation. In principle, combined with S-104, vessels will be able to read predicted live water depths for direct comparison with sounders. Potentially more dynamic safety contours.
S-104 Water level Information for Surface Navigation	Live values of water depths accounting for tides, winds, and pressure to allow for more precise navigation in harbors and channels. In the present system, tides do not enter into reported depths; in S-100 this will be different.
S-111 Surface Currents	Model forecasts of ocean and tidal currents including actual live measurements where available.
S-121 Maritime Limits and Boundaries	Interactive depiction on the chart of state, national, and international maritime limits, zones and boundaries, with potential for alarms and alerts when crossing.
S-122 Marine Protected Areas	Permanent, seasonal, and temporary boundaries can be clearly marked with live updates, with crossing alarms. Supplements S-101. Locations of the North Atlantic right whales is one.
S-123 Marine Radio Services	Which areas use which channels to contact which agencies can be found with a cursor pic on the chart, medical services, SAR, warnings. Also graphic display of things like Navtex, GMDSS, weather forecast zones, etc. Much of the Pub 117, Radio Aids to Navigation data.
S-124 Navigational Warnings	Missing buoys, incorrect lights, other hazards can show up on the chart in timely fashion, an improvement over scheduled radio announcements, or even slower published notices. Tied to S-201
S-125 Marine Navigational Services	Much like the Light List of data, plus Local and Broadcast Notices to Mariners. Tied to S-101.
S-126 Marine Physical Environment	Text descriptions of charted areas and waterways, much as we get from Coast Pilots and Sailing Directions will be available as cursor picks in S-100. Includes magvar. Tied to S-111 and others
S-127 Marine Traffic Management	Covers AMVER reports ("float plans"), scheduling changes, notices of VTS or pilotage requirements. Navy vessel notifications. Accident reports. Right whale sighting reports. Tied to S-211, 212, and 421.
S-128 Catalogue of Nautical Products	Just what it says: button click access to an updated list of all nation's maritime related products, print, digital, and online. Includes names and links to such things as tide and current tables, light lists, coast pilots, sailing directions, local inland navigation rules, including catalogs and sources of ENC.
S-129 Under Keel Clearance Management (UKCM)	Provides safe passage in shallow waters using sensors on the vessel and along the waterway. Takes into account live data for tide height, currents, ship motion (squat, heel), vessel speed, and the specific waypoints of the planned route to ensure safe depth below the keel. Tied to S-102, 104, 111 and others.

* IHO = International Hydrographic Organization

ISO = International Organization of Standardization

IALA = International Association of Lighthouse Authorities



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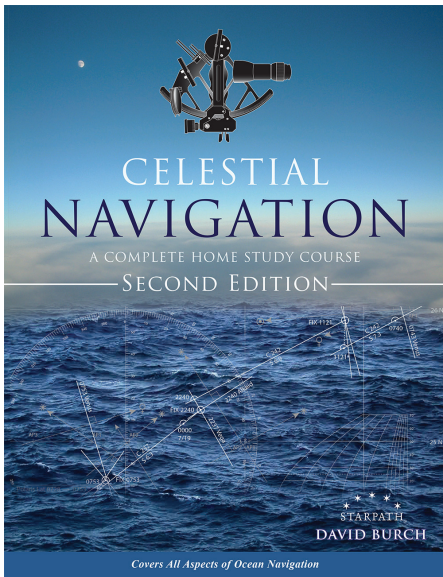
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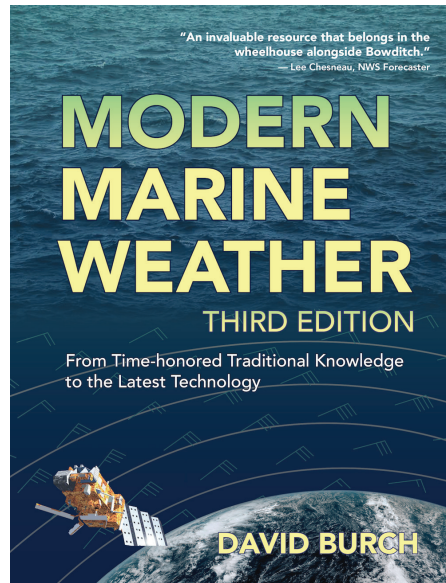
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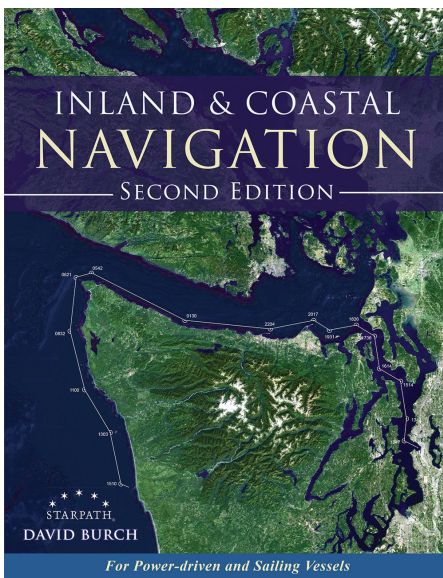
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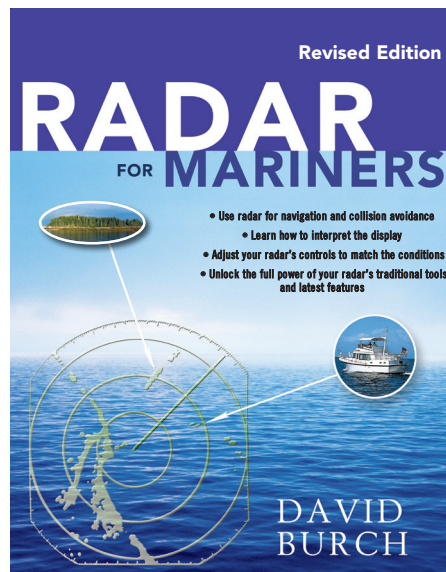
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There are two types of electronic charts: raster navigational charts (RNC) and electronic navigational charts (ENC). RNC are exact copies of paper charts and their use underway comes naturally to navigators accustomed to paper charts.

ENC (also called vector charts), on the other hand, include much more information than an RNC; they allow user-selected display options that enhance safety and efficiency, and they are easier to keep up to date. But they do not look like traditional charts, and they do not behave like traditional charts. Navigation with ENC is fundamentally different from navigation with paper charts or RNC.

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General

Mariners' Navigational Symbols



Positions, Distances, Directions, Compass

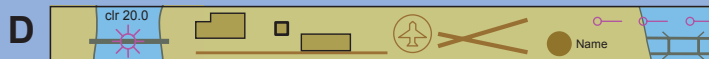


Topography

Natural Features



Cultural Features



Landmarks



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Tides, Currents



Depths



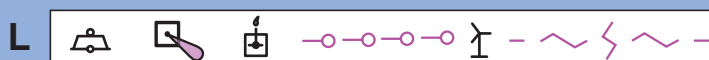
Nature of the Seabed



Rocks, Wrecks, Obstructions, Aquaculture



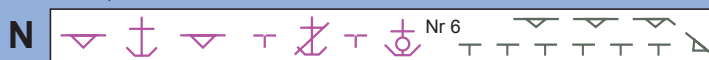
Offshore Installations



Tracks, Routes



Areas, Limits



Lights



Buoys, Beacons



Fog Signals



Radar, Radio, Sat Nav



Services



Navigation Aids and Services