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Article

NEXT GENERATION PAPER CHART

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Abstract

Throughout the ages, the navigation chart has adapted to meet the requirements of the mariner to ensure safety of navigation. The portrayal of chart information and its physical presentation on manuscript materials have also changed through innovation and human factors. In more recent times, the work of the International Hydrographic Organization (IHO) has established various standards to provide consistency to charting products to meet a truly global requirement. The transition from a manuscript to a digital electronic navigation world continues at a rapid pace. A new generation of users are more familiar and comfortable with electronic technology. One of the challenges facing the IHO is the future of the paper nautical chart. The ongoing need for paper charts is not the issue discussed in this paper. What is discussed, however, is the portrayal of chart data and the way in which paper charts may be generated in the future. The issue requires careful consideration to reduce Hydrographic Office (HO) production burdens, maintain relevance and meet the customers' expectations.

"In matters of style, swim with the current; in matters of principle, stand like a rock." Thomas Jefferson.

Résumé

Au cours des siècles, la carte de navigation a évolué pour répondre aux besoins du navigateur afin d'assurer la sécurité de la navigation. La visualisation des renseignements cartographiques et leur présentation physique sur les supports papier ont également changé du fait des innovations et des facteurs humains. Plus récemment, les travaux de l'Organisation hydrographique internationale (OHI) ont établi différentes normes pour rendre cohérents les produits cartographiques en vue de répondre à un besoin véritablement global. La transition de la navigation avec des documents papier au monde de la navigation électronique numérique se poursuit à un rythme soutenu. La nouvelle génération d'utilisateurs est plus familiarisée et plus à l'aise avec la technologie électronique. Un des défis auxquels l'OHI doit faire face est l'avenir de la carte marine papier. Le besoin continu de cartes papier n'est pas le sujet de cet article. Ce qui y est abordé, cependant, est la visualisation des données cartographiques et la façon dont les cartes papier pourront être produites à l'avenir. Cette question requiert un examen minutieux afin de diminuer les coûts de production des Services hydrographiques (SH), de préserver la pertinence et de répondre aux attentes des clients.

« Sur les questions de style, nage avec le courant, sur les questions de principe, soit solide comme un roc ». Thomas Jefferson.

Article

Resumen

A través de los tiempos, la carta de navegación se ha adaptado para satisfacer los requisitos del navegante con el fin de garantizar la seguridad de la navegación. La representación de información cartográfica y su presentación física en materiales manuscritos han cambiado también mediante la innovación y los factores humanos. En tiempos más recientes, el trabajo de la Organización Hidrográfica Internacional (OHI) ha consistido en establecer varias normas con el fin de proporcionar coherencia a los productos cartográficos para que satisfagan realmente un requisito global. La transición de un manuscrito a un mundo digital de navegación electrónica sigue avanzando a un ritmo rápido. Una nueva generación de usuarios se siente más familiarizada y cómoda con la tecnología electrónica. Uno de los desafíos a los que se enfrenta la OHI es el futuro de la carta náutica de papel. La necesidad continua de cartas de papel no es el tema que se trata en este artículo. Sin embargo, de lo que se trata, es de la representación de los datos de las cartas y del modo en el que podrán generarse las cartas de papel en el futuro. Este tema merece una cuidadosa consideración para reducir los gastos de producción del Servicio Hidrográfico (SH), mantener su pertinencia y satisfacer las expectativas de los usuarios.

"En cuestiones de estilo, nada con la corriente; en cuestiones de principio, mantente firme como una roca." Thomas Jefferson.

1. A TALE OF PORTRAYALS

From the very earliest recordings of sailing directions (periploi), to the 15th and 16th century portolans of the Venetians and Genoese, through to the current paper nautical charts, the depiction of chart detail has been an art form to serve a multitude of navigation purposes. The description and portrayal of real, fictitious, cosmological and embellished detail, was subject to the current school of thought, the imagination of the cartographers, the dominant cultural influences, the artists and the adventurers. Improvements in navigation methods and technology, the ages of discovery and enlightenment and more understanding of the real world combined with innovative charting practices and tools, have influenced the portrayal of information and the physical construction of navigation charts as supposition gradually retreated in the face of knowledge.

1.1 Paper Charts

The depiction of the current paper nautical chart is the result of some decades of cooperative standardisation effort championed by the IHO and described in the Regulations for International (INT) Charts and Chart Specifications of the IHO (known as S-4) [(IHB, 2013(a)]. This publication provides the framework for modern paper chart construction, colours, symbology and supporting textual information ***(Figure 1***). S-4 is supported by a number of technical specifications such as INT1 (Symbols, Abbreviations and Terms used on Charts), INT2 (Borders, Graduations, Grids and Linear Scales) and INT3 (Use of Symbols and Abbreviations).

Whilst the IHO has adopted Karte 1 (INT1) produced by the German Federal Maritime and Hydrographic Agency (BSH, 2011), a single, global specification for paper chart symbology has been elusive with many individual HOs developing their own version of INT1 (e.g. UKHO Chart 5011, NOAA U.S. Chart No. 1, Canada Chart No. 1, etc.). Fortunately, these documents basically follow the IHO INT1 content and structure, and include additional symbols and abbreviations that have been locally adopted within a national context. The key issue is that a mariner looking at charts produced by different HOs can interpret the charted features correctly through generally adopted portrayal standards.

The S-4 specification is maintained by the IHO's Chart Standardization and Paper Chart Working Group (CSPCWG). The CSPCWG has a set of defined objectives, operating procedures and guiding principles within its Terms of Reference (IHB, 2013(b)). Due to the diligence of the working group members over many years and the implementation of modern, advanced chart production software, S-4 and INT1 are mature specifications. Changes to S-4 are relatively minor and are implemented to support new charting requirements (e.g. Archipelagic Sea Lanes and various sensitive areas).

1.2. Electronic Charts

With the development of electronic charting in the late 1980s, the IHO soon realised that S-4 and its technical components (INT1 and INT2) would not

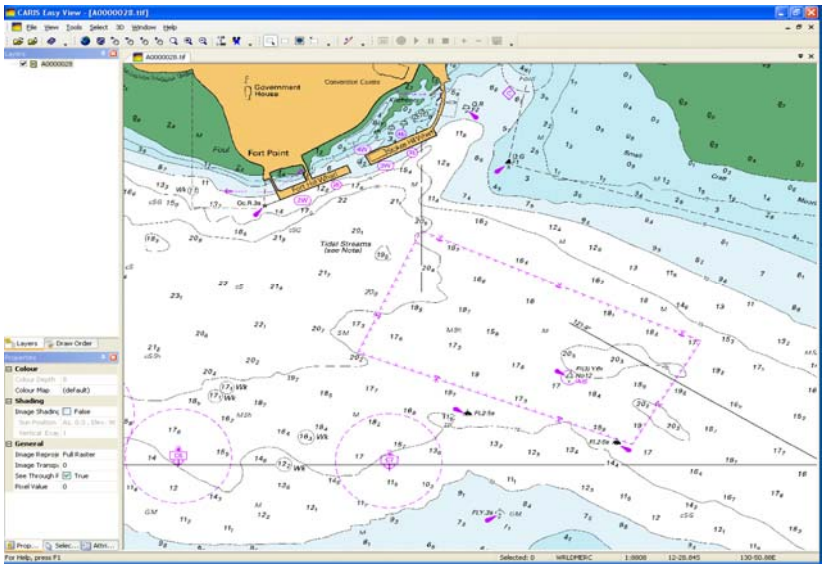

Figure 1. *A typical INT1 paper chart portrayal*
Extract of Chart Aus 28 Copyright Commonwealth of Australia (2008). Used with permission of the Australian Hydrographic Service.

satisfy computerised chart display for the Electronic Chart Display and Information System (ECDIS). For this reason, a new data portrayal specification needed to be developed. The Specifications for Chart Content and Display Aspects of ECDIS (S-52), describes the technical requirements for information display, symbology, environmental condition colour palettes, display screen configurations and various calibrations. S-52 includes Annex A - the Presentation Library (PL) (IHB, 2010(a)), and is maintained by the IHO's Digital Information Portrayal Working Group (DIPWG). The objective of this group is to maintain the IHO's specification for colours, symbols and display rules used to show Electronic Navigation Chart (ENC) information on ECDIS in a safe and ergonomic manner (***see Figure 2***). The membership of these working groups reflects wide international cooperation and this resulted in the general global acceptance of their resultant work.

Rather than being a paper-based portrayal specification such as INT1, the PL is provided in a machine-readable format so that electronic chart manufacturers can use it in their technology. The use of a standard set of symbology instructions should minimise the interpretation of symbology rules. This unfortunately is not always the case and a number of system manufacturers have either implemented the library with their own coding interpretations or developed their own libraries creating inconsistency issues with ENC data portrayal (Mohasseb, 2013). Through intensive stakeholder engagement, the IHO and ECDIS manufacturers continue to address and improve these interpretations with the aim of minimising encoding and portrayal variation and ambiguity.

2. THE CHALLENGE OF TWO CHART WORLDS

In the late 1980s when ECDIS was first conceptualised and the early systems were being prototyped, there was much speculation about the future of the paper chart. It was not uncommon to hear early statements that paper charts would not exist beyond 2000. It has hard to believe that after 20 years, the paper chart is still a preferred navigation tool by many mariners.

The continued preference for the paper chart in an ever-increasing electronic age is the result of a number of factors:

- Users are familiar with long-used, paper chart products. Often user's charts are marked up with historical routes or other important information;
- HOs have taken a long time to achieve a satisfactory level of ENC coverage. This has meant that HOs need to produce and maintain multiple products, often using multiple production systems that compound complex issues in production and maintenance work-

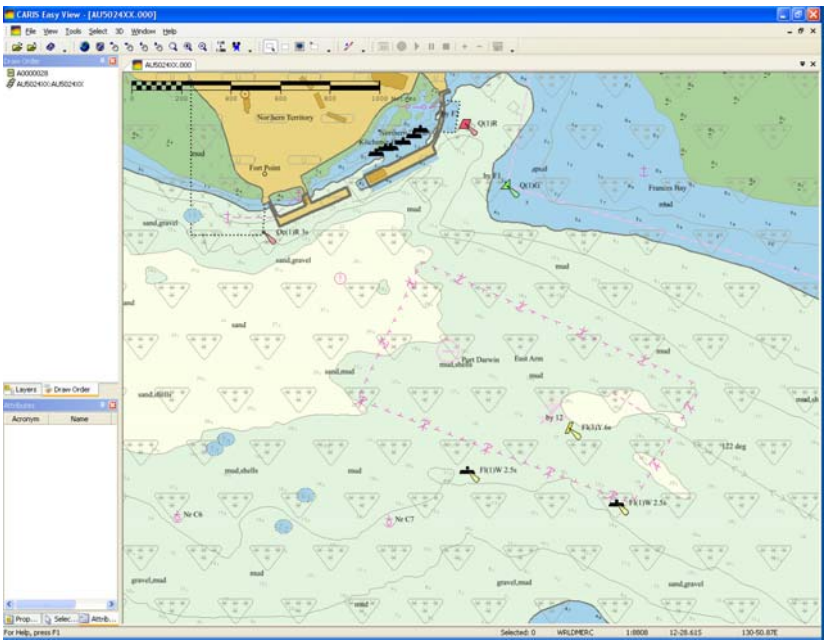

Figure 2. *S-52 portrayal of the same area depicted in Figure 1*
Extract of ENC Cell AU5XX24 Copyright Commonwealth of Australia (2008). Used with permission of the Australian Hydrographic Service.

flows, training, competency and technology and data refresh;

- The legislative process of the International Maritime Organization (IMO) has taken many years to mandate compulsory use of ECDIS resulting in a slower uptake of ECDIS technology and the necessary formal training of mariners to appreciate the technology and gain the necessary competencies;

- Official ENC data is used predominantly in type-approved ECDIS on large ships. A significant market segment doesn't require ECDIS technology (e.g. recreational users, fishing, small commercial vessels). For these users, official ENCs, non-official vector charts, raster charts and paper charts can all be used to meet their requirements;

- Many mariners are so familiar with the paper chart that a change in presentation, functionality and trust in technology can be difficult to embrace;

- The variety of cheaper electronic charting systems (ECS) product offerings, the varying levels of data quality and competitive business interests lead to a confused electronic chart market-place.

3. PAPER CHARTS AND SAFETY OF LIFE AT SEA (SOLAS) CONVENTION

The adoption at the IMO's Maritime Safety Committee 86th session (MSC86) of the amendments to SOLAS (IMO, 1974) regarding mandatory carriage for ECDIS equipment for ocean-going ships has an important impact on the future need for paper nautical charts (***see Figure 3***). Under the SOLAS revisions, the decision must be made either to fit vessels with dual or single ECDIS. Both must comply with the ECDIS performance standard and will require a back-up plan whose demands will vary between flag States. In the dual-ECDIS case, bridge staff will be able to significantly reduce (in some cases down to zero) their use of paper charts. In the single-ECDIS case, they will likely keep the paper chart as backup.

In Australia, the Australian Maritime Safety Authority (AMSA) released Marine Notice 7/2012 outlining Guidance of ECDIS for ships calling at Australian Ports. In accordance with IMO resolutions, AMSA considers the following will meet the back-up requirements for ECDIS (AMSA, 2012):

> "An independent, fully compliant second ECDIS unit, connected to ship's main and emergency power supply and connected to systems providing continuous position fixing capability; or

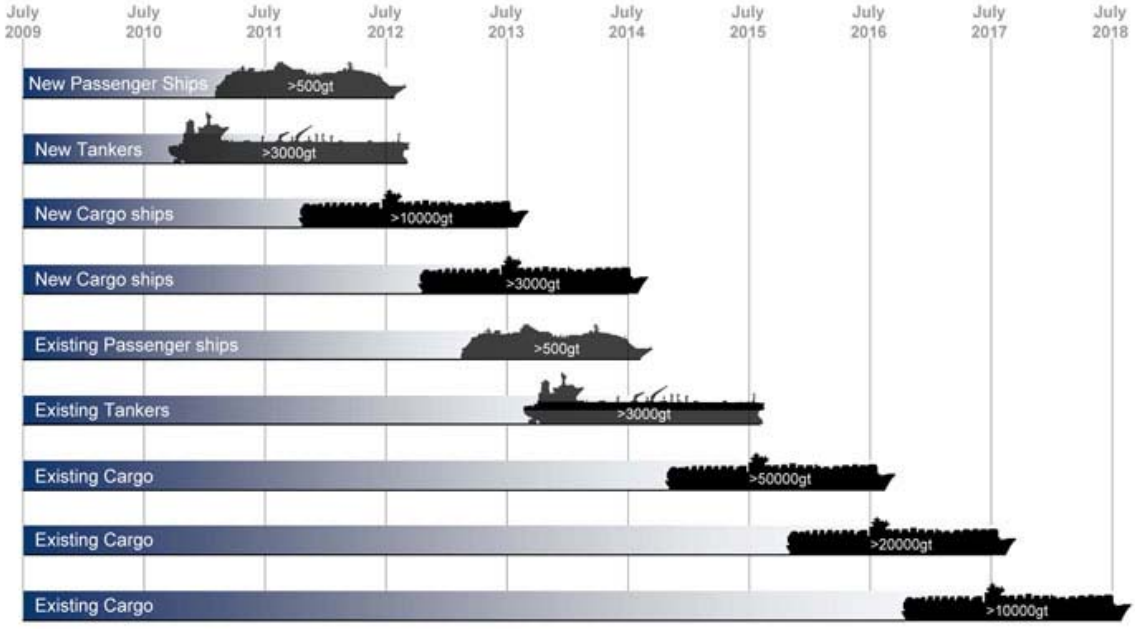

Figure 3. *ECDIS Compliance Dates for SOLAS (UKHO, 2013)*

> Adequate and up to date paper charts (including relevant large scale charts) necessary for the intended voyage."

The IHO describes a nautical chart in S-66 (IHB, 2010(b)) as:

> "Nautical charts are special purpose maps specifically designed to meet the requirements of marine navigation, showing amongst other things depths, nature of the seabed, elevations, configuration and characteristics of the coast, dangers, and aids to navigation. Nautical charts provide a graphical representation of relevant information to mariners for executing safe navigation. Nautical charts are available in analogue form as paper charts, or digitally as electronic charts."

A key component of nautical charting world-wide is standardisation of portrayal. This is emphasised in IMO SOLAS Chapter V Regulation 9, para. 3 (IMO, 1974):

> "ensure the greatest possible uniformity in charts and nautical publications and to take into account, whenever possible, relevant international resolutions and recommendations."

4. THE FUTURE OF PAPER CHARTS

Given the changes to the implementation of ECDIS, what is the future of the paper chart? In a 2011 article, the then UKHO CEO, Mike Robinson, expressed a view that paper charts would still be used for many years, even if they were only used in a "get me home" scenario. Despite a prediction that the sale of UKHO digital charts will exceed the sale of paper charts around 2018, there will still be a requirement to provide paper chart products to meet the varied usages and this will continue to be a production and maintenance issue for all HOs (Robinson, 2011).

In a world that is rapidly changing in technology *(in matters of style, swim with the current)*, along with a technically-savvy younger generation of users, it is time to look critically at what the paper chart represents and how it can be provided in different ways to a changing user-base without compromising navigational safety *(in matters of principle, stand like a rock)*.

4.1. Official ENC-Derived Paper Charts

If a paper nautical chart is to exist in the future, what should it look like? Is it practical or economically feasible for HOs to continue to publish paper chart products with different portrayals? Will this be confusing to the market place?

Irrespective of the ENC/paper chart equivalency, many HOs can produce INT1 paper charts fairly easily from an ENC source. The primary hydrographic software vendors all provide an INT1 paper chart output. Hence, there is no impediment to this capability continuing. However, as uptake of ENCs continue, can users be expected to put up with two different portrayals of the fundamental navigation data? An alternative approach is for HOs to publish paper charts with a predominantly S-52 (ENC) presentation and transition away from the traditional INT1 portrayal.

To assist in the adoption of electronic charts, the author believes that there is merit in considering the need to transition INT1 paper chart portrayal to a S-52 style portrayal. From a practical production aspect and debatably a customer perspective, it makes little sense to retain two separate product portrayals. In a small and limited customer market, the major HO production software vendors all support S-52 portrayal in their symbol libraries. All of the software systems are relatively mature and whilst they can support both INT1 and S-52, a transition to one portrayal specification can utilise the best of both specifications (e.g S-52 for colours and symbols, INT1 for graticules, marginalia, title blocks and text, etc.). As part of the IHO's S-100 family of product specifications, S-4 could/should be replaced by a new S-10x Product Specification: ENC-Derived Paper Chart.

4.2. User-generated Non-official paper charts

In the world of "apps", it should be possible for users to create and print their own ENC-derived charts. These charts can be plotted from the users own ECDIS or ECS technology where the ENC data has already been purchased. In this case the plot could be generated from the System ENC (SENC) or from the purchased ENC product. HOs will need to consider a pricing model for the ENC to include some level of cost recovery for user-sourced plotting. Chart agents and other value added resellers may also provide a plotting service.

5. S-100 PRODUCT SPECIFICATION FOR A ENC-DERIVED PAPER CHART

The traditional paper chart specifications are well described through S-4, INT1 and national variants. However, for the portrayal of ENC data on a paper format, it is recommended that a new S-10x product specification within S-100 be developed and managed either by a sub-group of one of the current IHO portrayal working groups or by a new technical working group. The purpose of the new product specification is to establish the minimum requirements for the portrayal of ENC data on a manuscript format whilst maintaining an appropriate level of maritime navigation safety. In developing such a specification, a number of issues need to be considered.

5.1 Data portrayal

S-52 specifications were designed for computer displays and not paper output. Hence, the ENC portrayal will not be aesthetic to the eye from a traditional paper chart user perspective. New symbols would need to be added to account for cartographic features such as a compass rose. With increased uptake of ENCs, users should be more familiar with ENC portrayal and so over time, portrayal interpretation issues should also reduce. To assist mariners with ENC portrayal, the UKHO has already issued the ECDIS version of INT1 - NP5012 Admiralty Guide to ENC Symbols used in ECDIS (UKHO, 2012).

5.2 Paper Plot Layout Elements

Certain “elements” need to be included in the plot layout to assist the mariner using the derived paper chart:

Graticule: Simplified latitude and longitude grid/ graticule

Scale bar: Simplified scale bar

Marginalia: Plot date, ENC EN/ER update status, Geographic extents, Producer agency ENC cell names used as the source, copyright and disclaimer statements.

Scale: The scale of the plot will be determined by various user-defined options – paper size, area coverage, etc. Some warning notation may be required if the inappropriate navigation usage or ENC scale is used for plotting. This may be similar to the “overscale” warning currently shown on ECDIS displays.

Available data: Where ENC coverage is not fully available, the paper plot may contain Raster Nautical Chart (RNC) content. The ENC content should always take precedence and some rules will be required to stop users from plotting RNC versions of the large portions of paper charts.

Data Content: similar to S-52, a minimum content of ENC data (e.g. Base) is required. The user should then have the ability to add extra content to the display.

Projection: At a certain scale, the output plot should be projected to aid the intended usage. For large scale situational awareness, a UTM projection may be best. For scales smaller than 1:75,000 where the chart may be used for course plotting and navigation, the plot should be output in a Mercator projection.

Colours: S-52 provides various colour palettes. For paper chart plots, the “bright-day” palette is likely to be the preferred colour palette.

Symbology: S-52 supports a simplified and traditional symbology palette. The user should be able to select the palette they are most familiar with. Some additional cartographic symbols will need to be developed.

Explanatory/Cautionary Notes: These notes are provided to assist the mariner to interpret potential navigational issues (e.g. chart omissions, dangers, etc.) or provide advice on where to find additional information (e.g. maritime boundaries). In the ENC, these notes are provided as text and/or picture files. Rather than plot the note content on the paper copy, the user could be given the option to print any relevant files separately.

6. PLOTTING SERVICES

HOs can continue to provide plotting services for official paper charts. In many cases, chart plotting is now undertaken using Print on Demand (POD) technology rather than offset lithographic printing. POD provides options for plotting charts as either traditional INT1 portrayal or ENC-derived portrayal at large formats. Most users do not have access to large A0 plotters. Hence, large format plotting, from an economic perspective will remain with the HO, any contractors or potentially chart agents or specialist service agencies. Most users will only have access to A3/A4 printers at most. The challenge for using A0 plotters on vessels is the maintenance of consumables (i.e. inks and paper) which can be bulky, messy, expensive and susceptible to temperature and humidity.

7. LEGAL ISSUES

If a paper chart is plotted from the official HO-published ENC or RNC data, or from an approved SENC, and it has been output using the minimum required portrayal settings, it should be deemed suitable as an official and legal product. Some criteria may need to be established to ensure that the plotted output is legible in terms of scale and colours (rather than a grayscale printout).

8. CONCLUSIONS

The increasing adoption of ENCs and the changes in mandatory carriage requirements for SOLAS vessels will result in mariners using a product that has significant portrayal and capability departures from the traditional INT1 paper chart and derived raster navigation products currently in the market place. Should users have to put up with multiple navigation chart portrayals or should there be only one product portrayal based predominantly on the ENC with additional portrayal functionality to provide "cartographic representations"?

The author does not question the ongoing need for paper charts - only how paper chart content should be portrayed to users. At all times the principle of safety of navigation cannot be compromised, but this doesn't preclude looking at opportunities to streamline the production or to simplify the provision of derived paper products from an official ENC source. There is no doubt that such considerations will spark debate. However, from experience of witnessing the battle that some HOs had with the ECS entrepreneurs of the early 1990s, the IHO needs to decide if this really is an issue and be on the front foot in defining an appropriate specification. Otherwise, industry will dictate the capability.

The opinions expressed in this paper are those of the author and do not necessarily reflect those of the Hydrographer of Australia or the Royal Australian Navy.

9. REFERENCES

AMSA, 2012. Guidance on ECDIS for ships calling at Australian ports, Marine Notice 7/2012, Australian Maritime Safety Authority.

BSH, 2011. *Karte 1 (INT1) Symbols, Abbreviations and Terms Used on Charts*, 7th Edition, German Federal Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie), 2011.

IHB, 2010(a). Specifications for Chart Content and Display Aspects of ECDIS (S-52) (including Annex A IHO Presentation Library for ECDIS (PL) Ed. 3.4, January 2008), Ed. 6.0, March 2010.

IHB, 2010(b). Facts about Electronic Charts and Carriage Requirements (S-66), Ed. 1.0.0, January 2010.

IHB, 2013(a). Regulations for International (INT) Charts and Chart Specifications of the IHO (S-4), Ed. 4.4.0, September 2013.

IHB, 2013(b). Chart Standardization and Paper Chart WG (CSPCWG) Terms of Reference, www.iho.int/mtg_docs/com_wg/TOR/CSPCWG_TOR.pdf, viewed 1/6/2013.

IMO, 1974. International Convention for the Safety of Life at Sea (SOLAS) as amended, London. http://www.imo.org/ourwork/facilitation/documents/solas%20v%20on%20safety%20of%20navigation.pdf viewed 20 Dec 2013.

Mohasseb, M. Anomalous ECDIS Operations, International Hydrographic Review, No. 9, May 2013, pp47-52.

Robinson, M. UKHO strives for worldwide leadership in hydrographic information, Hydro INTERNATIONAL, Vol. 15, No. 1, January/February 2011.

UKHO, 2012. Admiralty Guide to ENC Symbols used in ECDIS, NP5012, 1st Edition, 2012.

UKHO, 2013. http://www.ukho.gov.uk/Media/News/Pages/What_Mandation_Means.aspx viewed 18 Dec 2013.

10. BIOGRAPHY OF THE AUTHOR

Ian HALLS commenced work at the Australian Hydrographic Office (AHO) in 1979 as a trainee nautical cartographer and has been involved in the development of nautical data management and chart production systems since the mid-1980s. This period included serving several years on IHO ECDIS/S-57 technical committees. He is a past Director of HSA Systems Pty Ltd and resumed working at the AHO in 2009 after 15 years in private industry undertaking systems engineering, hydrographic surveying and charting activities.

He is currently managing the military hydrographic data, products and services section of the AHO. Ian is also working with a small dedicated team to sustain the Digital Hydrographic Database solution developed in early 2000. This involves the

software, hardware and ICT refresh of the various source data receipt, validated data, production, distribution, and workflow sub-systems using an enterprise architecture approach.
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CHRIS15-5.1A

15th CHRIS MEETING
IHB, Monaco, 10-13 June 2003

PRINTED ENCs
(June 2003)

United States (NOAA)

1. Summary

Executive summary:	Hydrographic offices that make (ENCs) would like to use one production system for all their products. Unfortunately, it is difficult to make traditional paper charts from S-57 databases without substantial additional attribution. Instead, it is proposed that a paper chart be defined that can be made directly from an ENC.
Actions to be taken:	The CHRIS committee is invited to start a work item to develop an IHO standard for a printed ENC that meets chart carriage regulations.
Related documents:	None

2. Introduction / Scope

Hydrographic offices that make Electronic Navigational Charts (ENCs) would like to use one production system and database for all their products: paper charts, raster charts, ENCs, etc. Such a consolidated production system is desirable to keep cost and manpower requirements lower, and to keep all products synchronized.

Reaching this goal is difficult because it is hard to produce a traditional paper chart from an S-57 database. Examples of problems include the placement of text; features that coincide; and items that are on paper charts but not in the S-57 database. Solutions emerging from companies making ENC production systems involve complicated additional software, and/or substantial extra attribution and its maintenance by the hydrographic offices.

To improve this situation, it is proposed that the paper chart be redesigned, or a new paper chart be created and standards written. This "printed ENC" would be designed to be manufacturable directly from an ENC while still providing a regulation-compliant printed product. Thus hydrographic offices would be working the problem of making a single production system both from the system end and the from product end.

3. Analysis/Discussion.

It has been noted that companies making ENC production systems are also trying to make paper charts from those systems. In general, they are following 2 approaches:

- adding additional attributes to the S-57 database that deal with depicting the data for a paper product – additional data that would have to be collected and maintained by a hydrographic office; and/or

- developing additional software using rules bases or artificial intelligence to make depiction decisions – software that would add expense and complexity, and which would be unique to each manufacturer's system.

Both of these approaches substitute a new problem rather than solving the original one.

What makes the problem difficult is our "requirement" to recreate paper and raster charts exactly as they exist today. The problem will be simplified if we are willing to change the charts into something closer to what can be readily made by existing ENC production systems. Such an approach would minimize additional data collection and expensive, proprietary software. Further important gains could be made if paper and raster products were made directly from ENCs rather than the underlying database. This simple but powerful idea has many beneficial consequences for hydrographic offices and for mariners.

The subject is within the scope of IHO objectives. It is not within the scope of a current IHO work program item. Adequate standards do not exist. The benefits justify the proposed action.

4. Benefits.

The benefits of redesigning the paper charts so they could be made directly from ENCs are significant. They would change the business of nautical charting in a fundamental way, and would immeasurably improve the service provided to mariners.

A. The amount of work required of hydrographic offices would decrease, and some of their activities would no longer be needed.
    1. Hydrographic offices could focus on gathering and quality controlling data, and updating their ENC production system database.
    2. Cartography as an art, and the labor it uses, would be minimized. The paper chart would be redesigned to eliminate many cartographic depiction decisions, and the remainder would be rules and conventions in the "ENC to paper" software.
    3. Maintenance for a hydrographic office's suite of products would be reduced to maintenance of the S-57 database only.
    4. The gathering and maintenance of additional attributes dealing with data depiction would be eliminated or substantially reduced.
    5. The goal of a single production system for all products would be achieved, regardless of which manufacturer's system was used. The ENC, in effect, becomes a neutral interface between a hydrographic office's S-57 database, and the manufacture of products.
    6. Hydrographic offices having trouble producing even paper charts would be able to offer a full range of products immediately upon completion of a set of ENCs.

B. Mariners would receive a significantly improved level of service.
    1. Mariners (or their agents) could produce paper or raster charts, ECDIS backup, updates or patches, and printed voyage planning documents directly from their regularly updated ENC. This would improve the timeliness and breadth of information distribution.

2. All of a mariner's chart products would be synchronized. ENC updates would be distributed and all other products could be immediately made or remade.
3. With such an increased value to mariners, and reduced cost for those products they make themselves, uptake of ENCs should increase.
4. Working from the standardized ENCs would provide this same level of service worldwide. Also, the resulting products should be more standard worldwide.
5. Clarity would be provided to mariners as to what is an official or acceptable product. It would be an ENC or any product produced from an official ENC that met the standards for that derived product.

C. ENC system manufacturers would also gain.
   1. System complexity would be reduced. By making ENCs the source of all other products, each manufacturer would be relieved of the need for tailoring his database and software to produce paper charts, and the need to customize that software for each nation's preferred depiction. Manufacturers may choose to make "ENC to paper" software or not.
   2. Since ENCs would now be the product from hydrographic offices, demand for production systems should be stronger.

5. Working Groups.

This task would be appropriate for either CSWG or for TSMAD. CSWG would be appropriate because a new or revised paper chart would be designed. TSMAD would be appropriate because there would likely be changes needed to S-57 and the ENC Product Specification.

Alternatively, a new committee with this as its sole task could be established.

6. Other relevant information.

None provided.

7. Priority.

High.

Hydrographic offices are actively collecting S-57 data and making ENCs. Some data collection decisions have been made that are incompatible with making a paper chart – either from the ENC or from the underlying S-57 data. It is important to establish sufficient information about the "printed ENC" to minimize the amount of data recollection that might be needed.

Additionally, ENC production system developers are making commitments and spending development time and money that could be eliminated if this proposal is successful.

8. Target completion date.

Task the appropriate CHRIS committee working group – June 13, 2003.
Finish the "printed ENC" standard – September, 2004.

9. Action Required.

The CHRIS committee is invited to task the appropriate working group to develop a standard for a carriage regulation-compliant, paper/raster chart that can be made directly from an official ENC. The working group should be advised that they have license to recommend substantial changes in the paper chart in order to make it manufacturable from an ENC. Further, the working group should be advised to minimize or eliminate the need for hydrographic offices to collect additional data for this "printed ENC", and to minimize the changes necessary to S-57 and the ENC Product Specification.

Printed ENC: An Analysis of Impediments to Printing Paper Charts Directly from IHO-Compliant ENCs

Contract 50DDNC090025 T005

Final Report
February 8, 2007

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1 Introduction

The purpose of this project was to identify all issues regarding the production of a paper chart directly from Electronic Navigation Charts (ENC). The aim established in the document "Instructions for Analysis of a 'Printed ENC'" was to "identify all the impediments, shortcomings, impossibilities, and problems" with making paper charts solely from ENC data. The "Printed ENC" concept requires that the paper chart be produced only from the data held within an ENC, without any user input or manual intervention between producing the ENC data and producing the paper chart.

The analysis was based on the following assumptions provided by the NOAA Office of Coast Survey:

- Automated production of printed ENCs is required, i.e., there would be no user input to the process.
- ENCs comply with IHO S-57 and the ENC Product Specification, and NOAA ENCs (as posted at http://nauticalcharts.noaa.gov/MCD/enc/index.htm) are the correct interpretation of S-57.
- Rules, algorithms, and practices that are stated or implied in IHO S-52 are assumed to be part of ENCs and may also be used.
- The desired paper chart symbol set is the international set of chart symbols, not NOAA's national symbol set.
- A "printed ENC" would be printed from a standard color plotter.
- Rules for paper chart design are those of NOAA (except for symbology). While it is expected that these rules could change to accommodate printed ENCs, existing rules were used in the analysis.

The project was organized as series of tasks, each examining the problem from a different viewpoint. These tasks were carried out in a systematic and thorough manner to provide as complete a picture as possible of the issues associated with producing a paper chart directly from an ENC.

2 Summary of Tasks

Following is a description and summary of the focus of each task. Full details of the findings of each task are included in the Appendices.

In Task 1 (Appendix A) we described an existing system for producing paper charts from ENC data. For this task the LAMPS2 ENC Chart production software from Laser Scan, Inc. was chosen because of prior experience and knowledge of this system. This system is fairly typical of a number of commercially available systems capable of producing paper charts from ENC data. The automated elements of the process entail: a) importing

the ENC data into a database, and b) executing a series of processes, which include complex rules for representation and data manipulation on the data. The output of these steps is the chart framework with ENC data represented using standard hydrographic symbology rules. Manual intervention is then required to complete the chart by creating, editing, and deleting text, rotating flares, altering light sector arcs, and creating additional objects such as compass roses, notes, and tables.

Task 2 (Appendix B) involved a detailed examination of the specifications used to produce ENC data, including the S-57 specification, the ENC Product Specification, and the S-52 specification used by the Electronic Chart Display Information System (ECDIS) to display ENC data on a computer. Each ENC object class was examined, and any issues related to displaying this object class were noted. In addition, by looking at the overall specification for an ENC, this task also examined the structural and organizational implications of the data for issues that would affect the production of paper charts directly from an ENC dataset.

In Task 3 (Appendix C) we examined a number of digital representations of paper charts to identify the characteristics of an existing paper chart that: a) could not be represented correctly, or b) could potentially cause problems when creating a paper chart directly from ENC data. Specific examples of areas or situations that would cause problems have been included to illustrate the issues. We examined a number of printed paper charts and compared those to the captured ENC data and the representation of the ENC using various ENC viewers. Analysis of the charts and the equivalent ENC highlighted a number of issues related specifically to the capture specifications used to produce compliant ENC data. The analysis also indicated the limitations of S-52 for cartographic representation.

In Task 4 (Appendix D) we reviewed a number of documents written over the past several years that deal with the production of paper charts from digital hydrographic data. Based on that review, it can be seen that many of the problems of generating paper charts from digital data are well known, but no comprehensive solution has been developed to date.

In Task 5 (Appendix E) we reported on input from two software companies that have experience in producing paper charts from digital hydrographic data. ESRI has been working on the electronic Print-On-Demand (ePODS) initiative for the National Geospatial-Intelligence Agency (NGA) in the USA, examining the production of paper charts and other mission-specific paper products directly from a Digital Nautical Chart (DNC) database. Their findings highlight the importance of the underlying data quality on products generated and the significant impact of collection rules on the production of paper charts. HydroService produces the dKart software and has considerable experience at a number of national hydrographic offices in producing paper charts from an ENC database.

To provide a graphical representation of the issues discussed in the Tasks 1-5, examples of ENC data were displayed in various ENC viewers. Appendix F includes examples of the outputs and summarizes the issues found.

3 Summary of Issues

Following is a summary of the issues identified in Tasks 1-5. It should be reiterated that the criterion used to identify issues was a fully IHO-compliant NOAA paper chart produced directly (with no user input or other data) from an ENC as they are distributed by national hydrographic offices. Some suggestions, solutions, or options to consider are noted where possible. The issues may have been identified in one or more of the tasks. The Appendix for each task contains additional information regarding each deficiency, how it was identified, what impact it has, and in some cases, how it could be overcome.

The issues below have been grouped into two themes: 1) Chart Layout and Structure and 2) Chart Objects. Chart Layout and Structure refers to the information that defines or is included on the chart (e.g., extents, styles, marginalia, furniture, and data) but is not related to specific real-world objects in the data. It also includes issues related to the organization and structure of ENC datasets and paper charts such as scale, insets, and overlaps. The Chart Objects theme highlights issues related specifically to displaying real-world objects and associated information that is normally shown on a paper chart. *Note: the issues are not listed in order of priority or impact.*

Deficiency	***Description***	***Solution/Options***
1) Chart Layout and Structure		
Graticule, including numbering, labeling, etc., not included in an ENC	There is a need to generate a graticule for the paper chart. A paper chart has a complex graticule that varies depending on scale and location of the chart. The graticule is numbered and has subdivisions and ticks that have to be created to provide the necessary reference information to enable the chart to be used for positioning and navigation.	There are various options that could be considered for producing the graticule and associated information, such as: - Include the graticule in the ENC data using cartographic objects. - Provide the necessary parameters to allow the graticule to be created in a separate file. - Provide the necessary parameters in the ENC data or in an associated file for use by the plotting software to generate the graticule dynamically.

Deficiency	***Description***	***Solution/Options***
Projection information not included in data	The coordinate system used for ENC is WGS 84. Paper charts should be produced in a projection such as Mercator, but each chart typically has its own specific projection parameters.	The projection parameters needed to print the chart could either be included in the ENC dataset or in a file associated with the ENC. Alternatively, the knowledge of which projection to use when printing a specific ENC could be built into the plotting system, or a set of standard defaults could be adopted by the IHO.
Border, including marginalia and other information outside the neatline of the chart	Need to generate a border around the chart, which may be irregular in shape. There is also a significant amount of information shown outside the neatline of the chart (e.g., chart numbers, scale bars, and indications of adjoining charts) that needs to be included.	Alternatives include: - Generate border and information, and include in the ENC data as cartographic objects. - Supply parameters in a separate file associated with the ENC data. - Supply parameters inside the ENC data. - Do not use a border. - Sequentially place marginalia in an enlarged margin. - Calculate the border parameters from the ENC data.
Tidal stream table	Usually need to generate tidal stream table that shows tidal information. The entries in the table refer to specific named or numbered locations on the chart.	Position the table outside chart area to avoid overprinting any other information. The data could be obtained from fully populated TS_PAD objects, if collected.
Source diagram	Usually need to generate source diagram showing survey dates and locations. This is a very generalized view of the chart with survey area and information marked on it.	- The background information could be created from a very generalized view of the data. - Use an auto-generated thumbnail copy of the plotted ENC Base Display for the background. - The diagram is usually placed in an area of the chart such as a land area where there is no navigation information; however, it could be positioned outside the chart area. The meta objects M_QUAL/M_SREL could be used to provide information to automatically generate the survey information shown on the diagram.

Deficiency	*Description*	*Solution/Options*
Dredged depths table and other tables shown on a chart	Tables of dredged depths, clearances, tides, conversions, etc., sometimes need to be shown.	These can usually be generated from the information in the ENC data. Their location on the paper chart needs to be defined, possibly in an external file or in the ENC data, or they could be positioned outside the chart area.
Compass roses	The compass rose needs to be generated and shown on the face of the chart, i.e., over existing data. A number of compass roses of varying sizes and styles can be included on a single chart.	- The compass rose needs to be positioned so that it does not obscure other chart data. There are different sizes and styles of compass rose, so some means of including this information would be needed, either in the ENC data or in additional information. The basic magnetic information can be stored in the MAGVAR object. - Simply allow overprinting, or overprint with partial masking.
Chart notes	Various notes are shown on the chart, usually on the land or in areas where there is no other data. The notes information is either supplied as separate text files or is included in the data in the INFORM attribute.	- Notes could be positioned in a default area outside the chart area that does not interfere with the chart itself. - The text files could be modified to contain positioning and style (e.g., font, size) information. - Such styling could be discontinued.
ENC cell limits	ENC cells do not follow current paper chart limits. This is usually either to reduce the size of the resultant ENC (there is a 5Mb limit) or because a larger scale chart is available for part of the chart. Data in ENC cells cannot overlap, whereas adjacent paper charts usually have some area of overlap between them.	To create a current paper chart may require the combination and plotting together of a number of ENCs. Options include: - Re-scheme ENCs so that the ENC cells match the paper chart boundaries. This option conflicts with the current restriction on overlapping data. - Create a catalogue that defines the ENCs needed for a particular chart. The potting software could access the catalogue. - Accept paper charts that follow the current ENC cell structures. - Depict all cells needed to cover a chart area and crop a subarea.

Deficiency	***Description***	***Solution/Options***
ENC scale bands	The ENC specification requires than an area of data appear only once in a particular usage band. Within a single ENC there may be data from different scale charts (e.g., insets on a chart). This means that if the ENC is plotted directly, some areas of data that will be too dense. There may also be "holes" in the coverage of an ENC where available larger scale charts are in the same ENC usage band.	- It may be possible to use the SCAMIN value (or another new attribute specifically designed for this purpose) to "thin" data for plotting at a smaller than source scale, while still plotting the larger scale data at its compilation scale on another part of the chart. - An alternative would be to leave a hole in the plot where there is a different M_CSCL object, and plot the larger scale data outside the main chart. - Accept different data densities within a printed ENC. - Accept that not all paper charts within an existing suite may be producible.
Inter chart information	There is information shown on the chart that refers to other charts, e.g., indications of adjoining charts, availability of charts at larger scales, or continuations of representations of objects such as light sectors that appear on more than one chart.	- A catalogue of ENC charts accessible by the printing software could provide some of the information. - Alternatively, do not include such information on printed ENCs. - A remaining problem, however, would be how to handle the continuation of object representations across charts.
Charts in feet	Currently paper charts from NOAA are printed with depth values in feet. However, the ENC data is in meters.	- Depth values would need to be converted using a standard mechanism. However, depth information contained in text attributes poses a problem. - NOAA could switch to meters for printed ENCs. This would permit the paper charts and ENCs to be in the same units.

Deficiency	*Description*	*Solution/Options*
2) Chart Objects		
Place name text	This is a generic heading for all objects that require the display of text to describe the object or provide the chart user with information about the object. It could be subdivided into text associated with points, lines, and areas or with specific classes. However, the general problem is that text must not overprint or obscure other more important information. The text must be legible and clearly associated with the related object.	This issue requires either a generic solution that will work for all text, such as including cartographic text objects in the ENC, or a case-by-case solution by object type. Options include: - Create cartographic text objects in the ENC data that have a reference (relationship) to the object referred to by the text. The text object would contain information about text font, size, orientation, and the text string to be displayed. (Note: Such objects might also improve the display of ENC text in an ECDIS where overprinting is also a problem. - Establish a minimal text "base" for display, and assume that text can be printed so it does not interfere with other information. - Permit some overprinting, but adopt advanced graphics techniques to lessen the impact on legibility. Additional changes that would complement these options include using other mechanisms for displaying information (e.g., improved symbology, linestyles and area fills) and moving information off of the chart (e.g., navaid information) as much as possible to reduce the requirement to display text on the chart.

Deficiency	***Description***	***Solution/Options***
Areas with complex boundary linestyles and text inside the area (e.g., military practice area)	It is difficult to automatically plot text/symbols shown inside areas so that they do not interfere with other objects.	Use a variety of area fill patterns and colors rather than text to indicate different areas. Experiment with different colors of text and overprinting text in a controlled order. Determine which areas need to be differentiated and the information that needs to be displayed.
Navigation objects text and display	Various components of information for navigation objects (e.g., lights, buoys, beacons) are shown in text or symbols.	Need to clearly identify the information required to meet the purpose of the chart. Options include: -Expand the use of colored symbols (as is done in S-52), colored areas, or lines to show light sectors. -Use minimal labeling with identifier on the chart, and show full information in a "list of lights" that is printed along with the chart.
Light flares	LIGHTS objects are shown with "flare" symbols that are usually rotated to avoid conflict with other objects	- Use different, symmetrical symbol. Use lighter color so that it doesn't interfere as much with other information. - Discontinue rotating symbols.
Traffic separate schemes	These require complex representations that are composed of multiple objects such as arrow symbols.	- There is no clear solution to automatically orienting arrows and placing them in the correct position within the area objects. One alternative is to use a cartographic object or a point object that could be formed into a TSS collection object. - Fill with sparse but oriented arrows.

Deficiency	***Description***	***Solution/Options***
Selective text display	In most cases, the text displayed for a particular object needs to be controlled. In some circumstances it is necessary to display abbreviated text or alter the text associated with a particular object in some way (including not displaying it), even though text for other objects of the same class may be displayed differently. For example, many objects of the same class may be close to each other, so only text from a single object should be displayed to refer to all of the objects.	Usually the OBJNAM or INFORM field is used to contain text that is displayed on the chart. A possible approach would be to create another attribute on an object that contains only the text to be displayed on a paper chart.
Selective text mask	Selective masking is required around text and symbols to improve clarity. For instance, magenta text may mask out a magenta line but not a black line, while black text may mask out black linework.	If masking is to be performed at the plotting stage, clear rules need to be developed to specify the circumstances under which a mask should be created and the size of the mask.
Text with leader lines	To enhance clarity, text is sometimes offset from the object to which it refers, and a leader line (line with arrow heads) is created that points from the text to the associated object. This usually affects small area objects or objects in congested areas.	It would be difficult to automate this capability in a generic mechanism (i.e., without the use of a run-time text placement engine). It would be necessary to limit the amount of text or use cartographic objects. Another option applicable to small areas is to reduce text size to minimize the requirement to offset text.
Areas with more than one purpose	Coincident areas with more than one purpose are indicated by additional text and/or symbolized boundary lines.	Use different colors or symbol fills to reduce the need for complex boundary line representations or additional text.

Deficiency	*Description*	*Solution/Options*
Objects with no representation in INT 1	There are numerous objects for which adequate representation is not defined in the INT 1 specification.	Define an appropriate symbol, linestyle, or area representation based on the object's attributes, possibly utilizing S-52 representation.
Complex representations	The complexity of some paper chart representations (e.g., rocky coastlines, cliff, etc.) causes an unclear depiction in congested areas.	Define a set of simpler representations that provide greater clarity in congested areas.

4 Additional Considerations

The issues identified above in the categories of Chart Layout and Structure and Chart Object are extensive. It may be useful to test the feasibility of resolving these issues by identifying a specific purpose for a "printed ENC" and addressing the subset of issues specifically associated with that purpose. The production of a current paper chart would require the most significant effort, while producing an ECDIS backup or other chart with a more limited purpose would narrow the effort.

For such a feasibility test, we recommend augmenting the assumptions established for this study to include the following:

- It should be possible to produce the same paper chart from different systems. The ability to create a plot file should not be system-dependent.
- The ENC data is captured to the equivalent specification of a paper chart in terms of scale and density of content.
- All the information must be explicitly defined in the ENC and not require further processing to calculate (e.g., points in areas).
- Systems can make complex decisions about representations from multiple attributes.
- Systems can access all the properties of an object, including spatial, attribute, and relationship information.
- Systems can produce a full range of symbols, linestyles, and area fills
- Systems can control the drawing order of specific objects down to the spatial entity level.

The features and the implication for creating these different products are described below.

4.1 Produce a Current Paper Chart

Producing a current paper chart from existing ENC data would require resolution of the following issues:

- Current paper charts include a large amount of information in text format, so a generic solution would need to enable the selective placement of text.
- ENC data collection so far has not taken into account the need to produce a cartographic product. There is no ability to selectively display text for some objects in order to provide clarity while omitting text for other objects where the text provides redundant information.
- The full paper chart content has not been collected in current ENCs. For example, very little land detail is captured.
- Currently ENCs do not match the paper charts limit. For instance, a paper chart could be composed of 4 or more ENC datasets. Thus, to produce a current paper chart, the plotting system would need to have prior knowledge of the ENCs required for a particular chart and then be able to combine them intelligently.
- Any system would require sophisticated chart layout facilities that could handle full charts, insets, irregular shaped charts, graticule options, and other INT 2 specifications.
- A means of predefining the location of notes and other chart furniture would be needed.

4.2 Produce a Basic "New" Paper Chart or ECDIS Backup

A simplified printed backup version of ENC data could provide adequate chart information to meet navigation purposes if the ECDIS were not operational or to meet other needs for basic data. Significant input from potential users would be required to ensure that the simplifications were clearly defined and "fit for use."

A simplified backup chart printed from ENC data would require resolution of the following issues:

- A substantial redesign would be required to replace text labels with some other indicator, for example, color indicators for point symbols or fill patterns for area features.
- Very limited text from the ENC would be displayed on the chart, e.g., place names, sea areas, and points of interest.
- Additional data could be included at the bottom of the chart, e.g., list of lights, wrecks, and tables of dredged areas.
- No change would be required to the ENC cell scheme, as these paper charts would simply reflect the area of the ENC.
- A minimal border and chart framework, including graticule, would need to be plotted in a projection.
- Additional metadata may need to be added to ENC to store information about the chart framework.

- The plotting software could generate the actual framework. Parameters could be supplied with the ENC data as an additional file or calculated from the ENC data.
- Notes could be automatically generated and placed in default locations outside of the M_COVR area. Locations may need to be defined either in the data or in a parameter file.
- More use could be made of multi-color plotting and area fill patterns since these printed ENCs would not be produced using 4 color printing separations.

4.3 Other Options

Another alternative would be to create mission-specific charts. These charts would contain significantly less information than is shown on a current paper chart, so there would be fewer problems displaying all the information clearly. Defining the purpose of the particular paper chart and the information required would be a critical step. Examples of mission-specific charts might include:

- Charts primarily for collision avoidance that show major obstacles based on certain criteria that could be customized, e.g., size of vessel.
- Coastal charts used just for offshore navigation.
- Leisure charts that just show information relevant to small boats.
- Non-navigational charts, i.e., charts from which all the navigational information has removed.
- Simplified charts used for voyage planning.

5 Conclusions

This analysis showed that most of the geographic information required for a paper chart is present in an ENC dataset and can be represented in a suitable manner. In addition, text information currently displayed on a paper chart is present in the ENC data, sometimes in multiple objects or encoded in some form. However, ENC datasets do not contain information regarding the cartographic placement of objects or chart-specific information such as borders, graticules, compass roses, tide-tables, and other non-geographic information required to produce a current paper chart.

The analysis also highlighted the obstacles to the automatic creation of a paper chart caused by the ENC cell structure. Charts produced directly from ENC data may have “holes” with no data in those areas where the ENC data was collected using the largest scale data for the area. Additional problems in representation are caused by the presence of data of different scales in the same ENC dataset.

This study identified the range of complex issues associated with producing a paper chart directly from ENC data. The amount of cartographic input in a traditional paper chart is high. They have evolved over centuries and are designed to meet multiple purposes.

They were also designed to be compiled and updated manually. Finding generic solutions to all the issues identified in order to duplicate that result will be difficult without significant changes to the ENC specification, the paper chart specification, or both.

Appendix A - Task 1: Analysis of Existing Chart Production System

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1 Introduction

The following sections list the features implemented in the Laser Scan LAMPS2 chart production system, which was designed to produce paper charts from ENC data with minimal manual intervention. The Laser Scan chart production system is based on the ENC production system currently in use in the NOAA Marine Charts Division.

The Laser Scan system combined external text files specifying the information required for a series of charts and information required for each chart with a variety of processes within the cartographic editing environment to provide the paper chart production functionality. The prototype system was developed to ingest ENC data and through the use of external files, rule-based representation routines, geoprocessing functionality, and manual effort, produce complete paper charts. This appendix documents all the items, parameters, and data that were:

- Included in separate non-ENC files and additional databases
- Manually entered at paper chart production time
- Externally calculated
- Omitted

Other assumptions and calculations needed to make a paper chart are also documented, as well as shortcomings with the resultant paper chart.

Figure 1 shows the basic process of creating a paper chart from ENC data using LAMPS2.

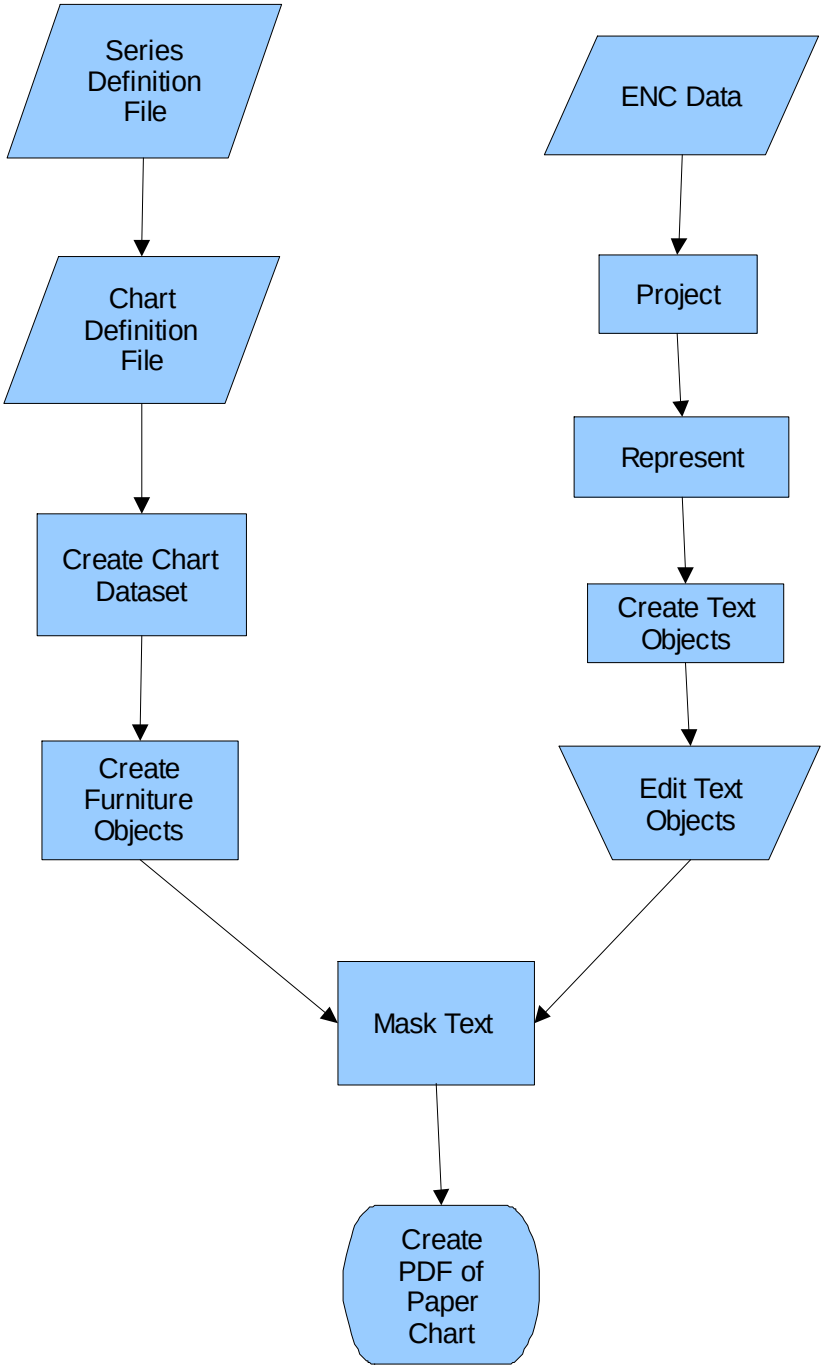


Figure 1: LAMPS2 ENC to Paper Chart Process

2 Series Definition File - Per Series Items

The following specifications are prepared for a complete series of charts to be produced using the Laser Scan LAMPS2 chart production system. The specifications define such items as the symbol library to use and global parameters that can be overwritten by individual charts but can be used as defaults. The file consists of a number of parameters, each with an appropriate defined value.

Parameter	***Description***	***What it does***	***Expected Value***
chart_flavor	The "flavor" of the chart being produced. This can either be an IHO standard or a national standard.	Determines a suitable set of defaults for the layout and style of the chart. In the prototype system only the IHO standard was implemented.	IHO Chart
neatline_follows_border	The outer border of the chart may be a different shape from the neatline of the chart that contains the actual data.	Determines if the neatline of the chart is the same as the border of the chart.	True/False
border_follows_border	The coordinates of the outer border for the chart need to be specified.	If this parameter is True then the border line follows the coordinates specified. If False, the border will follow the neatline offset by a specified amount.	True/False
neatline_in_projection	The neatline of the chart can either be drawn as a straight line between specified coordinates or generated in the projection of the chart.	If this is True then the neatline is drawn between coordinates in the projection of the chart.	True/False

Parameter	*Description*	*What it does*	*Expected Value*
grid_length	A chart can include a UTM grid.	Specifies the length of the grid ticks in millimeters on the chart.	4.0
border_offset	The border of the chart should be offset from the neatline of the chart.	Specifies the distance the border of the chart is offset from the neatline in millimeters on the chart.	12.0
grad1_offset	Ticks of varying lengths divide the graticule.	Determines the size of the smallest tick.	0.8
grad2_offset		Determines the size of the intermediate tick if there is one.	2.0
grad3_offset		Determines the size of the largest tick.	3.0
dicing_offset		Determines the size of the standard dicing tick.	1.4
border_width	The border of the chart is the outermost line.	Specifies the thickness of the line used to draw the border in millimeters.	1.0
dicing_width	The width of the lines used to draw the ticks on lines of latitude and longitude.	Specifies the thickness of the line used to draw the dicing in millimeters.	0.3

3 Chart Definition File - Per Chart Items

These items were defined specifically for each chart and define information specific to an individual chart such as:

Chart extents	Title	Tide tables
Scale	Number	Scale bars
Projection	Graticule	Information notes

A small subset of this information is mandatory for a particular chart. A large number of optional parameters are necessary only for more complex layouts or for cases in which the standard defaults are not sufficient.

The following table includes the description of mandatory parameters as well as the most common optional parameters or optional parameters that are representative of a class of parameters. The aim of these parameters is to provide the required flexibility to produce all forms of IHO-compliant charts.

Item	***Description***	***What is does***	***Default or Expected Input Type***
Mandatory			
chart_title	Name of chart.	Provides name to use in chart title text.	e.g., Annapolis Harbor
chart_number	International or local chart number.	Creates text on the chart.	e.g., 12283
scale	The True Scale of the chart, assuming a Mercator projection is used for the chart.	Creates correct size of symbology, text and representation for the chart.	e.g., 10000
scale_latitude	Assuming a Mercator projection for the chart, specifies the latitude at which the True Scale is correct.	Creates the correct projection in which to display the data and create the chart specific dataset.	e.g., 38 58 30N
data_coordinates	Coordinates defining the neatline in Lat/Long. These define the extents of the actual data in the chart.	A minimum of 2 coordinate pairs is required to define a rectangular chart. However, any number of coordinates can be used to specify more complex, non-rectangular charts.	e.g., 76 29 58.88W 38 55 55.70N

Item	*Description*	*What is does*	*Default or Expected Input Type*
Optional parameters (selected)			
border_coordinates	Coordinates defining the extents of the outer border. Defined by Lat/Long pairs of geographical coordinates.	The outer border of the chart may be different from the neatline of the data. Any number of coordinate pairs can be used to define the border.	By default the border will follow the coordinates of the data and be offset a specified amount.
neatline_in_projection	Determines if neatline should follow the graticule.	The neatline can be a straight line between corners or drawn in the projection of the chart.	By default the neatline is drawn in the projection of the chart.
grid_length	UTM Grid ticks should be shown around the border.	Length of grid tick lines around the border defined in millimeters on the chart.	e.g., 4.0
border_offset	Distance from neatline to border.	Defined in millimeters on the chart.	e.g., 12.0
border_width	Thickness of border line.	Defined in millimeters on the chart.	e.g., 1.0
dicing_width	Thickness of dicing line.	Defined in millimeters on the chart.	e.g., 0.3
lat_interval	Interval between lines of latitude.	Defined by dd mm ss.	e.g., 00 01 00
lon_interval	Interval between lines of longitude.	Defined by dd mm ss.	e.g., 00 01 00
add_degree	Full degree coordinates can be added in the margin.	Specifies the latitude or longitude at which to add additional degree numbering in the margin. Defined by dd mm ss(H).	e.g., 78 00 00(N)
add_letter	Sometimes a letter indicating the hemisphere (east or west of Greenwich) should be added to the full degree lines of longitude.	Adds a letter (E or W) to the farthest left and right degree lines on the map sheets.	E or W

Item	*Description*	*What is does*	*Default or Expected Input Type*
add_subsid_grad	Some lines of latitude or longitude can have additional graduation marks.	Adds subsidiary (additional) graduation (ticks and numbers) on a line of latitude or longitude.	e.g., 78 30 00(N)
grid_count	If a UTM grid is to be shown on the chart, the UTM grid interval needs to be specified.	Specifies the interval between UTM grid lines in meters.	e.g., 10000
border_scale_count	A scale bar can be drawn as part of the border line of the chart.	Specifies the number of meters that should be represented by the border scale.	e.g., 10000
text_box	The location of additional text to be shown on the chart needs to be specified. A box is created that can contain text elements on the chart face.	Specifies “n” number of boxes that contain a specific text element such as a cautionary note, explanatory note, or other chart text. Specifies the location of the box by 2 lat/long coordinates.	e.g., 1 followed by bounding coordinates of the rectangle.
text	Specifies text to put in a text box, including the type of text, font size and text box in which to place the text.	A number of types of text are defined including cautionary, explanatory, chart text, and source. Each type of text is displayed differently (e.g., font, color, style, etc.).	Text to be shown on chart.
tidal_stream_table	One or more tidal stream tables containing tidal information for a specific location on the chart is usually shown. The location of the tidal stream table needs to be specified so it does not interfere with other chart information.	Specifies bottom left position of tidal stream table in Lat/Long. The table will automatically be constructed to hold the specified tidal stream data.	e.g., 4 10 25W,50 22 01N

Item	*Description*	*What is does*	*Default or Expected Input Type*
Tidal stream information	Specifies the contents of the tidal stream table.	Lists the place and actual tidal data.	e.g., 14,PLYMOUTH (DEVONPORT),HW,100,0.1,342,1.1,346,1.6,347,1.3,352,0.7,30,0.1,148,0.4,148,1.1,147,1.6,145,2.3,150,2.4,143,1.3,139,0.5

Repeated parameters defining the appearance of the grid, graticule, border, and neatline for each side of the chart allow each side to have a different appearance. Some parameters such as the labeling of graticule lines and style of dicing and border scale are automatically calculated from the given information.

4 Post Processing Items

These items are generated after the ENC data is imported into the Laser Scan system. The information is generally present in ENC but requires significant intelligence in the processing system to represent it correctly. Each type of information is identified below, along with a description of the problem and solution provided in the system.

4.1 Navigation Aids

4.1.1 Navigations Aids Text

Description:

Navigational aids in ENC comprise a number of separate objects that share a common location. These objects include lights, buoys, fog signals, topmarks, etc. Text strings associated with complex objects such as aids to navigation need to be displayed. Complex text descriptions drawn next to navigation aids provide information about the aids. This information can include:

- Descriptions of the type, color, range, pattern of a light or group of lights
- Description of the color of the structure object such as lighthouse or buoy
- Name of the navigation aid
- Additional information such as the type of fog signal

Solution:

The system looks at the attributes of the objects that form the navigation aid and then constructs a complex text description from the information contained in the attributes. The composite text string is then placed in a default location near the navigation aid. The process involves looking up the attribute codes and translating those to text descriptions. This process is complicated when there are multiple objects such as lights objects on a navigation aid. A composite text string showing all the required information from all objects is created and then combined into a predefined format.

4.1.2 Symbology

Description:

The symbology used for navigational aids needs to be selected depending on the type of objects that form the navigation aid. The complete symbology for the navigation aid can be composed of several individual symbols including:

- Type of “structure” object, e.g., buoy or beacon
- Type of topmark
- Flare symbol if there is a light on the aid

Solution:

The system selects the correct symbology by looking at all the objects that make up the navigation aid and then creating a composite symbol from the different elements, e.g., combining the correct topmark with the buoy symbol. The various symbols are correctly offset and angled in relation to each other so that they form the correct composite symbol.

4.2 Light Flares

Description:
Light flare symbols are needed on navigation light objects. The flares need to be rotated to an appropriate angle so that they do not interfere with other details.

Solution:
A process automatically creates flares on appropriate objects in a default orientation. There is manual override of orientation of flare object that is essential if other text or more that one light exists at the location.

4.2.1 Light Sectors

Description:
In locations with directional lights, light sectors should be displayed. These give a visible indication of the angle and range of visibility of the lights.
Solution:
The visible angle is extracted from the light along with the visible distance. A display object is created by the system with default location and text on the outer edge. There is manual override of position of display object (range) and location of text on the outer edge.

4.2.2 Traffic Separation Schemes

Description:
Large arrows should be shown as part of a traffic separation scheme to indicate direction of travel. Arrows are shown inside area objects that may be irregular in shape.
Solution:
Arrows are generated by the system but may need to be modified for location, size, and orientation.

4.3 Descriptive Text

Description:
Text describing objects needs to be displayed at varying sizes and optimal position on the chart.
Solution:
The text string is extracted from the ENC data and placed by the system in default locations in relation to the object, i.e., in the center of an area if it is related to an area object, along a line if it related to a line object, and offset from a point object.
Process:
Initially text objects are created for all real world objects in the ENC that contain descriptive text requiring display on the printed chart. This process is completely automatic and creates text objects in default locations depending on the type of real world object the text is associated with (i.e., point, line, or area) and the object class. These text objects have reference links to the ENC real world objects. The link is used to get the actual text from one or more attributes of the ENC object (typically from the OBJNAM

attribute, but also from any other attributes) and display it in the default position. This mechanism separates the two elements of the text, the text itself and the location of the text as it is displayed on the chart. This allows the position of the text to be modified without changing the location of the related real world object. It also provides a means of "overriding" the text, i.e., changing, removing, or adding text, without altering the ENC real world object.

Result:

Using this process it is possible to create all the text that is shown on the chart, providing the ENC had been collected fully. However, this process requires a significant amount of manual chart editing to resolve conflicts in the text placement and to remove or edit some text.

4.4 Chart Furniture

4.4.1 Compass Rose Location

Description:

One or more compass rose objects should be displayed on the chart showing magnetic variation from True North.

Solution:

A point object is created that contains all the necessary attributes (year, change, variation, etc.). This object is used to generate the compass rose. Once generated, it can be moved, and individual elements such as pieces of text or graphic elements can be moved or deleted.

5 Intelligent Database

This is a description of items that require significant intelligence in the database to produce a correct result. The information is present in the ENC data, but complex processing is needed to display the information correctly.

Item	*Description*	*Solution*	*Result*
Create mask object	It is necessary to selectively mask some linework in order to increase the legibility of text and other features.	A mask is created around text objects to mask out mostly black linework. The mask is created automatically by creating a buffer around all the previously placed text.	While the result is good, the process of creating the mask can take up to an hour for complex charts.

Item	*Description*	*Solution*	*Result*
Soundings display	Soundings need to be displayed according to display rules that include rounding and displaying in the appropriate font and size depending on value of sounding and other attributes of the sounding, e.g., quality of sounding.	The sounding object is examined to obtain the sounding value and associated attributes such as water level effect and quality of sounding. The sounding is then displayed according to the chart rules. If a subscript is needed, the text string is broken up, and subscript text is offset appropriately.	The result is accurate in most cases.
Area objects with complex boundary representations that share the coastline, e.g., Anchorage areas	Parts of area objects that share a boundary with the coastline should generally not be displayed. This is particularly important for an area object such as an anchorage area with a complex representation that clutters the coastline and makes it difficult to identify other detail.	The spatial entities that are used by both the coastline and the area object are identified and are not represented as part of the area object. This requires knowledge of the underlying topology and the ability to set the representation for parts of an object at the spatial entity level.	Generally good. The area object representation does not interfere with the coastline representation.
Areas that share a boundary with other areas of the same class	In some cases, where two objects of the same class share a boundary, e.g., Dredged areas, the boundary between the two objects should not be shown.	With knowledge of the underlying topology it is possible to not display the shared boundary.	Good.

Item	*Description*	*Solution*	*Result*
Areas that share a boundary with other areas of different classes	Where area objects share a boundary with other objects that are of different classes, the shared boundary may need to be represented with a combination of both classes' styles, e.g., a fishing area and an international boundary.	With knowledge of the underlying topology it is possible display the shared boundary with a combination of styles.	Good. It is possible to create representations for areas that share boundaries. However, all possible combinations need to be identified and suitable representations defined. There can be problems with maintaining the symbology pattern around the object.
Coincident area objects	Coincident area objects may require modification of the representation of both the area fill and any text associated with the objects.	Both the boundary line symbology and the area fill may need to be modified, and any text that needs to be displayed inside the area needs to be offset appropriately.	Good. By examining the topology it is possible to identify coincident polygons and modify the representation accordingly.
Labeling of depth contours	Depth contours need to be labeled with their depth value at appropriate intervals along their length.	The lines are labeled. The labels need to be spaced appropriately, and they need to be displayed in the correct orientation so that they are legible.	Good. Contours are labeled automatically. The correct orientation depends on the contours being digitized in the correct direction.

6 Missing Items

Information for the following items is not contained in ENC data and cannot be produced automatically from data in the chart definition file. The following data needs to be manually created or entered:

- Tidal level tables
- Corner coordinates
- Magnetic information
- Linear scales
- Table of maintained depths in dredged areas
- Table of depths in maintained section of rivers

- Key to berths, jetties or mooring areas
- Table of clearances under bridges
- Zones of confidence diagrams (CATZOC)
- Depth unit conversion diagrams

7 Incomplete

These are items for which a partial solution was implemented in the Laser Scan software.

Item	*Description*	*Solution Implemented*	*Enhancement Required*
Source diagram	A diagram showing the survey dates for areas of the chart.	A partial solution was developed that required the creation of a separate graphic dataset in which the source areas were drawn and additional information was stored as attributes.	It should be possible to generate the source diagram from the meta objects (M_SREL) in the ENC data.
Tide stream table	A Tidal Stream Table should be shown on a chart.	Tidal information is not currently captured in the ENC. This information is added into the Chart Definition file.	The information needs to be added to the ENC data.
IHO and NOAA logos/seals, etc.	Chart should include standard logos, seals, etc.	Logos and seals are created in the legend dataset.	The chart definition file capabilities need to be extended to handle external images.
Border text	Text such as copyright information and chart numbering is shown outside the border of the chart.	Added manually to the legend dataset.	The chart definition file capabilities need to be extended to handle text outside the chart border.

8 Issues

8.1 Direction of Digitizing

The direction in which linear features with a non-symmetrical representation are digitized is critical. Features such as the coastline can have representations that are either offset

from the actual geometry or have symbols that should be oriented a particular way. The only way to ensure that the representation is always correct is to ensure that the features are always digitized in the same direction.

8.2 Units of Depth Measurement

Meters are the units of depth measurement in an ENC. However, some NOAA charts are collected from charts that are in imperial units, and the printed ENC is also required in imperial units. Conversion from meters to feet is required for both the values and any text that refers to depth values.

8.3 Layout

An actual paper chart can be composed of a number of individual charts all printed on one piece of paper. The layout of these charts, which may include inserts or charts of different scales, can only be done with prior knowledge of which charts are to be printed together.

9 Limitations

It is not possible in the Laser Scan system to define more than one area of data at a time. To create a chart containing insets or chartlets requires that each area of data be created as a separate chart and subsequently combined using other software.

Appendix B - Task 2: Analysis of the ENC Product Specification, S-57, and S-52

Table of Contents

1 Introduction

In this task, the various standards relevant to the production and use of ENC (the ENC Product Specification, S-57, and S-52) were examined to determine which features can and cannot be properly represented on a paper chart in an automated manner from information provided solely in the ENC.

Use was made of the various standards in printed and electronic form as well as electronic resources such as the ecPilot website (http://195.217.61.120:8080/), which provided a convenient means of cross referencing the various documents. Various example charts and ENC datasets provided on the NOAA website were also consulted.

2 Issues Identified from the ENC Product Specification

The ENC Product Specification (S-57 Appendix B.1) was examined to identify features that would affect the ability to create from ENC data a traditional paper chart that conforms to the specification. The following issues were identified as being relevant to the production of paper charts:

Issue	***Impact***
Cell overlap	An overlap of data between cells in the same navigational purpose is not allowed, so to produce a chart that has an overlap would require at least two cells. Current paper charts have an overlap between charts.
Cartographic objects	Cartographic objects defined in S-57 that begin with the "$" character are prohibited from ENC.
Time-varying objects	ENC can contain time-varying objects such as magnetic variation, tide information, current information, etc., but these are not currently collected in NOAA ENC datasets.
MASK attribute	The MASK spatial attribute can be used to affect the display of specific spatial entities. This can be used to enhance the display of certain objects (e.g., not displaying the boundary between two adjacent dredged areas).
Relationship objects	ENC includes the definition of relationship objects (C_AGGR, C_ASSO, and master/slave). These relationships could be used to improve the display of some objects, e.g., text associated with a group of objects.
Exchange language	ENC specifies that the exchange language must be English, however, national language names can be encoded in the textual national attributes (NINFORM, NOBJNAM and NPLDST). Any paper chart system would need to deal with the possibility that the ENC could be in a language other than English and thus use both the national and international attributes.

Issue	*Impact*
Projection	The ENC is in WGS 84, but the chart is in a projection. There would need to be a way of specifying the projection required for the chart.
Units	The unit of depth measurement on the ENC is the meter, but some charts need to be printed in feet. This would need to be specified and conversions applied.
Updating	The updating mechanism used for ENC would need to work for paper chart production, as well, e.g., text or symbol display should still be correct after applying an update.
Text and picture files	Objects in ENC can have text and picture files linked to them, but there is no positioning or display information associated with them that could be used when producing a paper chart.
SCAMIN attribute	The SCAMIN attribute is used to control the display in an ECDIS of objects at different scales. The SCAMIN value determines the minimum scale at which the object should be drawn. As the user zooms out, e.g., reduces the scale from 1:20,000 to 1:50,000, only those objects that have a SCAMIN greater then 50000 will still be displayed along with a core set of objects that must always be displayed, i.e., Group 1 and meta objects. For areas where data has been captured from a larger scale insert, the SCAMIN object could be used to filter out some data to display it at a smaller scale if required for a paper chart.
M_CSCL object	The compilation scale is stored as an attribute on this meta object. This is typically the scale of the paper chart that was digitized to create the ENC. A single ENC may have multiple M_CSCL objects, as there may be areas that have been captured from larger scale inserts.
"Unknown" attribute values	Where an attribute value is relevant or mandatory but unknown, it is encoded within the ENC as unknown. Often these attribute values are critical for the display of an object, e.g., to determine the exact symbol for a particular instance of object class to use. In S-52, the magenta "?" can be used to indicate an object display as being unknown.

3 Issues Identified from S-52 Appendix 2 Specification

The S-52 specification deals with how the ENC should be displayed in an ECDIS. When displaying ENC data, an ECDIS provides that following basic functionality not provided on a paper chart:

- Selectively displaying various types of chart and non-chart information

- Selecting full or simplified symbols
- Using cursor interrogation to obtain object details
- Changing the scale or orientation of the display

The following have been identified as some of the main features of the S-52 specification that affect the display of ENC data in a traditional paper chart form.

Feature	***Impact***
Text display	It is stated that text should be avoided on the ECDIS unless it is absolutely necessary, but some text is essential, e.g., buoy numbers.
Priority of drawing	There needs to be a tight control of the priority order for drawing objects so that the correct object appears "on top."
Selective display	A minimum amount of detail must always be displayed, the Display Base, but usually much more is displayed, the Standard Base. This is not an option for a printed ENC since object cannot be switched on/off.
Unambiguous identification	It is more important to be able to identify features unambiguously than to have perfect cartography, e.g., a symbol may not be perfectly spaced along a line.
Special symbolization	Special symbolization of areas is used to make them clearer and to enable the identification of an area even when only a small part of it is displayed on a screen.
Undefined symbolization	There are objects for which no symbolization is defined, including territorial sea areas. This works in ECDIS because the user can still "pick" the area and get the information.
Simplified symbols	Simplified symbols for buoys and beacons make them more obvious and reduce clutter.
Safety contour	The safety contour can be dynamically selected at display time.
Simplified labels	Buoy and beacon symbols are labeled with the number or name of the object prefixed with "By" or "Bn" to avoid clutter.
Unknown attributes	There is no equivalent to the magenta "?" that can be displayed on an ECDIS if the symbology cannot be determined for an object. Everything on a chart needs to be symbolized if it is to be identified correctly.
New/modified symbols	New or modified symbols have been defined for a number of features including: daymarks, glaciers, traffic routes, simplified buoys and beacons, isolated underwater dangers, radar, conspicuous coasts, prohibition and caution areas and points, Ramarks and Racons, and "no-data" areas.

4 S-57 ENC Object Classes

The following table lists all the S-57 object classes that are allowed in ENC, identifies whether or not they could be represented on a paper chart, specifies whether there is a requirement to generate text that should be displayed with or associated with an area object, and highlights any issues that may arise.

Each class is split into the different geometry types that are valid for that class since different geometry types for a class may pose different problems. For each object class there may be several different representations, depending on specific attributes and combinations of attributes an object may have or the location of an object with respect to other objects. Where feasible all these different possibilities have been taken into account when determining whether an object class can be represented satisfactorily.

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
ACHARE	P	Yes		
	A	Yes	Yes	Need to identify a point in the center of the area to locate the symbol within the area object. The symbol or text may also need to be positioned accurately to avoid other objects. A complex display routine is required to display the symbolized boundary correctly and to handle cases where the area is adjacent to or overlaps with other objects such as the coastline.
ACHBRT	P	Yes		
	A	Yes	Yes	
ADMARE	A	No		No representation is defined in INT 1, but this should not be difficult.
AIRARE	P	Yes		
	A	Yes	Yes	
BCNCAR	P	Yes		
BCNISD	P	Yes		
BCNLAT	P	Yes		
BCNSAW	P	Yes		
BCNSPP	P	Yes		

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
BERTHS	P	Yes		The size of the point symbol needs to vary with the size of the text string.
	L	Yes		
	A	Yes	Yes	
BOYCAR	P	Yes		
BOYINB	P	Yes		
BOYISD	P	Yes		
BOYLAT	P	Yes		
BOYSAW	P	Yes		
BOYSPP	P	Yes		
BRIDGE	P	Yes		
	L	Yes		
	A	Yes		The display routine requires the creation of other geometries to show vertical clearance symbols, clearance values, and other associated text. These need to be cartographically placed to avoid conflict.
BUAARE	P	Yes	Yes	Need to determine if other objects share the same geometry that could affect the display.
	A	Yes		
BUISGL	P	Yes		A unique symbol has not been defined for all FUNCTN attributes.
	A	Yes		
CANALS	L	Yes		
	A	Yes		
CAUSWY	L	Yes		
	A	Yes		
CBLARE	A	Yes		Complex symbolization of boundary line is required. Can become illegible in crowded areas. Small areas may use a different representation.
CBLOHD	L	Yes		Simple symbol required, however, text is usually displayed next to it. Text may refer to multiple objects if close together.
CBLSUB	L	Yes		May need special representation for small lines to avoid confusion.
CGUSTA	P	Yes		Need text offset from symbol.

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
CHKPNT	P	No		No representation defined in INT 1.
	A	No		No representation defined in INT 1.
COALNE	L	Yes		Complex offset lines with symbology required. Spatial QUAPOS attribute needs to be considered, and parts of the line may be represented differently from others as a result. Some coastlines such as coastal hillocks are not captured.
CONVYR	L	Yes		Requires text to be displayed for clearance as well as symbol.
	A	No		No representation defined for area.
CONZNE	A	Yes		
COSARE	A	No		No representation defined in INT 1.
CRANES	P	Yes		Text for lifting capacity needs to be displayed offset from symbol.
	A	No		No representation for an area defined in INT 1.
CTNARE	P	No		No representation defined in INT 1.
	A	No		No representation defined in INT 1, but text is used to describe the type and reason for the caution area, which may be surrounded by a magenta boundary.
CTRPNT	P	Yes		
CTSARE	P	No		No symbol defined in INT 1.
	A	Yes	Yes	Need to generate a point for text to appear inside area. Text may need to be carefully positioned to avoid conflict with other objects.
CURENT	P	Yes - partly		There is meant to be a distinction between currents in restricted water and those in oceans. This is not encoded in ENC but could be determined by looking at the underlying depth area.
CUSZNE	A	Yes		
DAMCON	P	No		No representation defined for point feature in INT 1.

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
	L	Yes		Needs to be digitized in the correct direction, as the linestyle is asymmetric.
	A	Yes		
DAYMAR	P	No		No representation defined in INT 1, but symbols are defined in S-52.
DEPARE	L	No		Linear depth areas do not need to be represented on a paper chart.
	A	Yes		
DEPCNT	L	Yes		Need to locate depth contour labels on the contour, display correct value and orientation, and avoid conflict with other objects. Need to examine spatial attribute QUAPOS as it can affect the line style used.
DISMAR	P	Yes		Text needs to be properly oriented to feature.
DOCARE	A	Yes		
DRGARE	L	Yes		
	A	Yes	Yes	Dredged areas need to be displayed with the dredged depth added as text inside the area. At NOAA dredged areas are captured as “quarters”. When displayed, the shared lines should not be drawn (using either topology or MASK attribute).
DRYDOC	A	Yes	Yes	In some circumstances the label “Dry Dock” should be shown. Clearance values may also need to be displayed.
DMPGRD	P	No		No symbol defined for point.
	A	Yes	Yes	No specific representation for CATDPG of 3 or 5. Multiple text elements need to be plotted and combined.
DYKCON	L	Yes		Linestyle is asymmetrical (a thicker line down one side), so direction of digitizing is relevant.
	A	Yes		

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
DWRTCL	L	No	Yes - along line and oriented arrow symbols.	No representation is defined, but a dashed line representation can be used and large arrows generated to show direction.
DWRTPT	A	No	Yes – along line and with oriented arrow symbols.	No representation is defined, but a dashed line representation can be used and large arrows generated to show direction.
EXEZNE	A	Yes	Yes – along line	
FAIRWY	A	No		No representation defined in INT 1.
FERYRT	L	Yes	Yes – along line	
	A	No		No area representation defined in INT 1.
FLODOC	L	No		No line representation defined in INT 1.
	A	Yes		
FNCLNE	L	No		No representation defined for fence lines in INT 1, but assume simple line style.
FOGSIG	P	Yes	Yes	Some require text display to describe fog signal type.
FORSTC	P	Yes		Some types of structures do not have symbols defined in INT 1.
	L	No		Not clear how a line geometry would be displayed.
	A	Yes	Yes	Type of structure is described next to object.
FRPARE	A	No		No representation defined in INT 1.
FSHFAC	P	No		No symbol for fishing facility.
	L	Yes		
	A	Yes	Yes	Text is displayed inside area to describe the type of fishing facility.
FSHGRD	A	No		No representation defined in INT 1.

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
FSHZNE	A	Yes		Boundary line symbology may need to be modified depending on the other areas with which it coincides.
GATCON	L	Yes		
	A	Yes		
GRIDRN	P	No		No symbol defined in INT 1.
	A	Yes		
HRBARE	A	Yes	Yes	Text needs to be displayed around the boundary line.
HRBFAC	P	Yes		Specific symbols have not been defined for many harbor facility types.
	A	No		No area representation defined.
HULKES	P	No		No specific point symbol defined for different types of hulk.
	A	Yes	Yes	Area is displayed with text next to it.
ICEARE	A	Yes		Complex symbology required along boundary depending on other objects around it.
ICNARE	P	No		No point symbol defined in INT 1.
	A	Yes	Yes	
ISTZNE	A	No		No specific representation is defined, but text is sometimes used to describe the type of area object, which is surrounded by a magenta boundary.
LAKARE	A	Yes	Yes	
LNDARE	P	Yes		
	L	Yes		
	A	Yes		
LNDELV	P	Yes		Text showing elevation needs to be displayed next to point symbol.
	L	Yes		Contours need to be labeled with the height at suitable intervals. Contours should be masked behind label.
LNDMRK	P	Yes		Unique symbols are not defined for all categories of landmark. Text is required to be plotted next to some landmarks depending on other attributes e.g. height, category, name, etc.

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
LNDMRK *(continued)*	L	Yes		
	A	Yes	Yes	
LNDRGN	P	Yes		Symbols for specific categories of land region do not exist, so text needs to be displayed next to generic symbol.
	A	Yes	Yes	Area symbol for some categories does not exist.
LIGHTS	P	Yes		Particular issues with light sector limits and flare symbols. Complex text strings need to be constructed from attributes, and these text strings need to be positioned carefully to avoid ambiguity.
LITFLT	P	Yes		Text associated with the object needs to be displayed.
LITVES	P	Yes		
LOCMAG	P	Yes		Reference to a chart note may be needed.
	A	Yes	Yes	Value is shown inside the area.
LOGPON	A	Yes	Yes	Text description is shown inside the area.
LOKBSN	L	Yes	Yes	Text needs to be aligned with the object.
	A	Yes	Yes	Text needs to be aligned with the object.
MAGVAR	P	No		No representation defined, but information on the object could be used to generate a compass rose.
	L	No		No representation is defined but could be displayed as isogonals.
	A	No		No representation is defined in INT 1.
MARCUL	P	Yes		No symbol is defined in INT 1 for some categories of object.
	A	Yes	Yes	Category of object is displayed inside or near the object.
MIPARE	A	Yes	Yes	Symbols and text need to be displayed in area.

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
MORFAC	P	Yes		Text sometimes refers to more than one object if they are close together. Not all types of MORFAC have specific symbols.
	L	No		No line representation defined in INT 1.
	A	Yes	Yes	
NAVLNE	L	Yes	Yes	Orientation should be displayed next to the line.
OBSTRN	P	Yes		No symbol defined for some categories of obstruction. Text and other information such as sounding value need to be displayed.
	L	No		No representation for lines defined.
	A	Yes	Yes	Areas can have symbols and text displayed inside them or near them.
OFSPLF	P	Yes		Not all categories have defined symbols.
	A	Yes	Yes	Names may be displayed next to area.
OSPARE	A	Yes	Yes	Description of type of production area may be displayed in area.
OILBAR	L	Yes	Yes	May need descriptive text along the line.
PILBOP	P	Yes	Yes	Additional information such as communications frequency may need to be displayed.
	A	Yes	Yes	Additional information such as communication frequency may need to be displayed.
PILPNT	P	Yes	Yes	Simple symbol. Text usually displayed next to symbol. May refer to multiple objects if close together.
PIPARE	P	No		No symbol defined in INT 1.
	A	Yes	Yes	Type of pipeline area and other restrictions are described.
PIPOHD	L	Yes	Yes	Line needs to be labeled with type of pipe, clearance value, and symbol.
PIPSOL	P	Yes		
	L	Yes	Yes	Pipe should be labeled with product it carries.

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
PONTON	L	Yes		
	A	Yes		
PRCARE	P	Yes		
	A	Yes	Yes	Symbol and text may need to be displayed.
PRDARE	P	Yes	Yes	Some types of production do not have symbols, so text is needed.
	A	Yes	Yes	Text used to describe type of production area.
PYLONS	P	Yes		Text needed to identify object as pylon.
	A	Yes	Yes	Text needed to identify object as pylon.
RADLNE	L	Yes	Yes	Some descriptive text required to identify object as radar line.
RADRNG	A	No		No area representation defined. Simple boundary and label used.
RADRFL	P	Yes		
RADSTA	P	Yes		Point needs text indication that it is a radar station.
RAILWY	L	Yes		
RAPIDS	P	Yes		
	L	Yes		
	A	Yes		
RCRTCL	L	Yes		Arrows need to be oriented.
RCTLPT	P	Yes		Arrows need to be oriented.
	A	Yes		Boundary line and large arrow required. Arrows need to be oriented.
RDOCAL	P	Yes		Symbol and text required.
	L	Yes		Text required.
RDOSTA	P	Yes		
RECTRC	L	Yes		Line and arrows need to be oriented.
	A	Yes		Arrows need to be oriented.
RESARE	A	Yes	Yes	Category of restricted area is described using text.
RETRFL	P	No		No symbol defined in INT 1.
RIVERS	L	Yes		Name needs to be displayed along line. Text may need to be stretched or curved to give good result.

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
RIVERS *(continued)*	A	Yes	Yes	Name needs to be displayed within area. Text may need to be stretched or curved to give good result.
ROADWY	P	No		No representation for a point defined in INT 1.
	L	Yes		
	A	No		No representation for an area defined in INT 1.
RSCSTA	P	Yes		
RTPBCN	P	Yes		Text needed next to symbol to describe type of beacon, e.g., Ramark, Racon.
RUNWAY	P	Yes		
	L	Yes		
	A	Yes	Yes	
SBDARE	P	Yes		Displayed as abbreviated text.
	L	Yes		Displayed as abbreviated text.
	A	Yes		Displayed as abbreviated text.
SEAARE	P	Yes		
	A	Yes	Yes	Name is displayed within area. Text may need to be stretched or curved over a large area to produce a good result.
SILTNK	P	Yes		
	A	Yes	Yes	Category of silo is described which may refer to multiple objects.
SISTAT	P	Yes		Described by text and symbol, e.g., SS(Traffic).
SISTAW	P	Yes		Described by text and symbol, e.g., SS(Storm).
SLCONS	P	Yes		
	L	Yes		Some symbology is complicated and requires a regular pattern, e.g., Mole, Seawall.
	A	Yes		
SLOTOP	L	Yes		
SLOGRD	P	Yes		
	A	Yes		
SMCFAC	P	Yes		
	A	Yes	Yes	

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
SOUNDG	P	Yes		Text and symbology required. Text may also be displayed out of position and so require some means of indicating the true position.
SNDWAV	P	Yes		
	L	Yes		
	A	Yes		
SPLARE	P	Yes		
	A	Yes		
SPRING	P	Yes		
STSLNE	L	Yes		
SUBTLN	A	Yes	Yes	Text and symbol (may refer to a chart note).
SWPARE	A	Yes	Yes	Text and symbol displayed inside area.
TESARE	A	Yes		
TIDEWY	L	No		No symbology defined in INT 1.
	A	No		No symbology defined in INT 1.
TOPMAR	P	Yes		Need to be angled correctly and combined with other symbols to form a complete navigational aid.
TSELNE	L	No		Need to look at whole TSS collection object.
TSEZNE	A	No		Need to look at whole TSS collection object.
TSSBND	L	No		Need to look at whole TSS collection object.
TSSCRS	A	No		Need to look at whole TSS collection object.
TSSLPT	A	No		Need to look at whole TSS collection object.
TSSRON	A	No		Need to look at whole TSS collection object.
TUNNEL	P	No		No point symbol for tunnel defined in INT 1.
	L	Yes		
	A	Yes		Display as an area with a pecked boundary line and text inside.
TWRTPT	A	No		No representation defined in INT 1.
UNSARE	A	Yes	Yes	

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
UWTROC	P	Yes		Additional text, including sounding value, sometimes displayed.
VEGATN	P	Yes		
	L	Yes		
	A	Yes		
WATFAL	P	Yes		
	L	Yes		
WATTUR	P	Yes		
	L	Yes		
	A	Yes		
WEDKLP	P	Yes		
	A	Yes		
WRECKS	P	Yes		Text next to symbol and sounding value sometimes displayed.
	A	Yes	Yes	Text either in or near area.
C_AGGR		No		No representation for collection objects.
C_ASSO		No		No representation for collection objects.
M_ACCY	A	No		No representation, but may be used to create chart notes or source diagram.
M_COVR	A	No		No representation, but could be used to form part of the source diagram.
M_CSCL	A	No		No representation, but may be used to create chart notes or source diagram or to scale text and symbology.
M_HOPA	A	No		No representation.
M_NPUB	P	No		No representation, but may be used to create chart notes.
	A			No representation, but may be used to create chart notes.
M_NSYS	A	No		No representation, but could be used to control the representation of other navigation objects.
M_QUAL	A	No		No representation, but could be used to form part of the source diagram.
M_SDAT	A	No		No representation.
M_SREL	L	No		No representation, but could be used to form part of the source diagram.

ENC Object Class	*Geometry Type (P = point L = line A = area)*	*Display OK?*	*Text or Symbol Required in Area*	*Comments*
	A	No		No representation, but could be used to form part of the source diagram.
M_VDAT	A	No		No representation.
T_HMON	P	No		No representation defined.
	A	No		No representation defined.
T_NHMN	P	No		No representation defined.
	A	No		No representation defined.
T_TIMS	P	No		No representation defined.
	A	No		No representation defined.
TS_FEB	P	Yes		Used to generate flood tide stream symbol.
	A	No		No representation defined.
TS_PAD	P	Yes		Could be used to generate tidal stream panel.
	A	No		No representation defined.
TS_PNH	P	No		No representation defined.
	A	No		No representation defined.
TS_PRH	P	No		No representation defined.
	A	No		No representation defined.
TS_TIS	P	No		No representation defined.
	A	No		No representation defined.

5 Summary

As shown in the above table, for the most part it would be possible to represent objects in an ENC dataset. There are, however, a number of exceptions:

- Objects that require additional text or symbols displayed associated with an area.
- Objects with no, or only partial, representation currently defined in INT but for which a default representation or specifically created one could be easily implemented.
- Objects with no representation defined and for which there does not seem to be an obvious means of representing them, e.g., tidal stream objects.
- Meta Objects – there is usually not a direct means of representing meta objects, but the information they contain may be used to create source diagrams or chart notes or may affect the display of other objects on the chart, e.g., to scale symbology.
- Some point objects, as indicated above, that require text or other information displayed next to them may present significant issues related to generating and placing the text.

- A number of classes without representation are those for which the ENC specification identifies a geometry type that does not occur normally and, as a result, does not have a representation defined in INT 1 (e.g., ROADWY – roads that are points or areas).
- Traffic Separation Schemes (TSS) – these are complex objects that have been split into many smaller objects in ENC. To properly represent these objects it would be necessary to look at them "in the whole," i.e., to group them into a C_AGGR collection object and then work out the proper representation. However, there may be parts of the TSS that still cannot be properly represented, e.g., direction arrows.
- Collection/Relationship Objects – ENC supports Collection objects and objects that have a master/slave relationship. Although no specific representation is defined for collection objects as such, they could be used to control the display of objects within the collection, such as navigational aids, that have a master/slave relationship or descriptions of groups of objects that are in a collection.
- Magnetic Variation – the object class MAGVAR supports magnetic variation information, but not necessarily all the information required to produce compass roses, isogonals, etc. NOAA does not currently collect this information.

Appendix C - Task 3: Analysis of Nautical Charts

Table of Contents

1 Introduction

The requirement of this task was to analyze a number of paper charts and identify all the items on the charts that cannot be properly generated directly from an ENC dataset. To identify as wide a range of issues as possible, a number of different charts covering different scales were selected, including two charts from NOAA and the IHO test chart.

2 Summary

The following is a summary of the information collected during the analysis of the paper charts:

- Chart framework – A number of issues relating to the chart framework and cartographic elements would need to be automated. For instance, it would be difficult to automate the use of "border breaks", unless this was taken into consideration at the collection stage, and the ENC cell was designed to include these elements. There are also references on the chart to other charts, either large scale charts for a specific area or adjoining charts. These are helpful to guide users to other charts that may be more appropriate for their purpose. However, ENC does not contain any information that would enable these references to be portrayed.

- Insets and larger scale charts – One of the main problems in producing a paper chart from ENC is that the ENC cell structure does not map to the current paper chart scheme. A paper chart may contain numerous insets of larger scale chartlets for specific congested areas. Paper charts are also produced at various scales for the same area. ENC enforces the rule that the same area can only appear in one usage band, which can cover a broad range of scales. Only the largest scale chart data is digitized for a particular usage band. This means that the ENC datasets are very often of irregular shapes and have holes where larger scale data may exist. Charts may also have been split into multiple cells due to the limitation in ENC on the size of files. There is a 5Mb file size limit on any individual ENC dataset. For large or complex charts where the limited size is insufficient to hold all the information, the chart is split into multiple datasets so that each ENC dataset falls within this limit.

- Text – The main element of difficulty in producing a paper chart is the positioning of text on the chart. There are numerous examples where standard rules have not been followed, and cartographic license has been used to position text in the most appropriate place, e.g., using arrows to offset text, positioning text at an angle, or curving, banking, or spreading text over large areas. The main intent is to avoid clutter, overprinting one piece of text on another, or obscuring another object.

- Collection rules –A number of features such as features on the land, tidal stream data, magnetic data, etc., are included in standard paper charts but not currently collected in ENCs.

- Notes and other information – A large part of a standard chart is dedicated to notes, tables, and other information, some of which refers to features on the chart and some of which may be generic (e.g., logos, conversion tables). Although much of this data could be contained in the ENC, there is no additional information clarifying how it should be displayed.

- Objects with no representation or incomplete representation – Some ENC objects do not map to a paper chart representation. The ENC may not contain adequate information (e.g., the light structure with a protective rip-rap is shown on the chart with a distinctive symbol, however, there is no specific attribute identifying it as such).

- Complex Representations – Some representations (e.g., rocky coastlines, cliff, breakwaters) may need to be simplified in order to automatically generate a consistently legible result.

- Selective Display – The ability to selectively display text for specific objects and alter the displayed text is required. Often only a representative object is labeled when many objects of the same type or with the same name or description are located in close to each other (e.g., piles). The normal text displayed may need to be altered to indicate the plural or to abbreviate the text.

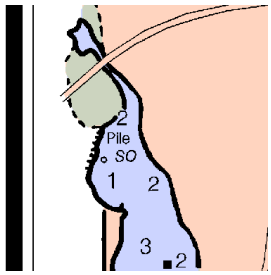
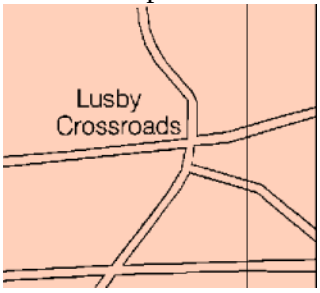
3 Analysis of NOAA Chart 12270 Chesapeake Bay (Scale 1:40,000)

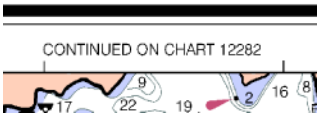
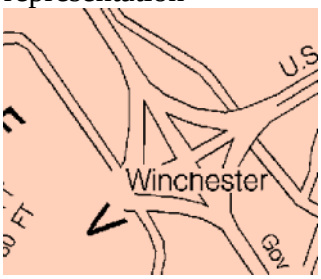
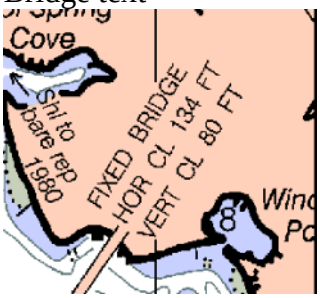
The chart was downloaded as a BookletChart™ from the NOAA website (http://nauticalcharts.gov/bookletcharts/). It comes as a large PDF document that is split into 16 pages, including an index, chart notes and coast pilot extract.

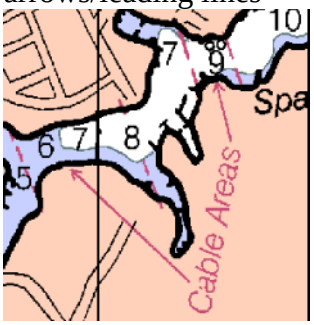
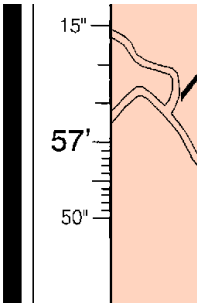
The chart is printed at a reduced scale to that of the original paper chart. The scale of the original paper chart was 1:40,000, and the scale of the BookletChart was 1:60,000. For the purposes of this analysis the scale difference was not an issue since the detail and representation of the chart could still be determined.

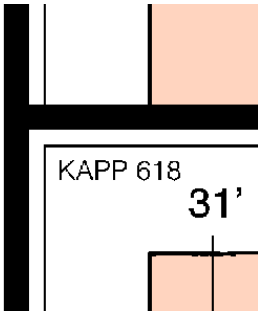
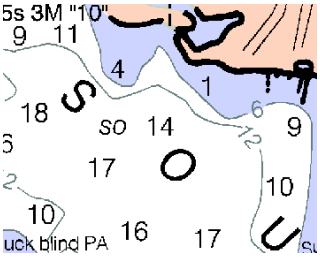
A color printed copy of the chart was examined. To identify and clarify how a feature on the chart might be encoded in ENC, the equivalent ENC charts were downloaded and examined using the SeeMyDENC data viewer from SevenCs (http://www.sevencs.com/index.php?page=123). The IHO publication M4 was also consulted.

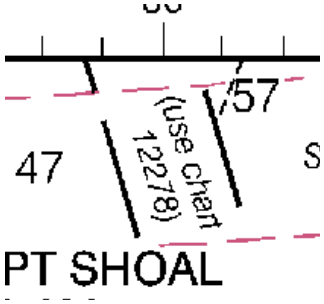
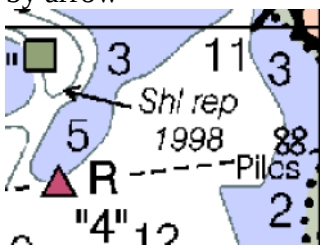
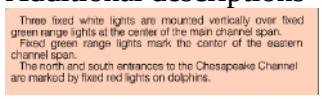
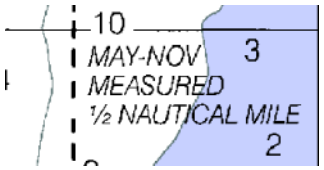
Note: Page numbers in the table below refer to the BookletChart page on which the issues appear.

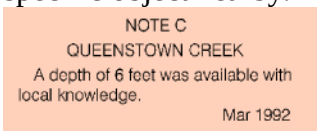
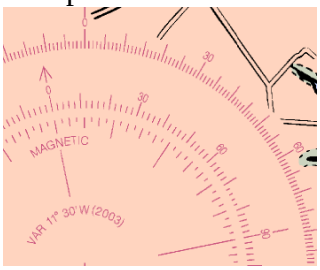
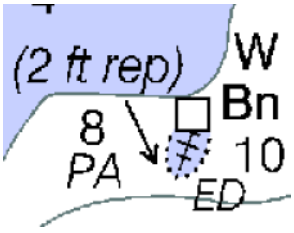
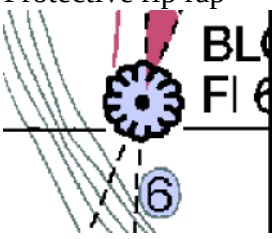
No.	*Problem*	*Description*	*Issue/Solution*
Page: 4			
1	Chart data bleeds into the border 	Border breaks are used to insert significant features lying just outside the limits of the neat line.	There is an issue regarding which ENC cell the data would be in. The data can only be in one ENC but may appear on multiple charts, possibly with different requirements for text placement for each chart.
2	Undefined places 	Place names (e.g., Lusby Crossroads) that appear on the chart without the display of associated built up area either as a point or an area.	Captured as point built-up areas, symbol is not displayed. Text needs to be positioned around other chart data.

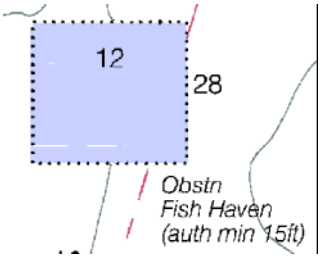
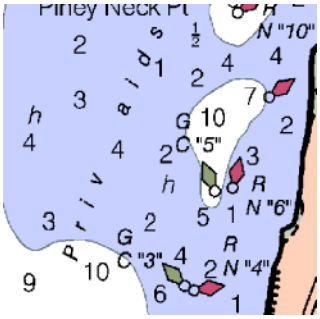
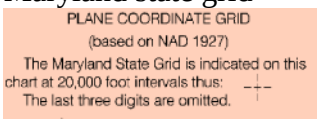
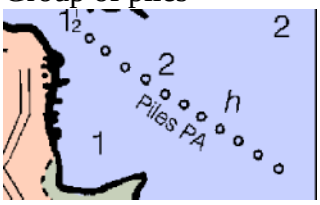
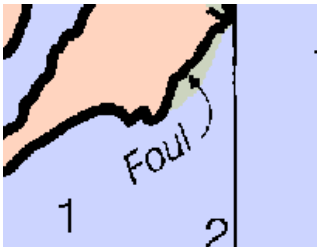
No.	*Problem*	*Description*	*Issue/Solution*
3	Additional border information 	There is information in the border of the chart such as the adjoining chart number (e.g. “Continued on chart 12282”).	Since this information would be outside the cell boundary, it is unclear where the information could be stored.
4	Road network representation 	The road network is shown with complex representation for junctions and different types of roads.	The CATROD attribute can be used to distinguish different categories of road, but attributes for priority at overpasses may be needed if there is a requirement to display the road network correctly.
5	Bridge text 	Additional text and information needs to be displayed for bridges over navigable water.	The vertical and horizontal clearance values and type of bridge need to be displayed in an appropriate place near the bridge but without obscuring other detail.
6	Creek text 	The names of creeks, coves, bays, ponds, etc., need to be displayed.	The object class SEAARE can be used to encode name, but the text needs to be placed carefully (possibly not inside the area it refers to) and aligned correctly.
7	Caution note 	A caution note that refers to an area of bridge construction that is filled with magenta color. The caution note is not located within the caution area.	This is not a standard representation for a caution area. The caution note is displayed some distance away from the caution area in a place where it does not interfere with other detail.

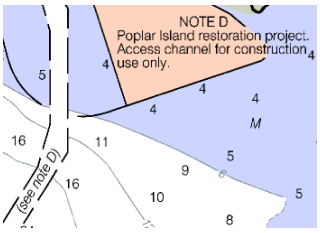
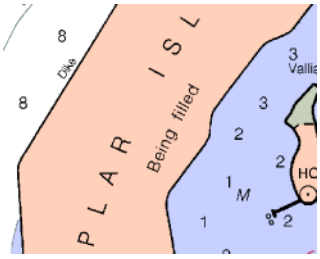
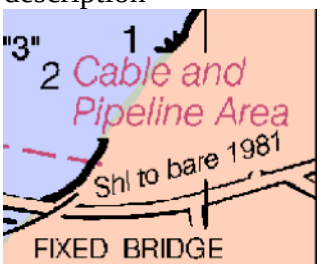
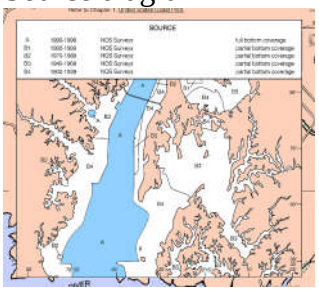
No.	*Problem*	*Description*	*Issue/Solution*
8	Various areas are identified by arrows/leading lines 	There are caution areas, restricted areas, pipeline areas, etc., that are identified by text with arrows pointing to the area in question.	There is no mechanism in ENC to associate arrows/leading lines with objects so as to offset the text description from the object and avoid interference with other detail around the object.
9	Additional graticule subdivisions 	The border of the chart has additional graticule subdivisions shown at apparently random locations.	If it is necessary to display these additional graticule subdivisions, it is unclear how their position would be determined.
11	Individual streets shown 	The chart shows individual streets in built-up areas. This has not been captured in the ENC.	ROADWY would need to be captured.

No.	*Problem*	*Description*	*Issue/Solution*
12	"Use Inset," referral to a larger scale insert 	The chart has an inset that shows a portion of the main chart at a larger scale. There is text on the main chart that tells the user to use the inset chart.	Data for an area in ENC can only appear in one cell for a particular navigational purpose. The inset has some duplicate information such as navigation aids, coastline, etc. There is no object in ENC that would support the "Use inset" text itself or contain the boundary of the inset chart.
13	Inset chart 	The inset needs to be positioned somewhere on the smaller scale chart so that it does not obscure detail. It is also an irregular shaped area.	There is nothing in ENC that would support the location of the inset chart.
14	Placement of individual text characters 	Numerous pieces of text include individual text characters that need to be positioned so they do not obscure detail e.g. "South River."	Requires sophisticated text placement capabilities to move individual characters in a text string.

No.	*Problem*	*Description*	*Issue/Solution*
Page: 5			
1	References to other charts 	Numerous references are made to other charts (larger scale or adjacent), e.g., “use chart 12278.”	There is nothing in ENC to support these references to other charts.
3	Light sector lines 	The chart shows sector lines that continue to the edge of the chart or to some other obstruction.	There is nothing in ENC that would control the length of the sector lines.
4	Obstructions signified by arrow 	Numerous obstructions are indicated by text with an arrow pointing to the exact location, e.g., “Shl rep 1998.”	See Page 4, No. 8.
Page: 6			
1	Additional descriptions  Three fixed white lights are mounted vertically over fixed green range lights at the center of the main channel span. Fixed green range lights mark the center of the eastern channel span. The north and south entrances to the Chesapeake Channel are marked by fixed red lights on dolphins.	Additional descriptions are included for some features, such as the lights on the bridge.	This information could be stored as a note, but the note then needs to be located near the object in question without obscuring other detail.
2	Navigation line attributes 	The navigation line includes additional information, in this case the May-Nov operational timeframe.	This information is encoded on the Buoys at either end in the PERSTA, PEREND attributes.

No.	*Problem*	*Description*	*Issue/Solution*
Page: 7			
1	Note referring to specific object nearby. 	NOTE C refers to a nearby creek.	This is encoded in the INFORM field of the SEAARE, but there is no positioning information that could be used to locate the note where it appears on the chart.
2	Chart titles 	Standard logos, text, etc., are shown on the chart.	There is no way to encode or position this information in ENC. Titles may be unnecessary if printed ENCs are made to coincide with ENC boundaries.
3	Compass rose 	Multiple compass roses of varying sizes and levels of detail are displayed.	Magnetic information can be encoded in ENC but not the size, style, etc., of the compass rose itself. Many such stylistic variations could be discontinued to ease production.
Page: 8			
1	Wreck with offset text 	A wreck is description is shown in offset text with an arrow pointing to the wreck.	See Page 4, No.8.
Page: 9			
1	Protective rip rap 	Light structures with protective rip raps have a different symbology. There is also a note warning boats to stay clear.	The information can only be encoded in the INFORM field as free text.

No.	*Problem*	*Description*	*Issue/Solution*
2	Text outside area 	The text describing a fish haven is outside the object in question.	Simple point in polygon text placement will not work.
Page: 10			
1	"Private aids" 	Text description is in the plural and relates to a number of objects.	There are a number of similar objects near each other. Normally these would be labeled individually, a single description in the plural relates to all the objects. There is no relationship between the objects encoded in ENC.
Page: 11			
1	Maryland state grid 	The chart shows the Maryland state grid by means of grid intersections and numbering.	There is no support in ENC to support the generation or display of grids.
Page: 12			
1	Group of piles 	Groups of piles are labeled in the plural.	See Page 10, No.1.
Page: 13			
1	Foul area with arrow 	If a foul area is very small, it can have an arrow pointing from the text to the area.	See Page 4, No. 8.

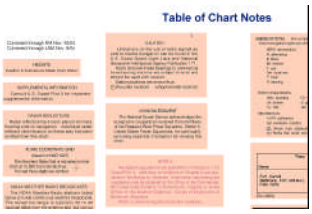
No.	*Problem*	*Description*	*Issue/Solution*
2	Unsurveyed area information printed as a note 	For an unsurveyed area (UNSARE) a note inside the object refers to an additional note not in the object.	Not all information that is shown on the chart has been captured in the INFORM field.
3	Land Area additional information 	A land area has additional information “being filled” associated with it.	This has been encoded in the INFORM attribute of the land area.
Page: 15			
1	Two objects with one description 	There are coincident cable areas and pipelines areas, and the textual description of them is combined into a single description “Cable and Pipeline area.”	Need to combine representations, including text descriptions.
2	Source diagram 	The source diagram needs to reflect the paper chart extents.	Meta objects can provide some of the information, but there is nothing in ENC to support the creation or positioning of the diagram.

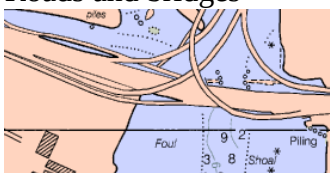
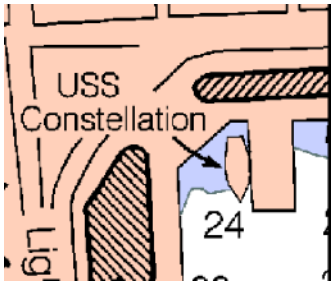
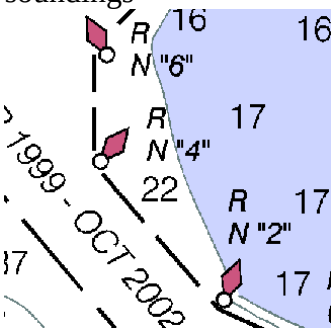
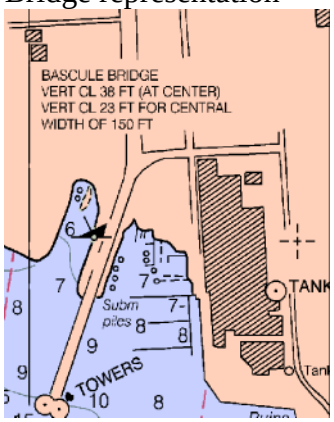
4 Analysis of NOAA Chart 12281 – Baltimore Harbor (Scale 1:15,000)

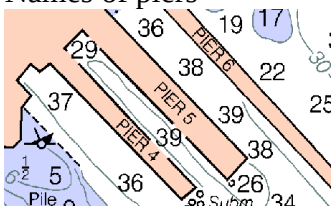
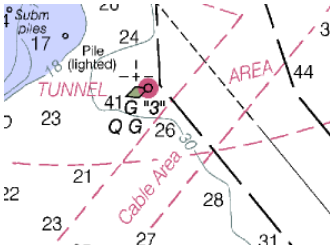
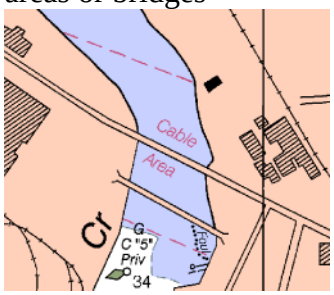
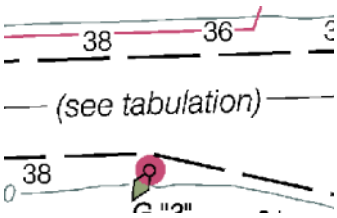
The aim of looking at this chart was to identify any additional features that could not be displayed from an ENC. This chart was chosen because it is a very dense chart of port facilities and controlled shipping lanes in a congested area.

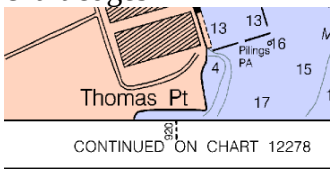
Only those problems that have not been identified previously are described in this section.

In addition to the PDF chart, the ENC for the corresponding area (US5MD11M) was examined, using SevenCs SeeMyDENC to identify how particular features were encoded, where appropriate.

No.	*Problem*	*Description*	*Issue*
Page3			
1	Table of chart notes 	All the chart notes have been extracted from the paper chart and displayed together on a separate page.	It might be possible to extract all the notes from the ENC and display them separately, but there would have to be a means of correlating them to features on the chart, e.g., create Note C and label as Note C the location on the chart to which it refers. The notes page also contains tables of tidal information that would need to be generated from the ENC data if it were present. Channel Depths tables are displayed that would need to be generated from Dredged Areas (DRGARE). These would be difficult to generate automatically because they are divided into left, center, and right channels, and some of the information is specific to only some channels.

No.	*Problem*	*Description*	*Issue*
Page 4:			
1	Roads and bridges 	Roads over bridges are not captured.	There is no continuity to bridges. On a traditional paper chart simplified road networks are shown, including overpasses and underpasses.
2	Names with leaders 	Some objects have names, but due to congestion they need to be displayed away from object with a leader line to the object, e.g., USS Constellation hulk.	
3	Numbered navaids and soundings 	Numbered navaids and soundings can get confused.	Using numbers instead of names to refer to navaids, could declutter the chart, however, the numbers could easily get confused with soundings.
4	Bridge representation 	Text for bridges can be placed at a distance from the actual bridge.	To avoid clutter, the description and characteristics of a bridge can be separated from the actual bridge with an obvious link between them.

No.	*Problem*	*Description*	*Issue*
5	Names of piers 	The name of the piers is encoded on points (BERTHS).	This would make placing the text correctly on the pier difficult.
Page 5			
1	Selective display of areas 	Because of the congestion and overlaying caution areas such as tunnels and cable areas, there is very selective description of these features.	With overlaying but unrelated area features, there is a danger of the information becoming confused.
Page 6			
1	Cable area includes land areas or bridges 	The text associated with the cable area should be placed so it does not interfere or overprint the land or other features.	The text for the cable area needs to be placed with reference to the other features, even though no relationship is explicitly defined in the data.
Page 10			
1	See tabulation 	The dredged channels include instructions to see tabulation.	The tabulation needs to be generated.

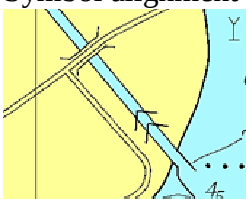
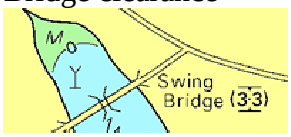
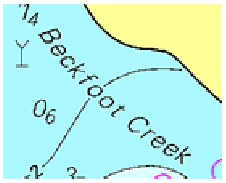
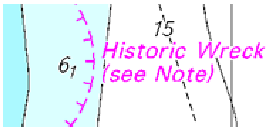
No.	*Problem*	*Description*	*Issue*
Page 14			
1	Text is never broken at chart edges 	Text at the edge of the chart is placed so that the whole text string is on the chart.	This would require knowledge of the chart boundaries. Text may not always appear in the same place, e.g., in the adjacent chart the same text may appear in a different location.

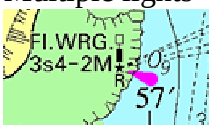
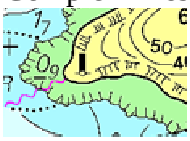
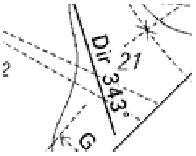
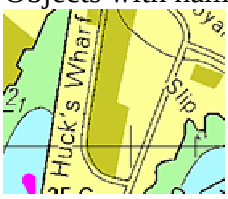
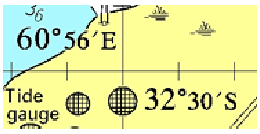
5 Analysis of Chart 19001 Micklefirth (Scale 1:25,000)

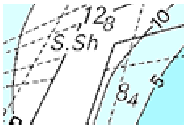
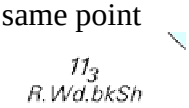
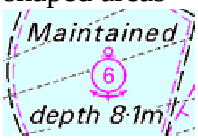
The IHO 5-57 test chart "Micklefirth" is a fictitious chart that contains an example of virtually every ENC object class. It is available as a printed paper chart that complies with INT 1/INT 2 standards.

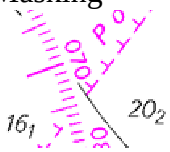
Where possible, only those issues that have not been identified previously are detailed in this section, however there may be some duplication where conditions are slightly different or the example is clearer. The aim was to identify specific instances of problem categories that could be expected to arise if an ENC dataset were printed directly with no user input.

A digital version of the Micklefirth chart was downloaded from the ecPilot website (http://195.217.61.120:8080/) as a PNG image. This was viewed in Microsoft Photo Editor. The paper chart version was compared to an ENC version that had been imported into ENC Cartographer from 7Cs/HSA for clarification of ENC object classes and typical representation.

No.	*Problem*	*Description*	*Issue*
1	Symbol alignment 	Bridge symbols and GATCON symbol need to be displayed correctly with respect to other object.	Symbols need to be aligned with other object or may be affected by other objects, even though there is no direct relationship.
2	Bridge clearance 	Bridge clearance values need to be displayed with symbol.	The symbol associated with the clearance value needs to change size depending on the value of the clearance.
3	Curved text 	Curved text is sometime required for cartographic reasons.	In numerous places curved text is used create a better cartographic result.
4	Reference to notes 	Text includes reference to notes related to the object.	References to notes may be displayed for information in the INFORM field or in a separate NOTES file.

No.	*Problem*	*Description*	*Issue*
5	Multiple lights 	Multiple lights in single location.	Multiple lights in single location means that text string needs to be created to combine information from all the lights.
6	Light sector ranges 	Light sector ranges may be different for different lights.	The lines representing light sectors may differ in length depending on the range of the light and any obstructions in the way.
7	Complex linestyles 	Complex linestyles contribute to clutter in areas.	Complex linestyles need to be simplified at sharp bends and in cluttered areas, and need to be masked for symbols and other text, e.g., soundings.
8	Direction indication 	Direction indication at the end of leading lights needs to be placed.	NAVLNEs should have the ORIENT value displayed at the end of the line.
9	Flare orientation 	Flares need to be oriented.	Each flare needs to be considered individually.
10	Objects with names 	Names for features such as SLCONS need to be displayed clearly.	Text needs to be displayed for objects with names, such as SLCONS, so that the object reference is clear and the text does not obscure other detail.
11	Graticule numbers 	Positioning of addition graticule numbers on chart face.	Additional graticule numbers on the chart face need to be positioned.

No.	*Problem*	*Description*	*Issue*
12	Broken lines 	Some lines need to be broken by other lines.	Some lines are broken or not displayed where they interact with other features. This could be particularly difficult to automate in cases where the other object is a line rather than an area.
13	Single description for multiple objects 	One description, in plural, is displayed for multiple objects.	Objects may be grouped together so that a single description covers multiple objects.
14	Multiple objects on same point 	For multiple objects on the same point, descriptions need to be combined and offset.	Where multiple objects are located close to each other, text strings should not overlap.
15	Light sector colors 	Light sectors need to have color added to them at variable distances.	At the end of light sector arc the color of the light is indicated.
16	Tidal streams 	Tidal stream tables are required.	Need to be able to generate tidal stream table from TS_PAD objects.
17	Navigational aids 	Correct placement of all information relating to navigation aid.	A navigation aid can have many separate pieces of information that need to be displayed correctly.
18	Text within irregular shaped areas 	Fit text to irregular shaped area.	Text needs to be fitted into areas, depending on size and shape.

No.	*Problem*	*Description*	*Issue*
19	Irregular area fill 	Complex irregular symbolized area fill.	There are some complex and irregular line styles or area fills.
20	Text outside area 	Text exists outside the area if refers to.	Sometimes text needs to be displayed outside the area it refers to if the area is not large enough.
21	Masking 	Masking of multiple features in different colors.	There are complex rules regarding which objects get masked.

Appendix D - Task 4: Review of Reference Documents

Table of Contents

1 Introduction

This purpose of this task was to review a selection of NOAA-provided and publicly available documents that address the issues associated with producing paper charts directly from ENC data.

2 **Review:** Development of Methodology – Paper Chart Production from ENC Source Data, NDI (Nautical Data International), Project Reference 01-392, May 18, 2002

This study outlined several options for producing paper charts from ENCs in a production process. All options described require some manual input to the process.

The authors identified the main challenges in the process as the placement of text strings, particularly the problem of "overplotting with other features, maintaining association with the feature or object the text is related to, selecting the right font and size." They concluded that to date there is not a complete solution the problem.

The authors proposed some interesting approaches to address the problem:

- Use raster images (separations from traditional cartographic process) for land areas to fill gaps in ENC coverage.
- Create a standardized chart layout (paper size, layout, etc.) with standard placement of all notes, legends and titles outside of neatline of chart.
- Re-scheme charts so that there is a direct relationship between paper charts and ENC, with no overlaps.
- Redesign navigation aids representation to make more use of colors, reducing the amount of text needed, e.g., use the color of the navaid, use the color of the light, fill light sectors with the light color.
- Reduce need for masking by using transparency effects.

3 **Review:** A Comparison of ENC Plots with NOAA Paper Charts, Arkenau, Heeley, Kennedy, Wong, Spring/Summer 2004

This study compared current paper charts with the S-52 output from various systems. The following fundamental issues or conflicts were identified between the paper charts and ENC data as displayed using S-52:

- Holes in the M_COVR object that would result in holes in the paper chart caused by largest scale charts being collected.

- Inconsistencies in the data collection of the ENC could mean inconsistent presentation of the data.
- Existing paper charts would need to be composed of several ENC datasets, possibly collected at different scales, which would result in different densities of data.
- Density of symbols and text can be such that overprints are inevitable and the information becomes illegible.
- There is a lack of marginalia in the ENC such as grids, graticules, borders, logos, etc. Some metadata shown on the chart (e.g., the last update date) would need to be extracted.
- There is a lack of chart furniture in the ENC, including compass roses, scales, titles, etc.
- Isogonals are not captured in the ENC.
- Text placement, orientation, font, size, spacing, etc., are all issues. Information such as aids to navigation text exists in ENC but needs to be displayed to avoid clutter and overlap.
- Dredged channels are captured in a manner that would make automatic display difficult. In addition, the table of dredged channels on a paper chart would need to be generated.
- Light sector display should match either the paper chart or range of light.
- Features that lie near the chart edge would need to be positioned so that they were still legible, i.e., so that chart border doesn't cut off text.
- Paper charts with overlaps may need to re-schemed to fit with ENC data in which there are no overlaps of data.
- Symbology of point features needs to be addressed and possibly simplified. Development of new symbols for features such as piles and dolphins may reduce the need for text.
- Depiction of bridges was significantly different on paper charts that in ENC displays. This raises the question as to whether it is necessary to include all the information shown on a paper chart.
- No text is shown for the majority of features where it needs to be generated e.g. restricted areas, landmarks, etc.
- Clearer symbology for area boundaries (including dual-purpose areas) may reduce the need for text to describe them.
- A hierarchy for display would be needed so that objects that are on top of each other draw in a predictable manner.

This is a comprehensive report on the display of ENC data in a variety of viewing software packages. A number of issues were identified that relate specifically to the limitations either of the S-52 specification for representation or the implementation of the symbology in the specific systems used to view the data. Although the symbology may be incorrect when compared to a paper chart, that does necessarily mean that the information required to display the symbol as in a current paper chart is absent from the data.

It is clear from the review, however, that ENC viewers attempt to make the display clear by omitting from the display a large proportion of the text that is normally shown on a paper chart. With the viewer, the user is able to select an object and examine the object's attributes. This is not possible with paper charts, where all information that the viewer may possibly want needs to be shown on the paper chart.

4 **Review:** ENC 2 CHT Problems document (no author or date provided)

This short document listed some of the problems and recommended approaches for producing charts from ENC.

All of the problems identified have been previously mentioned, e.g., holes in charts, overprinting, text placement, etc. The authors also discussed the problems associated with trying to recollect data, change existing processes, and attain user acceptance of a changed product. They suggested making an "alternate" paper chart that would run alongside the exiting paper chart. However, that approach would not solve the basic problem of trying to eliminate duplicate effort; it would, in fact, increase the effort required.

The authors noted that a form of "printed" ENC is already accepted, the screen display used for voyage planning. However, the S-52 display assumes the user can gain access to the underlying data, if needed, by selecting objects and showing their attribute or through the automatic system interrogation of the data. This additional level of information is obviously not available on a paper chart where only the data that is printed is accessible.

5 **Review:** Chart Redesign to Facilitate Data Streamlining, May 5, 2003, Memorandum for the Record (Filename ENC 2 paper7.doc, no author)

This document described the pros and cons of producing paper charts using different mechanisms, including adding additional attributes to ENC database, using complex software, and outlining the benefits that would be produced by generating paper charts directly from ENC data. This would be feasible if the paper chart were modified to be more readily produced from an ENC dataset. The author proposed generating paper charts (and raster) directly from the ENC data and not from the underlying ENC database but acknowledges that there may be significant technical and cultural problems in doing this. The author proposed that changing the specification of the paper chart would enable a paper chart to be made directly from ENC, while still satisfying the traditional paper chart user and minimizing the impact on ENC collection or changes to the ENC specification. The paper also highlighted the significant benefits that would accrue to the Hydrographic Office, the mariner, and the ENC software manufacturer from even partial

progress toward automated paper charts. The author suggested that an ECDIS backup printed directly from ENC would provide a significant benefit.

6 **Review:** Printed ENC PowerPoint Presentation, (Filename ENC 2 Paper.ppt, no date or author)

This presentation is a follow-on to the previous document and proposes an evolution that moves from today's entirely separate processes for producing paper charts and ENC data, to one in which cartographic elements are added separately to an ENC database to produce paper charts, and finally to an idealized scenario in which all products are produced from an ENC dataset with a minimum need for cartographic enhancement and manual input.

One key element mentioned is the need for clarity as to what constitutes an official or approved paper chart. This definitional work is required to determine the modifications to ENC that would be necessary to support the official paper chart.

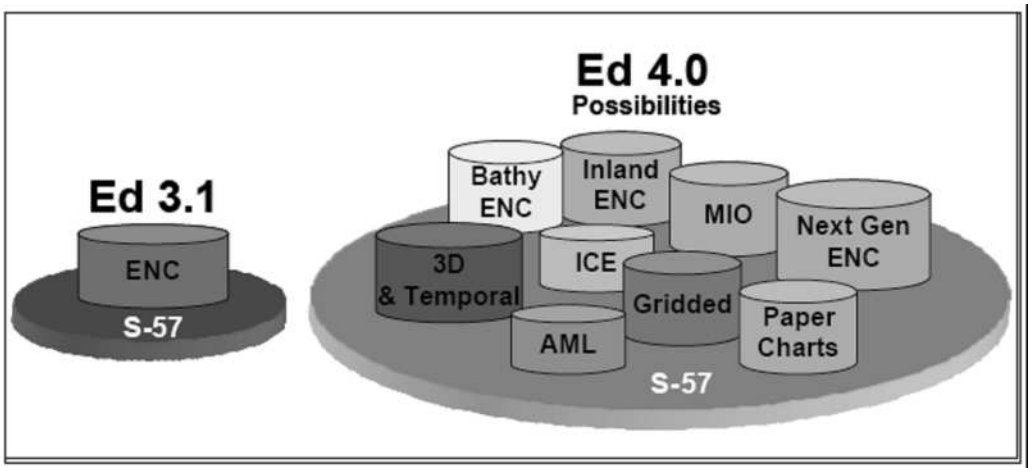
The list of problems given is a reasonable summary of the main issues with an emphasis on the problems of text placement and representation.

7 **Review:** S-57 Ed 4 – The Next Edition of IHO S-57 (Edition 4) and S-100 Framework Document (June 5, 2006)

Accessed from: http://www.iho.shom.fr/ECDIS/S-57_Ed4_Information_Paper.pdf and http://www.iho.shom.fr/COMMITTEES/CHRIS/TSMAD/TSMADSubWG/S-57_DevPages/S57_Edition_4_Dev_Page.htm

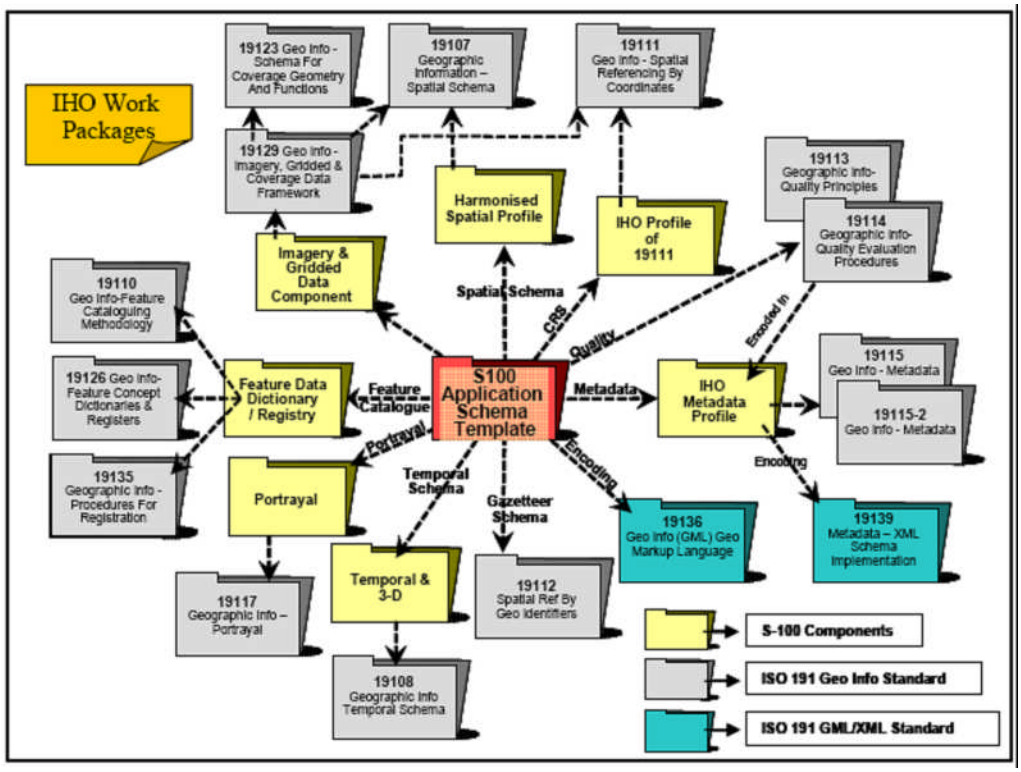
These documents contain the proposed new version of S-57, originally called Edition 4 but now renamed S-100. Although this is still in the development phase and a new version of the ENC Product Specification (provisionally called S-101) is not due until 2012, these documents provide the initial view into the structure and content of the new standard. There are some aspects of the new standard that may be of some benefit to producing charts directly from ENC.

The documents acknowledge the need to expand S-57 to accommodate new requirements. The Committee states that the "primary goal of the next edition of S-57 [now called S-100] is to be able to support a greater variety of hydrographic-related digital data sources, products and customers," and it provides the following diagram as an example:



Appendix D – Figure 1: S-57 Ed 4Possibilities

As can be seen in Figure 1, one of the possible future uses is to produce paper charts. An underlying philosophy of this standard is that additional Product Specifications and Application Schemas can be developed within a common framework, following rules on how to describe an application schema using S-100 components. These components (shown in Figure 2) include a Portrayal component based on ISO117 (Geographic Info Portrayal).



Appendix D – Figure 2: S-100 Components

A key question is whether it would be possible to either define an extension or new Product Specification that supports the production of paper charts. Topics under active international discussion include as how the new standard deals with issues such as navigational purpose, usage bands, cartographic objects, size limitation, cell layout and configuration, and scale dependant and independent objects. If the "paper-chart" specification data could be produced from the same database as the S-100 product, significant efficiencies in production would be gained.

8 **Review:** NGA, Maritime Division Transformation, Gary Rogan, 2004 ESRI User Conference

Accessed from http://gis.esri.com/library/userconf/proc04/abstracts/a2213.html

When looking for solutions it may be beneficial to look at the ePODS initiative being undertaken by NGA. NGA is working toward a completely digital environment with the capability of producing hardcopy charts, if required, directly from Digital Nautical Chart (DNC) data.

DNC is similar in many ways to ENC data in that it represents the same basic information and is structured into libraries that closely match the "usage bands" on ENC. The data has mostly been captured from existing paper charts; however, the Vector Product Format (VPF) data model used is significantly different from the S-57 data model. The ePODS initiative is aimed at generating all products from a digital database of DNC. The database will facilitate the creation of various products, including paper charts. NGA uses a mechanism called "geo-sectioning" that "inserts, over the same geographic area, a segment of a larger scale dataset into a smaller scale dataset." This improves the maintenance effort by reducing the number of features that require updating at different scales. However, problems stemming from the increased density of data in larger scale areas are seen when displaying the current data in an ECDIS-N viewer. NGA is using several of the features from S-57 such as unique feature identifiers and the SCAMIN attribute to help with database maintenance, update, and generalization. The SCAMIN attribute, in particular, is being used "as a 'poor-mans' generalization tool."

DNC data does have the advantage of including "name" text in the DNC data itself, which reduces the amount of text generation and manual placement required.

9 **Review:** OS MasterMap®

Accessed from: http://www.ordnancesurvey.co.uk/oswebsite/products/osmastermap/

Although not directly relevant to the production of ENC data, it may be interesting to look at other geospatial data products that are currently available. One of these is OS MasterMap data produced by Ordnance Survey UK. This is a relatively new "object

based" geospatial product that is primarily a large-scale data product, rich in attribution and topologically clean. It has been processed to create polygons and intelligently coded so that features can be grouped into themes and further refined. All objects have a unique feature ID, and the data is delivered in Geography Markup Language (GML).

Although this is primarily a data product, it also includes cartographic elements within it that enable the data to be printed quite simply from many different software systems, without the need for any additional processing or manual intervention. It achieves this through specific cartographic text objects that contain text strings, font, orientation, size, etc., attributes, as well as predefined rules for representation, including symbology, linestyles, and area fills.

A significant drawback to the current structure of OS MasterMap is that there is no relationship between the text objects and the real world objects to which they relate. This makes it difficult to tailor a product by selecting only specific features or to create a map at scales different from the source scale.

Of course, OS MasterMap is significantly simpler that a standard Hydrographic chart, with less text and information requiring careful positioning, but it does show the ability to create both a data product and a cartographic product in the same data and to produce a paper product directly from complex geospatial data. It also makes much more use of complex patterned fill area, unique symbology, linestyles, and colors to identify features without the need for a great deal of text on the map.

Appendix E - Task 5: Experiences of Suppliers of Paper Chart Production Software

Table of Contents

1 Introduction

The purpose of this task was to determine the status of efforts by key suppliers of existing systems that aim to produce paper charts from ENC. ESRI and HydroService responded to our initial queries. After initial email exchanges outlining the scope of the project, telephone discussions were held to clarify issues, and additional documents from their websites were also analyzed.

2 ESRI

The following information was received from ESRI (http://www.esri.com/):

"ESRI and NGA (National Geospatial Intelligence Agency) are currently involved in an on-going collaboration called Enterprise Product on Demand Service (ePODS). In simple terms, ePODS is an ESRI Server-based concept that creates hardcopy charts directly from DNC VPF data. The end-user has the ability to generate these charts using a thin-client such as Internet Explorer. Keeping in mind that the final hardcopy charts are only as good as the underlying data, a good portion of our challenges have been related to the data itself. Some of these specific data issues as well as other challenges have been addressed below.

- Quality and state of the original digital data → hardcopy only as good as the underlying data.
- "Black box" areas of larger scaled data embedded within smaller scaled data.
- Text placement issues (cannot place perfectly (i.e. 3 o'clock NAVAID text), overlapping text)
- Italic text (in water) vs. Upright text (on land) → information not stored in the data.
- Reef symbology is over-collected. Literally each reef scallop has been digitized thus creating an undesirable result on the hardcopy.
- Different portrayal of features in DNC vs. hard copy. For example, edge of Reef polygon coincident with coastline (and as result so is scallop), on hard copy charts this is not present. Another example is embankment symbology that is coincident with the coastline in the data, but is offset on the hard copy.
- Textual items in data are abbreviated, (i.e. reduced to the approx. level of MSL) rather than …Mean Sea Level, so MSL will be displayed on the hardcopy.
- If a shoal sounding is added by a Notice to Mariner and the surrounding depth contour isn't drawn proportionally, the hardcopy result will depict the sounding text overprinting the contour line.
- Compass roses and associated magnetic information aren't collected in DNC.
- Several notes aren't collected in DNC.
- Source diagrams aren't collected in DNC.
- Because of specific guidance and generalization rules, several features such as roads, buildings, lakes and rivers aren't collected in DNC.
- Generation of tide tables
- Generation of light sectors.
- Plans, panels, insets, and continuations extremely difficult to automate

- Technology to automate spec grids from the server
- Not much control over placement of surround elements (furniture). Currently anchored in lower left and expands up and out. "

3 HydroService

HydroService has summarized its status in this area in the paper "S-57 Based Paper Chart Production", HydroService AS (http://www.hydroservice.no/Office/do.asp). Following are the key points from the paper:

- HydroService has developed software to produce paper charts using S-57 as the source. Note the use of S-57, not just ENC, which is a subset of S-57.
- Any solution must take into account the need for national standards and specifications and provide the ability to change symbols, colors, text, marginalia, etc.
- Many products may be created from the same data, e.g., leisure charts, navigation charts, thematic charts, etc., so the system must allow for customization and selection of presentation rules.
- The ENC update mechanism must continue to work for derived products from the ENC data as well as the ENC data itself. There should only be one source of updates for cartographic product and ENC.
- Cartographic objects could be useful but pose certain problems, including:
  - The paper chart portfolio may be different from the ENC cell structure, and it is not know what charts may be required.
  - The same data may be used for multiple products, requiring different presentations, including text placement for different products.
- In general, use of cartographic objects should be limited, and over-simplification of the paper chart should be avoided to take into account national traditions.
- The software will convert ENC to paper chart using a configurable and customizable conversion tool.
- The process is not 100% automatic (HydroService estimates 80-85%), and manual intervention is required to place text, create masks, etc.
- The basic idea is that there is a core database capable of producing the ENC data, and the paper chart is produced from the ENC data.

The production process follows the following steps:

- The process starts by clipping and compiling multiple ENCs into a "virtual" ENC that is then projected and passed to the converter to form a paper chart.
- The conversion is automatic. It creates paper chart objects according to rules and uses the INT 1 symbol library.
- A link is created between the paper chart object and the ENC parent object.
- A final manual editing stage is required to place complex text, edit lines, and apply masking to avoid clutter.

- Additional components such as tables, compass roses, and other furniture are added using scripts.
- Paper chart objects can be updated directly from ENC updates (ER files).

The benefits of the approach are:

- Consistency between the paper chart and the electronic chart
- Automated updating of paper charts based on ENC updates.

Further automation of the process is feasible should paper chart specifications be modified to produce cartographically acceptable results.

Appendix F - Examples of ENC Data Displayed in ENC Viewer Software

Table of Contents

1 Introduction

This appendix includes examples of a small sample area of ENC data as it is currently represented in a number of off-the-shelf ENC viewer software packages. The intention here is to graphically portray some of the issues related to displaying and printing an ENC. All the system outputs displayed here have been automatically generated solely from the ENC data.

It should be noted that none of these systems claims to produce paper chart quality display directly from the ENC, but they show some of the possibilities and compromises that have been made to display the data, typically using S-52 rules. Most of the systems give some control over which object classes to display and the choice of "Display Base," "Standard." or other predefined set of objects.

Where possible a selection was chosen that included all options to display text, symbols, fills, patterns, etc., for all object. In all cases the scale of the display is considerably greater than the true scale of the chart (or the scale of the source data), so these enlarged images show less clutter. The sample shows a very small area of chart and chart features, but is typical of a reasonably dense area of paper chart.

It should be noted that this is not an exhaustive list of ENC viewer software available. All viewer software examined is available for free download either for a full or trial version.

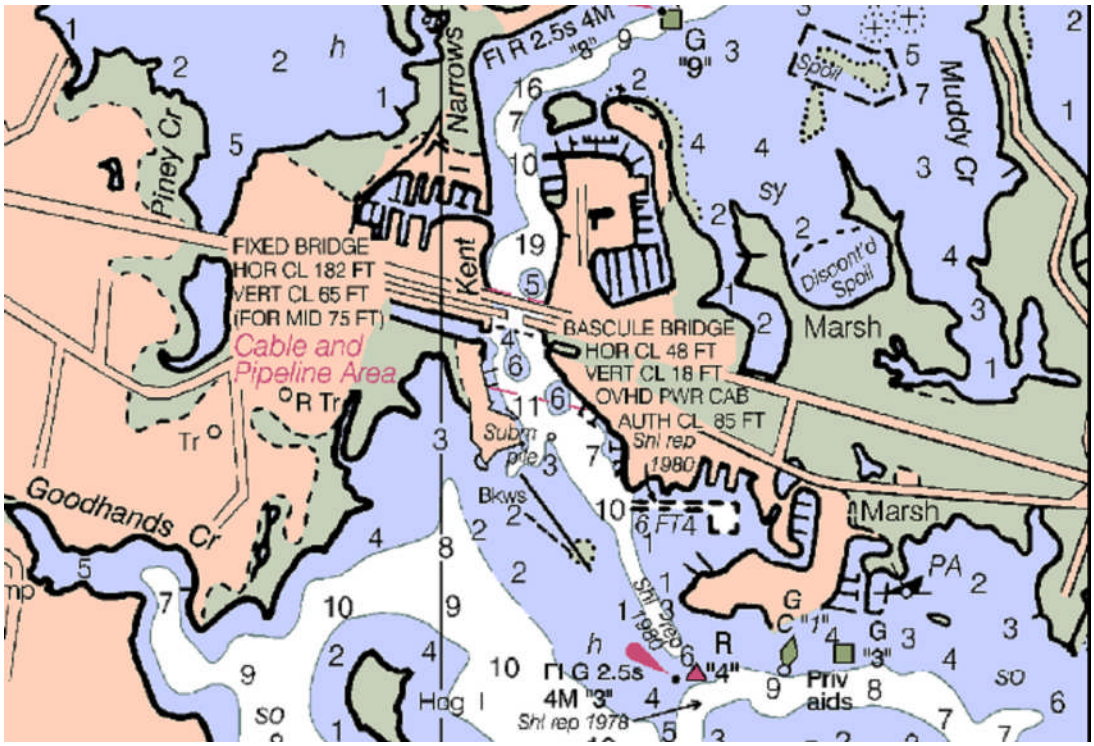
2 Summary

From all the following displays it can be seen that the decision has generally been made to display considerably less text than is on the equivalent paper chart, particularly in describing the bridge.

Also, for the area marked "Discont'd Spoil" on the paper chart, most systems show only the boundary and not the text. Text shown for areas such as creeks is placed rather ambiguously. Text that identified lights is often unclear. Text scaling is often incorrect, and symbols and text overprint.

3 Original Paper Chart

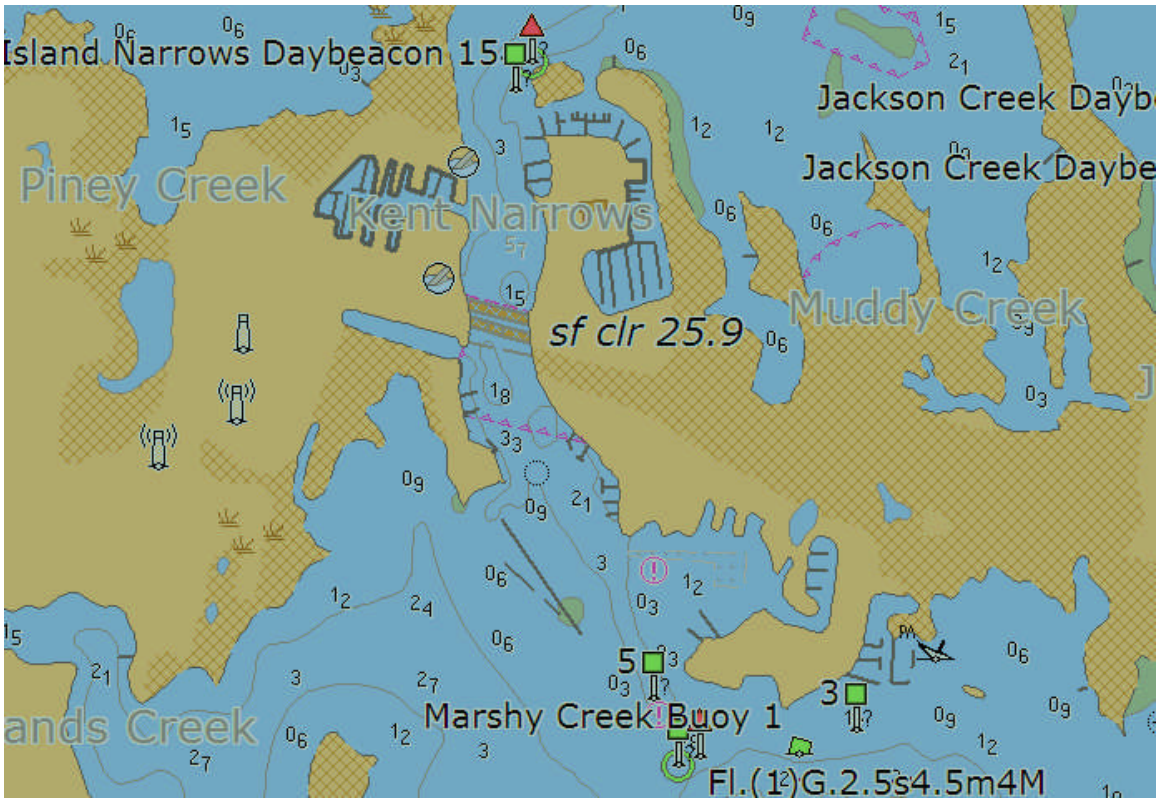
Figure 1 shows the area of the paper chart from NOAA Booklet chart 12270 with a source scale of 1:40,000, displayed at approximately 1:10,000



Appendix F - Figure 1: Paper Chart

4 SevenCs SeeMyDENC

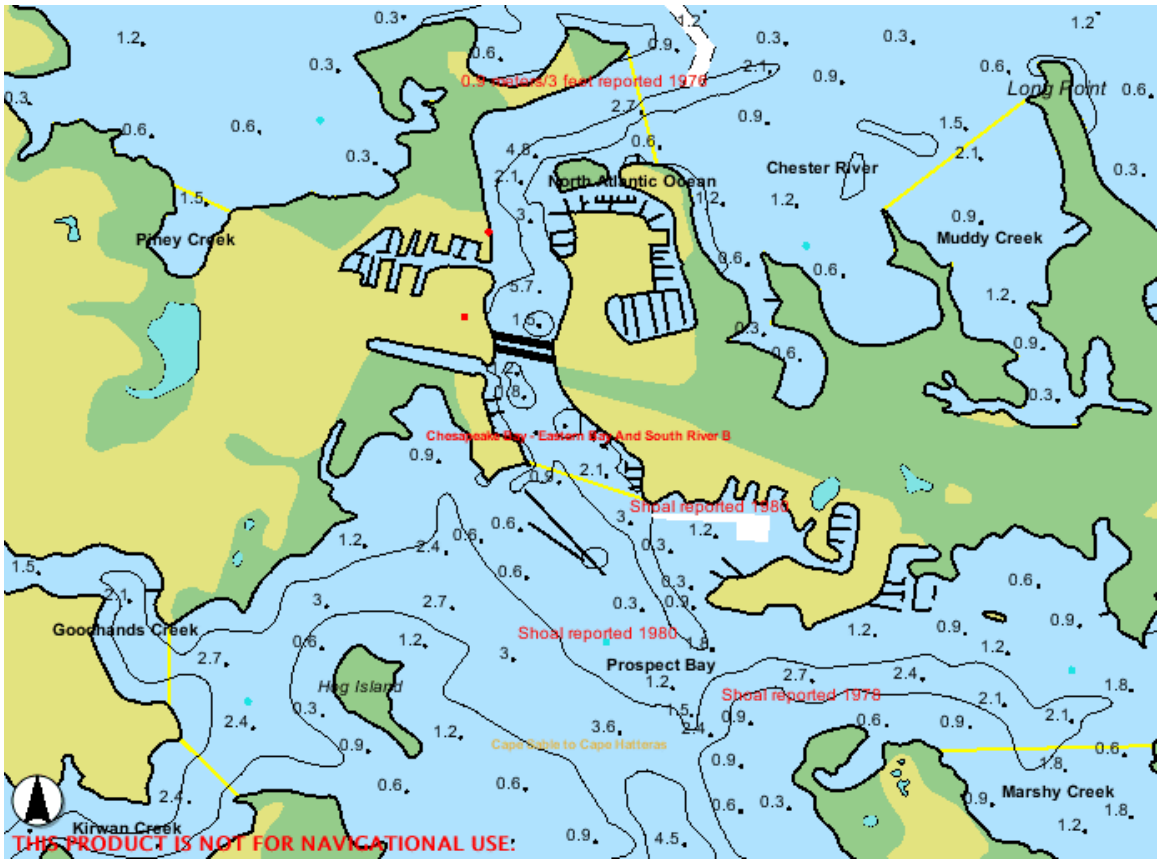
Figure 2 shows the equivalent area in SevenCs SeeMyDENC. Available from: http://www.sevencs.com/index.php?page=123&lang=



Appendix F - Figure 2: SevenCs SeeMyDENC

5 NOAA ENC Direct to GIS

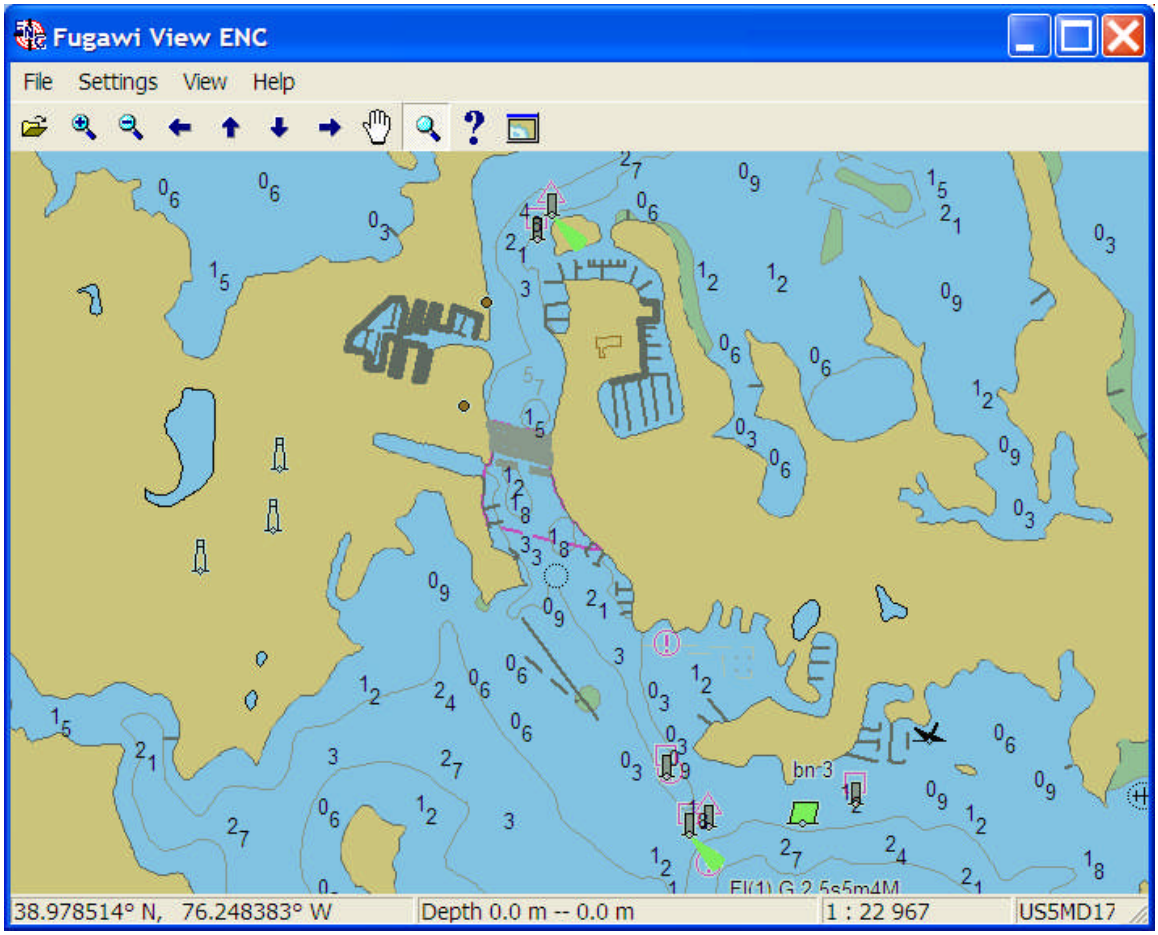
Figure 3 shows the same area as displayed in the NOAA ENC Direct to GIS application. It should be noted that this application's main purpose is not as a display or mapping tool. Its purpose is to enable the user to define an area of data to extract. Available at: http://ocs-spatial.ncd.noaa.gov/encdirect/viewer.htm



Appendix F - Figure 3: ENC Direct to GIS

6 Fugawi™ View ENC

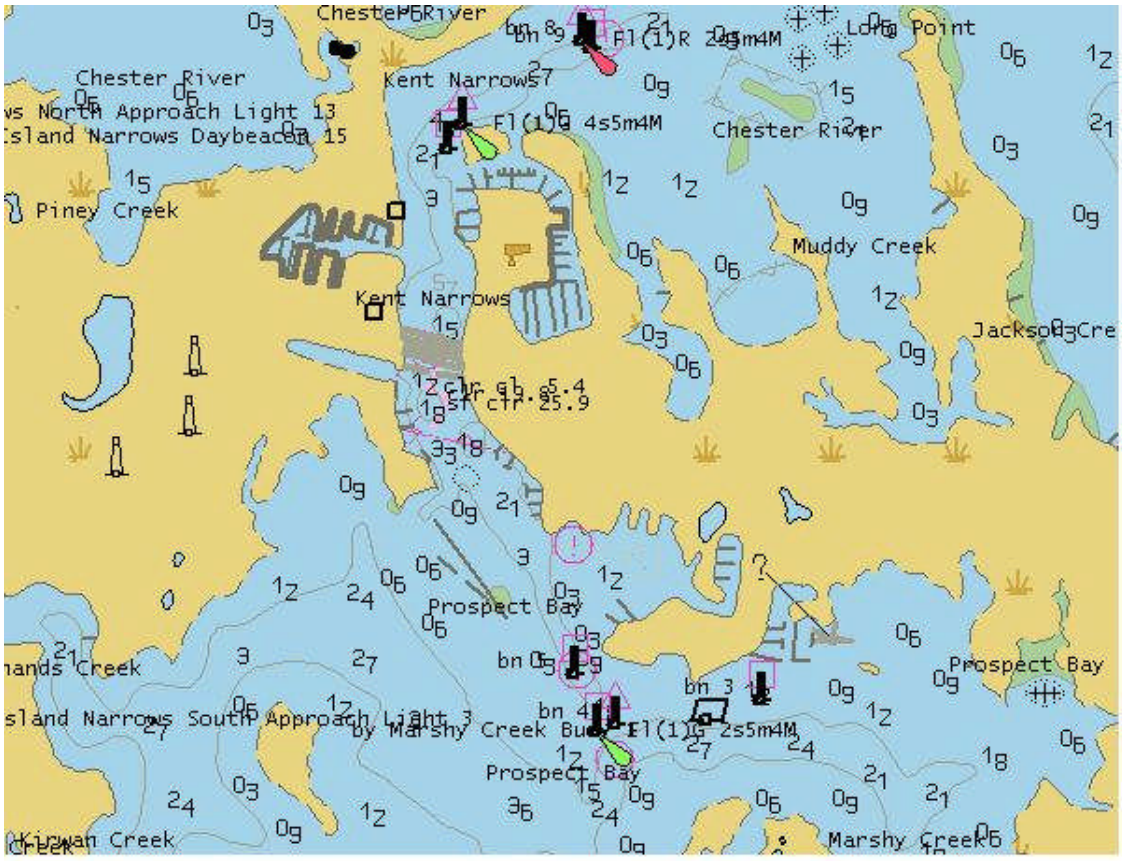
Figure 4 show the area in the Fugawi View ENC software. Available from: http://www.fugawi.com/web/products/fugawi_view_enc.htm



Appendix F - Figure 4: Fugawi View ENC

7 Caris EASY-ENC

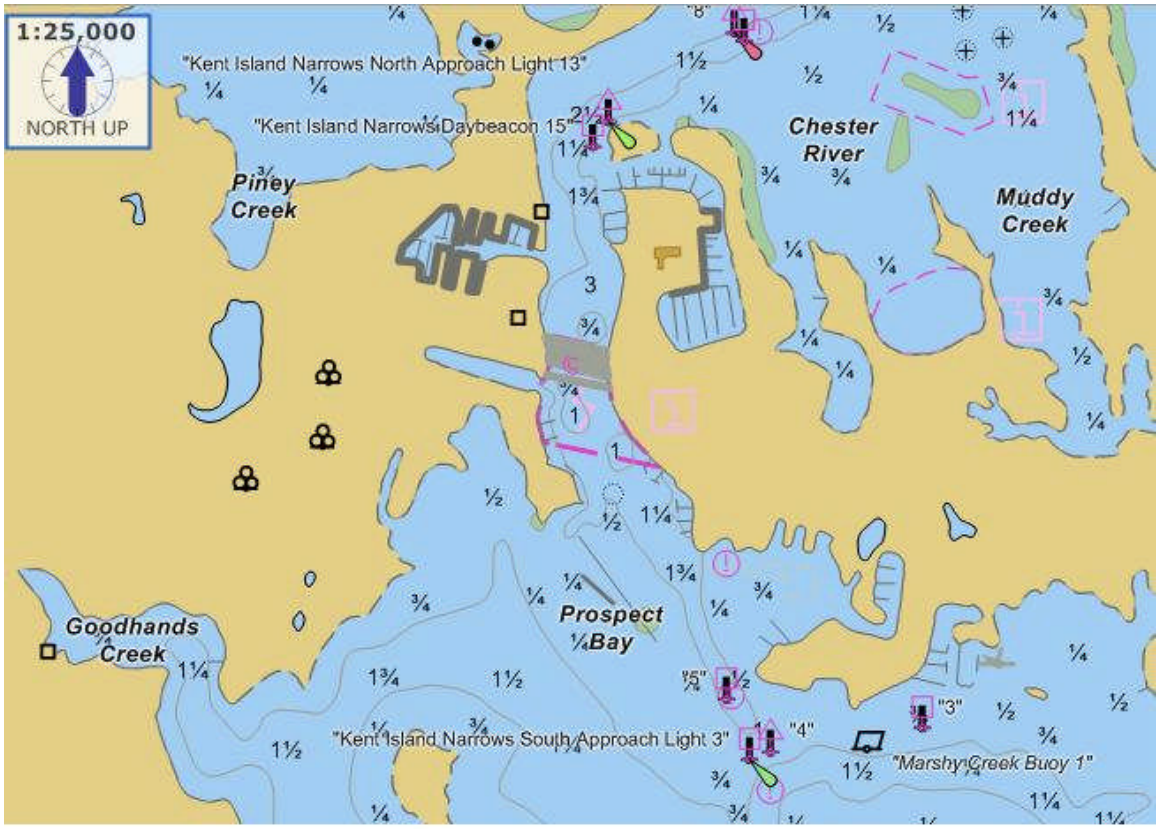
Figure 5 shows the same area displayed in Caris EASY-ENC software. Available from: http://www.caris.com/products/software.cfm/prodID/33



Appendix F - Figure 5: Caris EASY-ENC

8 Coastal Explorer

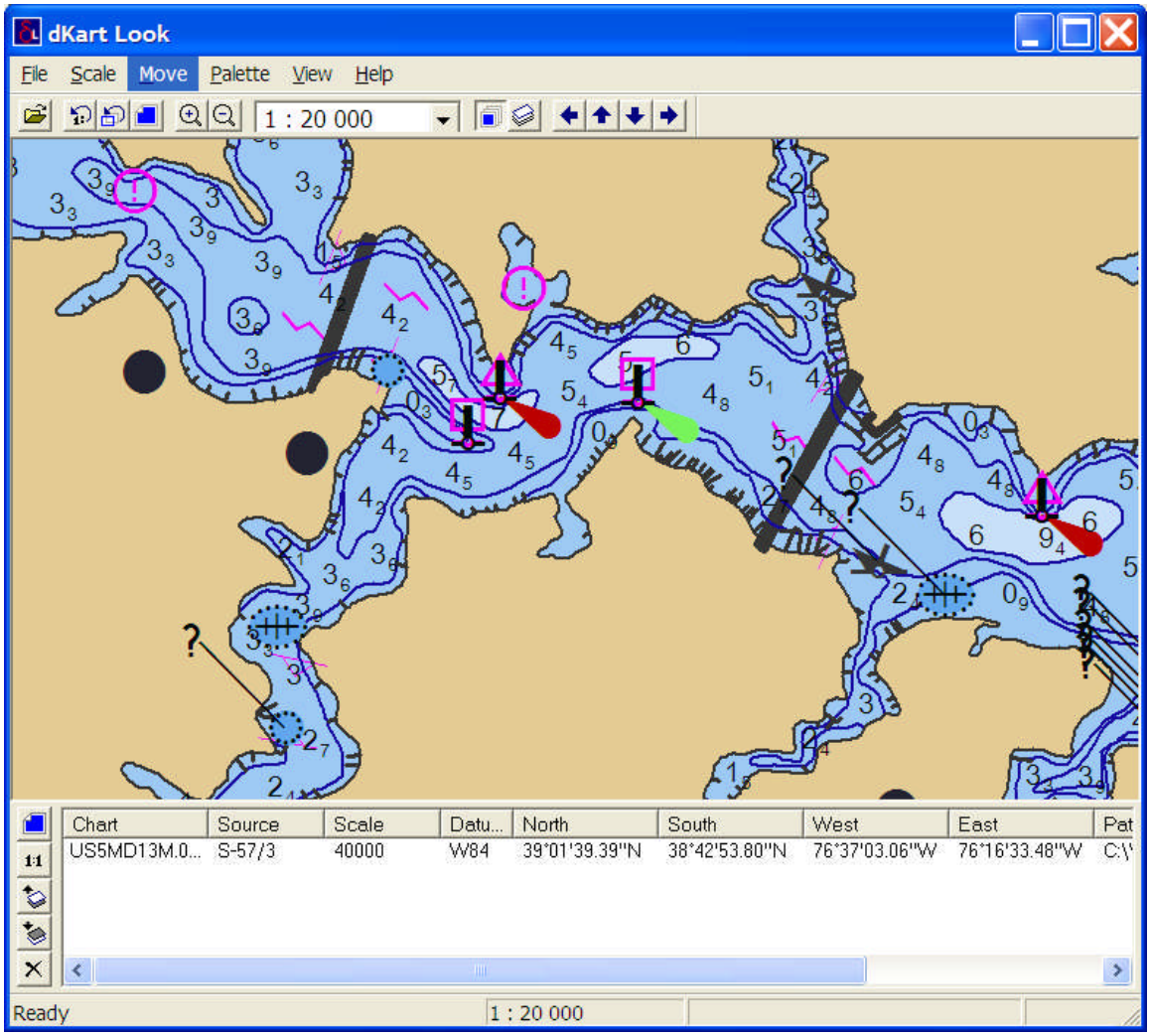
Figure 6 shows the same area displayed in Coastal Explorer from Rose Point Navigation Systems. Available from:
http://rosepointnav.com/CoastalExplorer/Trial/default.htm



Appendix F - Figure 6: Coastal Explorer

9 dKart Look

Figure 7 shows a slightly different area of approximately the same density displayed in dKart Look (there was a problem trying to display the previous data). Most text has been omitted for clarity. Available from:
http://www.hydroservice.no/Downloads/

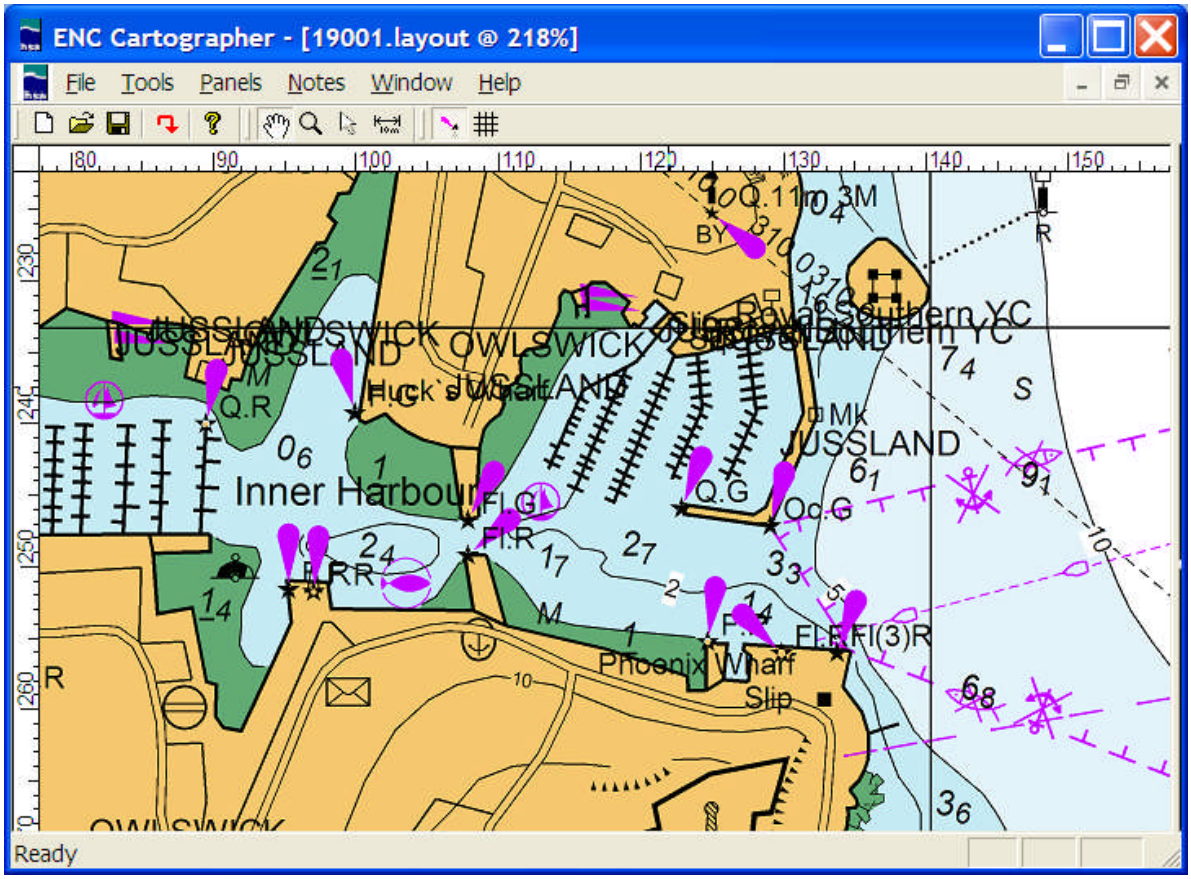


Appendix F – Figure 7: dKart Look

10 SevenCs ENC Cartographer

The SevenCs product called ENC Cartographer has been "developed to enable the production if INT 1/INT 2 compliant paper charts from ENC files" (http://www.sevencs.com/download/newsletter/newsletter-01-05.pdf)

Figure 8 shows part of the Micklefirth test chart and illustrates some of the problems encountered in congested areas of the chart with overlapping text, flares overprinting, boundary symbols confused, etc. It can be seen that although the text and symbology have been generated, manual intervention is required to convert the generated data to a cartographic product.



Appendix F – Figure 8: ENC Cartographer

A Comparison of ENC Plots with NOAA Paper Charts

Spring/Summer 2004

Authors: Leonard Arkenau, Robert Heeley, Russell Kennedy, Adeline Wong
Office of Coast Survey, NOAA (USA)

SCOPE

Our project group was tasked with evaluating samples of current paper charts with paper printouts of the S-52 display standard for Electronic Navigation Charts, ENC. This report is a summation of the differences we noted between the two display mediums as currently depicted. During the course of our evaluation we utilized the following ENC viewing packages to make our comparisons and evaluations; Fugawi, SevenCs SeeMYDENC and Dkart Inspector 4.0.

The following is a list of differences between examples of the current paper charts as compared with a direct screen capture printout of the ENC S-52 display from the Dkart viewer for the same areas. Sections from the following charts were used in the evaluation, New York – 12333 and 12334, Portland - 13292, Baltimore – 12278 and 12281, Boston – 13270 and 13272, Rochester-14815, Seattle-18450, Oceanside CA. – 18758, and Puerto Maunabo, PR- 25659.

The NOAA ENC database is not as up to date as the NOAA raster / paper database.

There are inconsistent collection and presentation methods in the ENC database

Holes exist in MCOVR areas on small scale ENC's where a larger scale ENC was collected. Data quality, density and generalization issues will arise when attempting to create a small scale paper ENC from combinations of same scale and larger scale ENC MCOVR areas.

The areas of some printed ENC's would have been pieced together from data collected at different scales, resulting in different densities of data.

The data in the ENC database is often so dense, symbols and type frequently overprint, making the plot unreadable.

Items such as shoreline, depth contours and depth soundings usually present no issues translating from the S-52 Dkart display to a paper screen capture printout.

There are no projection grid, neatline border, NOAA seal or chart border textual data, edition dates or corrected through dates on the printed screen captures of the ENC data sets. These would need to developed and added to produce a paper ENC chart.

There are no compass roses, bar scales, logarithmic speed scale, loran lattices, loran interpolator, depth conversion scale, or title block data such as type of projection, scale and mid-latitude on the printed screen captures of the ENC data sets. These would need to developed and added to produce a paper ENC chart.

Isogonic lines are not shown in the ENC.

Text is not aligned in the ENC database with features that are not aligned with the baseline.

Source diagrams are not shown on the paper ENC plot.

The bar code and National Stock Number are not shown on ENC plots.

Channel tabulations, channel depth legends and depth notes aren't depicted on the printed screen captures of the ENC data sets. This information does reside in the S-57 attribution of quartered dredged areas, and a software application would need to be developed to extract this data in either a textual or tabulated format for inclusion on a paper ENC product.

The symbology used on NOAA ENC's for dredged channels is a "busy", cluttered and annoying dot pattern.

Tide Box data and Great Lakes Hydrographs aren't depicted on the printed screen captures of the ENC data sets. This information would need to be developed and added to a paper ENC chart that required this information.

In the majority of cases chart features that have a label or text associated with them on the paper chart weren't depicted on the printed screen captures of the ENC data sets. In most cases this information does exist in the S-57 attribution and would need to be extracted in a consistent and uniform manner to avoid cluttering and overlap with other chart features, while maintaining minimal labeling to insure understanding of the chart feature on a paper ENC. This would require the development software, and in all likelihood some amount of human intervention.

Aid to navigation text does display on the paper screen capture of the ENC, but would need to be standardized to display the minimum useful label for paper chart users and avoid textual overlap with other chart features.

An aids to navigation symbolic display standard would need to be developed to avoid symbol overlap and unneeded depiction of color labeling versus color fill.

Sound signal labels are missing from aids to navigation, the ENC screen capture uses a sound symbol, but doesn't indicate type, i.e. whistle, gong, bell, horn etc. This data does reside in the S-57 data attribution.

The ENC screen capture depicts sector lights with a complete 360° arc of different colors to distinguish the different sector areas, and the sector ray lines didn't extend to the limits of the nominal range for the light. The current paper chart extends the sector rays either to the end of the chart limits or to the extent of the nominal range for the light; a color label and a color line show the different sectors.

Point features such as wrecks, rocks, obstructions associated with danger curves or danger curves with depths were not depicted with labels on the ENC paper screen capture. The small, solid circle obstruction symbol on the paper chart is shown as a dotted danger curve with blue tint on the ENC screen capture. Usually this symbol associated with vertical type as an opposed the slating type indicates a visible obstruction. The depiction of both visible and submerged obstructions need to by addressed for any paper product generated from an S-52 display. The questions arises is the specific label essential for submerged dangers, or can we standardize this to a singular label "Obstn"?

Rock elevations and drying heights are almost indistinguishable from depth soundings on S-52 paper plots.

Piles are portrayed as thick black dots on the paper ENC screen capture, they are sometimes not easily distinguished with a low water line, and dolphins are depicted as buff tint filled platform symbols, there are no text labels to indicate if the feature is submerged. The current paper chart scheme shows these features small open circles with textual labels to indicate submerged or visible. New symbols need to be developed to distinguish between piles and dolphins and visible versus submerged, this could be accomplished without text labels.

Submerged ruins are depicted as thin solid lines and blue tint with no text labeling on the ENC paper screen capture, while the paper chart shows these as dashed lines. The dashed line approach would be the preferred method with a label “Ruins”.

Visible ruins are depicted as thin solid lines and buff tint with no text labeling on the ENC paper screen capture, while the paper chart shows these as dashed lines. The dashed line approach and buff tint would be the preferred method with a label “Ruins”.

Blue tinted foul areas on the paper charts were depicted on the ENC screen captures that we examined were inconsistently depicted some with blue tint some with green tint. The ones depicted with green tint made them indistinguishable from low water areas; also they are delineated by large black dots and could be confused with the previously mentioned pile or piling symbol. In all cases there was no associated test label indicating a foul area.

Bridges are depicted on the paper chart by different symbols for each type of bridge with black lines, buff tint and a textual label describing the bridge type and clearances. The ENC screen capture showed the bridge as a dark gray screen with no textual label describing type and clearances. The locations of bridge openings are not shown in the ENC database. The question of the need to continue depicting various bridge types by different symbolic display on the paper versus just indicating bridge type by the bridge label will be a topic for discussion. This information does exist in the S-57 attribution, and will need to be extracted clearly by software for a paper ENC product.

Landmarks on the paper chart distinguish between accurate and approximate with a textual label. In the ENC screen capture there was only a standard symbol with no label, there needs to be symbol distinction between accurate and approximate and a textual label needs to display on an ENC paper product. This information is available in the S-57 attribution and would need to be extracted clearly by software.

All textual labels for CFR regulated areas, anchorage’s, pipeline and cable areas, and all other area depictions such as prohibited and restricted areas, disposal areas etc. were not depicted on the ENC screen capture. Other issues about how to symbolize the various magenta areas on a paper chart will need to be examined to insure consistency from the S-52 display of the data. This information will need to be shown on any paper ENC product and could be extracted from the S-57 attribution for these area two features by software.

Dual purpose areas on the paper chart such as “Pipeline and Cable Areas” weren’t labeled on the ENC screen capture, and there wasn’t a clear magenta symbol to indicate that the area was marking a dual purpose.

A tunnel area was shown on the ENC screen capture as a dashed gray line with no label, the symbol on the paper chart was a magenta dashed line with the label. The information for the label is in the S-57 data and would need to be extracted by for a paper product.

Several questions arose concerning the differences between quartered dredged area limits in the S-52 ENC display and the channel limits as portrayed on the paper charts. In S-57 does the outside quarters or the fairway limits constitute what is displayed in S-52 as the official channel limits? Is it preferable for screen filled quartered limits to be displayed on a paper version or will we need to convert to the traditional paper chart display of just the channel limits? In all cases concerning either quartered or non-quartered dredged areas the controlling depth data doesn't portray on an ENC screen capture, i.e. tabulations, depth legends and depth notes. In all cases this information exists in the S-57 attribution and would need software intervention to display on an ENC paper product.

Approximate depth contours are depicted as small dashed open rectangles on the ENC screen capture, while the traditional paper chart shows these as dashed black lines.

Unsurveyed areas on the ENC screen capture are tinted with a gray screen that masks underlying line work depicting ruined piers, while the paper chart shows these areas as a combination of blue and white tinting allowing the ruined piers to be more easily seen. Also any text related to the ruins or area didn't display on the ENC screen capture, but could be extracted by software from the S-57 attribution.

In harbor areas where pier numbers or names are displayed on the paper chart, the ENC screen capture didn't display these and they would need to be extracted from the S-57 attribution.

A "Being filled" area on the paper chart is depicted by a dashed black line with blue tint. The ENC screen capture shows the same area as a solid black line with buff tint. Again there was no associated label for the area on the ENC screen capture.

Features and type are clipped by the neatline on ENC plots.

Anchorages are shown; the type of anchorage (General, Naval, Commercial, etc.) is not.

Reported features and surveyed features appear the same on the S-52 paper plots, there was no apparent way to distinguish between quality of data types.

Type frequently overprints other type or symbolization and text is normally not aligned correctly for clarity with the associated feature.

Geographic names associated with wide areas appear on the S-52 paper plots in localized areas, while place names do not appear.

Closely spaced symbols often overlap into unreadable overprints.

Land contours indicating areas of elevations that are significant for navigation are not shown on the S-52 paper plots.

Facility information wasn't indicated on the paper plots.

Notes in the S-57 database appear to have been modified from the standard notes authorized for printed charts.

Blue tint areas were not set the same depth for the different viewers showing the same area.

The printed ENC will need to accommodate an ability to place curved text.

Currently navigable lakes or rivers are not always collected on the ENC.

Textual type sizes and styles are not indicated in the ENC database, and it appears that each viewer package displays text differently.

There is no chart overlap in the ENC database.

Currently there is no established naming convention or chart limits proposed for a paper ENC chart suite. It appears that a new chart suite re-scheming project will need to be undertaken to accommodate the paper ENC product.

There is no hierarchy established for concurrent line or point symbols for an S-52 paper ENC product.

Fish Havens will need labeling and minimum authorized depth information displayed with the symbol.

Any place where the S-52 paper plot shows an "information" symbol, that specific information would need to be extracted form the S-57 data and displayed on a paper ENC product.

Symbols aren't rotated in the S-52 paper plot, which presents data overprint issues.

Depth curve indicators aren't depicted on the S-52 paper plot.

Certain features such as peak elevations, overhead cables, ramps and trees \ snags didn't show up in the S-52 paper plots we examined against the standard paper charts.

Presentation of marine railway symbols needs improvement on the S-52 paper plot.

The seaward limit and shoreward limit of narrow marshes overprint each other on ENC plots.

Large airports are shown as a collection of many airplane symbols, cluttering the chart.

One viewer dropped the shoalest sounding in an area in order to show the depth curve.

SOME CONCLUSIONS

Screen captures of the same areas from viewers made by different manufacturers, presented different data in terms of generalization, missing data, symbology and tinting. A minimum standard of presentation of printed ENC's produced using the NOAA ENC database is strongly recommended.

There were apparent collection errors \ inconsistencies noted during this evaluation. Inconsistencies in collection policies over time have not been resolved, and an independent quality assurance program for collected ENC data and maintenance is strongly recommended.

A public education effort would need to be established to familiarize traditional paper chart users with any newly established chart scheme and symbolic depiction scheme for the paper ENC product.

Definition – "Compiled chart image" means the manually compiled raster image of a char that is used for printing, Raster Navigational Charts, On-Line Chart Viewer, BookletChart. promotional materials, used by others as a base map or backdrop, and which is in many ways the identity of the Coast Survey

Hypotheses – The paper chart is obsolete and its preparation by the government should be discontinued.

Reason for Discontinuing the Compiled Chart Image

1. OCS has 4 Branches performing paper chart maintenance. Eliminating that product(s) would recover about 50% of that labor for other uses or eliminated to reduce costs. (Note: The remaining 50% of the paper chart workforce does dual-use activities that would continue for electronic products.)
2. The paper chart uses other resources such as Bentley Maps Enterprise software, computers and support, private sector distribution services that could be recovered or expenses reduced
3. The paper chart stopped evolving decades ago. It's 'one size fits all' design and static nature are not as well suited to navigation as it was 100-200 years ago. Positioning is different, dynamic data, public expectations of 'maps', particularly digital maps, have changed.
4. A significant effort and expense will be incurred as we try to force NCSII to make these compiled chart images.

Reasons for Not Discontinuing the Compiled Chart Image

1. This image is used to produce many very popular products.
2. OCS has no strategy for satisfying those other uses with purpose-built products
3. This image has also become the image of the Coast Survey.
4. It is asserted that by precedents the public expects it is a government function to satisfy these other uses
5. The negative public and political outfall from such a decisive action would impact OCS negatively and thereby harm its ability to perform the remaining mission, e.g. by congress reducing our budget to reflect our reduced output
6. For an undetermined amount and in an undetermined amount of time, NCS II may be able to make the compiled chart images automatically thereby achieving some of the reason for considering their discontinuance.

1. The mandatory carriage of electronic charts by regulated vessels will eliminate the need for the paper chart after 2018. "Support of interstate commerce" and "compliance with federal regulations" will cease to be justification for paper charts.
2. The sale of printed, full size paper charts has been decreasing for decades and is assumed to be bottoming out at 50-70,000 copies per year.
3. Support of recreational boaters is asserted to be at our option although precedence and public expectations may be stronger. Only 1/3 of recreational boaters carry any paper chart-like product.
4. Recreational boaters are assumed to be transitioning to electronic devices or are starting to use charts via electronic devices

1. By July 2018, mandatory carriage of electronic charts will encompass all SOLAS vessels and it may no longer be legal to navigate on a paper chart. "Support of interstate commerce" and "compliance with federal regulations" will cease to be justification for paper charts.
2. U.S. electronic chart carriage regulations will be more inclusive than SOLAS and will also cover most smaller commercial vessels (those required to carry AIS).
3. ECDIS manufacturers are successfully selling dual ECDIS systems thus reducing the role of paper charts for backup.
4. Only about 1/3 of recreational boaters carry any type of nautical chart product and not all of those are NOAA charts.
5. Recreational boaters are moving to electronic devices for information consumption. Reduced capability, e.g. field of view, is being accepted in exchange for the other features of those electronic devices.
6. Many users of charts as "base maps" and other non-navigation purposes are converting to GIS.
7. U.S. Paper chart sales are 30% of the level of 30 years ago in spite of increased vessel traffic.
8. With the 'regulated carriage' use of paper charts removed, the traditional rules driving chart content, availability, form factor, coverage, user and uses, etc. are no longer applicable.

Future of the Paper Chart

The Situation – A shrinking role for paper charts.

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8. With the 'regulated carriage' use of paper charts removed, the traditional rules driving chart content, availability, form factor, coverage, user and uses, etc. are no longer applicable.
9. DoD & DHS are committed to going paperless and to use ePODs for residual hard copy needs.

Conclusion – By July 2018 the paper chart will be an outmoded product that may not be accepted for its original purpose of regulated navigation. Usage may be so low as to question the need for its production.

Meanwhile – Further investment in paper charts is needed.

1. OCS is facing a $7.5M (±), multiyear work item of building "templates" to be able to make paper charts from its new NCS II production system.
2. There will be further expense to attribute with depiction information all the items in the NCS II data base – both for paper charts and for S-101.
3. Additional development effort and expense will be needed to complete NCS II to the point where it can efficiently make paper charts.
4. Work is needed to make the paper chart printing and distribution services (both lithographic and Print-on-Demand) more responsive and robust.
5. IHO is completing a multi-year effort to rewrite the S-4 Standard for paper charts with an expected completion date in 2014.

Conclusion – These investments may be unnecessary if the traditional paper chart is discontinued. Now is a good time to consider alternatives that recognize the situation. Work might be avoided and the paper chart redesigned to be better tailored to its remaining uses.

Alternative courses of action

1. Do nothing. Continue to bear the paper chart compilation, printing and distribution costs. Continue NCS II to its full completion for paper chart production.
2. Continue paper charts but abandon the NCS II paper/raster software and continue to use Bentley Maps for that purpose.
3. Contract for paper chart compilation and provide the ENC database as the source of data.
4. Discontinue the paper chart but develop a "Printed ENC" as a minimum product for navigation.
5. Exit the paper chart market and let the private sector fill those needs since an official paper chart will no longer needed for regulatory compliance.