

THE END OF TRADITIONAL PAPER CHARTS: THE FINAL TRANSITION TO ELECTRONIC NAVIGATIONAL CHARTS

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1. Abstract

In late 2019, the United States' National Oceanic and Atmospheric Administration (NOAA) started a five-year program to end production and maintenance of its traditional paper nautical charts and corresponding raster chart products and services. This decision was driven by many factors. These included the challenge of maintaining two separate nautical chart production systems, one for raster and one for electronic navigational charts (ENC); growing demand for more timely and more detailed nautical chart coverage; diminishing use of paper nautical charts; and greater acceptance and use of ENCs by commercial vessels and recreational boaters. NOAA is refocusing resources to provide higher quality, more up-to-date, larger scale (more detailed), electronic navigational chart coverage and other ENC-based products and services.

2. Introduction – What is Happening to NOAA's Paper Nautical Charts?

The U.S. National Oceanic and Atmospheric Administration (NOAA) is canceling its entire suite of 1,007 traditional paper nautical charts. These charts and the corresponding digital raster chart products are being removed from the NOAA inventory in a process that will be completed by January 2025. NOAA is no longer able to satisfactorily maintain both traditional paper nautical charts and the modern NOAA electronic navigational chart (NOAA ENC[®])¹ product. NOAA is ending production of traditional paper charts to enable the creation and maintenance of higher quality, more up-to-date, larger scale (more detailed), electronic navigational chart coverage and other ENC-based products and services.

NOAA is now cancelling 20 to 30 paper and raster charts per month – generally canceling larger scale charts first. In addition to traditional paper charts, NOAA produces three other products from the same raster images used to make paper charts. These are raster navigational charts (RNC)², full-sized images of nautical charts in portable document format (PDF), and NOAA BookletCharts™ – reduced-size replicas of nautical charts that have been divided into a dozen or more 8½ x 11-inch pages for home printers. All of these associated products will be discontinued when the corresponding paper chart is canceled. The ENC will remain as NOAA's premier nautical chart product.

¹ The format and content of ENCs are currently specified by the International Hydrographic Organization (IHO), *S-57 Transfer Standard for Digital Hydrographic Data*. This and other IHO standards and specifications may be downloaded from <https://iho.int/en/standards-and-specifications>, accessed 20 Jan 2022.

² NOAA produces the "BSB format" version of RNCs, specified by the IHO *S-61, Product Specification for Raster Navigational Charts (RNC)*.

3. History and Scope of U.S. Nautical Charting

The U.S. Survey of the Coast was founded in 1807 and published its first nautical charts in the 1840s (**Figure 1**). Now an office within NOAA, the Office of Coast Survey has a staff of nearly 200 cartographers, hydrographers, scientists, and other skilled technicians. The office maintains nautical charts and publications for U.S. coastal waters, the Great Lakes, and the U.S. Exclusive Economic Zone (EEZ), which collectively comprise over 3.6 million square nautical miles (over 12.3 million square km). NOAA nautical chart products include over 1,000 traditional paper and raster charts, over 2,100 ENC, and ten volumes of the U.S. Coast Pilot™ sailing directions.

The retirement of traditional paper nautical charts is the next logical step in a transition that began in the 1980s. This is when NOAA started modernizing its analog chart production system by scanning color-separates used to make press plates for the multi-color lithographic printing of paper nautical charts. These digital files were initially used to make NOAA's suite of RNCs, and ultimately used as the basis for the NOAA ENC product created in the 1990s.

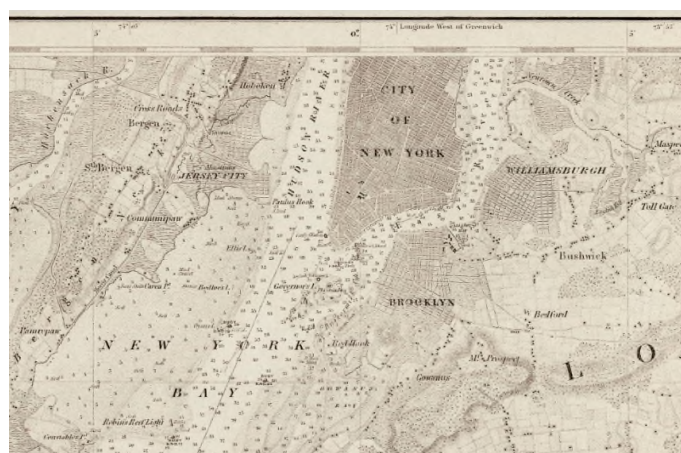


Figure 1: Detail from 1:80,000 scale chart, “New York Bay and Harbor and the Environs”, published in 1845 by the U.S. Survey of the Coast.

NOAA paper nautical charts are printed and distributed through NOAA certified print-on-demand (POD) chart agents. POD charts contain all critical corrections published in the U.S. Coast Guard (USCG) Local Notice to Mariners (LNM) and the Notice to Mariners (NM) published by the National Geospatial-Intelligence Agency (NGA). After purchase, mariners must consult these same publications and apply weekly changes manually.

NOAA ENCs can be downloaded, free of charge, from the Office of Coast Survey website (<https://nauticalcharts.noaa.gov/>), or obtained through a regional ENC coordinating center (RENC) subscription service for a nominal fee. Digital ENC updates are posted weekly and can be applied automatically by electronic navigation systems.

4. Rationale for Focus on ENCs

At the end of 2020, NOAA maintained 1,007 paper and raster charts, comprising over 2,000 separate main chart panels and insets – compiled in over 100 different scales. Producing and distributing raster charts requires separate computer software and data storage systems from those used to produce ENCs, as well as other specialized cartographic training and processing. NOAA now maintains over 2,100 ENCs and is carrying out an ambitious program to replace much of the existing ENC coverage with more detailed (larger scale) data. When completed, the enhanced ENC product suite will consist of over 7,500 ENCs in just 11 standard scales. NOAA has only been able to create and maintain this enhanced suite of ENC products by redirecting resources previously used to update and distribute traditional paper and raster charts.

There are many other reasons why NOAA is moving to focus exclusively on ENC production after publishing paper nautical charts for over 170 years. There is a need for more detailed nautical charts that enable real-time plotting of a vessel's position. Larger ships are entering ports and transiting channels with the tightest of underkeel clearances. For example, guidelines for underkeel clearances of as little as two feet (61 cm) are provided for vessels approaching berths in the Ports of Los Angeles and Long Beach, California, under normal circumstances. Exceptions are occasionally made for even tighter passages.

Advances in the accuracy and availability of equipment using GPS (Global Positioning System) and other global navigation satellite systems (GNSS) have led to greater adoption of digital charts and electronic navigation. The International Maritime Organization (IMO) and the International Convention for the Safety of Life at Sea (SOLAS)⁴ now require nearly all commercial ships on international voyages to use an Electronic Chart Display and Information System (ECDIS) with ENCs for route planning and navigation while underway. In 2002, the USCG accepted ECDIS as meeting relevant nautical chart regulations⁵. Since 2016, USCG policy has provided that ENCs may be used in lieu of paper nautical charts in ECDIS, and in some non-ECDIS systems that meet certain display and other criteria, for U.S. vessels subject to U.S. chart carriage requirements⁶.

In March 2022, the USCG published an Advance Notice of Proposed Rulemaking (ANPRM) for "[Electronic Chart and Navigational Equipment Carriage Requirements](#)". This ANPRM outlines a broad strategy to revise the chart and navigational equipment requirements for commercial U.S.-flagged and foreign-flagged vessels operating in the U.S. waters. Public input is being sought regarding any proposed modifications of chart carriage requirements and information will be gathered as to how widely electronic charts are currently used. Nearly two dozen different regulations have been identified that may be affected by the rule making effort.

ENC data is produced by many countries and used by mariners around the world. In addition to the ECDIS equipment used by large ocean-going vessels, ENCs can also be used in a growing variety of electronic chart systems (ECS), chart plotters, and mobile devices by professional mariners and leisure craft owners alike. Use of ENCs also enables real-time vessel positioning and automated alarms or indications of unsafe conditions during voyage planning and while underway – safety features that paper charts cannot provide. The IHO has developed a new "S-101 ENC"⁷ that will eventually replace the "S-57 ENC" data currently used for navigation. The new ENC product specification enables interoperability with a growing family of maritime related products⁸ that comply with the IHO's *S-100 Universal Hydrographic Data Model*⁹. As hydrographic offices, including NOAA, start to produce S-101 format ENCs in the coming years, some systems will likely use the ENC as a "base map" over which other S-100 based products, such as marine protected areas, navigational warnings, surface currents, and other types of data, might be displayed. These are clear indications that ENCs are already an important part of the marine navigation "ecosystem" and will be even more so in the future.

³ Port of Los Angeles, *Mariners Guide*, "Underkeel Clearance," pages 14-15, at: <https://kentico.portoflosangeles.org/getmedia/8fa75362-e477-4748-ab2c-383e2d25563e/2021-pola-mariners-guide>, accessed 20 Jan 2022.

⁴ International Maritime Organization (IMO), SOLAS Consolidated Edition 2014 (with supplements), Chapter V, Regulation 19, London, 2014.

⁵ U.S. Code of Federal Regulations, 33 CFR § 164.33 - Charts and publications at: <https://www.govinfo.gov/content/pkg/CFR-2016-title33-vol2/pdf/CFR-2016-title33-vol2-sec164-33.pdf>, accessed 20 Jan 2022.

⁶ U.S. Coast Guard, Navigational and Vessel Inspection Circular No. 01-16 (NVIC 01-16) at: https://www.navcen.uscg.gov/pdf/navRules/USCG_NVIC_01_16_electronic_charts_and_publications_Ch2.pdf, accessed 20 Jan 2022.

⁷ IHO, *S-101, Electronic Navigational Chart (ENC) Product Specification*.

⁸ IHO, "S-100 based Product Specifications," at: <https://iho.int/en/s-100-based-product-specifications>, accessed 20 Jan 2022.

⁹ IHO, *S-100, IHO Universal Hydrographic Data Model*.

While ENC use is increasing, the use of traditional paper nautical charts is decreasing. Sales of NOAA paper nautical charts have dropped nearly 60% since 2010, sustaining a downward trend that started over two decades ago (**Figure 2**). The IHO Nautical Cartography Working Group documented similar declining sales of paper charts published by many other hydrographic offices around the world in their “Future of the Paper Nautical Chart Final Report,” released in August 2020¹⁰.

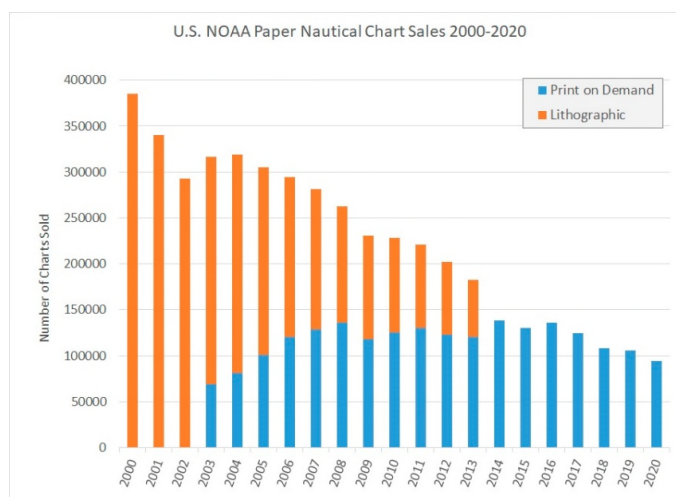


Figure 2: NOAA has distributed paper nautical charts exclusively through commercial print-on-demand partners since 2014. Sales of both lithographic and print-on-demand paper charts have been declining for over two decades.

Guided by these trends, NOAA initiated a program to phase out its traditional paper nautical charts and their corresponding raster chart products and services.

4. Notification of Chart Cancellations

Six months before a chart's scheduled cancellation, NOAA announces that the current edition of the chart will be its last edition. Charts purchased during the six-month interval before cancellation will include a note in the lower left corner of the chart stating, “This is the Last Edition of this chart. It will be canceled on < date >” (**Figure 3**).

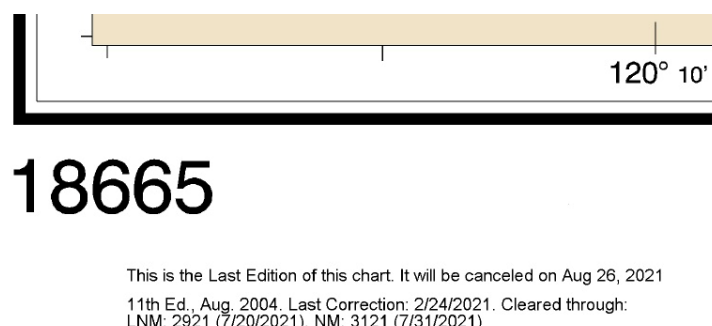


Figure 3: Last-Edition note on a chart scheduled for cancellation.

When a chart enters last-edition status, the USCG publishes a Local Notice to Mariners (LNM) announcing the change in status and the scheduled cancellation date (**Figure 4**). The LNM includes a hand correction instruction to add the last-edition note to previously purchased charts. Twenty-six weeks later, the chart is canceled and another LNM is issued to announce the cancellation (**Figure 5**).

¹⁰ IHO, Nautical Cartography Working Group, “The Future of the Paper Nautical Chart Final Report,” pages 28-29, at: <https://iho.int/uploads/user/Services%20and%20Standards/HSSC/HSSC12/2020-08-28%20Future%20of%20the%20Paper%20Nautical%20Chart%20Final%20Report%20FINAL.pdf>, accessed 20 Sep 2021.

18665	11th Ed.	01-AUG-04	Last LNM: 32/14	NAD 83
ChartTitle: Lake Tahoe (Metric)				
Main Panel 1865 LAKE TAHOE. Page/Side: N/A				
ADD	Lower Left of Chart: This is the Last Edition of this chart. It will be canceled on 26-Aug-21.			
ADD	Visible Wreck			
LAST EDITION	No new editions of chart 18665 will be published. It will be canceled on 26-Aug-21. Comparable or larger scale Electronic Navigational Chart (ENC) coverage is available. See "Cancellation of NOAA Paper and Raster Nautical Charts" in Section I of this LNM for details. A list of all canceled NOAA charts is at https://www.charts.noaa.gov/MCD/Dole.shtml .			

Figure 4: Last-edition announcement for Chart 18665 in the 3 Mar 2021 edition of USCG, District 11, Local Notice to Mariners (LNM 09/21).

18665	11th Ed.	01-AUG-04	Last LNM: 09/21	NAD 83
ChartTitle: Lake Tahoe (Metric)				
Main Panel 1865 LAKE TAHOE. Page/Side: N/A				
CANCELED	55Chart 18665 is canceled. No Print-on Demand or digital raster formats of this chart are available. Comparable or larger scale Electronic Navigational Chart (ENC) coverage is available. See "Cancellation of NOAA Paper and Raster Nautical Charts" in Section I of this LNM for details. A list of all canceled NOAA charts is at https://www.charts.noaa.gov/MCD/Dole.shtml .			

Figure 5: Chart cancellation announcement for Chart 18665 in the 1 Sep 2021 -edition of USCG, District 11, Local Notice to Mariners (LNM 35/21).

A comprehensive list of charts in last-edition status and charts canceled since 2018 is available on the Office of Coast Survey's Dates of Latest Editions website (<http://www.charts.noaa.gov/MCD/Dole.shtml>).

5. Shutdown of RNC Services and New Ways to Portray ENC Data

NOAA has also shut down three related raster chart web map services: the NOAA RNC Viewer, the RNC Seamless Service, and the RNC Tile Service. These enabled RNC data to be viewed as a background map in geographic information systems (GIS), and other online and offline platforms. As more raster charts are canceled, the growing patchwork of holes in the RNC data would render these services of little use. Thus, these services were all shut down early in the chart cancellation process. To support the many online and offline applications and services that use NOAA raster charts as a basemap for the display of other data, NOAA has expanded its similar online ENC Display Services. An existing service enables users to view ENC data portrayed with the same symbology used by ECDIS¹¹. A new [NOAA Chart Display Service](#) portrays the same ENC data using symbology and colors more familiar to paper chart users, either as an online basemap or to download data tiles for offline applications. This service is not intended to be used for navigation.

6. ENC-Based Paper Chart

Similar to the ENC display services, the NOAA Custom Chart¹² application provides a traditional paper chart-like rendering of ENC data. The application enables users to create their own customized nautical charts directly from the latest NOAA ENC data, specifying paper size, scale, and location. Depths can be displayed in meters, feet, or fathoms and there are other display options, such as changing the depths at which blue shading is applied to portray shallow water. The application renders the appropriate scale ENC data and outputs a chart image as a PDF file. NOAA Custom Charts do not have numbers and USCG LNMs will not be issued for corrections to these charts. These charts will be especially useful for recreational boaters or for planning and situational awareness for vessels required to use ENCs.

¹¹ ECDIS symbology for S-57 format ENCs is specified by the IHO S-52, *Specifications for Chart Content and Display Aspects of ECDIS*.

¹² NOAA Custom Chart application is at: <https://devgis.charttools.noaa.gov/pod/>, accessed 20 Sep 2021. More information about the application is on the NOAA Office of Coast Survey website at: <https://nauticalcharts.noaa.gov/charts/>

NOAA is collaborating with several other hydrographic offices in the IHO Nautical Cartography Working Group's Baseline Symbolism Project Team. This team is endeavoring to create standardized digital symbology and portrayal rules – different from existing ECDIS symbols and rules – that will automate all or most of the effort of creating a paper chart rendering from ENC data. The NOAA Custom Chart application is an early example of this capability (**Figure 6**).

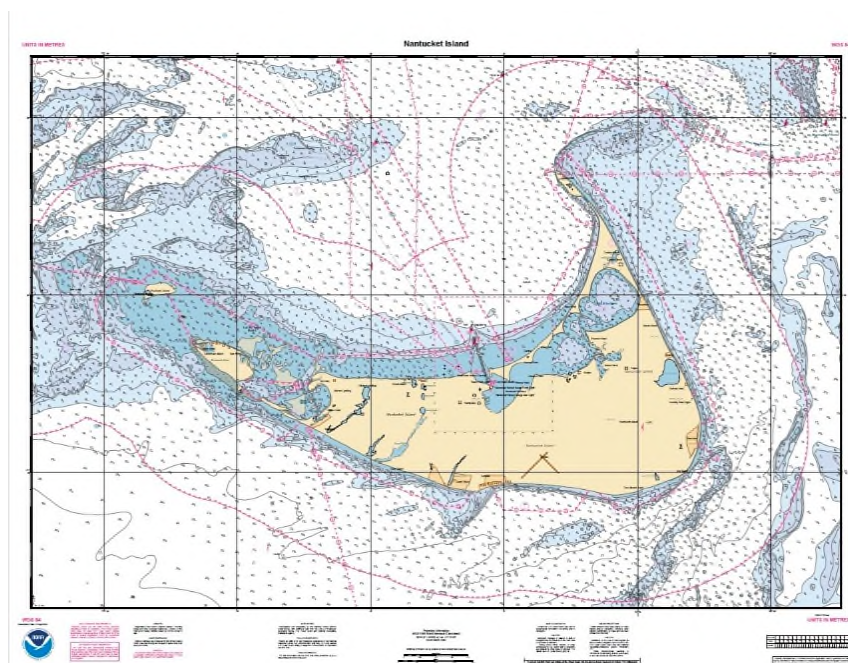


Figure 6: Example of NOAA Custom Chart output for Nantucket Island, Massachusetts.

7. Canceling Paper Charts has Enabled Improvements to ENC Content and Coverage

NOAA is creating a new gridded layout for its entire ENC product suite – compiled in just 11 scales. This will replace the irregular ENC footprints – compiled in over 100 scales, that were inherited from the paper charts that ENCs were created from (**Figure 7**).

Each new ENC will cover a smaller footprint – about a quarter to a tenth of the area covered by the ENCs that they replace. This enables greater chart production efficiency, because several cartographers can now be assigned compilation work in separate, adjacent ENCs. Many of the reschemed ENCs will also be compiled at a larger scale. This will ultimately quadruple the number of ENCs in the product suite. Having fewer scales makes “edge matching” between adjacent ENCs easier, as features crossing ENCs are more likely to be compiled at the same scale and portrayed in a similar manner. This is especially true for depth contours, which will be compiled in a consistent set of metric depth intervals, eliminating “hanging contours” at ENC boundaries. Depth contours – which are now primarily compiled in feet or fathoms – are being recompiled in meters (and tenths of meters in shallow water). Since U.S. hydrographic survey data is collected and processed in meters, compiling the data in the same metric units avoids conversion errors and other complications. Topographic contours and road networks, which were not typically compiled on NOAA ENCs, are now being added, something that users – especially in remote areas with few landmarks – have been requesting for some time.

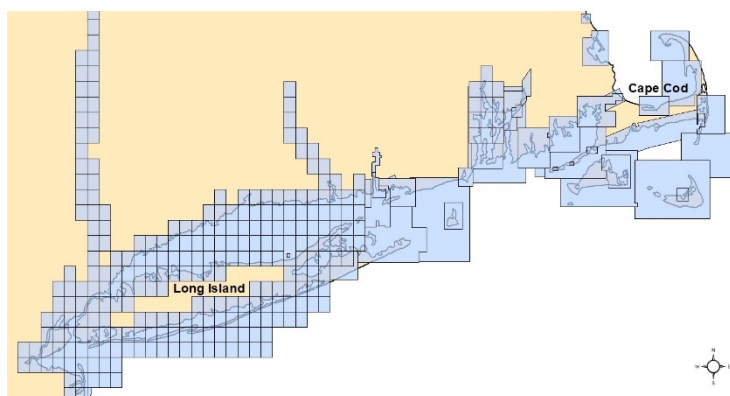


Figure 7. ENCs bounding Long Island, New York have been rescheduled as a grid of 1:10,000 and 1:20,000 scale ENCs. ENCs around Cape Cod, Massachusetts still show their paper chart scheme origins.

8. After Chart Numbers

Once a chart is in last-edition status, critical corrections – such as changes to floating and fixed aids to navigation, and newly identified rocks, wrecks, obstructions, and shoals – will continue to be applied and released as updates to the same edition of the chart. After a chart is canceled, all maintenance on the paper chart will cease and the USCG will no longer issue LNM corrections for the chart. The USCG [LNMs](#) and [Light Lists](#), and the NOAA [U.S. Coast Pilot®](#) sailing directions currently make copious references to NOAA chart numbers. Once all NOAA paper charts are canceled, the chart correction section of the LNM will be removed and references to chart numbers in other sections, such as special notices and aids to navigation discrepancies, will be removed.

As charts are canceled, chart number references in LNMs, Light Lists, and the U.S. Coast Pilot will be replaced by a hierarchical set of place and waterway names that will “drill down” to identify distinct locations, such as “Atlantic Seacoast > Chesapeake Bay > Potomac River > Saint Marys River.” These names are derived from the USCG led Waterway Harmonization Project that is defining waterway extents and standardizing waterway names used by several federal agencies. This effort will also provide standardized names to describe specific stretches of rivers and channels.

9. Historical Charts

The last edition of cancelled charts (**Figure 8**) are archived on the Office of Coast Survey’s Historical Map & Chart website (<https://historicalcharts.noaa.gov/>) as JPEG files. Other previously superseded editions of charts are also available in this collection for historical research, non-navigational purposes, or for framing.



Figure 8: Note added to canceled charts when they are archived on the Historical Map and Chart website.

10. Conclusion – Prospects for the Transition from Paper to Electronic Navigational Charts

NOAA may be the first hydrographic office to cancel its entire suite of traditional paper nautical charts, but it is unlikely to be the last. Doing so has enabled NOAA to create higher quality, larger scale, electronic navigational chart coverage of U.S. waters. Advances in equipment and software have made use of ENC's accessible to large and small commercial vessel operators, recreational boaters, and other non-navigational data users. Transitioning to ENC's from paper nautical charts will improve chart production efficiency, and greater use of ENC's and electronic navigation will improve maritime safety.