CAN THE MARINER TRUST HIS CHART ?

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Presented at the 20th Annual Meeting of the
American Congress on Surveying and Mapping, Washington, D. C., March 21-23 1960.

Note on Author. — Mr. Robert J. BEATON received a B. S. degree in Forest Biology at the University of Maine, class of 1942, and attended George Washington University 1956-58, majoring in Engineering Administration. From 1942 to 1946, Mr. BEATON served in the Caribbean and Pacific area on board the U. S. Navy survey ship U.S.S. *Bowditch* as Officer-in-Charge of the Ocean and Lakes Division. At present he holds the rank of Commander in the Naval Reserve. Robert BEATON was first employed at the U. S. Navy Hydrographic Office in 1942, and then after military furlough, resumed his duties in 1946. Since 1955, he has been Deputy Head of the Cartographic Branch. In addition to his regular supervisory duties that involve the planning and production of charts for the merchant marine and Navy, he participates in the preparation of map and chart plans issued by the Department of Defense, and is a frequent representative of the Navy Department at various international charting conferences. At present he is Chairman of the Technical Division on Cartography, American Congress on Surveying and Mapping.

I have been asked to discuss the broad subject of nautical chart evaluation, with particular attention to some specific merits and limitations of existing and potential systems. To tackle this assignment one must first be clear about the general approach. It makes all the difference, for example, whether we are thinking of the evaluations made of sources that concern a chart being compiled, or whether we suppose the evaluation is made of the published chart whose sources are unavailable and, perhaps, partly unknown.

Objective

The first suggestion I wish to make is that our present objective should be to identify the various factors that affect both types of evaluations and to develop workable criteria and meaningful terms that make it possible to classify a chart's characteristics. If this task can be done with success, there is a chance of being able to answer specific queries by other nations who possess similar requirements for establishing understandable terms and standardized methods to assess the accuracy of charts.

The Mariner's Method of Evaluating Charts

How the mariner, who has over 240 000 nautical miles of seacoast and more than 105 000 000 square nautical miles of ocean areas in which to navigate, evaluates each chart for his particular route is largely a matter of personal knowledge, experience, and judgment. Some of the practical considerations that he may apply in determining a chart's worth include the identity and reputation of the publisher; chart scale and sheet limits relative to intended use; overlap on adjacent coverage including consistency of geographic graticule; lack of caution notes; currency of information and the amount of detail accurately and legibly presented with respect to the character of the sea bottom, safe channels, main terrain details, and other navigational features that ensure safe passage. The mariner weighs these factors, usually in the light of his own personal knowledge of the area, and makes prudent allowance for possible unreported or incompletely charted dangers.

To some extent, the mariner's task of evaluating charts is not difficult, because most of the information needed to form an opinion has become reasonably standardized on charts during the last 39 years, through the efforts of the International Hydrographic Bureau established in 1921. Therefore, from mariners long accustomed to judging charts by the criteria described, no particular demands have been made for additional evaluation data—although many have requested improved chart coverage.

The Cartographer's Reluctance to Print Evaluations

Moreover, chart makers have hesitated to print evaluation terms on charts for fear of unduly alarming the mariner and, consequently, interfering with his normal navigational use of the chart. This reluctance on the part of cartographers is perhaps justified in view of the lack of accepted chart appraisal standards, the tendency to use the chart for purposes that exceed its functional design, and the need to accomplish systematic field editing of the chart proof.

The difficulties associated with any nautical chart evaluation system are intensified by the fact that charts do not completely reflect the physical features of an area. As Lloyd BROWN described the early sea charts in his book, *The Story of Maps,* "They treated in a simple, direct way the problem which concerned the navigator and ignored the rest." So it is that generalization is accomplished on modern charts: some details are suppressed by combination or omission, while other details are stressed. Nevertheless, their design as functional tools of the navigator makes them unique documents that show marine features and often coastal details more accurately than other publications.

Requirements for Chart Appraisals

Since World War II, however, a greatly increased number of users has developed for nautical charts as a source of geographical information.

Much of this need is attributable to advances in instrumentation and weaponry, such as electronic systems and guided missiles. Today, in addition to the marine navigator, numerous cartographers, marine geologists, military intelligence analysts, and naval planning staffs consult charts and employ them in various ways. For example, charts are frequently used as base maps on which to apply specialized information for merchant shipping and naval operations. The need for assessing chart accuracy also has international aspects as I have already mentioned.

Unfortunately, many nonmarine users are not so familiar with charts of the area covered as the navigator, while others possess specific requirements that cannot be satisfied unless more information is known about the chart's background. One of the facts most sought after by researchers, for instance, is the exact positional relationship of the charted details to the geodetic datum accepted for the area. Of course, only through a complex procedure that embraces the influence of all operations from the field surveys to the printed chart, is it possible to gain some perception of the position error of points on the chart. Information of this nature, however, in conjunction with other data, is essential to the cartographer for planning the most economical method of compiling new charts and to the military planner for determining the positional accuracy of potential targets.

Significance of Supporting Data

The quality of the chart compiled by the cartographer is often reflected in the chart record by the exactness and completeness of his entries concerning pertinent historical facts, sources used, and compilation methods selected. On occasion, however, the cartographer may retain vital information in his memory instead of in the written record, and while he may know intimately the chart's qualities—no one else does. The problem of tracing a chart's history is further complicated, of course, when more than one cartographer is assigned to various compilation or revision phases. Nevertheless, accurate analysis of compilation errors, source material quality, and generalization encountered during these phases depends on the cartographer who has access to the original surveys and field revision data, plus other maps, charts, and photography of known reliability. Unless such sources are examined, an appraisal of a chart is likely to be largely a matter of conjecture despite its apparent accuracy and completeness.

Need for Standardized Evaluation Processes

To promote thorough appraisals, chart producers require a method of matching their product to an agreed standard of quality; in effect, a standardized system of evaluation for classifying nautical charts in the different categories of reliability. If such a method for appraising original sources incorporated on charts were adopted by chart production agencies, then the reproduced or recompiled charts would reflect the same evaluation, provided the proper cartographic standards were maintained. Eventually, the basic charts of each nation would exhibit an evaluation note which copying cartographers and other users could emulate..

Current Chart Evaluation System:

The current system of evaluating published nautical charts at the U. S. Navy Hydrographic Office contains elements of conjecture because so little original data in the form of surveys are available for foreign areas. To classify hydrography (coastal and offshore), culture, and relief, we use the terms good, fair, and poor. Hydrography is evaluated according to chart scale, pattern of soundings, and currency. Depiction of cultural detail is classified from good to poor by comparison with maps of similar scale; and presentation of relief is similarly categorized depending on whether or not the method of portrayal is by spot lights, form lines, hachures, contours, or contours plus shading. The internal control accuracy of each chart is determined by a cartometric analysis. This system, supplemented by additional descriptive data and graphic indexes, finds its primary use in chart appraisal studies of regional coverage.

For individual chart appraisals based on examination of basic, original sources and other materials of known value the element of conjecture, however, can be minimized. Assuming the competency of the analyst, appraisal reliability can be achieved by employing available techniques that provide reasonably correct, if not exact, assessment of a chart's accuracy and completeness. The chief requisite is to adopt a standard method of appraisal and to employ meaningful terms of reliability.

Author's Purpose

The purpose of this paper, then, is twofold: (1) Advocate the portrayal of more complete and specific basic compilation data references and/or compilation diagrams as being highly desirable on nautical charts; and (2) Suggest a practical procedure for expressing qualitatively the reliability of nautical charts.

Development of Evaluation Processes

Figure 1 indicates how a beginning can be made by amplifying existing information shown on charts; namely, the addition of specific details concerning the type and timeliness of source materials.

Figure 2 illustrates a proposed compilation diagram which delineates sectors of the chart where specific sources were used. The supporting data shown adjacent to the diagram are similar to that given in figure 1, except that by letters keyed to the diagram an index of sources is provided. This diagram and accompanying list of sources reveal the identity, scale, and date of each source, and indirectly furnish an index of reliability in accord with the practical considerations applied by the mariner. In the author's opinion, this kind of precise information on charts is long overdue and,

H.O. Chart 236,1: 50 000, 1st Edition 1953
Argentine Chart 1720, 1: 135 000, 4th Edition 1948.
AMS Series L751, Sheet 1024 IV, 1: 50 000 Edition 1949.
C & GS Smooth Sheet No. 011798, 1: 10 000, 1946.
H.O. Smooth Sheets (Archive No. 71650). 1:20 000-1:50 000, 1953
U. S. Navy Aerial Photography, 1: 40 000, 1955.
Stereo-compilation, 1958.

FIG. 1. — Compilation data.

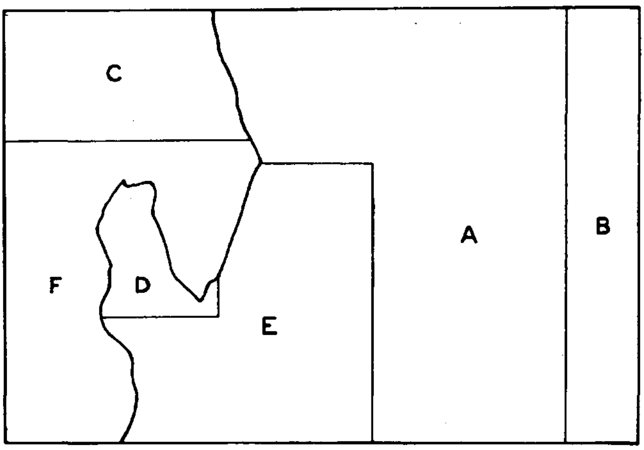

FIG. 2. — Source data.

A — H.O. Chart 236. 1: 50 000, 1st Edition, 1953.
B — Argentine Chart 1720, 1: 135 000, 4th Edition 1948.
C — AMS Series L751, Sheet 1024 IV, 1: 50 000, Edition 1949.
D — C & GS Smooth Sheet No. 011798, 1: 10 000, 1946.
E — H.O. Smooth Sheets (Archive No. 71650), 1: 20 000, 1953.
F — U. S. Navy Aerial Photography, 1: 40 000, 1955.

certainly should not inhibit use of the chart from the mariner's viewpoint, but rather enhance his appreciation of its worth.

Figure 3 represents a proposed reliability diagram which, in addition to the data given in figure 2, expresses the evaluation results in terms of adjective ratings and horizontal displacement (in feet) of detail relative to the chart datum and accepted datum. The appendix describes the alphabetic-numeric code and criteria by which a chart is evaluated. Annex A to the appendix defines the adjective rating system, with its correlation to the ratings of the alphabetic-numeric code.

Derivation of Evaluation Criteria

The proposed evaluation criteria are based on the Inter-American hydrographic survey accuracy standards and international topographic map evaluation criteria, both of which are modified here for application to nautical charts. The hydrographic survey standards were adopted by the American nations at the VIIth Cartographic Consultation of the Pan American Institute of Geography and History at Mexico City in 1955. These standards are currently being circulated by the International Hydro-

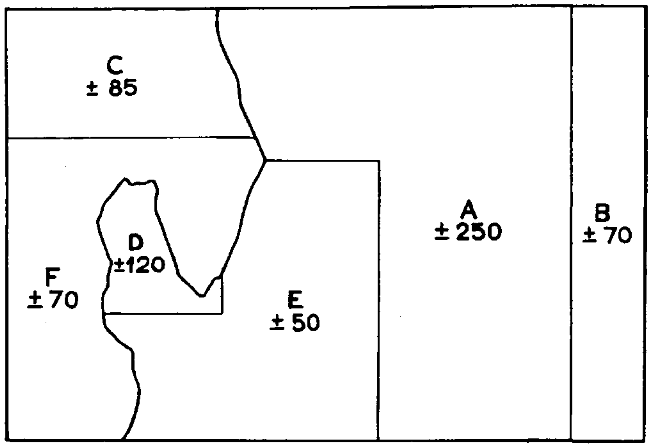

FIG. 3. — Source data.

A — H.O. Chart 236. 1: 50 000, 1st Edition, 1953. — Poor-Inadequate.
B — Argentine Chart 1720, 1: 135 000, 4th Edition 1948. — Good-Adequate.
C — AMS Series L751, Sheet 1024 IV, 1: 50 000, Edition 1949. Good-Usable.
D — C & GS Smooth Sheet No. 011798, 1: 10 000, 1946. — Fair-Usable.
E — H.O. Smooth Sheets (Archive No. 71650), 1: 20 000, 1953. — Excellent-Adequate.
F — U. S. Navy Aerial Photography, 1: 40 000, 1955. Stereo-compilation, 1958. — Good-Adequate.

Reliability Information Horizontal datum : Argentine. Figures in diagram represent geodetic positional accuracy (in feet) of chart relative to *Argentine datum*. The evaluated relationship of *Argentine datum* to *South American datum* is ± 600 feet.

graphic Bureau for comment by Member States. The topographic map evaluation criteria for military purposes have been established by mutual agreement in several countries during recent years.

Chart Evaluation Defined

Fundamentally, chart evaluation is an appraisal made for a specific reason before or after publication, and it concerns the accuracy and adequacy with which the features of a portion of the earth's surface, including underwater topography, are represented on charts. The principal data to be assessed are geodetic control, hydrography, coastal topography, tides, currents, and geomagnetic phenomena. Significant valuation factors relative to the chart and its method of preparation include the extent of geodetic control; survey instruments and methods; accuracy and currency of hydrographic detail, land planimetry and relief; completeness and legibility of data portrayed; and degree of standardization, producing authority, and comparison with other data.

How To Evaluate The Chart

The practical evaluation techniques employed by the mariner may also be used to advantage by the analyst as a preliminary step in evaluating published charts. Key information is ordinarily found in the title block, various notes, and marginal entries. These data include the control datum, identity and date of survey compilation and publishing sources, scale, units of measurement, tide and current characteristics, symbol references, and glossary of abbreviations. Other available sources of possible interest should be reviewed for mapping and charting developments, including the history of natural geographic factors and man-made facilities in the area.

The qualitative evaluation is made by examining and rating systematically the principal chart elements for adequacy according to scale and in terms of hydrographic, planimetric and relief accuracy, and completeness criteria. The appraisal system is described in the appendix, supplemented by a discussion of the various elements in the following pages.

Scale

The evaluation criteria given in the appendix are divided into two scale categories: (1) 1/600 000 and larger and (2) smaller than 1/600 000. The elements of evaluation take into account the scale as well as intended purpose of the chart and reason for the appraisal. For example, a large-scale (1/75 000 or larger) chart with some data displaced or inadequately detailed may possibly meet medium-scale (1/75 000—1/600 000) chart requirements.

Hydrographic Accuracy

Charts based on standard hydrographic surveys made in accordance with specifications acceptable to hydrographic authorities are reliable and accurate. The degree of accuracy to be achieved in navigation is on the order of 1 second or 30 metres; therefore, chart makers should strive for an accuracy at least twice as great as the mariner is able to plot. When remoteness of the area, or desired results do not justify carrying out a standard control survey of second- or third-order geodetic accuracy, a limited exploratory or running survey may be conducted with less rigorous methods and lower precision instruments. Therefore, some adjustment in adjective ratings should be made to account for the type of area being evaluated. Accuracy criteria for shore-controlled surveys and depth measurement are given in tables 1 and 2 of the appendix.

The control points for shore-controlled hydrographic surveys are determined by astronomic observation and by triangulation or trilateration methods. If points obtained by either of the last two methods are tied into the accepted national or international network, they may be regarded for evaluation purposes as relatively error free. Local triangulation or trilateration nets that are based on astronomic stations inherit latitude and vertical deflection errors of the astronomic stations. Comparatively few hydrographic surveys are based on astronomic stations which have been corrected for plumb line deflections by means of gravimetric surveys. In coastal survey nets the usual method is to determine the relative deflection of the vertical at selected points (Laplace stations) by measurements of latitude, longitude, and azimuth .

The deflection of the vertical is of interest to the mariner only when establishing a position relative to a fixed point on land, such as a shore-based electronic aid. For normal purposes of celestial navigation the error is not significant, especially as the vessel nears land the deflection of the vertical tends to approach the value on land. Ordinarily, the mariner is chiefly interested in possessing a chart with adequate internal consistency, i.e., all features charted in accurate relationships to each other. This interest includes overlapping charts which should be on the same horizontal datum in order to minimize positional differences when navigating from the coastal waters of one country to those of another and when using radiolocation systems whose position lines span the coasts of several countries. Many charts covering oceanic islands possess these control deficiencies, for they are based on a conglomerate number of unconnected, local astronomic datums. Because the distances between these astronomic origins have not been measured, it has not been possible to determine the geodetic accuracy or the suitability of the ellipsoid for use in these particular areas. As more precise methods for measuring long distances over water develop, this deficiency will gradually be corrected for the benefit of mariners and geodesists.

The maximum error of plotted position when out of visual fixing range and using electronic methods such as Decca, Shoran, Lorac, or Raydist should not exceed 50 yards or 50 metres. Although the accuracy of the hyperbolic systems varies with position relative to the transmitters, it is sufficient for offshore surveys. For ocean surveys requiring the search and development of shoals, the maximum error when fixing a reference beacon by astronomical or electronic means should be 0.5 mile (1 km). When running sounding lines, the error of an astronomical position should seldom exceed 2.0 miles (4 km).

Evaluations of soundings are influenced by how carefully they are positioned on the chart. Because of unavoidable exaggeration of the symbolized sounding, the original depth in fathoms can easily be considerably misplaced when transferred to the compilation. For example, a 1-digit depth figure (0.16 cm high and 0.10 cm wide) covers an enormous area of 262 feet by 164 feet at 1/50 000 scale. The centre of the space occupied by the figures normally represents the position of the sounding, with the subscript figure merely attached. On some charts, however, soundings are shown in metres, and the protrayal may include the subscript figure as part of the sounding position.

Planimetric and relief accuracy

The first requirement for large-scale charting is that it be based on accurate, rigid geodetic control (plotted to 0.1 second or 2 to 3 metres). In some remote regions charts, through necessity, are based on reconnaissance data (as previously noted for hydrographic surveys) or uncontrolled aerial photography. Charts based on ground or photogrammetric surveys, executed in conformance with specifications of the national mapping agencies, are reliable and adequate. Accuracy criteria are discussed in tables 3 and 4 of the appendix.

The accuracy of the chart may be determined by comparison of relationship of chart detail to its geographic graticule with maps and charts of known reliability and other reliable data such as the accuracy standards of the producing agency. When a local datum is used to orient chart details, the relationship of the local datum to an international datum should be noted when feasible. Where discrepancies are irreconcilable, a cartometric and/or photogrammetric analysis is necessary.

The cartometric analysis compares the geographic position of identifiable control points, i.e., triangulation stations measured on the chart with listed coordinate values. A preliminary investigation may result in sufficient data on which to estimate the chart's accuracy. The well-defined features on a chart compilation should be compared with the original sources for accuracy of transfer and generalization. Because nautical charts are often drawn from mosaics of foreign charts, the error associated with displaced detail points is likely to be larger than the error of the plotted control points.

The stereo-photogrammetric map accuracy test checks the alignment, position, and completeness of planimetric and inshore hydrographic features, as well as shape and detail of relief on selected stereo models. Contour elevations along arbitrary profile lines are compared with those of the test compilation and differences statistically analyzed. The results of those investigations, including field checks when practicable, are integrated into the total evaluation of the chart's accuracy.

Completeness

The criteria of completeness includes the state of revision and of standardization with respect to up-to-date status and legibility of information portrayed on the chart.

Planimetry on charts is usually limited to the coastal regions and, even in these areas, certain features like roads, buildings, and vegetation are omitted, unclassifield, or unidentified because of their invisibility from seaward. Similarly, portrayal of topographic relief on charts is restricted to coastal landforms such as hills, ridges, cliffs, etc., which are of value for navigation by radar and other position-fixing methods. Further inland, navigational requirements for the portrayal of these features diminish rapidly. Generally, however, modern nautical charts portray waterfront facilities and manmade landmarks, along with shaded and contoured relief, in sufficient detail to compare favorably with land maps at similar scale.

Completeness also embraces the density and character of charted hydrography and other related detail, commensurate with scale and area covered.

Hydrography

The most important features of the chart are the soundings and depth curves which depict the main characteristics of the ocean floor configuration. The selection of soundings depends on the physical characteristics of the bottom, and no set specifications can be established. Least depths on shoals and practicable channel depths must be selected. Also, narrow passages and critical areas of uneven bottom should be depicted clearly and as uniformly as possible, without the clutter of unnecessary soundings. The sounded depth pattern on the chart with well-delineated depth contours should be indicative of systematic surveys. On large-scale charts, the 1-, 6-, and 10-fathom curves are desirable; on medium-scale charts, the 6-, 30-, and 100-fathom curves.

For evidence of adequate hydrographic development, the survey sheets should be examined for adherence to the following standards. If the hydrographic survey sheets are not available, the chart itself may be appraised on the same general guidelines and standards.

(a) Spacing of principal lines at all scales shall be 0.4 inches (1.0 cm) or less (for example : 1 667 feet at 1/50 000), except where depth and character of the bottom will permit wider spacing, e.g., over drying banks and in large shallow areas that ocean-going vessels cannot transit. Spacing of cross-check lines should be 3 inches (7.5 cm) or less.

(b) Spacing between soundings on line shall be less than that between lines, with peak and deep soundings shown.

Wrecks and obstructions

In order to be certain that an area is free of all hidden obstructions to navigation, which soundings alone do not reveal with certainty in uneven and rugged areas, the charts should show the clearance results of wire-drag surveys if available. Wrecks and other obstructions that are considered dangerous to surface navigation (10 fathoms or less) must be charted. Also, for submarine navigational safety, wreck locations should be shown in depths to 300 fathoms on new chart editions of coastal charts.

Tides and Currents

The complete chart shows tide and current data if the phenomena exist and data are available. The configuration of the shoreline must be delineated, heights on land must be measured, and soundings made from the surface of the sea corrected with reference to some specified tidal datum or zero of elevation. Tidal data are especially essential in connection with the use of the chart because the navigator must know the available depth at all stages. Basic tidal data are listed in annual tide tables; consequently, the up-to-date status of the chart's tide note should be verified in the latest tide table.

Information relative to general ocean or tidal currents is depicted in various ways on charts such as current roses, diagrams, or notes that give directions and velocities of currents. The up-to-date status of the chart's current information should be verified, where possible, in the latest annual current table.

Geomagnetic Data

Above all things a navigator must know his direction, for without it he may never arrive at his destination. For the benefit of magnetic compass users, magnetic variation information is depicted on charts in the form of compass roses, notes, or isogonic lines. Iso-magnetic charts of the world are available for the 1960 epoch; therefore, the correct status of the chart's magnetic information should be verified with the appropriate sectional chart.

Bottom Samples

In general, a sufficient sampling is required to demarcate the limits where one general type of bottom changes to another. In waters that are liable to be used for anchoring, samples should be taken at frequent intervals (a bottom sample to every one or two square inches (10 to 15 sq. cm) of survey sheet). In other areas, shoaler or deeper, a spacing of 3 inches (8 cm) on the survey sheet is sufficient depending on the regularity of the bottom. Deepwater samples (over 100 fm (200m)) are classed as oceanographical observations requiring special equipment, and samples should be taken as required.

Scales

Large-scale charts are published at various scales depending on the importance and size of the harbor or channel and close-in coastal features. Harbor charts are generally larger than 1/50 000, and are intended for navigation and anchorage in harbors and smaller waterways.

Medium-scale charts are also published at various scales according to their intended use. Coast charts are usually from 1/50 000 to 1/100 000 scale, and are intended for close coastwise navigation when a vessel's course carries her inside out-lying reefs and shoals and for use in entering bays and harbors of considerable size. General charts are published at scales from 1/100 000 to 1/600 000, and are designed for coastwise navigation where a vessel's course is well offshore but where her position can be fixed by landmarks, lights, buoys, and characteristic soundings.

Small-scale charts are published at scales of 1/600 000 and smaller, and are used for offshore sailing between distant coastal ports and for plotting the navigator's position out of sight of land. They show offshore soundings and the most important lights, outer buoys, and natural landmarks which are visible at considerable distances.

The suitability of chart scale depends on many factors, the most important of which is the need to locate all significant bottom features. Other factors which must be considered include (1) purpose of the chart, (2) scale of the survey which is never smaller than the chart, (3) geographical features and other navigational aids, (4) scales of existing or proposed overlapping charts, and (5) importance of the area to shipping and other interests.

State of Revision

The up-to-date status of information portrayed on the chart can be partially determined by inspection of the various chart dates exhibited.

Most charts show information in a reasonably standardized format along the bottom margin, which indicates the date of publication in terms of new edition, large correction, and small corrections or revised printings. In addition, the credit line in the title provides the year in which the original survey or chart was made, whereas the compilation sources note usually lists the charts used. Finally, charts are hand-corrected for changes in the *Notice to Mariners* published prior to the date of the chart's distribution. The date of the latest *Notice* issue for which hand corrections have been made is stamped in the margin. Important changes after the date of the latest hand-corrected changes are published in the weekly *Notice to Mariners* and should be applied by the chart user.

Comparison with other data

The overall status of revision necessary on charts cannot be determined, of course, without making a field edit or comparing other charts, maps and photography of known reliability, plus intelligence files, and related data. New data do not necessarily supersede completely older information. The extent to which hydrographic detail remains current depends on the character of the coast; for example, a rocky bottom remains fairly stable over the years, whereas shoals, banks, and estuaries sometimes change seasonally. It is obviously infeasible to attempt to classify the various degrees of revision that may be necessary. Consequently, the major chart features are evaluated, in terms of data significant to the safety of navigation, as either being in need of revision or not.

Legibility

The degree of clarity achieved in delineating and symbolizing on charts the featured characteristics of an area is important. Factors such as number of colors, scales, symbols, graticules, or size and placement of type do not materially affect the reliability of a chart, but their clarity of portrayal, e.g., exact color registration, consistent treatment, and standard symbols profoundly affect the chart's legibility.

Conclusions

At present there is no standard evaluation system or terminology although the general terms good, fair, and poor are often used in regional chart studies. These terms are too indefinite and give rise to uncertainty.

How effective the proposed evaluation system becomes is dependent upon its implementation by the major hydrographic services throughout the world. If acceptable in principle, it may be feasible to print the results of the evaluation on the chart in a modified form of note or reliability description (figure 3). The explanation of the alphabetic-numeric and adjective codes (appendix, with annex A) will be submitted to interested charting nations for consideration as a standardized procedure. In the interim, the addition of more specific references to compilation sources by means of a note or diagram (figures 1 and 2 respectively) will increase the users appreciation of the chart.

The ultimate in chart evaluation is to accomplish an analysis of the chart by competent analysts prior to its lithographic stages of production. The cartographer is in an excellent position to make the evaluation because the quality of sources used, the compilation techniques employed, and the rendering of the chart's characteristics by means of selection, judgment, and retention are quite fresh in his memory. Unless the evaluation is based on examination of all available sources, it will be largely a matter of conjecture regardless of the apparent completeness and accuracy of the chart.

Most important : if each producing agency were to evaluáte its charts using common standards the problem would be made enormously easier because the originator's evaluation would be largely retained. If the evaluation does not appear on a source chart, then the originating nation will be consulted for the necessary information prior to incorporation of an adjective rating in the reliability diagram on a chart compilation.

The timeliness of a chart evaluation from a user viewpoint is of paramount importance. During war, for example, extraordinary demands are sometimes made for an evaluation of chart coverage for an entire region. Whether charts are handled as one study on an area basis or individually as acquired, the application of the evaluation procedure described in the preceding pages is similar, except for certain generalizations that are more apropos on an area basis. The evaluation factors can be entered in an electronic data processing system and stored on cards for use under a variety of requirements.

The mariner can perform a real service to himself and others if he detects errors on the charts and submits as complete and accurate corrective information as practicable, including an evaluation of the reliability of the data submitted.

The evaluation system should not be too complex for operating personnel to implement; on the contrary, simplifying assumptions must be made that can be translated into approximations that are easy to use. An approximate evaluation which is used may be a great deal better than a more exact evaluation which is not.

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Comments from the U.S. Coast and Geodetic Survey

IHB Note. — The IHB has received from the USC & GS the comments which are reported below. It would be pleased to receive other comments with a view to their publication in the Review.

As suggested in your letter of 4 November 1960, I wish to furnish the following comments on BEATON's paper :

Mr. BEATON has clearly expressed some of the many problems involved in the adoption of a standard method of chart evaluation and reliability terminology. I wish to call attention to how the U.S. Coast and Geodetic Survey has overcome some of the difficulties mentioned.

To eliminate the chance of losing vital information, for every chart drawing our cartographers compile and maintain a file of permanent record cards ($8 \times 10\frac{1}{2}$ inches) entitled *History of Cartographic Work.* As indicated on the sample, these histories contain all pertinent data relative to the compilation and maintenance of the 822 nautical charts currently on issue. Responsibility is defined by numbering the items and naming the compiler and verifier of each item.

The use of compilation and reliability diagrams is not considered practicable on nautical charts of the Coast and Geodetic Survey. Considerable expense and time would be required to maintain these diagrams, especially in active, congested areas where numerous overlapping source material presents complex problems.

My congratulations to Mr. BEATON for his presentation of chart evaluation problems, the discussion of which will prove beneficial to all nations.

CHART 6188 — HISTORY OF CARTOGRAPHIC WORK – NAUTICAL CHART BRANCH FILES — REMARKS (over)

DRAWING # 12 — NC REC (CORR) FUTURE — TO REPRODUCTION NC NE (NP) RP T.O. — LITH. Rec'd. 6/10/60

SHEET 1 — LITH. Ver. 6/11/60 — B

PROJECT 50150 — DATE MAY 5 1960 — DATE MAY 5 1960 — PRINT DATE JUN 20 1960

APPLIED Part	APPLIED Full	Item	SOURCE OF INFORMATION File No.	Date	Authority	Type of Information	LOCALITY	INFORMATION APPLIED
*		1	T-8840	1959	C&GS	Topo	vic James Is.	Examined for critical changes; added several piers at James Is.
*		2	H-9121	1959	C&GS	Hydro	Rock Pt. to Wicomico R.	Hydro completely applied before verification and review
	✓	3	H-9122	1959	C&GS	Hydro	Wicomico R. to Reeder Pt.	Hydrography
	✓	4	Bridge Book	1951-60	C of E	Clearances	Entire chart	Added bridge clearances
	✓	5	Reeder Quad	1958	USGS	Topo	" "	Contours, add'l roads and streams
	✓	6	Geog. Names Std.	6-20-60	C&GS	Names	" "	All names checked
*		7	Bp 78355	1960	C of E	Channels	Victoria Reef to La Plata	Only critical corrections applied at this time
	✓	8	Dwg. No. 11 Chart 6188	Sept 59	C&GS	Hydro	Victoria Reef	Rock referred to in Descr. Report H-9122 (pg 7) charted. All sunken rocks added as recommended
	✓	9	Chart 6189	9-23-59	C&GS	Topo	Portland Pt.	Common area compared and brought into agreement
	✓	10	OP-330	Dec 59	C&GS	Airport	Portland Airport	Examined and checked against T-8840. Not used.
	✓	11	L-981	1959	C&GS	Topo	Parker Dam	Plotted 3 landmarks
	✓	12	L-1031	1959	C&GS		" "	Added 2 Restricted Areas
	✓	13	Project Maps Portland Dist.	1960	C of E	Hydro	" "	Revised bridge and ship lock notes
*			These items (partially applied) are to be underscored in red					

Items	Compiled by	Started	Completed	Time (hrs.)	Items	Verified by	Started	Completed	Time (hrs.)
1-6	John Jones	3-2-59	3-8-59	42	1-6	John Doe	3-8-59	3-10-59	16
7-13	James Smith	3-14-59	3-27-59	63	7-13	William Brown	3-28-59	4-2-59	21

APPENDIX TO Mr ROBERT J. BEATON'S PAPER

EVALUATION CRITERIA FOR NAUTICAL CHARTS

For scales of 1/600 000 and larger, the criteria which determine the different categories of reliability of water and land features are divided into four classes : (1) hydrographic accuracy, (2) planimetric accuracy, (3) relief accuracy, and (4) completeness. The total evaluation is obtained by combining the separate evaluation ratings and by attaching as a suffix the year in which the evaluation of completeness was made; for example, IiA2cd, 1960. Serial numbers do not appear in the evaluation results. Limits of error for nonstandard scales can be obtained pro rata from the figures at serials 1, 2, 9, 10, 13, and 14.

The criteria for hydrographic accuracy are listed at serials 1—7 in tables 1 and 2. Roman numerals in the last column of each table denote a chart's rating based on horizontal accuracy of plotted hydrographic detail and accuracy of measured depths, respectively.

Criteria for Hydrographic Accuracy at Scales of 1/600 000 and Larger

The horizontal positions of charted soundings based on survey fixes shall fall, with 90 percent assurance, within 0.05 inch (1.27 mm) of the positions as plotted on the hydrographic survey sheet. The horizontal positions of charted navigational aids and dangers such as beacons, visible rocks, etc. shall fall, with 90 percent assurance, within 0.025 inch (0.63 mm) of the positions as plotted on the survey sheet. These criteria are based on survey positions relative to a shore control which consists of a triangulation scheme of at least third-order accuracy.

TABLE 1

Ground Distance Equivalents of Error Limits

Scale of Chart	1/25 000	1/50 000	1/100 000	1/200 000	1/250 000	1/500 000	Rating
Serials							
1 Navigational Aids and Dangers	16 m (52 ft)	32 m (104 ft)	64 m (210 ft)	128 m (420 ft)	160 m (525 ft)	320 m (1 050 ft)	I
2 Soundings	32 m (104 ft)	64 m (210 ft)	128 m (420 ft)	256 m (840 ft)	320 m (1 050 ft)	640 m (2 100 ft)	I
3	Will not meet serials 1 or 2						II
4	Horizontal position accuracy undetermined						III

Charted depths based on survey measurements by echo sounder or leadline (reduced to a tidal reference plane on the continental or insular shelf) shall fall, with 90 percent assurance, within the limits of error set out below.

TABLE 2

Criteria for Measurement of Depth Accuracy at All Scales

Serials	Soundings of 0—11 fm (0—20 m)	Soundings of 11—55 fm (20—100 m)	Soundings of 55 fm (100 m) and deeper	Rating
5	1.0 ft (0.3 m)	3 ft (1.0 m)	1 % of depth	i
6		Will not meet serial 5		ii
7		Depth measurement accuracy undetermined		iii

Criteria for Horizontal Accuracy at Scales of 1/600 000 and Larger

The horizontal positions of well-defined planimetric features based on controlled surveys shall fall, with 90 percent assurance except where unavoidably displaced by exaggerated symbolization, between 0.02 inch (0.5 mm) and 0.04 inch (1.0 mm) of the positions as plotted on the topographic or photogrammetric survey sheet. The foregoing criteria are given in terms of error limits on the chart; the criteria set out below, in terms of error limits on the ground.

TABLE 3

Ground Distance Equivalents of Error Limits

Scale of Chart Serials	1/25 000	1/50 000	1/100 000	1/200 000	1/250 000	1/500 000	Rating
9	12.5 m (41 ft)	25 m (82 ft)	50 m (164 ft)	100 m (328 ft)	125 m (410 ft)	250 m (820 ft)	A
10	25 m (82 ft)	50 m (164 ft)	100 m (328 ft)	200 m (656 ft)	250 m (820 ft)	500 m (1 640 ft)	B
11			Will not meet serials 9 and 10				C
12			Planimetric accuracy undetermined				D

Criteria for Relief Accuracy at Scales of 1/600 000 and Larger

The criteria for relief accuracy are listed at serials 13—17 in table 4. The rating in Arabic numbers denotes a chart's classification in terms of the accuracy of relief portrayed.

Ninety percent of the elevations taken from the chart and elevations of points interpreted from charted contours will depart from the surveyed elevation by no more than the errors set out below. In checking elevations taken from the chart, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error mentioned for serials 9—10.

TABLE 4

Scale of Chart

Serials	1/25 000	1/50 000	1/100 000	1/200 000	1/250 000	1/500 000	Rating
13*	5 m (16 ft)	10 m (33 ft)	20 m (66 ft)	40 m (131 ft)	50 m (164 ft)	100 m (328 ft)	1
14*	10 m (33 ft)	20 m (66 ft)	40 m (131 ft)	80 m (262 ft)	100 m (328 ft)	200 m (656 ft)	2
15	Relief shown only by approximate contours, form lines, hachuring or shading						3
16	Relief not shown						4
17	Relief accuracy undetermined						5

* See following paragraphs

The contour interval that is appropriate will not only vary with the chart scale, but also with the terrain. For example, the normal contour interval in use at 1/25 000 scale is 10 metres or 25 feet although the optimum contour interval may vary from 5 feet in the flat country to 80 feet in mountainous country. Charts which show contours at wider intervals than is appropriate for the scale in order to depict shaded relief may be rated " 1 " or " 2 " depending on all the factors concerned.

The criteria for relief accuracy given at serials 13 and 14, may be replaced by the following as an alternative :

Rating	1	2
Limits of error in terms of the appropriate contour interval (as given in preceding paragraph) in use at the scale.	Half contour interval	Contour interval

Criteria for Completeness at Scales of 1/600 000 and Larger

Criteria for completeness at chart scales of 1/600 000 and larger are listed at serials 18—19 in Table 5. The alphabetical rating, plus the year in which the evaluation was made, denotes a chart's status with respect to the various completeness factors (See next page).

*
* *

For chart scales smaller than 1/600 000, general criteria and a single letter rating are adopted in table 6. These charts are invariably derived from larger scale charts, and the criteria of the latter are not too applicable. The separate criteria of serials 20-22 have therefore been adopted (See next page).

TABLE 5

Completeness Criteria for Scales of 1/600 000 and Larger

Serials		Rating
18	Chart meets criteria for completeness, up-to-dateness, standardization, and legibility (give date of evaluation).	x, 19—
19	Chart needs revision of one or more of the items indicated below in order to meet standards of serial 19. (Give date of evaluation.)	
	a. Items needing revision undetermined	a, 19—
	b. Cultural information (to the extent required on charts)	b, 19—
	c. Hydrography (including tide and current data as required)	c, 19—
	d. Magnetic variation	d, 19—
	e. Vegetation (mangrove, marsh, rice, conspicuous trees, etc.)	e, 19—
	f. Bottom characteristics	f, 19—
	g. Acceptable scale	g, 19—
	h. Place names	h, 19—
	j. General legibility	j, 19—
	The items deficient or requiring revision are indicated in the evaluation category by the appropriate letter suffix or suffixes.	
	Examples :	
	In a 1960 evaluation, revision of the chart is considered to be necessary but the specific items requiring revision are not determined.	a, 1960
	In a 1959 evaluation, revision of culture to show new port facilities is required. Also, the scale is too small for a harbor chart, and place names are not treated in accordance with official usage.	bgh, 1959

TABLE 6

Serials		Rating
20	Hydrographic, planimetric, and relief information up to date and complete for scale. (Give date of evaluation.)	A, 19—
21	Hydrographic and relief information generally up to date. Planimetric information incomplete or relatively out of date. (Give date of evaluation.)	B, 19—
22	Hydrographic and relief information not shown correctly. Recompilation or a major revision is necessary to produce a Class A or Class B chart. (Give date of evaluation.)	C, 19—

ANNEX A TO APPENDIX

Expression of Evaluation on Nautical Charts

An evaluation of each chart source may be indicated on a chart by an adjective rating system which is equivalent to the alphabetic-numeric code outlined in the preceding pages. Figure 3 illustrates the use of adjectives with each source cited in the Reliability Diagram. In the following table examples of ratings are given, but other combinations of letter-number ratings are possible which result in the same adjective equivalents : Good-Usable, etc.

Charts at scales of 1/600 000 and Larger

Rating Example	Adjective Equivalent	
IiA1x	Excellent-Adequate	Chart meets all standards for accuracy of hydrography, planimetry, and relief; and all standards for completeness.
IiA1b	Good-Adequate	Chart meets same accuracy standards as above, but requires revision to meet one more standards of completeness.
IiiB2x	Good-Usable	Chart meets at least secondary standards for accuracy of hydrography, planimetry and relief; and all standard for completeness.
IiiB2b...	Fair-Usable	Chart meets at least secondary standards for accuracy as above; and requires revision to meet one or more standards of completeness.
IIiiC3bc..	Poor-Inadequate	Chart does not meet secondary standards for accuracy ; or requires recompilation or major revision to correct deficiencies in completeness standards.
IIIiiiD5a	Undetermined	Chart is of undetermined accuracy that may or may not meet standards for completeness.

Charts at scales smaller than 1/600 000

Rating	Adjective Equivalent	
A	Good-Adequate	Chart with hydrographic, planimetric, and relief information up to date, complete, and legible commensurate with scale.
B	Fair-Usable	Chart with hydrographic and relief information reasonably up to date, but planimetric detail incomplete or relatively out of date.
C	Poor-Inadequate	Chart with hydrographic and relief information incomplete or out of date. Recompilation or major revision necessary.