CHAPTER 5

Analysis and Interpretation of Hydrographic Surveys

51. GENERAL STATEMENT

This chapter deals primarily with the early inshore hydrographic surveys of the Coast Survey because it is in this area, and of this period, that most of the problems of interpretation arise. This is especially true when they are used for the establishment of waterfront property boundaries. In the evaluation of these surveys, methods and practices in use at different periods will be described and analyzed, and these will be tied in with particular surveys. But it should be borne in mind that complete uniformity in all the surveys of a given period was never fully achieved, so that the practice as evidenced by a cited survey in the text is not necessarily representative of all the surveys of that period and variations will generally be found. Nevertheless, it does indicate a practice that was in use, and to that extent will assist in a better understanding of the practices and procedures as developed through the years.

Except for the very earliest period of the Bureau's work, there were always certain standards of accuracy to which the work had to conform. If the work was done at all, it was done with that accuracy. But accuracy must not be confused with detail. For example, the absence of soundings in a particular portion of a hydrographic survey would simply mean that no soundings were taken there, possibly because it was not considered of sufficient importance to navigation to justify surveying it, or for some other reason. But where soundings are shown, it can be assumed that they are just as accurately taken, although perhaps not as complete where no navigation is possible, as they are in the main channel.

Broadly speaking, hydrographic surveying may be defined as the process of developing upon a survey sheet all that portion of the earth's surface which

lies beneath the water. It aims to delineate with accuracy the submerged contour lines of channels, banks, and shoals, in a manner similar to features delineated by topography on the visible land, and to collect specimens of bottom material and water samples. It also includes that part of physical hydrography which takes into account tide and current phenomena, and in the modern surveys it embraces temperature and salinity characteristics of the water insofar as they relate to the accurate measurement of depth by echo sounding.[1]

Although the hydrographic surveys of the Coast Survey are made principally for use in the construction and maintenance of nautical charts, they have many collateral uses. Both the high- and low-water lines are frequently of importance in establishing political and civil boundaries; an accurate knowledge of the foreshore is essential for successful amphibious operations; and offshore surveys extending over the continental shelves and slopes are continually revealing significant underwater features which serve as landmarks for the navigator and provide scientific information of value to oceanographers, geologists, marine biologists, and other students of the earth sciences.

The hydrographic survey is in many respects similar in character to the topographic survey (*see* fig. 56). The delineation of the sea bottom may be regarded as the survey of a series of shorelines occasioned by successive changes in elevation of the water level, but with this important distinction: The plane-table topographer maps the visible portions of the terrain, always using the land before him as a model, whereas the hydrographer maps features concealed from his view. The hydrographic engineer must therefore rely upon his experience and knowledge of bottom formations in order to determine the best plan of development for a given area (*see* note 9 *infra*) so that no important feature will go undetected.

1. The velocity of sound in sea water is a function of the temperature, salinity, and depth of the water through which the sound impulse passes. Echo-sounding instruments are calibrated for a standard velocity and any variation from the actual velocity is applied as a correction to reduce the observed depth to true depth. During the period between 1924 and World War II, when a method known as Radio Acoustic Ranging was developed and used in offshore surveying for the determination of the survey vessel's position (*see* fig. 7), temperature and salinity observations were also necessary for the computation of the horizontal velocity of sound. ADAMS, HYDROGRAPHIC MANUAL 556, 573, SPECIAL PUBLICATION NO. 143, U.S. COAST AND GEODETIC SURVEY (1942). The latest Hydrographic Manual was published in 1960 as "Publication 20–2," under a new numbering system (*see* note 24 *infra*). Since then a number of changes have been made in the text, these being designated as "Change No. 1 (April 1, 1963)." The pages affected have been reprinted in 1963 and are available from the Government Printing Office in packet form. The manual is now designated as "Third (1960) Edition" (*see* note 22 *infra*). Although obsolete in many respects, due particularly to rapid developments in hydrographic control systems and echo sounders, the 1942 manual is still an excellent reference work (*see* 537). In subsequent sections, wherever reference is made to present practice, the 1960 manual will be cited, but, wherever pertinent, references will also be given to the 1942 manual.

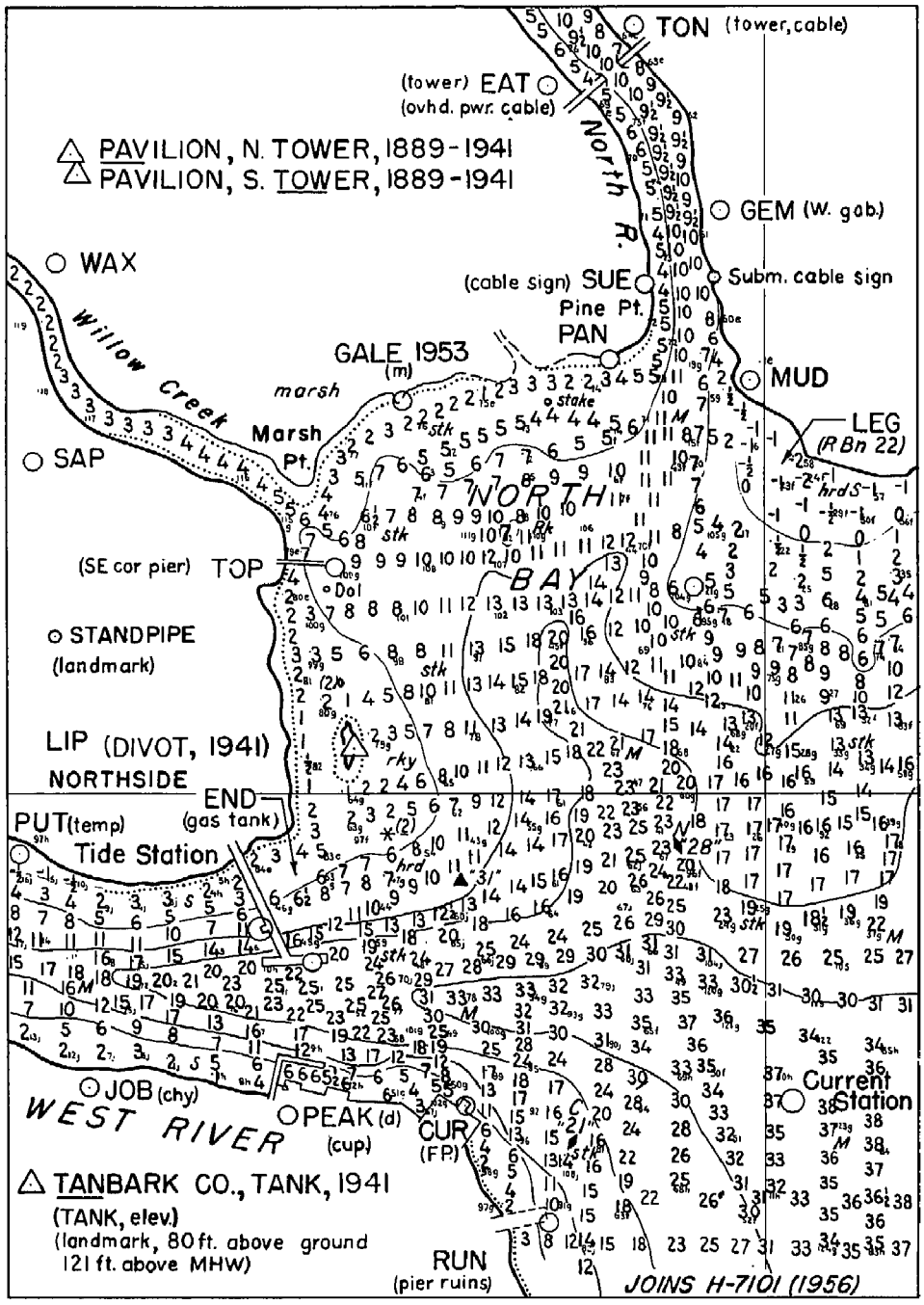

FIGURE 56.—Black and white copy of section of completed hydrographic survey showing specified plotting of topographic and hydrographic detail.

52. FIRST HYDROGRAPHIC SURVEY

The first hydrographic survey by the Bureau was made in 1934 (Register No. H–44), at a scale of 1:10,000, and covered the area of Great South Bay, Long Island, N.Y.[2] The sounding lines consist generally of a number of zigzag lines running between points on opposite shores, or radial lines from an anchored position of the survey vessel to points on shore. The spacing of lines are approximately 500 meters apart, and by modern standards would be considered as of no more than reconnaissance value.[3] No identification numbers for boat's positions are shown nor are the days of operation distinguished. (The sounding records for this survey could not be found and it was not possible to determine what method of identification was used nor how the boat's positions were ascertained.) [4] A geographic grid is shown on the sheet in pencil and the actual lines of the triangulation system are also shown. The high-water line is a transferred line from the contemporary topographic survey and the area between the high- and low-water lines is sanded. There are indications on the survey that the latter line was determined by soundings but none were plotted. All soundings are given in feet, the maximum being 44 feet, but only the 6-foot depth curve (a dotted line) is traced. (On Register No. H–45 (*see* note 4 *supra*), both the 6- and 12-foot depth curves are shown, the latter by a series of double dots.) A few bottom characteristics are given. The plane of reference is stated as "approximate mean low water," but this was added at a later date.

This survey, with some variations, can be considered as typical of the hydrographic surveys of the period. The first written instructions for hydrographic work had not yet been issued (*see* 53) and much in the way of procedures was no doubt left to the judgment of the individual hydrographer. This

2. Normally, the first hydrographic survey would have been indexed as Register No. H–1, but for some reason, not apparent now, this number is assigned to a later survey, made in 1837. The earliest survey filed in the Bureau archives as an original survey is Register No. H–1961 (1817). This is a replotting, on a reduced scale (1: 20,000), of the survey of Boston Harbor made by the Navy Department. There is no absolute certainty when the plotting was done, but the "Comparative Map of Boston Harbor, Massachusetts" (Register No. H–1960 (1846–53))—which includes the survey of 1817 (in red), selected soundings from Register No. H–221 (1846–48), and other soundings—states that it was "Executed in the Office of the U.S. Coast Survey for the U.S. Commissioners on Boston Harbor" in 1860. The presumption therefore is that Register No. H–1961 (1817) was plotted some time prior to 1860.

3. Register No. H–7800, covering the same area and surveyed in 1950, has an average spacing of 100 meters for the general sounding lines and about one-third this spacing in the channels. This is an excellent example of a modern survey in which due regard has been paid to the development of important areas, such as channels and the low-water line, and would be of value for many collateral uses.

4. On Register No. H–45, which is a replotting in 1845 of Register No. H–44 but on a smaller scale (1: 20,000), position numbers are shown in red and the identifying day letters by various shapes. The title note for the survey states it was plotted from the original notes.

was the early, formative period of the Coast Survey. Hydrographic methods had not yet been standardized nor were the importance of keeping lucid records fully appreciated. It is therefore not infrequent to find on some of the early surveys long lines of soundings controlled by few boat's positions, no record kept of the time of taking soundings in between positions, and a failure to reference the plotted work with the sounding volumes. This makes it extremely difficult at times to identify a plotted line of soundings in the original records. But some of the early surveys gave full identification information (position numbers and day letters) and even included the date of survey on some of the lines (Register No. H–47 (1835)).[5]

53. INSTRUCTIONS FOR HYDROGRAPHIC WORK

For a correct evaluation of the early surveys, a knowledge of the field and office methods used and the changes made during different periods is essential. The early instructions for hydrographic surveying furnish the best source material for such evaluation. Because many of these are no longer available for distribution, they will be examined in this chapter and those matters pointed up that will assist in a better understanding of the early surveys. These will include such matters as standards of accuracy for soundings, methods of control for hydrographic surveying, planes of reference, low-water line delineation, and symbolization.

For the interpretation of the more recent hydrographic surveys, that is, those made since the early 1920's, when echo sounding was first introduced, the published manuals, which are still extant and to which reference will be made, can be used as guides. Where germane, present-day practices will be contrasted with earlier ones.

531. Earliest Instructions (*Circa* 1844)

The earliest instructions for hydrographic work were in manuscript form, of which the following is a copy: [6]

5. Often, in studying early surveys, a trial-and-error method of identification must be resorted to. By recording the sequence of soundings in question on a sheet of paper, a corresponding sequence is searched for in the sounding volumes.

6. The instructions, neither dated nor signed, are filed in the volume (17) of correspondence marked "Coast Survey, Scientific, 1844–1846."

THE SOUNDING SHEETS OF THE COAST SURVEY
TO BE FILLED UP IN THE FOLLOWING MANNER

1st. The projection parallels and meridians corresponding to the locality to be surveyed to be ruled and numbered.

2nd. The points of triangulation to be laid down from the manuscript tables and names printed.

3rd. The shore line and such plane table points and houses and ranges as may be useful in sounding to be transferred preserving the plane table names—when names are not given on the plane table sheet—those given in the sounding book to be placed on the sheet. All the topography may be omitted.

4th. The line of soundings to be so disposed as to render it probable that no inequalities in the bottom have been overlooked, and to extend to the low water line/except in the soundings of the coast/—The soundings to be reduced to the lowest water observed during the survey—The curve of the low water line to be drawn and the space between it and the high water line to be dotted. All shoals bare at low water to be dotted in the same manner—The curve at every fathom to be traced up to 4 fathoms—the character of the bottom to be marked with soundings. The position of beacons and ranges and buoys at ebb and flood to be marked—the set and drift of the tides to be shown particularly in the channel ways.

On the margin of the chart insert
The plane to which the soundings have been reduced—
The establishment of the port
Rise and fall of tides—/see form/
Magnetic Variation—
Title

U.S. Coast Survey
—— Sup' ——
Sounding Sheet No.
From *point* to *point*
from Jan. —— to Sept. —— 184—
Soundings by ——
Adjusted by ——
(Original)
or
/Copy/

The significant aspect of these instructions is their lack of detail as to method of surveying. Much was left to the judgment of the individual hydrographer who was probably guided to an extent by the methods used in some of the European countries. The preparation of definitive instructions applicable to all survey parties no doubt awaited the experience gathered by the chiefs of party during this early, formative period.

Another item of importance, in evaluating the surveys covered by these early instructions, is the plane of reference used for reducing the soundings—namely, "the lowest water observed during the survey." This plane would be lower than the plane of mean low water which was later adopted for all the surveys along the Atlantic and Gulf coasts. Where a plane other than mean

low water was used in the original work, a correction note was usually added to the survey at a later date so the soundings could be brought to the plane of mean low water.

532. First Published Instructions (*Circa* 1860)

The first published instructions appeared under the title "General Instructions in Regard to The Hydrographic Work of the Coast Survey (Printed for the Use Only of the Hydrographic Parties)," and were signed by Superintendent A.D. Bache. No publication date appears, but a reference on page 10 to "Coast Survey Report for 1856" and a written date 1861 appearing on page 1, establish these as the limiting dates of publication, with 1860 as the probable date.[7]

The instructions consist of 28 printed pages, in a 6- by 9-inch format. References are made within the text to Appendixes 1 to 11 and to Plates 1 to 11 as accompanying the instructions, but in the only copy now available these are not included.[8]

Although in condensed form by comparison with later manuals, these instructions contain a considerable amount of detail with respect to soundings and tides.

From the standpoint of evaluating surveys of this period, it is important to note the emphasis that is placed on the sufficiency of soundings to show the configuration of the bottom. It is stated that "The best *test* of whether they are sufficiently numerous is to ascertain if *horizontal curves* can be drawn by them, without leaving doubt as to their direction in any case" (par. 2). It is also

7. In the printed pamphlet entitled "Directions for Observations of Tides" (*see* note 36 *infra*), the authority for the opening paragraph on page 3, which sets out the object of establishing permanent tide stations along the coast, is given as "Genl. Hydrog. Instruc., 1845, Par. 19." No copy of these instructions could be found. It is noted, however, that the published paragraph is practically a verbatim copy of a portion of paragraph 19 of the *circa* 1860 instructions (*see* above). Inasmuch as the tidal pamphlet has no publication date (*see* note 36 *infra*) and the earliest published instructions are also undated, it is concluded that either the "1845" date is incorrect or the instructions referred to are identical with the *circa* 1860 instructions. The fact of the identical language and paragraph number would seem to support the first alternative. This assumption is also borne out by the fact that the varied practices on the surveys made around 1845 do not support the existence of detailed instructions, such as existed in 1860, but rather the existence of generalized instructions as those of *circa* 1844 (*see* 531 and 563).

8. The appendixes refer to printed forms for recording soundings, angles, tides, and currents, and descriptions of tide and current instruments. The plates refer to illustrations of a hydrographic signal, a sounding chair for a steamer, tide gauges, specimen tide curves, current apparatus, conventional signs, lettering, form and size of soundings, forms for describing bottom specimens, and current diagrams. Appendix No. 1 contained printed forms for registering the soundings, angles, etc. These are apparently the "sounding sheets" referred to in the instructions, one or more being taken out for the day's work and placed upon a board for convenience of recording, or bound in a book of the width of half the sheet. These were the original notes of which duplicates were required (par. 18). No record of this form of original notes could be found in the Coast Survey archives and it is possible they were destroyed after being transcribed in another form.

emphasized that the best direction for running lines is in the general direction of the curve and not across it, the reason being that "the changes of depth for a given change of position being then the least" (par. 6).[9]

The sounding accuracy is specified as tenths of a foot to 3 fathoms, with greater latitude beyond and reaching whole fathoms for offshore work. The allowable error at sounding-line crossings was not to be more than 3 percent of the depth, with a limiting error of 5 percent.[10] For sounding in depths up to 15 feet, a graduated pole was used with a disk on the lower end to prevent it sinking into muddy bottom (par. 15). Beyond this depth, the leadline was used. Comparisons of the marked leadline with a measured length were required to be made three times a day for use in correcting the soundings taken during the day.

Reference is made to "*Diagrams* of the work which is laid out, corrected to represent the actual working" (par. 5). This no doubt refers to what is now termed a "boat sheet" (*see* 551) on which the system of sounding lines was laid out in advance of the work and the lines corrected to correspond to the actual running of the lines as the work progressed. This designation was still included in the 1894 instructions (*see* 535).

Three methods of position determination are given: (1) by running out ranges and timing the soundings; (2) by observing angles with a sextant from the boat on three signals; and (3) for offshore work, by measuring angles to the survey vessel with theodolites at two shore stations and, for verification, by measuring the angle at the vessel between the two shore stations.[11]

The section on "Tides" provides for the establishment of permanent tide stations (with self-registering or other forms of tide gages) at suitable places along the coast for the study of tidal phenomena, and of temporary tide stations for use in the reduction of the soundings to the same plane of reference. *Mean*

9. This requirement was eliminated from the 1878 instructions (*see* 533). Subsequent experience has shown that a system of lines normal to the depth curves provides the most convenient and economical development of any area, but it is often advantageous to adopt some other system for various reasons. The selection of the most appropriate systems is governed by the type of control used, the configuration of the area, and its location with respect to an anchorage or base of operations. Three systems of sounding lines are in general use—parallel straight lines, radiating lines, and concentric arcs (*see* fig. 57). JEFFERS, HYDROGRAPHIC MANUAL 137, PUBLICATION 20-2, U.S. COAST AND GEODETIC SURVEY (1960, 3d ed.) (*see* note 1 *supra*).

10. This requirement, it is stated, is based on "Observations made expressly for the purpose have shown that in the smooth water and moderate depths of harbors the accuracy attainable is to fractions (say tenths) of a foot, and in off-shore soundings to fractions of a fathom" (par. 2).

11. The method of observing theodolite angles from stations on shore and measuring verification angles on the boat was used in the early surveys for inshore work. *See,* for example, Register No. H-106 (1840), where the sounding record contains notations on accidents to the flag signal, missing angles taken from the vessel, and occasions when the angles were only taken on shore at the times given by the vessel. *See also* H. Rept. 43, 27th Cong., 3d sess. 38 (1843).

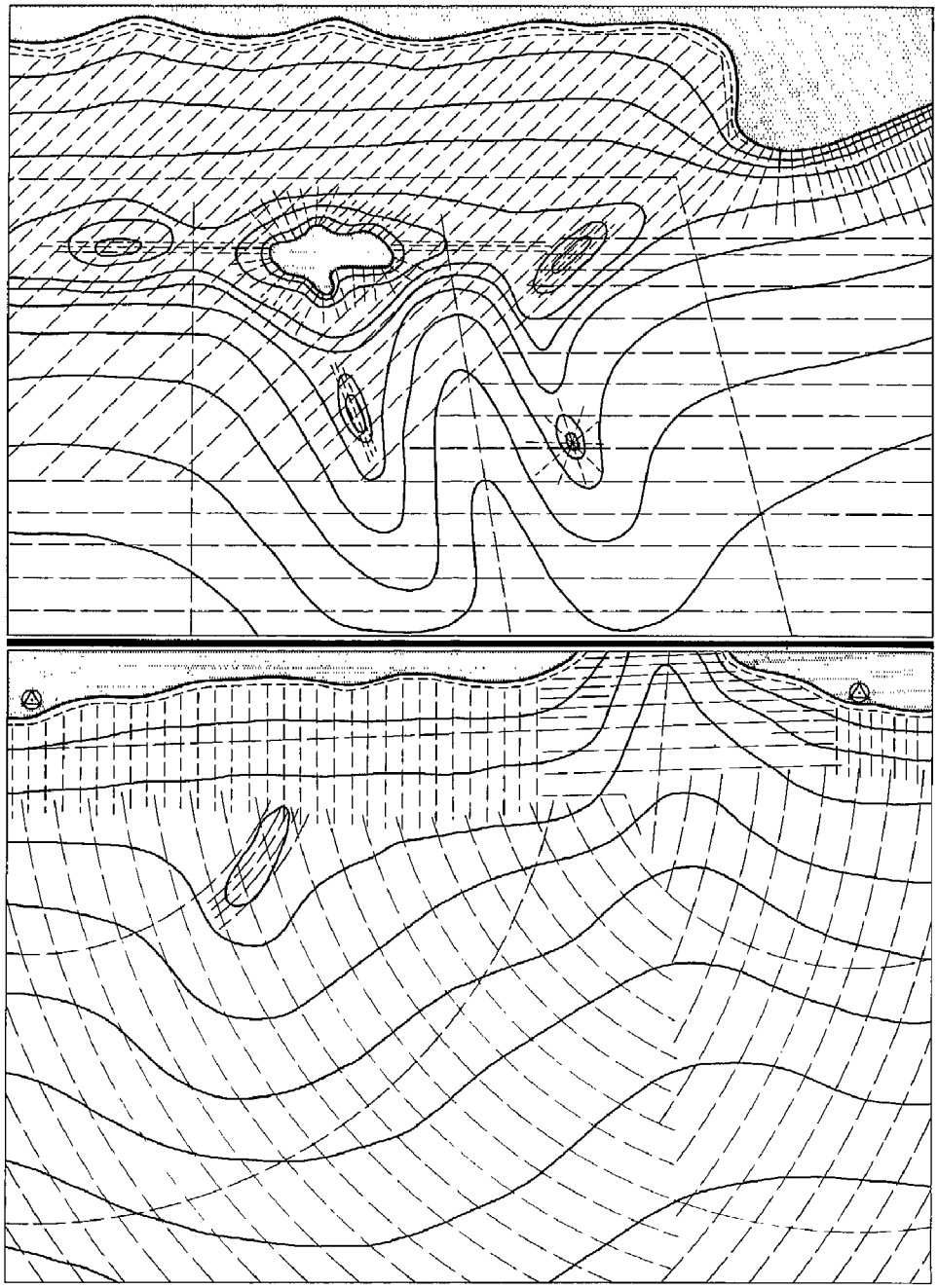

FIGURE 57.—Systems of sounding lines for developing underwater features. The solid lines represent depth contours and the broken lines represent appropriate systems of sounding lines for the various conditions encountered.

low water is specified as the plane of reference except on the Pacific coast where the *mean of the lowest low waters* was to be used (par. 26).[12]

Under the section on "Office Work," it is stated that "The original note books of observations, and the duplicates, should be *bound* and *lettered* according to the specimens of the work of 1845" (par. 67). These specimens could not be traced, but it is possible that the field parties used sheets in the form of unbound note books which were later bound in a permanent volume. It is also stated that every "finished" hydrographic sheet when turned into the office must show "The lines of soundings, with the angles marked to distinguish them from the soundings" and with identification letters for the day of the month and numbered in reference to the day, the soundings to be in black and the angles and references in color (par. 72*d*).[13]

The requirement for depth curves was to show the 6-foot curve in green, the 12-foot curve in red, and the 18-foot curve in blue, all to be shown as continuous lines (par. 72*e*). (This color scheme has been continued to the present day.) The requirement was also for the shoreline to be shown in a continuous black line if obtained from the topographic survey, and in a broken line if sketched by the hydrographic party (par. 72*c*). (This practice was still followed in 1894.)

Shoals bare at the plane of reference were to be shown with their heights above the plane (par. 72*i*). This general instruction was variously interpreted by the field parties, and soundings above the plane were shown on the smooth sheets in at least three different forms (*see* 5613).

Of additional interest in these early instructions are the references to trolling for rocks with a single boat or with two boats (par. 9), to obtaining bottom specimens and preserving them in small vials in order "to trace the formations along the coast in which particular kinds of *soil* occur" (par. 16),[14] and to obtaining the correct geographic names in an area (pars. 48 and 49).

12. On several surveys made around 1858 and thereafter along the Pacific coast, the plane of reference is noted as the mean of the lowest low waters of each 24 hours (*see* 5642). This has been interpreted to be the same as mean lower low water for all practical purposes (*see* Descriptive Report for Register No. H–464 (1853)). This practice was apparently continued until the issuance of the 1878 instructions (*see* 533, and note, for example, Register No. H–1340*a* (1876) and Register No. H–1508 (1881)).

13. As far as could be determined the instruction for showing the angles at positions was not universally adhered to. This requirement may have been intended to refer to the position numbers and day letters only. A similar provision was included in the 1878 and 1883 instructions but was omitted from the 1894 instructions. The instruction for "binding" and "lettering" the original note books appears to have been followed (*see* 553), but the originals were the only ones generally retained and are now in the Coast Survey archives. One case of the "duplicate" soundings was found, this being for Register No. H–268 (1851). This volume is also marked "Fair Journal" (*see* 5531) and is identical with another volume marked "Original Soundings." All entries in these volumes are in ink.

14. This provision was included in the later instructions through those for 1894.

533. Instructions of 1878

Although these instructions are titled "General Instructions in Regard to Inshore Hydrographic Work," they actually cover offshore work as well (par. 146). In general they are an attempt at greater standardization, with some earlier procedures modified. They were issued during the superintendency of Carlile P. Patterson. In commenting on these instructions, cognizance will be taken only of those items that fall within the purpose of this publication, pointing up significant departures or additions from previous instructions.

A section on "The Projection" was added and included information on the recovery of triangulation stations, on the erection and location of signals for hydrography, on the naming of signals, and on the method of recording angles used in fixing the location of signals. The projection was generally furnished by the Washington Office and included the shoreline and triangulation and other forms of control points. Triangulation points were indicated by a point enclosed in a triangle and all other control points (topographic or hydrographic) were indicated by dots inclosed in circles (par. 2). Black ink was presumably used for all such symbols, but this was not specified. Reference is made to "angle books" in which all angles taken for locating signals were to be entered as well as those taken from shore stations for locating the position of the survey boat while sounding (par. 13). Additional signals that were located by "cuts" during the sounding work were to be recorded in the sounding volume and later transcribed into the angle book.

In the section on "Soundings," emphasis is placed not only on the location of the dangers to navigation but also on the development of the bottom configurations as an aid to the mariner in recognizing his position by casts of the lead.[15] Four systems of sounding lines are described and illustrated to replace the system described in the 1860 instructions (*see* text at note 9 *supra*).

More detailed information than was contained in the 1860 instructions is given for limits of error at sounding-line crossings based on observations made expressly for the purpose.[16]

A subsection on "Minus Soundings" (par. 26) was included for the first time. This applied to both shoals and flats and therefore took in the low-water

15. This idea would seem to be the forerunner of the present-day method of depth-contour charting (*see* 6241).

16. Lines of soundings at their crossings were not to exceed, "in depths of 15 feet and under, two-tenths of a foot; between depths of 15 and 30 feet, three-tenths; 30 and 48 feet, five-tenths; between 48 and 72 feet, three-fourths of a foot; between 72 and 96, one foot and a half; and between 96 and 150 feet, two feet. In the sea-depths the limit of error should not exceed 1 percent. With proper care and close attention, these limits of error are quite attainable." (Par. 19.) This was continued in the 1883 instructions.

line. Soundings over these areas were to be taken at or near high water and all soundings above the plane of reference (heights) were to be shown as "minus soundings." (*See* 5613.)

Angles for position were to be observed often enough to insure that the line preserves its direction. This included position angles at the beginning and ending of a line, and whenever a marked change in depth or change in course occurred (par. 47).

As in the 1860 instructions (*see* note 8 *supra*), reference is made to printed forms for recording soundings, etc., in "books of a width of one-half the sheet." Details are given for making the various entries, including the angles observed for locating the boat's position while sounding. Soundings were recorded in "feet and tenths" or "fathoms and feet." [17]

Identification of the sounding lines were better standardized. Each day's work was assigned a day letter, using capital letters in color for the vessel and lower-case letters of different colors for the boats (*see* Register No. H–1573 (1883)). The requirement of showing the observed angles at positions (*see* note 13 *supra*) was still continued.

Under the section on "Tides," the plane of reference for soundings is given as the mean of all the low waters for the Atlantic and Gulf coasts, and the mean of all the lower low waters for the Pacific coast. (This was carried into the 1883 and 1894 instructions). The latter is a modification of the requirement in the 1860 instructions which called for the mean of the lowest low waters (*see* note 12 *supra,* and accompanying text).

The field plotting of the "finished" hydrographic sheet (now termed the smooth sheet (*see* 552)) is covered in the section "Plotting of Work During the Surveying Season." The requirement was for each plotted position to be marked by a prick point to permanently establish its exact location, the point being enclosed by a small circle, using red ink for the vessel's work and for each boat's work the color corresponding to its letter. The identifying number for each position was to be shown and the day letter given at least for the beginning and end of each line and where there was a change in course. The soundings, day letters, and position numbers were all to be left in pencil. (Par. 140.)

17. This form of sounding record, and method of recording, was continued in the 1883 instructions (*see* 534) except that no reference is made to "books of a width of one-half the sheet." Essentially, it was the same form that was used up to the publication of the Hydrographic Manual in 1942 when some changes were made to reflect new methods of sounding and position determination, and for other reasons. One of the changes made was in the order of recording the angles in three-point fix hydrography when instead of recording the right angle first and then the left angle, the reverse order was adopted. ADAMS (1942), *op. cit. supra* note 1, at 764. This is also the practice in 1963. JEFFERS (1960), *op. cit. supra* note 9, at 170.

534. Instructions of 1883

These instructions were titled "General Instructions for Hydrographic Work" and were issued during the superintendency of J. E. Hilgard. The principal difference between these and the 1878 instructions is the addition of a section on "Reports, Accounts, etc."

Under the section "Soundings," greater detail is given for making leadline comparisons with a measured distance. Standard markings for the leadline up to 20 fathoms and for the deep-sea line beyond were also included for the first time. A method was also given for running sounding lines on exact ranges (par. 47).

In the section on "Office-Work," a third hydrographic sheet, called a "sounding-sheet," is referred to for the first time for use in plotting the soundings each day so the chief of party could keep track of the work and lay out the next day's work. The boats' positions each day were transferred from the "boat-sheet" by tracing paper, and approximate reductions for tide used in case the plane was not yet established (par. 143).[18] Mention was also made of a "working-sheet" for the first time (pars. 140 and 148), which also seems to be the same as the "boat-sheet" and the "diagram" previously referred to, and of "fair journals" which were part of the records submitted by the field party (par. 153).

Duplicates of all records were required but these were not sent to the Washington Office until receipt of the originals was acknowledged (par. 157).

In addition to the new section on "Reports and Accounts," which was not included in the previous instructions, there were added for the first time a short section on "Deep-Sea Sounding Record," a table of bottom abbreviations (par. 158), and a page of "Conventional Signs and Symbols."

535. Instructions of 1894

The 1894 instructions were titled "General Instructions for Hydrographic Parties" and were issued under the superintendency of T. C. Mendenhall.

18. Apparently, the three sheets were: (1) the "finished" hydrographic sheet on which the final plotting of positions and soundings was made (par. 141) and turned into the office (this corresponds to what is now called a "smooth sheet" (*see* 552)); (2) the "boat-sheet" (this is the first mention of the term in any of the instructions for hydrographic work) on which apparently only the boat's positions were plotted showing the different sounding lines; and (3) the "sounding-sheet" (mentioned in the text) on which the soundings were shown. (The "boat-sheets" referred to in par. 143 would seem to be the same as the "diagrams" referred to in par. 21, otherwise it would have meant that four sheets were required. It is noted, however, that the term "boat-sheet" is not mentioned in the 1894 instructions, but "diagrams" and "sounding-sheets" are.) This practice of having a "sounding-sheet," while still mentioned in the instructions of 1894, was later departed from and the "boat-sheet" was used for plotting the soundings as well. The "sounding-sheet" referred to in these instructions was apparently something different from that referred to in the 1860 instructions (*see* note 8 *supra*).

They were the last to be issued in this form, as separate instructions for hydrographic work, until the first "Hydrographic Manual" was published in 1928 (*see* 537). Except for some differences, which will be noted in subsequent paragraphs, and the addition of sections dealing with certain administrative aspects of the work, the instructions are essentially the same as those of 1883.

One of the changes made from previous practice (*see* 533) was to designate a triangulation station by a dot surrounded by a black circle which in turn was inscribed in a red triangle. All other points were to be represented by dots enclosed in small circles, using red ink for those of topographic origin and blue for hydrographic origin. (Par. 2.)

In the section on "Soundings," four additional systems of running sounding lines are described and illustrated—a system of radial lines for use in searching for rocks and for development of bars, a system for developing an outlying rock, a system for developing an awash shoal or sand bar, and a system for developing a shoal that is under water (par. 19*e, f, g, h*).

An important addition was made to the instructions for hydrographic work by incorporating the following rules for the reduction of soundings, preparatory to plotting (par. 24):

1. The reduction for tide to the nearest tenth of a foot will be entered in the sounding book in its appropriate column.
2. The soundings will be taken with sufficient accuracy, depending upon the depth of water, to enable them to be reduced as follows, viz:
   A. Deep-sea soundings—to nearest fathom.
   B. Outside 15 fathom curve—to nearest half fathom.
   C. Between 15 and 10 fathom curves—to nearest foot.
   D. Between 10 and 4 fathom curves—to nearest half foot.
   E. Between 24 and 12 foot curves—to nearest quarter foot.
   F. Inside 12 foot curve—to nearest tenth foot.[19]

It was also stated that the admissible percent of error at sounding-line crossings was a maximum of 1.5 percent of the depth at that point. This was based upon observations made in smooth water (par. 25).

An addition to the previous instructions was the requirement that the chief of party compare his work with existing charts and publications to make certain that rocks and shoals have either been verified or disproved (par. 32).

A modification from previous instructions was the use of the sounding pole for depths of 10 feet or less instead of a limiting depth of 15 feet (par. 39).

A specimen of sounding pages for a leadline survey was also included. For the depths shown (3 to 6 fathoms), the soundings were entered in fathoms and

19. Occasionally, when a survey was made for a special purpose all depths were plotted in feet and tenths (*see* Register No. T–2196 (1895) which is a combination topographic and hydrographic survey of Port Orchard, Wash., for the Navy Department).

feet, the tide reducers in feet and tenths, and the reduced soundings in feet and tenths. (This is somewhat contradictory to the requirement given in *D* and *E,* above, which calls for a sounding accuracy that would permit the soundings to be reduced to the nearest half foot and quarter foot, respectively.)

Reference is no longer made to a "boat-sheet," but the "working-sheet," the "sounding-sheet," the "finished-sheet," and the "diagrams" are still mentioned (*see* note 18 *supra*). Several additional plates of conventional symbols are included.

In addition to the colors previously prescribed for the 6-, 12-, and 18-foot depth curves, brown is prescribed for the 24-foot curve, and purple for the 30- and 60-foot curves (par. 168*n*).

536. General Instructions for Field Work (1908, 1915, 1921)

Between 1908 and 1928, the instructions for hydrographic work were part of a volume covering all field work of the Survey. Three such volumes were issued—in 1908, 1915, and 1921. The first was titled "General Instructions for the Field Work of the Coast and Geodetic Survey." The last two carried similar titles but were further identified as Special Publication No. 26.[20] These were complete rewrites of the previous instructions, but the procedures by this time were fairly well standardized and fewer changes are noted in successive instructions.

5361. *Instructions of 1908*

In the 1908 instructions, the following essential additions or departures were made:

(*a*) Position angles were required to be observed at sudden changes of depth, at all changes of course and of speed, when the boat gained full headway, and when the boat slowed down in approaching shoal water (pars. 230–232). These requirements were intended to give greater certainty to the locations of the soundings on the sheet so as to avoid irregular and improbable depth curves.

(*b*) A new form of sounding record was introduced but actually it represented but little change from the previous one (par. 259(*b*)).

(*c*) The practice of duplicating records was eliminated, except when specially directed (par. 263). References were no longer made to "diagrams," "sounding-sheets," or "working-sheets," but only to "boat-sheet" (par. 283).

(*d*) Soundings were to be recorded generally in fathoms and integral feet, and "only in exceptional cases need fractions of feet be recorded" (par. 264).

20. The 1921 issue is labeled as the second edition of Special Publication No. 26. Some copies were printed with a 1920 date on the cover but with an identical authority date (Mar. 1, 1921). As far as could be determined the two volumes are the same in every respect and the 1920 date must be presumed to be in error.

(*e*) In the reduction of soundings, certain changes were made—tide reducers and leadline corrections to be entered to tenths of feet, but the latter could be omitted if not more than one-half of 1 percent of the depth; reduced soundings to be entered to the nearest foot, ordinarily omitting decimals; tide reducers to be omitted for depths over 50 fathoms except where the range of tide was in excess of 2 percent of the depth; and for important critical soundings depths could be plotted in feet and fractions (par. 277).

(*f*) The planes of reference to be used for soundings on the various coasts were specified with particularity for the first time as follows: the mean of the low waters for the Atlantic and Gulf coasts and for Porto Rico; the mean of the lower low waters for the Pacific coast, Alaska, and the Hawaiian and Philippine Islands; 2 feet below the mean of the lower low waters for Puget Sound; and 3 feet below the mean of the lower low waters for Wrangell Narrows (pars. 279–281).

(*g*) Boat's positions were no longer to be indicated by small circles but by pen dots in color (par. 293).

(*h*) The low-water line was to be indicated by a dotted line and minus soundings were to be enclosed within this dotted line, the sanding of the area between high and low water being specifically prohibited (par. 286(*c*) and (*d*)).

(*i*) Colors were prescribed for additional depth curves extending to 1,000 fathoms. Some change in colors were made from previous practice—the 24-foot curve to be shown in yellow, the 30-foot curve in red, the 36-foot curve in green, and the 60-foot curve in yellow. (Par. 288.)

(*j*) The depth units for plotting the soundings were prescribed as follows: all soundings to be in feet only, except in deep water when fathoms could be used, but the whole of any one sheet had to be in one unit (par. 303). (The latter was a significant change from previous practice.) On sheets plotted in feet no fractions were to be shown except that in critical places on navigable bars and in channels fractions of feet (¼, ½, and ¾) could be shown where important (par. 304). On sheets plotted in fathoms, quarter fathoms could be used to 7 fathoms and half fathoms from 7 to 10 fathoms (par. 305).[21]

(*k*) Use was made for the first time of the term "smooth sheet" instead of "finished hydrographic sheet," as formerly used (pars. 284, 285, 290).

(*l*) For lines beginning or ending near the shore the requirement was that the estimated distance in meters to the shore, reef, or breakers be stated (par. 259(*e*)). This was the first appearance of this requirement, although it was generally required that a distance be estimated where no position angles were obtainable.

5362. *Instructions of 1915*

The 1915 instructions were for the most part a verbatim reprint of the 1908 instructions. Some new provisions were added, others modified or amplified, and still others omitted. Of the changes made, the following bear on the interpretation of hydrographic surveys:

(*a*) In the reduction of soundings, greater detail is given for the entry of tide reducers. Thus, tide reducers for depths over 7 fathoms or for open ocean areas were to be entered

21. When plotting in feet, fractions less than 0.8 were omitted, and those of 0.8 or more were plotted as the next whole foot. Rules were also given for converting fractions. Thus, when plotting in quarters, 0.1=0, 0.2 and 0.3=¼, 0.4 to 0.6=½, 0.7 and 0.8=¾, and 0.9=1; when plotting in halves, 0.1 to 0.3=0, 0.4 to 0.7=½, 0.8 to 1=1; when converting from feet to fathoms and quarters, less than 1 foot=0, 1 foot and less than 2.5 feet=¼ fathom, 2.5 feet and less than 4 feet=½ fathom, 4 feet and less than 5.5 feet=¾ fathom, and 5.5 feet and over=1 fathom; when converting from feet to fathoms, for less than 4.5 feet=0, and 4.5 feet and over=1 fathom (par. 306).

in the sounding record to integral feet; [22] on bars and over inside water areas for depths less than 7 fathoms but more than 3 fathoms, to nearest half foot; and for depths of 3 fathoms or less, to the nearest tenth of a foot. The reduced soundings were to be entered in integral feet except on developments in less than 40 feet at critical points where the reductions were to take account of the fraction of a foot. (Par. 313.)

(*b*) The limiting depths for plotting fractions of feet or fathoms are given in greater detail as follows: feet and fractions at critical points in extensive enclosed waters and inside routes with 2 to 5 feet of water or less, but to whole feet at other places; fathoms and sixths to depths of 6⅚ fathoms; fathoms and quarters from 7 to 8¾ fathoms; and for greater depths in whole fathoms (par. 337). In critical places (under 40 feet) on navigable bars, in channels, in shallow enclosed waters, and in inside routes quarter feet were shown (par. 338).

(*c*) Where the first position of a sounding line was taken when the boat was at rest, an additional position was called for after an interval of 1 minute or when the boat had attained sounding speed (par. 354).

5363. *Instructions of 1921*

The 1921 instructions showed very few departures from those of 1915. The changes that were made have no special bearing on the interpretation of inshore hydrographic surveys except for the addition of yellow as the color for the zero curve when determined by soundings, and the provision that the 24- and 36-foot curves were to be omitted except in special cases (par. 321).[23] A small change was also made when converting feet to fathoms: for depths less than 4.9 feet, the fraction was dropped and for 5 feet and over the next whole fathom was used (par. 338). (*See* note 21 *supra.*) A change was made in the plane of reference for Puget Sound from 2 feet below the mean of the lower low waters to the mean of the lower lows (par. 315). The exact sizes of the symbols for the various control points are specified and black ink is specified for the names of triangulation points. The section on typical errors to be considered in studying discrepancies in the work (par. 353) was greatly expanded from the 1915 treatment.

22. This modified the 1908 instructions allowing tide reducers to be omitted for depths over 50 fathoms where the range of tide was less than 2 percent of the depth. The practice in 1963 calls for the omission of all corrections to soundings of over 101 fathoms where the algebraic sum of the tide correction and other corrections, excluding velocity corrections, is less than one-half percent of the depth. For depths less than 101 fathoms, special rules are applicable depending upon the depth range and character of the area or bottom. JEFFERS, HYDROGRAPHIC MANUAL 174 and Table 2, PUBLICATION 20–2, U.S. COAST AND GEODETIC SURVEY (1960, 3d ed.). Subsequent citations to this manual will omit the edition reference but should be understood to reflect the changes to Apr. 1, 1963 (*see* note 1 *supra*).

23. In the instructions, the zero curve is designated as the "mean sea-level curve," which was clearly an error and should have been "plane-of-reference curve." This was corrected in the Hydrographic Manual of 1928. This scheme of depth-curve colors is generally in use today except that the zero (plane-of-reference) curve is shown in orange and some intermediate curves have been added and colors are prescribed for depth curves extending to 3,000 fathoms. *Id.* at 15 and Tables 3 and 4.

537. The Hydrographic Manuals

Beginning with 1928, the instructions for hydrographic work were published under the title of "Hydrographic Manual." Three such manuals have been issued to date—in 1928, in 1942, and in 1960. The 1928 manual is identified as Special Publication No. 143 and went through a 1931 reprint and a 1935 reprint in the form of "Errata and Addenda" inserts. It is divided into two parts: Part 1 covers "General Requirements for Hydrographic Work," and Part 2 "Equipment and Methods Used for Hydrographic Work."

The Hydrographic Manual of 1942 was labeled a "Revision" and retained the same Special Publication number as the 1928 manual. Actually it was a radical departure from the previous one, being more comprehensive in scope and designed to serve not only as manual but as textbook for the new methods of hydrographic surveying then developed, or being developed, and for which there was a scarcity of published material. It contains 940 pages and is one of the most complete manuals ever published by the Bureau.

The 1960 Hydrographic Manual (identified as Publication 20–2 under a new numbering system) [24] was issued to reflect the many new developments in hydrographic control systems and in echo-sounding instruments which made the 1942 manual out of date in many respects. Although parts of the previous manual were carried forward into the 1960 text much useful information was not repeated. The 1960 manual is printed in loose-leaf form so that changes or new material can be added as necessary in an expeditious manner. (*See* note 1 *supra.*)

54. MAKING AN INSHORE HYDROGRAPHIC SURVEY

The work of actually surveying the water area on a given project usually followed the establishment of the triangulation control and the completion of the topographic mapping. Both of these operations furnished the latitudes and longitudes of the stations that were to be used in the hydrographic work for locating the boat's positions during the progress of the survey.

24. Beginning with Jan. 1, 1957, a new numbering system for Bureau publications was inaugurated based on identification of class of subject matter covered. The entire scope of Bureau activities is divided into 13 categories and all publications issued in a particular category carry the same numbered prefix. The prefix is followed by the number of the publication, each category having its own range of numbered publications. The word "Special" is no longer used in the designation. "General publications of Bureau-wide scope" are in the "10" category, "Hydrography" is in the "20" category, etc. Thus, the designation for the Hydrographic Manual of 1960 is "Publication 20–2," which indicates it is the second publication in the "Hydrography" category. *Change in Numbering of Bureau Publications,* 7 Journal, Coast and Geodetic Survey 121 (1957).

A working sheet (now termed a boat sheet) was prepared on which a projection (meridians of longitude and parallels of latitude) was laid down, the triangulation points plotted, and the high- and low-water lines and secondary control points transferred from the planetable survey. Occasionally, additional control stations were established by the hydrographic party. These were usually located by means of sextant angles from "cuts" taken in the boat or from angles at the station. The observed angles were either entered in the sounding volumes or in a separate angle book.[25]

Proposed sounding lines were plotted in pencil on the working sheet in accordance with a planned system designed for most effective development of the bottom features. The hydrographer attempted to follow these lines as he progressed with the work.

A typical field party, engaged on inshore hydrography and sounding with a leadline, usually consisted of the following: two engineers (one to direct the operations) to measure the angles for locating the survey boat's positions; a leadsman to take the soundings; a recorder to record the soundings and the observed angles; and the necessary crew to operate the boat. (*See* fig. 58.)

There are two essential operations in the prosecution of every hydrographic survey, both of which are carried on simultaneously: (1) the measurement of depths (soundings), and (2) the determination of the geographic positions (latitudes and longitudes) of the soundings so that they may be charted in correct relation to each other and to the surrounding topographical features.

541. Measurement of Depth

Various methods of measuring depths of water have been used in the hydrographic work of the Bureau. These included the use of a graduated pole for depths to 10 or 15 feet, the handlead and marked line for depths up to 15 fathoms, pressure tubes between 15 and 90 fathoms (Register No. H-4547 (1926)), various types of mechanical sounding machines for depths beyond the handlead limit, and echo-sounding devices for all depths.[26]

25. Different symbols were used for the different categories of control, but with no great consistency in the early years for a given category. Thus, triangulation stations have been variously shown by black triangles, by red triangles, by red triangles circumscribing black circles, by two concentric black circles (Register No. H-15 (1837)), by red circles (Register No. H-1437 (1879)), and by needle points alone without any symbols (Register No. H-44 (1834)). Topographic stations have been designated by black circles and by red circles, and hydrographic stations by black circles and blue circles. The modern practice is to use red triangles for triangulation stations, small red circles for topographic stations, and small blue circles for hydrographic determinations, and small green circles for stations spotted fom aerial photographs. Jeffers (1960), *op. cit. supra* note 22, at 206 and fig. 79.

26. In the survey of the Potomac River in 1959, a 16-foot sounding pole was used for all shoal-water sounding from the shore to a depth of 8 to 10 feet.

FIGURE 58.—Sounding with a handlead and line from a whaleboat in a survey of Baltimore Harbor on November 7, 1900.

Since this publication deals primarily with the early surveys of the Bureau and this chapter considers in the main inshore hydrographic work, leadline surveys only will be discussed.

The handlead and line consisted of a suitably graduated line (in fathoms and feet) to one end of which was attached a lead weight called a sounding lead, the bottom of which was scooped out to receive tallow or soap for picking up specimens of the bottom while sounding.[27]

Before the advent of the gasoline engine and the steam vessel, pulling boats and sailing vessels were used in hydrographic work. In measuring depths, the leadsman usually stood on a small platform, which projected over the side of the sounding boat, and while the boat was proceeding at slow speed he heaved the lead forward far enough so that when the lead struck the bottom it was vertically below him and he was able to obtain an accurate reading of the depth from the markings on the line. When the water surface was broken by waves or swells, the leadsman estimated the mean water level so that the depth as read was from the mean surface. (*See* fig. 58.)

27. Changes in the line caused by stretching or shrinking during the sounding operations were accounted for by applying corrections to the measured depths after comparing the leadline with a standard measure (*see* text following note 10 *supra*).

542. Determination of Position

As with the measurement of depths, various methods have been used in the past for determining the position of the sounding boat or the survey vessel (and in turn the soundings) while engaged on hydrographic work. There is a striking similarity between the development of position-fixing methods in the Coast Survey and the development of depth-measuring methods. Both have retained earlier methods, have discarded intermediate ones, and have reached a climax in the utilization of sound (in the case of depths) and electronics (in the case of positions) for their determination. These methods included, for the early period, sextant angles taken in the survey boat upon three stations on shore, theodolite angles taken at two shore stations upon a flag hoisted in the boat and measuring the angle in the boat between the two shore stations for verification, and by running out ranges from shore and fixing the positions by time (*see* 532).[28] These methods were still included in the 1894 instructions, but subsequently the 3-point fix method was primarily used, the method of angles from stations on shore being reserved only where extreme accuracy was demanded, as in harbor improvement surveys.

In the early years of the Bureau's history, when the Nation's commerce was carried in comparatively small, shallow-draft, sailing ships, it was unnecessary to extend the surveys offshore into deep water. With the advent of the steamer, however, and its subsequent increase in size, draft, and speed, the early requirements were radically modified, and the emphasis gradually shifted from shoal to deep water. The determination of position became more difficult and complicated. Many factors had to be taken into account which could be ignored when in sight of shore signals. This gave rise to a method of position determination known as "Dead Reckoning" which resembled very much the method used in navigation.

In 1914, and the years following, a more precise method of dead reckoning was developed and was termed "Precise Dead Reckoning." Every known element affecting the vessel's position was carefully observed by the survey party: the deviation of the compass, the effect of the wind in pushing the vessel sidewise through the water, the careful calibration of the log for the determination of distance, and, above all, the frequent observations for current to determine its velocity and direction. But notwithstanding the many precautions that were taken, there were still enough indeterminable factors to make

28. In the earliest instructions for hydrographic work (*see* 531), no mention is made of the method of position fixing, but in the volume (17) of early correspondence marked "Coast Survey, Scientific, 1844–1846," notice is taken that one of the methods used is to observe angles on the boat from two stations ashore (*see* note 11, *supra*). On Register No. H–268 (1851), the sounding lines were run between shore signals with the distances from the signals noted at the beginning and ending of the lines.

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the results anything but precise. In consequence, later surveys have revealed occasional errors in the earlier work of as much as 5 miles in the location of some of the offshore depth curves.[29]

With the advent of echo sounding in the 1920's and the realization of their great potential in aiding the navigator to better determine his position, more precise methods were developed for position fixing—for example, a buoy-control method and the method of Radio Acoustic Ranging (R.A.R.). During and following World War II, the latter two methods were replaced by electronic methods, to wit: Shoran, Electronic Position Indicator (E.P.I.), and Raydist.[30] But for the close inshore work, the 3-point fix method is still resorted to.[31]

543. The Surveying Operation

Having determined the system of sounding lines for best coverage and laid it down on the boat sheet, the hydrographic party starts work at any convenient point in the area to be surveyed. The two observers with sextants in hand, the recorder with a watch or clock and record book, and the leadsman with his "leadline," take their respective positions in the boat. The officer-in-charge directs the recorder to make a note in the sounding record, say, as follows: "Line begins at position 1, about 5 meters from shore." The observers measure

29. This method was first described in Seran, Precise Dead Reckoning in Offshore Soundings, Special Publication No. 73, U.S. Coast and Geodetic Survey (1921). Its later use in conjunction with other methods is described in Adams (1942), *op. cit. supra* note 1, at 232–238. The present use of dead reckoning in hydrographic surveying is described in Jeffers (1960), *op. cit. supra* note 22, at 198. In comparing such surveys with later, more accurate surveys, it is important to keep these limitations in mind, in order to avoid erroneous conclusions regarding changes in the ocean bottom. Unless the earlier survey can be correlated with the later survey by the superposition of characteristic submarine features, no intelligent deductions would be possible. Even on the dead-reckoning survey alone, exaggerated underwater slopes may be indicated as a result of soundings on successive lines not being in correct relationship due to the variation in the elements encountered on different lines. This is especially true when attempts are made to combine data from different sources subject to the same or even greater uncertainties. The relationships may become so complex as to challenge even approximate analysis. An excellent example of this is the outer Hudson River submarine canyon. Until accurately controlled surveys were made in the 1930's, this important physiographic feature was represented on the charts and in physiographic studies by an S-shape, an interpretation resulting from inaccuracies in locating the earlier soundings which connected the part of the valley immediately below the 50-fathom depth curve with the lower part of what turned out to be an entirely different declivity. *See* Patton, *The Physiographic Interpretation of the Nautical Chart*, 5 International Hydrographic Review 205, 218 (May 1928), and Smith, *Submarine Valleys*, 10 Field Engineers Bulletin 150, U.S. Coast and Geodetic Survey (1936).

30. The buoy-control and R.A.R. methods are described in Adams (1942), *op. cit. supra* note 1, at 109 *et seq.* and at 555 *et seq.*, respectively. Shoran and E.P.I. are described in Burmister, *Electronics in Hydrographic Surveying*, 1 Journal, Coast and Geodetic Survey 3 (1948), and Raydist is described in Hickley and Bolstad, *ER-Type Raydist System of Position Control*, 7 Journal, Coast and Geodetic Survey 45 (1957), and in Fish, *Raydist on Georges Bank*, Technical Bulletin No. 5, U.S. Coast and Geodetic Survey (1959). The present use of Shoran, E.P.I., and Raydist in hydrographic surveying is described in Jeffers (1960), *op. cit. supra* note 22, *passim*.

31. *See* Register No. H–8152 (1954–1955) where Raydist was used to within 1 mile of shore and the 3-point fix method from there inshore.

with the sextants the two angles between three signals on shore, the middle signal of which is common to both angles, and read the angles so measured;[32] the leadsman measures the depth with the leadline and calls out the number of feet, or fathoms and feet; and the recorder enters all these in the sounding record together with the time. The boat starts ahead at a constant speed on the predetermined course, and position angles are taken every 3 or 4 minutes, or as frequently as necessary, and soundings taken at every 15 to 20 seconds, or at irregular intervals where the depths are changing rapidly, the time of each sounding being noted to seconds. This procedure is continued until the end of a line is reached and the boat is maneuvered to a new line where the routine is repeated. As position angles are observed, the officer-in-charge plots each position on the boat sheet which enables him to make the necessary changes in course so as to follow the predetermined line.[33]

It is a fundamental principle in hydrographic work that the boat must maintain a straight line between adjacent positions and that if a change in the boat's direction is to be made a position must be taken at the time of change (*see* 533). In plotting the soundings, therefore, the assumption is made that the boat followed a straight course between consecutive positions, unless otherwise noted in the record.

When a sounding line ended or began near shore, it was customary to note in the record the estimated distance from shore, in addition to the observed position angles. This served as an independent check on the accuracy of the shoreline as surveyed by the topographer because the boat's position is deter-

32. For measuring angles from a moving boat, no handier instrument has ever been devised than the sextant. It is so called because a true sextant encompasses one-sixth of a circle, or 60°. Based on the optical principle on which the instrument is constructed, namely, that when a ray of light undergoes two successive reflections in the same plane, the angle measured is actually twice the angle through which the index arm has passed. Therefore, the markings are doubled at the time of manufacture. Thus, the 5° graduation is marked 10°, 10° is marked 20°, etc. The maximum horizontal angle that can be measured with a sextant is thus approximately 120°. The instruments, almost universally known as sextants, are actually quintants, constructed for the measurement of angles up to 144° or slightly larger. To measure the horizontal angle between two objects, the observer sights directly on the one on the left and brings the object on the right into coincidence with the one on the left by moving the index arm as needed. The angle is then read on the graduated limb. For a detailed description of the sextant and its use, together with the principle of its construction, *see* ADAMS (1942), *op. cit. supra* note 1, at 361–372. A briefer account of the sextant, including the micrometer drum type (a modern development), and its use in hydrography is given in JEFFERS (1960), *op. cit. supra* note 22, at 45 (*see* fig. 59).

33. The instrument universally used for plotting three-point sextant fixes is the three-arm protractor (metal or celluloid) (*see* fig. 60). It is in reality a graphic solution of the three-point problem and was in use at a very early date in the Coast Survey. It is referred to in the instructions for hydrographic work published around 1860 (par. 57) (*see* 532). It consists essentially of a graduated circle with a fixed center arm and right and left movable arms pivoted at its center so that the extension of each fiducial edge always passes through the precise center of the graduated circle. The observed left angle is set with the left arm and the right angle with the right arm. The protractor is then placed on the plotting sheet so that each arm passes exactly through the corresponding control station that was used in the measurement of the angles, that is, the center arm is made to pass through the center station, the left arm through the left station, and the right arm through the right station. The center of the protractor then marks the position of the sounding boat or vessel.

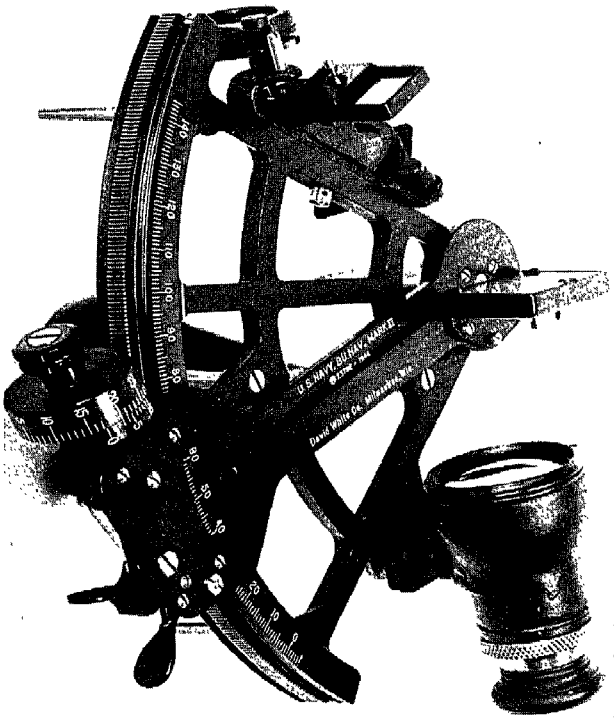

FIGURE 59.—Micrometer drum sextant with endless tangent screw.

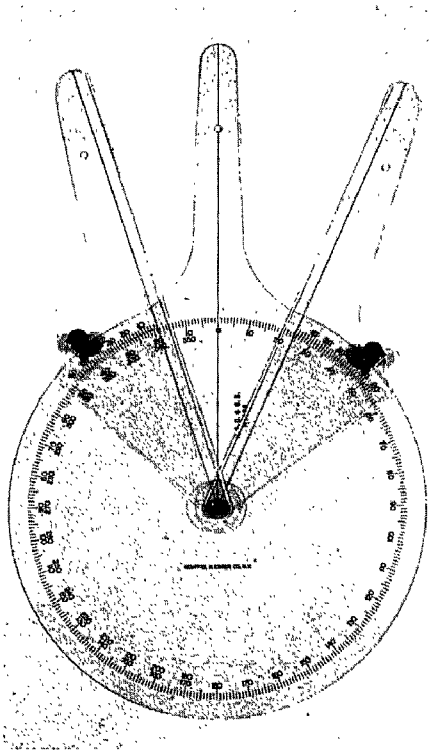

FIG. 60.—Three-arm plastic protractor.

mined by a different method, namely, by angles to objects that are often on the opposite shore. Any inaccuracy became apparent in the relative position of the boat to the shore. Also, if the boat was aground at the end of the line, or if the line ended on the beach, such notes were usually entered in the record. In marsh area, these were helpful in interpreting the nature of the marsh with respect to the planes of high or low water (*see* 4432).

During the progress of the survey, while soundings were being taken, the leadsman noted the character of the bottom either by "feel" or by bringing up small specimens that clung to the tallow on the bottom of the lead. The recorder entered in the sounding record notations such as hard, soft, sandy, rocky, grassy, or the like, as the case might be.

As a check on the accuracy of the work, most hydrographic surveys contain a number of sounding lines that intersect the main system either at right angles or at an oblique angle. When all soundings are reduced to the same plane of

reference, the soundings on one system must agree, within certain limits, with the soundings which they cross on the other system, otherwise the work is revised.[34]

While the survey has progressed, the water has not maintained the same level due to the rise and fall of the tide, which is a continuing phenomenon. Soundings are entered in the sounding record as measured from the water level without regard to the height of the tide (*see* fig. 61). Each sounding as recorded is therefore corrected for the height of the tide at the time in order to refer the depth to the sounding datum or reference plane. If this were not done, uncorrected soundings shown on the hydrographic survey or on the nautical chart would be no more than a group of numbers without significance or coordination (*see* 564). Tide observations are therefore always made in conjunction with the hydrographic work.[35] They are obtained from readings on a tide staff or from an automatic tide gage operated during the progress of the survey (*see* Part 1, 2312, 2314).[36]

Tide observations serve a two-fold purpose: they provide the data for defining the plane of reference for the area, and furnish the data for determining the height of the tide at any time with respect to that plane. With this information, it becomes a simple matter to derive the corrections to be applied to the recorded soundings to reduce them to depths below the plane of reference. Thus, the plane of mean low water is derived by averaging all the low waters observed on the tide staff or on the automatic tide gage (*see* Part 1, 2312). If this represented a reading of 3 feet on the staff, then a sounding of 12 feet obtained at a time when the water level registered 8 feet on the staff—5 feet above the plane of reference—would have to be reduced by

34. On some of the hydrographic surveys, two systems of parallel lines were run in regular checkerboard fashion (*see* Register No. H–2229 (1895)).

35. This was always a requirement. There are some isolated exceptions as, for example, Register No. H–106 (1840), where no register of tides was kept and an arbitrary value was used for the height of high water above the sounding datum and the soundings corrected accordingly.

36. Instructions for tide observations were issued under the title "Directions for Observations of Tides," and carried the notation "Printed for the Use of the Tidal Observers from the Manuscript Instructions, 1852." This date is interpreted to be the date when the manuscript instructions were issued, rather than the date of publication of the pamphlet (*see* note 7 *supra*).

Early Tide Observations.—The first self-registering tide gage used by the Coast Survey is described in Appendix 38 to the Annual Report of 1853. The longest continuous tide records available from any one station are those from the Presidio at the entrance to San Francisco Bay and date back to July 1897, but the earliest automatic gage to be established was at Governor's Island, N.Y., and was kept in operation during the winter of 1844–1845. *See* Annual Report, U.S. Coast and Geodetic Survey 315 (1897). The earliest tide observations of any kind made by the Bureau were those of 1834 when a staff was established at the Lighthouse Wharf at Fire Island Inlet in Great South Bay, N.Y., in connection with the survey of the bay (*see* 52). The observations covered the period from Oct. 22 to Nov. 27, 1834. Copies of tide observations made in 1833–1835 in Cape Cod Bay and at Race Point, Mass., are on file in the Bureau archives, but it is not certain whether these were made by the Coast Survey, or by the Bureau of Topographical Engineers who made the hydrographic survey (*see* Map File, Accession No. 645). On a survey of a portion of San Francisco Bay (Register No. H–2246 (1895–1896)), five tide gages were used to control the area.

Locality COAST OF MAINE — *Sublocality* FRENCHMAN BAY

Date JULY 23 1958 — *Boat used* LAUNCH 182 ; 1 *day*

POSITION NUMBER	TIME MER 75	SOUNDINGS FEET	SOUNDINGS TENTHS	CORRECTIONS ECHO FEET FATHOMS	CORRECTIONS TIDE REDUCER FEET FATHOMS	CORRECTIONS FEET CASTLINE	REDUCED SOUNDINGS FIELD FEET FATHOMS	REDUCED SOUNDINGS FIELD TENTHS	REDUCED SOUNDINGS OFFICE FEET FATHOMS	REDUCED SOUNDINGS OFFICE TENTHS
	h. m. s									
157	15 26 00	78		-0.5	-2.5	0.0	75			
	20	70					67			
	40	62	5*	-0.4	-2.4	-0.2	59	5		
	27-	53	0				50	-		
	20	42	5				39	5		
	½	37	0				34	-		
158	40	40	5				37	5		
	28-	32	0	-0.4			29	-		
	20	21	0	-0.2			18	2		
	⅓	8	4	0.0			5	8		
	40	16 3	5	-0.2	-2.4		10	7		
	29-	11	5		-2.2	-0.2	8	9		
159	20	10	5	-0.2		0.0	8	1		
	40	6	0	0.0			3	8		
	30-	4	5*				2	3		
		7	5	0.0			5	3		
160	20	10	-	-0.2	-2.2		7	6		
161	16 57-	12	2	-0.2	-0.8	0.0	11	2		
		12	OHL				11	2		

BOTTOM HEADING BY COMPASS	POSITION NUMBER	POSITION CONTROL DATA		REMARKS
Boat				
010	157	Leg	51 40	Phase meter 60.1
		Nay 4		Adjusted to 60.0
		Ole	24 03	
		Kim-Nay	32-16	Cut to check
				O Kim
				* A scale
005				
	158	S	74 51	
		S	30 51	
				Nun No.2 30m. port
				Adjusted initial
	159	Got	52 45	51.S. Entering
		Leg		Kelp
		Ole	101 44	
				*RK. bare 2ft. 10
				m ~~O O~~ Kim.
				Leaving Kelp
	160	Leg	77 11	Line breaks to
		Ole		Search shoal.
		Par	84 58	
RK.	161	Leg	34 09	Least depth on
		Nay		sharp pinnacle RK.
		Ole	63 55	Item No.4 of
				presurvey review. Searched area
				with leadlines for 1 hr. & 20 min.
				Bottom not visible. Scattered Kelp
				in surrounding area.

FIGURE 61.—Sounding record of echo soundings with three-point fix sextant control. (Double page of sounding record reduced about one-half.)

5 feet to obtain the depth of water below the plane of reference. A depth of 7 feet would therefore be shown on the survey sheet and on the nautical chart.

55. TERMS ASSOCIATED WITH HYDROGRAPHIC SURVEYS

In the use and interpretation of hydrographic surveys, it will be helpful to know the meaning and significance of certain terms associated with such surveys, particularly where they are to be used in waterfront boundary litigations. These terms will be explained in the light of present practice, with references to earlier practice where a significant difference exists.

551. The Boat Sheet

The name "boat sheet" is given to the work sheet which the hydrographer uses in the field during the survey operations for plotting the details of the work as it progresses. Its use enables the hydrographer to cover an area with lines of soundings in a systematic and economic manner, to judge the adequacy of the survey, and to ascertain where additional soundings are required.[37] The boat sheet is prepared in advance of beginning the actual hydrographic operations. It resembles the "smooth sheet" (*see* 552) and contains the same kind of information (*see* 54), but is necessarily less accurate because of the haste with which the positions are plotted, the use of predicted tides for reducing the soundings, and the exposure to which the sheet is subjected.

The second important function of the boat sheet is its use as a guide in the plotting and verification of the smooth sheet, and as an aid in clarifying uncertainties which may arise at such times. Occasionally, when a conflict cannot be completely resolved, a boat position may be transferred from the boat sheet to the smooth sheet and used in place of the recorded data on the theory that the hydrographer being in the boat at the time of the survey knew his position and plotted it on the boat sheet in accordance with the known facts. Often, the boat sheet contains supplemental details and notes which aid in interpreting the sounding records and which should be transferred to the smooth sheet.

The boat sheet is retained during the verification and review of the smooth sheet and for sometime thereafter. Eventually it is destroyed.

37. The first reference to "boat sheet" as such was in the 1883 instructions for hydrographic work (*see* note 18 *supra*), but there is reason to suppose that some form of work sheet was used from the earliest date. The "sounding-sheet," also first mentioned in these instructions, was in reality a form of boat sheet inasmuch as it was a preliminary to the "finished sheet" (*see* 534).

552. The Smooth Sheet

The "smooth sheet" is the name given to the hydrographic survey when reduced to plot form. It is essentially a record of the soundings taken during the field survey, but contains other data necessary for a proper interpretation of the survey, such as depth curves, bottom characteristics, names of geographic features, and control stations.[38] As a rule, the smooth sheet is plotted in the field as the survey progresses or after it is completed, all soundings being left in pencil. After verification and review in the Washington Office (*see* 5521), the smooth sheet becomes the official permanent record of that particular survey. It is as complete for the water area as it is practicable to make it, and subsequent reference to the original sounding records is necessary only for some special investigation. (*See* fig. 56.) In the figure, none of the colors used to represent the different features on the finished smooth sheet are shown (control stations including their names, depth contours, low-water line, and position numbers and day letters). The prescribed colors for these features can be seen by reference to figure 82 of Jeffers (1960), *op. cit. supra* note 22.

5521. *Verification and Review*

In the verification process, the hydrographic survey undergoes in effect a complete check of the field observations and of the accuracy of the smooth plotting. A thorough examination is made of the survey data as submitted from the field to ensure that the work has been completed in accordance with the general instructions for hydrographic work and with the specific instructions covering the particular survey. Subsequently, the soundings, bottom characteristics, and other details in the sounded area are inked.[39] The verification deals primarily with a specific survey and its accompanying records, and with correlating it to other contemporary surveys—the hydrographic surveys which adjoin it, and the contemporary planetable or photogrammetric survey. The consideration of prior surveys in the same area is deferred for the reviewing process. In the verification process, the boat sheet is constantly referred to as a check on the protracting and for supplemental details and helpful notes, some of which are added to the smooth sheet. When the verification is completed,

38. In the early instructions for hydrographic work, this is called the "finished" hydrographic sheet (*see* 532). The use of the term "smooth sheet" did not come into being until the instructions for field work were issued in 1908 (*see* 5361(*k*)).

39. In the 1860 instructions for hydrographic work reference is made to the soundings being shown in black on the finished hydrographic survey when submitted to the office (*see* text at note 13 *supra*), but this was modified by the 1878 instructions which required soundings to be left in pencil (*see* 533).

the survey is a complete and accurate record of all hydrographic information currently obtained in the area.

The review of the hydrographic survey is the final step in processing the field data. The survey then becomes available for application to the nautical charts and for many collateral uses.[40]

The purpose of the review is to consider the survey in its broader aspects, to correlate it with all prior surveys of the Bureau covering the same area and with any historical data that may have been received from other sources, and to lay the foundation for future surveys in the area because of indicated changes or inadequate development or for resolving conflicting information. This comparison may involve as many as 25 prior surveys among which may be surveys running back a hundred years or more. Although the hydrographic coverage on the early surveys did not generally measure up to the standards required by modern navigation, the investigation of individual features in many cases showed a remarkable thoroughness. It is not uncommon in unchangeable areas to carry forward to the new survey a shoal sounding from an early survey. Discrepancies between old and new surveys may sometimes be resolved by reference to the old original sounding volumes. This examination may reveal the use of an incorrect shore signal, an interchanged angle, a leadsman's error in reading the markings on the leadline, or an error in the plotting. The aim of the review is to make the survey complete with respect to all information on prior surveys. In comparing early hydrographic surveys with later surveys, it has often been found that apparent discrepancies in the inshore portions of such surveys, where there was no reason to suspect filling or scouring, were due to a failure to allow for a change of speed when the soundings were plotted. This was true in cases where no fix was taken as the boat approached the shore (*see* 5361(*a*)). A replotting of the inshore soundings making allowance for such change in speed corrected the discrepancy.[41]

40. Circumstances may arise where it becomes important to apply critical soundings, or even the entire hydrographic survey, to the nautical chart prior to verification and review. Modern chart practice provides for such contingencies. EDMONSTON, NAUTICAL CHART MANUAL 12, 39, U.S. COAST AND GEODETIC SURVEY (1956).

41. Some form of review of hydrographic surveys must have been practiced at an early period. This is based on the statement in the 1860 instructions (par. 49) which called for a comparison with "Charts made by former authorities" (*see* 532), and the 1894 instructions which called for a comparison by the field party with existing charts and publications (*see* 535). But as an active and systematic office operation it was not begun until the late 1920's and was fully standardized by the middle 1930's (*see* Review contained in Descriptive Report for Register No. H–5546 (1934)). For complete details regarding the verification and review of modern hydrographic surveys, *see* JEFFERS (1960), *op. cit. supra* note 22, at 228–239.

5522. *The Basic Survey*

In modern terminology, hydrographic surveys are classified as basic, revision, special, and reconnaissance. Reconnaissance surveys are discussed in 121. Revision and special surveys need no elaboration other than that they are usually confined to a restricted area where, in the case of the first (revision), changes are suspected, and, in the case of the second (special), it is to serve some special purpose. A survey in which additional work is accomplished in a restricted area (*see* 568) is in a sense a revision survey.

A basic survey is fundamental. To be so classified, it must be so complete and thorough that it does not need to be supplemented by other surveys, and it must be adequate to supersede, for charting purposes, all prior hydrographic surveys of the area. It must be adequately controlled by the best practicable means in current use; it must be sufficiently intense to discover and determine the least depths on all dangers to navigation; it must verify or disprove all dangers, critical depths, and other important features appearing on the charts or prior surveys; it must develop significant submarine features that may be useful to the navigator; and it must provide sufficient permanent control so that future revision surveys will require the establishment of a minimum of additional control.[42]

When all of these requirements have been complied with, the survey can be classed as a *basic* survey. However, from an office viewpoint the basic field survey becomes truly basic only after it has gone through the reviewing process (*see* 5521) and comparisons have been made with all prior hydrographic surveys of the area and all conflicts in important features have been resolved, or where impossible of resolution the earlier features have been brought forward to the later survey.

553. The Sounding Record

The *sounding record* is the most important record associated with a hydrographic survey. It is the official record of the soundings, and generally of the position data. It was always a requirement that the records be so complete and self-explanatory that it should be possible to be used "by any one acquainted with the subjects of them, without necessity for reference to the chief of party personally."[43]

Sounding records have undergone many changes in both form and detail. The earliest form was indeed crude when compared to the later forms and par-

42. Adams (1942), *op. cit. supra* note 1, at 267, and Jeffers (1960), *op. cit. supra* note 22, at 126.

43. General Instructions in Regard to the Hydrographic Work of the Coast Survey (*circa* 1860), par. 70 (*see* 532).

ticularly to those in use today. For example, the sounding records for Register No. H–15 (1835) exhibit the following characteristics: The entries are crudely made; the recordings on some of the pages run from the bottom to the top; no headings are given for the columns; time is recorded only when angles are taken but not for any of the intermediate soundings, although 20 soundings between positions are not unusual; the only information given on a page is the sounding entry, the tide reducers to half feet, the line number, and the angle number; no reduced soundings are shown; and the paper is of the roughest texture. The page size is approximately 6 by 10 inches and the volume averages 2 to 3 inches in thickness.[44]

Separate volumes were used for recording the angles for locating the boat's positions (*see* volumes for Register No. H–47 (1835)), which at this time were taken from two stations ashore.[45] The greatest difficulty is sometimes encountered in tying in the plotted soundings with the original recordings, which frequently presents a challenge to the engineer's resourcefulness. (*See* note 5 *supra.*)

By 1840, only a slight change had been made in the sounding record (*see* Register No. H–56 (1840)). The format remained the same but headings of "Fath.," "Feet," "Time," and "Angles" were added.

In the 1852 sounding records for Register No. H–336, covering the mouth of the Columbia River, additional headings were added for "Red. for Tide," "Reduced Soundings," and "Bottom" and "Ranges" in the angles column. However, no reduced soundings were actually shown. The book size was changed to 4 by 13 inches.

This form continued generally until the issue in 1894 of the instructions for hydrographic work which required a time entry for every cast of the lead whether sounding at regular or irregular intervals. This was an important addition because it permitted a more accurate plotting of the soundings on the smooth sheet, especially where the bottom was irregular.[46]

44. Based on the character of the information on the back of the sounding volume (a finished lettering job such as would be done in a book bindery) it appears that the original sounding data may have been entered on separate sheets and bound after receipt in the Washington Office.

45. The sounding records and angles for some of the very early surveys may be found to be incomplete and in some cases the records are no longer available (*see,* for example, Register No. H–44 (1834)). The soundings for several sheets were sometimes bound in the same volume which later caused considerable confusion when sounding lines on a survey sheet had to be identified. This may ofttimes account for failure to locate the sounding data for a particular sheet. (The soundings for Registers Nos. H–1 (1837) and H–3 to H–12 (1836–1837) are recorded in the same volume.)

46. The 1878 and 1883 instructions required only the time of sounding to be recorded when sounding at irregular intervals. As far as the actual records are concerned, there is no sharp dividing line for the adoption of this practice. Thus, the sounding records for Register No. H–1573 (1883), in Monomoy Passage, Mass., show times recorded for every sounding, yet those for Register No. H–1728 (1886), in Possession Sound, Wash., show times only when position angles were taken.

By the turn of the century, the form of sounding record was well standardized and no material change was made until publication of the 1942 Hydrographic Manual. This record is designed to give the complete story on the hydrographic operation and is adapted for use in leadline or echo sounding. The big change was in recording the left angle first, then the right angle, instead of the reverse, as had heretofore been done.[47]

The sounding records often contain notes made by the hydrographer at the time of the survey. These may not be reflected on the hydrographic sheet, but may help clarify an ambiguity that might arise many years later when the survey is used for a collateral purpose—for example, defining the low-water line of an early date. The actual depth of water deduced from the sounding records may differ by several tenths of a foot from the plotted soundings because of the rules pertaining to the plotting of fractions (*see* 5622).

5531. *Fair Journal*

This term was first used in the instructions of 1883 (*see* 534). It was apparently a smooth copy of the original sounding records and the records used to record the angles taken at shore stations, and may be the same as the duplicate mentioned in the same instructions. Very few of the fair journals are now available, the one examined being of the main ship channel of Boston Harbor, surveyed in 1879, but attached to the records of Register No. H–652 (1858). The size of this journal is 8 by 13 inches.

56. SIGNIFICANT FEATURES ON HYDROGRAPHIC SURVEYS

561. The Soundings

Without doubt the most important feature on a hydrographic survey is the soundings (or depths), for that is the purpose for which the survey is made. By means of the soundings, the locations of channels, of shoals and other dangers to navigation, and of characteristic formations of the bottom topography are determined. They are always shown in black ink on the smooth sheet. There has never been any departure from this practice, except in the case of transferred soundings from an adjoining contemporary survey or from an early survey (*see* 5522), "minus soundings" on some of the early surveys (*see* 5613), and

47. Adams (1942), *op. cit. supra* note 1, at 764 and fig. 172. The latest form of sounding record is essentially the same but with some slight modifications in the column headings (*see* fig. 61).

soundings resulting from additional work in the area (*see* 568), when they are shown in color.

Soundings are of two kinds—those below the plane of reference (the true depths), and those above the plane (actually heights and usually indicated as minus soundings). All soundings taken are not always plotted on the smooth sheet. This also applies to minus soundings. This fact should be kept in mind when it becomes necessary to study in greater detail a particular depth curve, such as the low-water line, or some other aspect of the survey. Reference should then be made to the sounding record.

5611. *Two Depth Units on Early Surveys*

On the early surveys, two depth units were generally used—feet and fathoms. This was true for both the Atlantic and Pacific coasts, but there was no uniform dividing line. Thus, on the Atlantic coast, on Register No. H–22 (1837), soundings of 4 fathoms and greater are plotted in fathoms, and soundings less than 4 fathoms in feet; on Register No. H–1 (1837), the dividing line is 10 fathoms; while on Register No. H–44 (1834), with depths to 44 feet, all soundings are in feet. On the Pacific coast, on Register No. H–268 (1851) (San Diego bar), with depths as great as 80 feet, all soundings are in feet; but on Register No. H–336 (1852), at the mouth of the Columbia River, the soundings are plotted in feet to 18 feet and in fathoms beyond. Where two depth units are used, the change to fathoms is often indicated by the addition of the abbreviation "fths" after the sounding (Register No. H–22 (1837)). On a combination hydrographic and topographic survey in Alaska (Register No. H–1737 (1886)), sanding with gradations is used for the area where the depth unit is in feet, leaving clear the area where fathoms are used.

Except for the early surveys, it can be stated generally that, with some isolated exceptions, the inshore surveys along the Atlantic coast used a single depth unit—feet. (This also applied to the Gulf coast surveys.) On the Pacific coast and in Alaska, the dual system was continued for a considerably longer period (*see*, for example, Register No. H–2246 (1895–96)). By 1908, the use of two depth units on one sheet was specifically prohibited in the published instructions (*see* 5361(*j*)).[48] On Register No. H–3212 (1910), feet only were used.

48. The manner of showing fractions of fathoms or feet on the smooth sheet did not always follow a uniform pattern, and soundings were sometimes plotted in whole feet, in feet and tenths, in feet and quarters, in whole fathoms, in fathoms and quarters, and in fathoms and feet. The 1908 instructions for field work incorporated specific rules for converting fractions and for plotting on the smooth sheet (*see* note 21 *supra*).

5612. *"No Bottom" Soundings*

No bottom soundings are those where the bottom was not reached because the general depths were too great for the method of measurement. Thus, if depths of 30 fathoms or so were suddenly encountered in an area where a 20-fathom leadline was being used, the lead would not reach bottom and a "no bottom" sounding at 20 fathoms would be recorded. They provide only negative information. On the smooth sheet they were sometimes shown by a line underneath the figure or by a line and a dot under the line (Registers Nos. H–268 (1851) and H–289 (1851)). Later, the symbol adopted was a line over the figure and a small circle over the line (Register No. H–1737 (1886)). This was also the practice in 1942 (*see* ADAMS (1942), *op. cit. supra* note 1, at 762).

5613. *"Minus" Soundings*

Soundings that reduce to heights above the sounding datum (plane of reference) are termed *minus soundings,* since ordinary soundings are depths below the sounding datum and are considered positive values. If viewed on the ground such areas would be above water when the height of the tide is at the plane of reference. Where minus soundings appear on a hydrographic survey, it presupposes the existence of a low-water line with all such designated soundings falling within the line (*see* 562).

The earliest general reference to the use of minus soundings, although not expressly stated as such, is in the *circa* 1860 instructions (*see* 532), where it is stated (par. 72*i*) that "Shoals bare at low water must be given with their height above the plane of reference, and great care must be taken to determine their limits. These limits correspond to the line of mean low water." The lack of greater particularity accounts for the fact that during the period covered by these instructions the soundings above the plane were variously represented on the survey sheets as *underscored soundings* (Register No. H–790 (1861)), as *minus soundings* (Register No. H–1064 (1869)), and as *red soundings* (Registers Nos. H–790*A* (1871) and H–1426*b* (1878–1879)).

The 1878 instructions for hydrographic work were the first to spell out the use of minus soundings (*see* text following note 16 *supra*), and such soundings are shown on Registers Nos. H–1759 (1886) and H–3423 (1913). This is also the present practice, with the addition that the soundings on both sides of the low-water line are plotted to the nearest half-foot.[49]

49. JEFFERS (1960), *op. cit. supra* note 22, at 219 (*see* fig. 56). Prior to this, manuscript rules had been promulgated clarifying the use of fractional feet in general and in the vicinity of the low-water line in particular. Shalowitz, *Units for Recording, Reducing, and Plotting Soundings,* 6 FIELD ENGINEERS

It is obvious, that where it becomes important to know the actual depths represented by plotted minus soundings, recourse should be had to the sounding records. This is especially true where the low-water line is the object of study (*see* 562).

5614. *"Zero" Soundings*

Prior to the period covered by the *circa* 1860 instructions, soundings above the plane of reference were either omitted from the hydrographic sheet (*see* text following note 4 *supra,* and 531), or were generally shown as *zero soundings,* without regard to the actual elevations above the plane of reference, the low-water line being traced to encompass the most seaward zeros (*see* Register No. H–421 (1854)).[50] In such cases, if it becomes important to know the *actual* position of the low-water line or the actual elevation of the ground above the plane of reference, without regard to the conversion rules adopted for plotting the soundings on the smooth sheet, the sounding records should always be consulted (*see* note 49 *supra* and 5622).

5615. *Identification Letters and Numbers*

For proper identification and as a means of reference to the original sounding records, sounding lines on the smooth sheet are identified by position numbers and day letters (in colors) corresponding to those used in the sounding records. Positions are numbered consecutively, starting with number 1 at the beginning of each day; and each day's work is identified by a letter or combination of letters assigned in alphabetical order, starting with the letter *A* on each hydrographic survey. Capital letters of one color are used to identify the hydrography surveyed from the ship or the major survey vessel of the party, and lower-case letters for the supplementary launches, a different color being assigned to each separate unit. The numbers and letters (including the colors) correspond to those used in the sounding records.[51]

BULLETIN 80, U.S. COAST AND GEODETIC SURVEY (Dec. 1932). Although this was the earliest that such requirement was spelled out, the practice has been observed on surveys between the years 1873 and 1931. (*See,* for example, Registers Nos. H–1217 (1873), H–2146 (1892), H–2985 (1909), and H–5129 (1930–1931) where soundings on both sides of the low-water line are plotted in half feet and in quarter feet.) There is no assurance, however, that this was the general practice for the period. In the Hydrographic Manual of 1928, the following equivalents were prescribed for plotting minus soundings: 0 to —0.5 ft.=0 ft.; —0.6 ft. to —1.5 ft.=—1 ft., etc. Prior to this, no rules were given for the conversion of minus soundings.

50. On a survey made in 1875 (Register No. H–1256), soundings inside the low-water line are still shown as zeros, but this is considered an exception rather than the rule.

51. JEFFERS (1960), *op. cit. supra* note 22, at 10.

On the earliest hydrographic survey (Register No. H–44 (1834)), no position numbers nor day letters are shown. However, on Register No. H–45, which is a replotting in 1845 of Register No. H–44, position numbers are shown in red and the day letters are identified by various shapes. A distinction was sometimes made on the early surveys between positions determined from the boat and those determined from shore stations. Thus, on Register No. H–22 (1837), positions from the boat are identified by blue numbers and those from shore by red ones. By 1857, the form of identification was standardized to use letters of the alphabet for the day of the month (Register No. H–573 (1857)). Still later, the major vessel's work was identified by capital letters and the auxiliary boats and launches by lower-case letters (Register No. H–1573 (1883)), the same as is done today.

On some of the early surveys, small circles were used to mark the positions (Registers Nos. H–1425*a* (1877–1878) and H–1425*b* (1878)). In such cases, the soundings were not plotted exactly at the positions but were offset slightly. This practice of using small circles began with the Instructions of 1878 (*see* 533) and continued generally until the publication of the 1908 General Instructions for Field Work, when it was specifically prohibited (*see* 5361(*g*)).

The frequency with which day letters were plotted has also undergone changes but without a progressive trend. Thus, on Register No. H–1425*a* (1877–1878), practically every position number is identified by a day letter, and on Register No. H–2129 (1892) they are shown for about every fifth position, yet on Register No. H–2411 (1898–1899), the day letters are given generally only at the beginning and ending of the line. With the publication of the Hydrographic Manual of 1928, the practice was standardized so as to require position numbers to be shown at each position, and the day letter at the beginning and end of each line, at every fifth position, and at the point of any decided change in direction of the line.[52]

562. The Low-Water Line

Next to the soundings, the low-water line is one of the most significant features on a hydrographic survey, at least from the standpoint of waterfront boundaries. The low-water line in any given area may be defined as the line where the established sounding datum or plane of reference for soundings

52. Hawley, Hydrographic Manual 18, Special Publication No. 143, U.S. Coast and Geodetic Survey (1928). This is substantially the practice followed in 1963. Jeffers (1960), *op. cit. supra* note 22, at 217 (*see* fig. 56).

intersects the shore (*see* 5622).[53] It is the curve of zero depth and its best delineation for hydrographic purposes results from soundings taken in its vicinity. But because of the difficulties attending its location by the topographer alone or by the hydrographer alone, it was recognized at an early period in the work of the Survey that the final delineation must be left to both (*see* 4461). This is still the practice in 1963.[54] Where possible, the inshore sounding lines were run at high water so as to define as much of the low-water line as possible, but on many stretches of open coast this was manifestly impossible—for example, in regions where the range of tide is extremely small, as in the Gulf of Mexico; or along a rocky coast where it is ofttimes dangerous for the survey boat to approach too close to shore, even at high water, as along many sections of the Pacific coast or along the northeastern Atlantic coast.

Where the hydrography failed to establish the low-water line, the line was transferred from the topographic survey, the chart compiler making the necessary adjustments for charting purposes.

5621. *Symbolization*

The low-water line on the early surveys was represented by either a dotted or a dashed black line, the weight of the line being an indication of its origin. If it was transferred from the topographic survey (in whole or in part) it was drawn lighter than if it originated with the hydrographic survey.

On the first hydrographic survey (Register No. H–44 (1834)), the area between the high- and low-water lines is sanded, and this seems to have been the requirement when the earliest instructions were promulgated (*see* 531). Register No. H–500 (1855) showed the area sanded, and it was still so shown on some surveys as late as 1892 (Register No. H–2129). On Register No. H–790 (1861), a specialized treatment was made of the area between the low-water line and the high-water line. The area of zero soundings was left open with a dashed black line indicating the offshore limits of the zeros, or the low-water line, and only the area of minus soundings sanded. A reference to the contemporary topographic survey (Register No. T–967 (1860 and 1864)) showed the area of minus soundings to be a marsh area, thus enabling a distinction to be made between those areas bare at low water and those with elevation zero at low water. Sometimes the low-water line was accentuated by a gray wash, as were low-water shoals (Register No. H–2315 (1897)).

53. This is to be distinguished from the *mean* low-water line, which is defined as the intersection of the tidal plane of mean low water with the shore—a specific technical concept not necessarily related to the plane of reference used for soundings in a particular area (*see* Volume One, Part 1, 631, 64).

54. *Id.* at 135–136, 208.

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No reference is made to the method of symbolizing the low-water line in any of the published instructions, including those of 1894. But generally it was shown by a dotted black line (*see* Registers Nos. H–2161 (1892–1893) and H–3214 (1910)). In the instructions for field work issued in 1908, the first mention is made that the low-water line is to be indicated by a dotted line (*see* 5361(*h*)). The instructions of 1921 changed this and required it to be shown in yellow where defined by soundings (*see* text at note 23 *supra*). The Hydrographic Manual of 1942 continued this practice but provided for two additional situations: (1) where the low-water line on the topographic survey was rodded in at low tide, it was shown as a black line of alternate dashes and dots; and (2) where the low-water line was reasonably well determined from notes in the sounding records and sketches made on the boat sheet by the hydrographer at the time of the survey, it was shown as a yellow dashed line.[55] The present requirement (in 1963) is to symbolize the low-water line by an orange color (*see* fig. 62). In the figure, the colors used for various types of control stations and for aids to navigation and landmarks on the hydrographic surveys have been omitted. For shoreline and low-water line, the colors used have been indicated by legend when other than black. The prescribed colors for all these features can be seen by reference to figure 79 of JEFFERS (1960), *op. cit. supra* note 22.

5622. *Use for Boundary Purposes*

Where the low-water line as shown on a hydrographic survey is to be used for boundary purposes, the original sounding records, if available, should always be consulted. This is especially important where the low-water line is defined by zeros, as was the early practice (*see* 5614). The sounding record will show the exact depths obtained on the lines crossing the low-water line, and by correcting them for height of tide a much closer approximation of the low-water line location will be obtained.

Even where the low-water line is defined by minus soundings, the original sounding records should be consulted for the reason that in plotting the soundings for charting use they were generally shown in integral feet, fractions of 0.7 foot or less being omitted; that is, 0.7 foot was actually plotted as zero, and 1.7 feet as 1 foot. Obviously, a more realistic location of the low-water line would be had if the actual depths were taken into account.

55. ADAMS (1942), *op. cit. supra* note 1, at 694. The use of the yellow dashed line actually antedated the 1942 Hydrographic Manual. The instructions (unpublished) for the review of hydrographic surveys promulgated in the middle 1930's called for this same treatment (*see* Register No. H–6141 (1935–1936)). A yellow line was used for the low-water line on some of the surveys even before the publication of the 1921 instructions (*see* Register No. H–3719 (1914)).

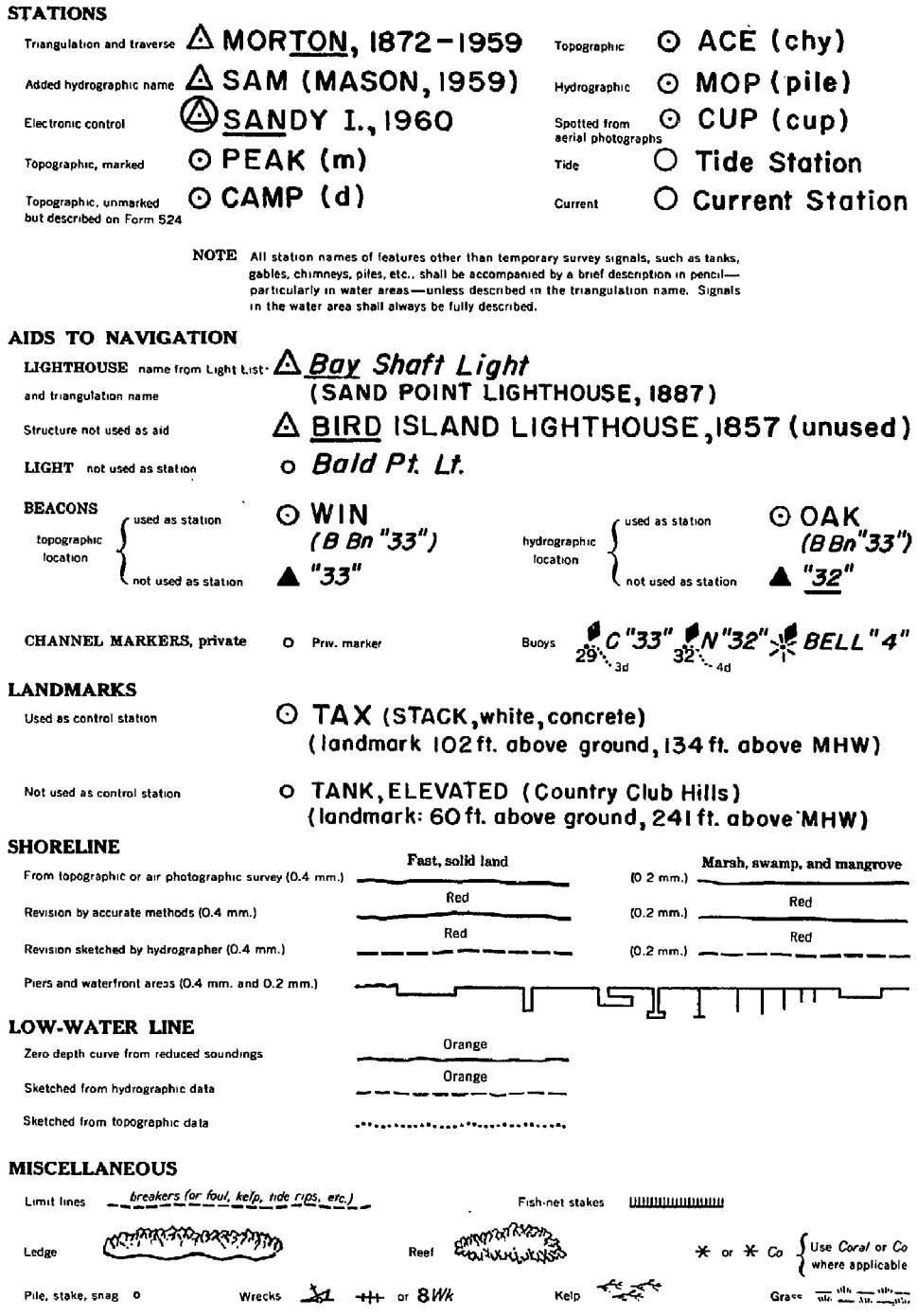

FIGURE 62.—Black and white copy of special symbols used on hydrographic smooth sheets. Colors are used on the completed sheet (*see* text).

Another factor to be kept in mind in using hydrographic surveys is the plane of reference adopted for the soundings (*see* 564). Along the Atlantic and Gulf coasts, it is the plane of mean low water, therefore, the low-water line shown on surveys along these coasts is the line of mean low water—the intersection of the plane of mean low water with the shore. Along the Pacific coast, the plane of mean lower low water is used and the low-water line on the surveys is the line of mean lower low water—the intersection of the plane of mean lower low water with the shore.

A. MEAN LOW-WATER LINE FROM MEAN LOWER-LOW-WATER LINE

If the tidal boundary to be extracted from a survey is mean low water where the plane of reference is mean lower low water, it can be accomplished by the following procedure: The basic principle involved in this process is that the low-water line is located to the landward of the lower-low-water line a distance that varies with the bottom slope and the difference in elevation between the two planes. Where minus soundings are plotted on the survey inshore of the mean lower-low-water line, the mean low-water line can be plotted on the sheet by first obtaining the difference in elevation between the plane of mean low water and the plane of mean lower low water from the tidal data (this is available in the Coast Survey). The mean low-water line can then be defined by drawing a curve through all the minus soundings corresponding to the difference in elevation between the two planes. Thus, if mean low water is 1.5 feet above mean lower low water, the line is drawn through the minus 1.5 feet soundings.[56]

Where no soundings are shown on the survey sheet inshore of the mean lower-low-water line, and none are available in the sounding records, the horizontal displacement in feet of the mean low-water line can be determined approximately from the relationship (in the example given) 1.5 feet times the cotangent of the angle of slope of the bottom (*see* fig. 63). This assumes a uniform bottom slope between the high- and low-water lines and can be computed from the horizontal distance between the two lines as scaled from the survey sheet (in this case 1,000 feet) and from the difference in elevation between the two planes as derived from the tidal data (in this case 9 feet). The mean low-water line can then be drawn parallel to the mean lower-low-water line. This

56. If the plotted minus soundings are in integral feet, they should first be converted to fractions based on actual values in the sounding records before delineating the mean low-water line. The same principle and procedure should be followed where the survey is on any plane other than mean low water. For example, for some of the surveys in Puget Sound, allowance would have to be made for the fact that the plane for the soundings is 2 feet below the plane of mean lower low water (*see* 5643).

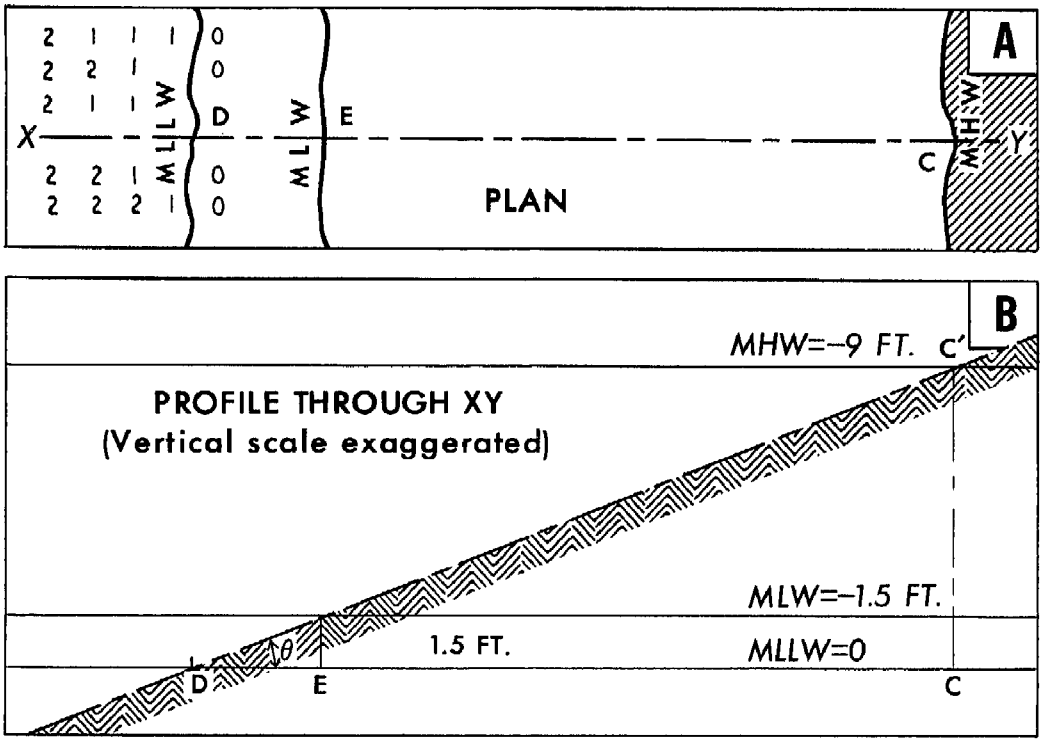

FIGURE 63.—Method of deriving a mean low-water line from a mean lower-low-water line on a hydrographic sheet where no soundings above the sounding datum are given.

will be better understood by reference to the figure, where the upper part (*A*) is a plan view of a portion of the hydrographic survey sheet and the lower part (*B*) a profile through *XY* between the mean lower-low-water line and the mean high-water line. In the lower part (*B*) of the figure, the slope of the beach (θ) is computed from the relationship $\tan \theta = \frac{9}{1{,}000}$, or $\theta = 0°30'56''$. From this and the value 1.5 feet (the vertical distance between the planes of mean lower low water and mean low water), the distance *DE* is computed from the relationship $\frac{DE}{1.5} = \cot \theta$, or $DE = 1.5 \cot 0°30'56'' = 166.71$ feet.

563. DEPTH CURVES

Depth curves, or curves of equal depth, are shown on the hydrographic survey for the purpose of bringing clearly to the eye the general configuration of the bottom, and for emphasizing important navigational features, such as shoals and channels. They are also of value in studying the adequacy of a

survey and whether additional examination is required in the field. While it cannot be stated with certainty when depth curves were first introduced, it is known that more than 200 years ago the Dutch engineer N. Cruquius used them to show the bottom of the Merwede River, and Philip Buache, a Frenchman, used them to outline the depths in the English Channel.[57]

Depth curves are comparable to contours on land, each curve representing an imaginary line on the ground (in the water area), every point of which is at the same depth below the sounding datum. The principles which govern the delineation of land contours are equally applicable to the drawing of depth curves.[58]

Some depth curves were shown on the earliest surveys of the Bureau, but the number to be shown and the symbolization to be used were not standardized until the instructions of 1860 were published. Generally the early surveys used groups of dots for the curves, the 1-fathom curve being represented by single dots, the 2-fathom curve by 2 dots, etc. On the first hydrographic survey (Register No. H–44 (1834)), only the 6-foot depth curve is shown, even though the depths range to 44 feet, and it is symbolized by a dotted black line. (This is the symbolization also used for the low-water line except that the area between the high- and low-water line is sanded.) On Register No. H–45, which is a replotting of H–44 on a smaller scale, the 12-foot depth curve is added as a series of double black dots.

The earliest instructions (*see* 531) called for depth curves to be shown for every fathom up to 4 fathoms, but the method of representation was not stipulated. This accounts for such variations as Register No. H–268 (1851), where the 6-, 12-, and 18-foot depth curves are all shown as dotted, black curves, while on Register No. H–336 (1852), the 3-fathom curve is shown in black ink by a series of 3 dots, and the 4-fathom curve by a series of 4 dots, but in red ink.

The 1860 instructions were the first to assign colors to the 6-foot curve (green), the 12-foot curve (red), and the 18-foot curve (blue), all to be shown in a continuous line (*see* text following note 13 *supra*). There has been no variation from this color scheme up to the present time (1963), but additional curves with designated colors have been prescribed from time to time and some

57. VEATCH AND SMITH, ATLANTIC SUBMARINE VALLEYS OF THE UNITED STATES AND THE CONGO SUBMARINE VALLEY 72 (1939) (Geological Society of America Special Paper Number 7).

58. Although "depth curve" is the terminology that has always been used in the Coast Survey and is so used in the 1960 Hydrographic Manual (*see* JEFFERS (1960), *op. cit. supra* note 22, at 154, 223), when their delineation is based on intensive development as exemplified by modern echo-sounding surveys, the term "depth contour" would seem to be appropriate as reflecting a more precise determination than "depth curve." Since the advent of echo sounding and the development of more precise methods of position fixing at sea, this term has appeared in the literature. *See,* for example, VEATCH AND SMITH (1939), *op. cit. supra* note 57, at 49–84, particularly at 71.

modifications made.[59] On many of the earlier surveys, a color legend was given. Occasionally, where significant, an intermediate depth curve was shown in a dashed line. Thus, where the 3-foot curve was significant, a dashed green line was used (Register No. H–1197*b* (1874)), and where the 9-foot curve was significant, a dashed red line was used (Register No. H–1565 (1884)). Today, the 3-foot curve where used is symbolized by a continuous violet line, but no provision is made for a 9-foot curve.[60]

564. Planes of Reference

The plane of reference of a hydrographic survey is the tidal datum to which the soundings are reduced. It has already been noted that the rise and fall of the water surface due to the tide is a continuing phenomenon, so that soundings taken during the progress of the survey must be reduced to some fixed datum plane. If this were not done, the soundings would be meaningless in their relation to each other and no idea could be gained of the true topography of the sea bottom.

In studying successive hydrographic surveys for possible changes in the underwater topography, it is just as essential to bring them to the same sounding datum before comparisons are undertaken as it is to bring them to the same geographic datum (*see* Chap. 2). This is basic. And in the analysis of any individual hydrographic survey it is important to know the particular plane of reference used, especially if the low-water line is the object of study, since it corresponds to the plane of reference for the survey.

Because of the different characteristics of the tide on the coasts of the United States and in Alaska (*see* Part 1, 2321 B(*b*)), the planes of reference are not the same for all hydrographic surveys. This is true even today, but it was more true in the early days of the Survey before tidal concepts became crystallized and final standards were adopted.

One point should be kept in mind in connection with the use of different planes of reference: whatever the plane, the submarine topography, as delineated by depth curves, will remain the same. The plane adopted merely determines the elevation of the water surface from which the charted depths are to be reckoned. They will be greater or less depending upon the use of a higher or lower plane. But the relationship of the charted depths to each other will

59. Jeffers (1960), *op. cit. supra* note 22, at 15 and Tables 3 and 4.

60. *Ibid.* The colors prescribed for depth curves in the various instructions were not always adhered to in the earlier work. Thus, the 1894 instructions (*see* 535) called for the 24-foot depth curve to be shown in brown and the 30-foot curve in purple, but on Register No. H–2315 (1897), which is a survey of San Francisco Bay, the 30-foot curve is shown in brown and the 24-foot curve is omitted.

always remain the same. The lower the plane the less likelihood there will be of having negative corrections in the *Tide Tables* (*see* Part 1, 2321 B, 2322 A). Also, shoals in channels or elsewhere would be given greater emphasis through the charting of shoaler depths. It was this concept that motivated the use of the various low-water planes on the Pacific coast, as discussed below. The picture, however, is not wholly one-sided. The other concept is that of having depths on a chart reflect normal rather than unusual conditions. In some areas, where the channel depths approximate the draft of vessels, the use of a plane that fulfills the first concept would give a false idea of the navigability of these channels.

These two concepts for many years represented two schools of thought in the Coast Survey. Ultimately, the question became one of balancing off the advantages against the disadvantages. The second concept has prevailed and the plane of mean lower low water uniformly adopted for the whole Pacific area, including Alaska.[61]

5641. *Atlantic and Gulf Coasts*

During the first 10 or 15 years following the year 1834, when the first hydrographic survey was made, planes other than the ones finally adopted were in use. (On some of these surveys, no plane of reference was given originally but was added at a later date.) Thus, on the first hydrographic survey, made in Great South Bay (Register No. H–44 (1834)), the plane of reference is "approximate mean low water." [62]

The earliest written instructions for hydrographic work (*circa* 1844) called for "soundings to be reduced to the lowest water observed during the survey" (*see* 531). This, of course, applied at the time to the Atlantic and Gulf coasts only, since work on the Pacific coast was not begun until about 1850 and Alaska was not acquired until 1867. This datum corresponded approximately to low water spring tides, which was lower than the datum of mean low water. It was designated on the published charts variously as "lowest spring tides observed" (New York Harbor chart of 1845), "lowest water observed" (Little Egg Harbor chart of 1846), and "mean low water of spring tides" (Long Island Sound chart of 1855, Eastern Part). Other charts covering this period were

61. By using the *Tide Tables* in conjunction with the charted soundings, the navigator can readily ascertain the relatively few times when the tide may fall below the plane of reference and make proper allowance therefor.

62. One survey made in 1840 (Register No. H–108) bears the note that the plane of reference is mean low water, which was also added at a later date. Another survey made in the same year (Register No. H–106) states that no register of tides was kept by which the soundings could be reduced so a 6-foot tide was asumed and the soundings reduced accordingly.

referred to "mean low water" (Annapolis Harbor chart of 1846 and Boston Harbor chart of 1857). As far as is known, the plane of reference for soundings along the Gulf coast was always mean low water (Cat and Ship Islands chart of 1850, the first finished chart published along the Gulf).

The 1860 instructions established mean low water as the general plane of reference for soundings (*see* 532) except on the Pacific coast where a different plane was used (*see* 5642). This has been continued to the present day and applies to the Gulf of Mexico, Puerto Rico, the Virgin Islands, and the Atlantic entrance to the Panama Canal.[63]

5642. *Pacific Coast*

On the Pacific coast (California, Oregon, and Washington (including Puget Sound)), some of the early surveys (between 1849 and 1853) used the plane of mean low water or low water (*see,* for example, Registers Nos. H–288 (1849) and H–337 (1852)). The great majority of the surveys, however, make no mention of the plane to which the soundings were reduced (Registers Nos. H–250 (1851) and H–405 (1853)), and this is also true of the surveys extending to 1855. Between 1853 and 1855, the plane of mean lower low water or an equivalent expression, such as, mean of the lowest low water for each 24 hours, was used.[64] (*See* Registers Nos. H–421 (1854), H–456 (1855), H–463 to H–466 (1855), of San Francisco Bay.) Subsequently, the plane of mean lower low water was adopted for the coasts of California, Oregon, and the outer coast of Washington.[65]

The 1860 instructions called for the use of the mean of the lowest low waters as the plane of reference (*see* 532), but the 1878 instructions adopted the term mean lower low water for the Pacific coast (*see* 533) and this has been used ever since.[66] This applies also to the Hawaiian and Philippine Islands, but at the Pacific entrance to the Panama Canal, the plane used is the mean of the low water springs (*see* note 63 *supra*).

63. The publication of charts of the Canal Zone was transferred to the jurisdiction of the Navy Hydrographic Office in Sept. 1949 (*see* 1271B). Prior to that time the Bureau had made two hydrographic surveys at the Atlantic entrance (Registers Nos. H–2724 to H–2725 (1905)), using the plane of mean low water, and ten surveys at the Pacific entrance (Registers Nos. H–3360 (1912), H–3362 to H–3368 (1912), and H–4806 to H–4807 (1928)), using the plane of mean low water springs.

64. Letter of Oct. 23, 1911, from Chief, Tidal Division to Assistant in Charge of Office. *See also* Annual Reports, U.S. Coast Survey (Sketches 42–44, 46–48, 50–53) (1854), and page 97 (1855).

65. Letter of Oct. 23, 1911, *supra* note 64.

66. But a survey of 1897 (Register No. H–2315) still used the expression mean of the lower low waters for each 24 hours, and the 1901 chart of the Entrance to San Francisco Bay gave the plane as the average of the daily lower low waters. This, however, was not the general practice. Occasionally, the soundings were reduced from data based on a short series of tide observations, the number of days in the series being usually given on the survey. In such cases, the surveys generally contain notes indicating the correction to be applied to the soundings to bring them to the plane of mean lower low water (Register No. H–1887 (1888)).

5643. *Puget Sound, Washington*

Puget Sound, Wash., has had a rather varied history insofar as planes of reference for soundings are concerned, and has gone through almost a complete cycle. It began with the use of mean low water for the period between 1849 and 1853. In 1854, the plane used was the mean of the lowest low water of each 24 hours (*see* Annual Report, U.S. Coast Survey (Sketches 52, 53) (1854)), which is considered to be the same as mean lower low water. Some time during the late 1870's, the plane was changed to the mean of selected lowest low waters (Register No. H–1426*b* (1878–1879)). For the area of this survey, the plane was 3.2 feet below the plane of mean lower low water (*see* note on smooth sheet). In 1897, this was changed to the harmonic or Indian tide plane (Register No. H–2483 (1900)).[67] In 1902, the plane of reference was changed to 2 feet below the plane of mean lower low water, which plane was in use in 1911.[68] For Puget Sound this plane closely approximates the harmonic tide plane.[69] The plane of mean lower low water was again adopted with the publication of the General Instructions for Field Work in 1921, and this is the plane in use today (*see* 5363).[70]

5644. *Alaska*

Alaska too has had a varied history with respect to planes of reference in use. From its purchase in 1867 to 1897, the soundings were variously reduced to mean lower low water and the mean of a few selected lowest lows, according

67. The Indian tide plane or the harmonic tide plane, as it is sometimes called, has been used for a number of ports in India. It is also called the plane of Indian spring low water and corresponds approximately to tropic spring lower low water and is usually somewhat lower than low water ordinary springs. It is best derived from harmonic analysis. MARMER, TIDAL DATUM PLANES 129, 130, SPECIAL PUBLICATION No. 135, U.S. COAST AND GEODETIC SURVEY (1951). On Register No. H–2483 (1900) this plane is 2 feet lower than the plane of mean lower low water (*see* note on smooth sheet).

68. Letter (1911), *supra* note 64. One survey during this period was noted as being on the plane of mean lower low water (Register No. H–2985 (1909)), but this is noted in the accompanying Descriptive Report as an inadvertence and the soundings should have been reduced to the plane of 2 feet below mean lower low water, the plane adopted for the area. Register No. H–3423 (1913) showed the plane as 2 feet below the plane of mean lower low water.

69. Based on the computations for seven stations in Puget Sound, the mean difference between the harmonic plane and the plane of 2 feet below mean lower low water was found to be —0.03 foot. Letter of May 15, 1902, from Chief of Tidal Division to Assistant in Charge of Office.

70. It should be pointed out that the date of the published instructions does not necessarily represent the exact line of cleavage for the change from one plane to another. In some cases, surveys were already based on a new plane (probably as a result of specific written instructions to a chief of party) before the use of the plane was actually codified in the published instructions. In Puget Sound, for example, the first mention of a return to the plane of mean lower low water was in the 1921 instructions but the plane was already in use in 1917 (Register No. H–3999).

to the locality.[71] The first mention specifically of planes of reference for Alaska was in the General Instructions for Field Work of 1908 (*see* 5361(*f*)).[72] The plane of the mean of the lower low waters is there called for except in Wrangell Narrows where a plane 3 feet lower than the mean of the lower low waters had been used. This was continued in all the subsequent instructions and manuals to the publication of the 1942 Hydrographic Manual (*see* 537), which gave mean lower low water as the plane of reference for all of the Pacific Ocean, including Alaska (*see* 5645).[73]

More specifically, the first big change came late in December 1897 when the use of the harmonic tide plane was authorized for all Alaskan waters, except at the mouth of the Yukon where the plane of mean lower low water was continued because the harmonic plane was found impractical to use there. The harmonic plane was soon found unsuited for portions of the Bering Sea and for other localities, and in May 1902 this plane was replaced by a plane 2 feet below the mean of the lower low waters except in Norton Sound, where mean lower low water was used, and in Wrangell Narrows, where 3 feet below mean lower low water was adopted.[74] But in April 1903, this was again changed to mean lower low water except in Wrangell Narrows, Peril Strait, and Sitka Harbor.[75]

By January 1908, Peril Strait and Sitka Harbor were also brought within the plane of mean lower low water, leaving Wrangell Narrows the only exception.[76] In January 1929, this exception was also eliminated, thus establishing a uniform plane of mean lower low water for all Alaska and thereby bringing it into harmony with the plane of reference for the rest of the Pacific coast.[77]

71. Letter (1911), *supra* note 64. The first comprehensive survey of Alaska was begun in 1882 by the steamer *Hassler*. Prior to that time only sporadic surveys were made. The first systematic and continuous hydrographic surveys were begun in Southeast Alaska in 1901. Colbert, *Programming Field Operations in Alaska*, 2 JOURNAL, COAST AND GEODETIC SURVEY 3 (1949).

72. Prior to this only the Pacific coast was mentioned (*see* 533).

73. ADAMS (1942), *op. cit. supra* note 1, at 773. *See* text following note 76 *infra* for date of change in Wrangell Narrows.

74. Letter of May 23, 1902, from the Superintendent to the Assistant in Charge of Office, and Letter (1911), *supra* note 64. The 1902 letter states that "the plane of 2 feet below mean lower low waters may be taken as identical with the harmonic plane and that of selected lows."

75. Circular No. 45 of Apr. 8, 1903, and Letter (1911), *supra* note 64. The plane of reference for Peril Strait was 2 feet below lower low water (*see* chart 8282 of 1904), and for Sitka Harbor it was 2 feet below mean lower low water (*see* chart 8244 of 1904).

76. Letter of Jan. 8, 1908, from Superintendent to Assistant in Charge of Office, and Letter (1911), *supra* note 64. *See also* 5361(*f*).

77. Action of Chart Board on Jan. 16, 1929.

5645. *Summary of Present Planes of Reference*

The following is a summary of the planes of reference in use when the 1942 Hydrographic Manual was issued, and are currently in use in 1963:

(*a*) For the Atlantic Ocean and Gulf of Mexico—the mean of the low waters (MLW).

(*b*) For the Pacific Ocean—the mean of the lower low waters (MLLW), except for the Pacific entrance to the Panama Canal where it is the mean of the low water springs (MLWS).

(*c*) For certain of the larger navigable rivers and lakes, special planes have been adopted.[78]

In studying successive hydrographic surveys of an area that are based on different planes of reference, the mathematical relationships of the planes are available in the tidal records of the Bureau. Sometimes the surveys themselves or the accompanying Descriptive Reports (*see* 1242) contain notes giving the corrections to be applied to bring the soundings to the current datum (*see,* for example, Register No. H-1426*b* (1878–1879)). These should always be consulted.

565. Rock Symbols

Features on hydrographic surveys that often call for interpretation are the symbols used for the various types of rocks encountered during the survey operations. There are three such types, characterized as *bare, awash,* and *sunken.* The first (bare rock) is almost always delineated on the contemporary topographic survey; the second and third may be delineated on the topographic survey but are usually determined during the hydrographic operation.

By convention, and for general purposes, rocks are defined in relation to the tidal datums of the locality, as follows:

(*a*) *Bare rocks* are those extending above the plane of mean high water (*see* 5655(*a*)).

(*b*) *Rocks awash* are those exposed at any stage of the tide between mean high water and the sounding datum, or that are exactly awash at these planes (*see* 5655(*b*)).

78. Adams (1942), *op. cit. supra* note 1, at 773. The following planes of reference were in use in 1963: (*a*) Columbia River, from Harrington Point to the dam at Bonneville (charts 6152 to 6156 inclusive)—mean lower low water during lowest river stages (this is known as the Columbia River Datum); from the dam at Bonneville to Pasco (charts 6157 to 6164 inclusive)—normal pool level as established by Bonneville, The Dalles, and McNary Dams, which are 72, 160, and 340 feet, respectively, above mean sea level (MSL) and the adopted low water gradient established by the Corps of Engineers for the reach between Lake Celilo and McNary Dam (a profile is shown on each chart of the elevations on the adopted gradient); (*b*) Willamette River from Columbia River to Oregon City (chart 6171)—Columbia River Datum; from Oregon City to Newberg (charts 6171, 6172)—normal pool level at Oregon City, which is 50 feet above MSL (this is known as the Willamette River Datum); (*c*) Pend Oreille Lake, Idaho (chart 6170)—mean winter level of the lake, which is 2,048.15 feet above MSL; (*d*) Franklin D. Roosevelt Lake (charts 6168, 6169)—the normal lake level, which is 1,288.6 feet above MSL; (*e*) Lake Tahoe, Calif.-Nev. (chart 5001)—the lowest lake level, or 6,223 feet above MSL; (*f*) Sacramento River, Sacramento to Colusa (charts 5529, 5530)—reference plane established by the Corps of Engineers from Sacramento to Ord Ferry; and (*g*) Lake Mead, Ariz.-Nev. (charts 5457 to 5459 inclusive)—the mean lower lake level, or 1,100 feet above mean sea level.

(*c*) *Sunken rocks* are those covered at the sounding datum that are potentially dangerous to navigation (*see* 5655(*c*)).

The earliest rock symbols to be published by the Bureau were contained in a topographic symbol sheet engraved around 1840 and probably prepared to accompany the earliest instructions for topographic surveys (*see* fig. 46).[79] Between 1840 and 1960 (the date of the most recent Hydrographic Manual), a number of symbol sheets were published containing designations and notations for the various types of rocks. The progressive changes in the rock awash and the sunken rock symbols are shown in figure 64.

5651. *Bare Rocks*

Bare rocks were always represented by their shapes, if of plottable size, or by solid dots, if otherwise, and need no special comment from the standpoint of interpretation. They are identified more with topographic than with hydrographic surveys.

5652. *Rocks Awash*

It will be noted that on the earliest symbol sheet (*see* fig. 46), the symbol for what is now generally known as a rock awash (three lines crossing, one of which is horizontal) was confined to a rock that was awash at exactly low water, but for rocks seaward of the low-water line that were awash at any stage of the tide, a special symbol as used. This consisted of the symbol for a ledge formation with a "T" superimposed on it.[80]

Since these early designations, the rock-awash symbol has undergone several modifications. In the symbols published in 1892 and 1897 it was represented by four lines crossing, but in 1900 it reverted to three lines crossing, one of which was horizontal. In 1905, a distinction was again made, as in 1840, between a rock awash at exactly low water and one that covered and uncovered at an intermediate stage of the tide, except that a new symbol (three lines crossing encircled by a solid line) was introduced for the latter. But on Register No. H–2859 (1906) the symbol is encircled by a dotted line. (This rock being also shown on the topographic survey was in all probability bare at low water.)

79. The symbol sheet itself is not dated, but the record of the plate shows it to have been engraved around 1840.

80. As far as could be ascertained, there is no evidence that such symbol was ever used on any of the early surveys of the Bureau; however, the symbol without the "T" has been encountered. A symbol very similar to this was used in France to indicate an isolated rock which is never covered. HERRLE, A MANUAL OF CONVENTIONAL SYMBOLS AND ABBREVIATIONS 29, PUBLICATION NO. 121, U.S. HYDROGRAPHIC OFFICE (1903).

Date	Sunken rock	Rock awash	Other rocks
Topographic Surveys			
1840	+ Single projecting rocks whose positions and depths below the surface have been exactly determined, sometimes forming part of a ledge.	⁎ ⁎ Single projecting rocks whose positions have been determined and which at low water are awash.	Rocks bare at low tide, outside, i.e. seaward of low water line.
1860	+ Sunken rock	⁎ Rock awash	
1892	+ Sunken rock	⁎ Rock awash	
1897	+ Sunken rock	⁎ Rock awash	
1905	+ Sunken rock	⁎ Rock awash at low water	Covering and uncovering rock
1916	+ Rock under water	⁎ Rock awash (at any stage of the tide)	
1922	+ Rock under water	⁎ Rock awash (at any stage of the tide)	
1928	+ Rock under water	⁎ Rock awash (at any stage of the tide)	
1949	+ Sunken rock	⁎ Rock awash	Bare rock (shape or dot)
Hydrographic Surveys			
1883	+ Rock under water	⁎ Rock awash	
1894	+ Sunken rock	⁎ Rock awash	
1900	+ Sunken rock	⁎ Rock awash at low water	
1928	+ Rock under water	⁎ Rock awash (at any stage of the tide)	
1941	+ Sunken rock Individually located	⁎ Rock awash Individually located	Bare rock (shape or dot)
1960	+ Sunken rock (depth unknown)	⁎ (4) Rock awash, elevation above sounding datum.	(2) or greater. Bare rock, elevation above MHW.
Maps and Charts			
1911	+ Rock under water	⁎ Rock awash (at any stage of the tide)	
1925	+ Rock under water	⁎ Rock awash (at any stage of the tide)	
1932	+ Rock under water	⁎ Rock awash (at any stage of the tide)	
1941	+ Sunken rock below chart datum; depth not known	⁎ (2) Rocks that cover and uncover, with height in feet above chart datum.	
1956	+ Sunken rock (depth unknown)	⁎ (2) Rock which covers and uncovers, with height in feet above chart (sounding) datum.	Rock awash at the level of chart (sounding) datum.

FIGURE 64.—Rock symbolization used on surveys and charts between 1840 and 1960.

In 1916, following the symbols adopted by the United States Geographic Board (*see* 468), the symbol was changed to three lines crossing, one of which was a vertical instead of a horizontal line. This applied to rocks that were awash at any stage of the tide and therefore eliminated the need for the 1905 symbol for a covering and uncovering rock. This was continued through the 1928 Hydrographic and Topographic Manuals.

5653. *Sunken Rocks*

The symbol for a sunken rock was always a simple cross. This was sometimes also referred to as "rock under water" (*see* fig. 64). No evidence could be found to substantiate the notation on the 1840 symbol sheet that the simple cross was used for "single projecting rocks, whose positions and depths below the surface have been exactly determined, sometimes forming part of a ledge" (*see* fig. 46). Comparisons with later surveys have shown that on topographic surveys such symbols frequently represented a generally foul area and that individually they indicated neither exact position nor depth. The simple cross encircled by a dotted line was also used on some of the early surveys, but not exclusively (Register No. H–405 (1853)). On later surveys, the symbol was omitted, and the legend "Rock" or "Rk" was shown with the depth (Register No. H–3719 (1914)).

5654. *Reconciling Rock Symbols*

In studying some of the early and later surveys some inconsistent treatments have been noted. Thus, on Register No. H–790 (1861), rocks exposed between the planes of high and low water are shown by the rock-awash symbol and by the sunken-rock symbol. Obviously, the latter symbol is completely inconsistent with an area that bares at the sounding datum. On Register No. H–1064 (1869), the sunken-rock symbol is used with a depth of ½ foot and accompanied by the legend "Rock," but on Register No. H–1525*b* (1881), the symbol is used with the note "Rock with 1 ft. uncovers at extreme low tides." On the later survey, Register No. H–2129 (1892), offshore rocks awash are shown variously by minus soundings with the name of the rock without any notation, or with the notation "R" alongside; and a sunken rock is shown by the actual depth and the name of the rock.

A striking fact in connection with rock representation on the early surveys is the relative absence of the rock-awash symbol and the wide use of the sunken-

rock or bare-rock symbol. The 1840 symbols and legends shown in figure 64 offer a rational explanation for this condition. The awash symbol being used only for those rocks which were actually awash at low water, the number would be relatively small in comparison with the number of rocks above or below such plane. The large number of bare-rock symbols may be traceable to the fact that the symbol for bare rocks of small extent would have been indistinguishable from the symbol for a rock bare at low tide (without the "T"), so that many of the bare-rock symbols may actually represent rocks awash.

The stage of the tide also has a significant bearing on the symbolization of offshore rocks. A rock just awash at low tide may been seen only as a breaker at half tide and hence shown as a sunken rock on the topographic survey, while a rock awash at half tide would show as a bare rock at low tide. If the early topographer failed to take cognizance of the actual stage of the tide when locating such offshore features (this possibility is strongly suggested by the absence of descriptive notes on the topographic surveys), the symbolization would be erroneous. On the other hand, the disintegrating effect of surf on an exposed coast, the rise in sea level, or the emergence of the land, may also account for the apparent discrepancies in the rock representation on early and later surveys. What a century ago may have been a bare rock may today be only a rock awash and what was then a rock awash may now be a sunken rock.[81]

In attempting to reconcile two surveys of different periods, consideration should be given to the above factors.[82]

5655. *Modern Practice*

The present practice for rocks awash is to use the symbol of three lines crossing, one of which is parallel with the latitude line, without any encircling

81. Pierce, *Is Sea Level Falling or the Land Rising in S.E. Alaska?* 21 SURVEYING AND MAPPING 51 (1961). This paper is based on a special tidal survey in Southeast Alaska made by the Coast and Geodetic Survey in 1959 to determine the magnitude of the vertical changes suspected of having taken place in this area. It is stated that "many critical depths in the area have shoaled about one-half to one fathom since the original survey. Rocks that were previously charted as covered at all stages of the tide have in recent years been observed by local inhabitants as baring at low water." *Id.* at 56. Based on the tidal survey and on the evidence provided by studies of sea level along the coasts of the United States and other countries throughout the world that a slow general rise in the level of the oceans has taken place during the past 50 years or more, the conclusion was reached that, since sea level could not be falling in the limited area of the survey while rising in the great oceanic basins, "the movement in the Icy Strait-Lynn Canal area of Southeast Alaska, consequently, represents land emergence rather than falling sea level." *Ibid.* For the whole area investigated, the average change north of Icy Strait was at the rate of 0.09 foot per year. Southward, along the shores of Cross Sound and Icy Strait and the waterways in the general vicinity of Juneau the average change is of the order of 0.05 foot per year. *Id.* at 55.

82. Differences in symbolization have also been noted on successive hydrographic surveys separated in time by only a few years. Thus, on Register No. H–1616 (1884), a named rock (*Spike Rk*) is shown by a minus 1-foot sounding, but on Register No. H–1737 (1886), the same rock is shown by the rock-awash symbol.

line (*see* fig. 65).[83] Elevations of rocks awash above the sounding datum are indicated by slanting figures, in parentheses and underscored, as, for example, (2) (*see* fig. 65).[84]

For sunken rocks the practice is to use either the symbol or a sounding accompanied by the legend "*Rk*," depending on the nature of the available information.[85] But the legend may be used with the symbol where there is danger that the latter may be overlooked. However, in no case is the depth and the symbol used for the same rock.[86]

The present practice also allows some flexibility, for cartographic purposes, in the designation of the different types of rocks with respect to the sounding datum and in their departure from the strict conventional definitions (*see* 565), in order that the charted symbols may reflect the most probable condition of the rock as seen by the mariner. On the hydrographic survey, therefore, the following rules are applied (diagrammatically shown in fig. 65):

(*a*) *Bare Rocks.*—Rocks with elevations of 2 feet or more above mean high water on the Atlantic and Gulf coasts, or 3 feet or more on the Pacific coast, are shown with the bare-rock symbol.

(*b*) *Rocks Awash.*—Rocks, the summits of which are in the zone between 1 foot above mean high water and 1 foot below the sounding datum on the Atlantic and Gulf coasts, are shown with the rock-awash symbol. On the Pacific coast the limits are 2 feet.

83. JEFFERS (1960), *op. cit. supra* note 22, at 209. In the 1942 Hydrographic Manual, a distinction was made in the symbolization for accuracy of location of the rock awash. If accurately located, either by the topographer or the hydrographer, the symbol was encircled by a dotted line, but if the rock was located by estimation or plotted from generalized symbolization it was not encircled. ADAMS (1942), *op. cit. supra* note 1, at 736 and fig. 169. The encircled symbol was also used in the past to emphasize a detached rock or the outermost rock of a cluster of rocks. On a number of the early hydrographic surveys, a simple cross with a dot in each quadrant has been identified as the symbol for a rock awash but no written authority for its use could be found. The symbol, however, has been used by Great Britain to indicate a rock awash at low water, by France and Germany for rocks awash, and by Spain for a rock or shoal awash. HERRLE (1903), *op. cit. supra* note 80, at 25, 30, 45, 65. Several such symbols appear on Register No. H–18 (1835). On one named offshore rock, an appended note states "on this rock 2 feet at ordinary low tides, bare at very low tides." On Register No. H–3 (1836–1837), such symbols have been identified, either by a notation on the survey or in the *Coast Pilot*, or by comparison with a later survey (Register No. H–5546 (1934)), as awash at the sounding datum (plus or minus 1 foot). In 1956, this symbol was used on the nautical charts to indicate a rock awash at the chart datum only. EDMONSTON (1956), *op. cit. supra* note 40, at 53.

84. JEFFERS (1960), *op. cit. supra* note 22, at 210. This was also the usage according to the 1942 Hydrographic Manual but with the alternate use of a note, such as, "uncovers 2 ft. at MLW." ADAMS (1942), *op. cit. supra* note 1, at 737 and fig. 189 (part IX). On some hydrographic surveys, the notations "awash ¼ tide," "awash ⅓ tide," etc., have been encountered (*see* Register No. H–4865 (1928)). This gives rise to some ambiguity because of the uncertainty of the end of the tidal cycle referred to. A study of the sounding records revealed unmistakably that such notations refer to the low stage of the tide, that is, "awash ¼ tide," means the rock was awash when the tide had risen to one-fourth its height above the sounding datum.

85. If the depth over the rock has been definitely determined, the sounding with legend is used, but where it has not been so determined, as where breakers have been cut in but no soundings taken, or where the depth does not represent the least depth on the rock, the symbol is used, with a notation "breakers," if so noted in the sounding record. JEFFERS (1960), *op. cit. supra* note 22, at 209–210.

86. ADAMS (1942), *op. cit. supra* note 1, at 736.

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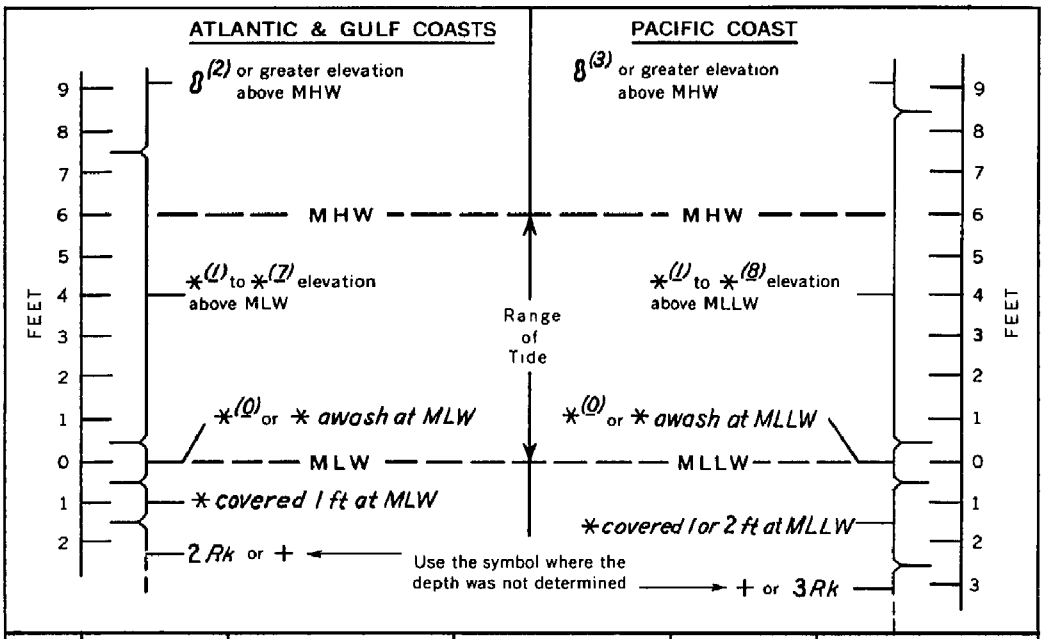

	REFERENCE PLANE	SYMBOL COLOR Source		ELEVATION COLOR Source		ELEVATION UNDERLINED	SIZE	
		Hydro.	Topo.	Hydro.	Topo.		Symbol	Elev.
(5)	MHW	*RED	BLACK	*BLACK	RED	NO	SHAPE	2 mm.
(5)	ML(L)W	*BLACK	BLACK	*BLACK	BLACK	YES	2.2 mm.	2 mm.

*Plotted in pencil and inked during Verification

FIGURE 65.—Rock symbolization and elevations referenced to tidal datums, and color characteristics for use on finished hydrographic smooth sheets.

(*c*) *Sunken Rocks.*—Rocks potentially dangerous to navigation, whose summits are below the lower limit of the zone for rocks awash, are classed as sunken rocks (*see* fig. 65).[87]

566. REEFS AND LEDGES

A *reef* is a rocky or coral elevation, dangerous to surface navigation, which may or may not uncover at the sounding datum. A rocky reef is always detached from shore, but a coral reef may or may not be connected with the

87. JEFFERS (1960), *op. cit. supra* note 22, at 209. These rules for symbolization on the survey sheet are substantially the same as given in the 1942 Hydrographic Manual with the exception that the limits for the bare-rock symbol was 1 foot or more on the Atlantic coast and 2 feet or more on the Pacific coast (more than 1 foot and more than 2 feet would have been more consistent designations). ADAMS (1942), *op cit. supra* note 1, at 735. The rules given in the latter publication were actually a codification of what had been the practice on hydrographic surveys since 1934. Shalowitz, *Treatment of Rock Symbols on Hydrographic Surveys,* 7 FIELD ENGINEERS BULLETIN 125, U.S. COAST AND GEODETIC SURVEY (June 1934).

shore. A *ledge* is a rocky formation connected with and fringing the shore, and generally uncovers at the sounding datum.[88]

On the earliest symbol sheet (*see* fig. 46), a rocky reef or a ledge bare at low water carried the same symbol as a rock bare at low water except for the absence of the superimposed "T". The sunken reef or ledge symbol was very similar but because of the possibility of it being confused with the one bare at low water, it was later superseded by the cluster of sunken-rock symbols (this was also used to represent foul ground) (Register No. H–1616 (1884)), and still later by a broken line enclosing sunken-rock symbols, or an appropriate legend.[89]

The rocky reef or ledge that uncovered at the sounding datum was shown by a distinctive symbol to simulate the appearance of continuous bedrock or coral formations (Registers Nos. H–1616 (1884) and H–2859 (1906)). This continues generally to the present time (*see* fig. 62).[90]

567. Bottom Characteristics

The determination of the character of the sea bottom—that is, its consistency, color, and classification—is an essential part of every hydrographic survey. Although only the immediate top layers are sampled, such information is nevertheless of value to the mariner for choosing an anchorage with the best holding ground and free of rocks; to the fisherman for selecting places where fish are likely to congregate and for avoiding types of bottom likely to damage his equipment; to the engineer engaged in dredging operations in harbors and channels and for any underwater construction; and to the student of the earth sciences for supplementing his knowledge of that part of the globe covered by water. In some instances, bottom data may still be helpful to the mariner in

88. Jeffers (1960), *op. cit. supra* note 22, at 209.

89. Swainson, Topographic Manual 8, 69, Special Publication No. 144, U.S. Coast and Geodetic Survey (1928). This was also the procedure in the 1942 Hydrographic Manual, no distinctive symbol being used for a submerged reef or ledge. Adams (1942), *op. cit. supra* note 1, at 736.

90. Jeffers (1960), *op. cit. supra* note 22, at 209. The conventional symbols included in the General Instructions for Hydrographic Work for 1883 and 1894 (*see* 534 and 535) seem to be a departure from this practice and follow more the symbol used in 1840 (*see* fig. 46) but connected by sanding and interspersed with bare rock shapes. The practice in 1942 was to show these features by symbol or by broken line and legend, depending on which method showed the feature clearly with the least amount of work. No distinction was made between the symbol for a rocky reef and a ledge. Where the reef was continuous at the sounding datum, the standard rocky-ledge or coral symbol, as the case may be, was used, but where it was generally submerged and projected only in spots above the sounding datum, rock-awash symbols were used to represent the protuberances, and sunken-rock symbols, the depressions. Adams (1942), *op. cit. supra* note 1, at 736 and fig. 189 (part II). *See also* Jeffers (1960), *op. cit. supra* note 22, at 209.

determining his position, although generally their value for this purpose has decreased because of the use of echo-sounding apparatus in navigation.

Obtaining the character of the bottom was always a requirement in the Coast Survey. It is shown on the first hydrographic survey (Register No. H–44 (1834)), and the earliest written instructions available (*see* 531) call for such information to be obtained. The first published instructions for hydrographic work (*see* 532) emphasized in considerable detail the manner and frequency of obtaining bottom specimens, the procedure for preserving them in small vials, and the method of classification in order "to trace the formations along the coast in which particular kinds of *soil* occur" (*see* text at note 14 *supra*).[91]

The character of the bottom is determined either by "feel" or by bringing up a sample with the leadline or with a special snapper device. The present classification of sediments is based on the size of the particles composing them. No mechanical analysis is used for typing a sediment. An estimate of its dimensions is made by eye and classification is based on an available table covering the range from "ooze" to "boulders." [92]

5671. *Application to Hydrographic Surveys*

Bottom characteristics have always been applied to the hydrographic surveys. In some of the early surveys, no abbreviations were used (Register No. H–288 (1849)). Abbreviations were standardized and first published in the 1883 instructions for hydrographic work (*see* 534), but were already used on surveys prior to this date (Register No. H–1197*b* (1874)). Identical abbreviations with some additions and some minor changes have been included in all subsequent instructions and hydrographic manuals.[93] Register No. H–1341*b* (1875) is an example of profuseness of bottom characteristics—fully 90 percent of the soundings plotted show the character of the bottom.

A complete designation of the character of the bottom at any particular geographic location usually included one or more adjectives descriptive as to size or consistency, one or more adjectives designating color, and one or more nouns naming the class of bottom material. The noun portion of the characteristic always began with a capital letter, sometimes followed by one or two

91. Identical provisions for obtaining and preserving such bottom specimens were included in the later instructions through those of 1894. Subsequently, no specimens were retained as a permanent record, except by prearrangement with a scientific institution or a commercial establishment.

92. *Id.* at 159 and Table 10. Where a more detailed study of the ocean floor is contemplated, as in modern oceanographic research, bottom samples are obtained by means of a coring device or by dredging. For a description of some of this equipment, *see id.* at 102–103.

93. *Id.* at 164.

lower-case letters; and the adjective portion with lower-case letters, two letters being used for color or shade and three letters for quality. The order of arrangement was as follows: descriptive adjective, color, noun. Thus, *"soft gray sand, shells, pebbles"* was designated by *"sft gy S Sh P."*

568. Additional Work

When a closer development of an area was required, or an investigation was to be made of a possible danger to navigation after the original survey was completed, the new work was considered as "additional work." In the early surveys, there was no uniformity in the method of showing such work on the smooth sheet. In some cases, the new soundings were plotted in color (Register No. H–103 (1840)), and in other cases the soundings were black, but the position numbers were in color (Register No. H–859 (1864)).[94] Marginal notes (in pencil, black ink, or colored ink) placed in the vicinity of the additional work gave the date and other information regarding the work.

In some instances, when the additional work was fairly extensive it was plotted as a separate sheet but given an "a" number. In such cases, the soundings were shown in black, with a few of the overlapping soundings shown in color on the original survey (Registers Nos. H–2662 (1902–1903) and H–2662*a* (1904)). But generally "a" sheets were reserved for contemporary, adjoining surveys that were part of one project (Registers Nos. H–5551, H–5551*a*, H–5551*b*, H–5551*c* (1934)).

The modern practice is to show the additional work in color and in a corresponding color give information in the title relative to the date of survey, the name of the chief of party, and the name of the surveyor (Registers Nos. H–7152 (1946–1949) and H–7079 (1945–1955)).[95]

569. Miscellaneous Features

Besides the features discussed above that are common to all hydrographic surveys, the following additional features have been encountered on some of the surveys examined during the research on this publication. They are in-

94. In one case, where additional work was done several years later, the soundings were in black but were distinguished from the original work by giving them a different form and slant (Register No. H–790 (1861)). On the same survey, additional work done at a still later date was shown in blue. Occasionally, the additional work was plotted on an overlay tracing and either attached in place to the smooth sheet (Register No. H–1573 (1883)) or marked "To Accompany H——" (Register No. H–2146 (1892)).

95. Jeffers (1960), *op. cit. supra* note 22, at 232.

cluded here because of their significance, and because of their possible historical interest.

(*a*) *Kelp.*—This type of marine vegetation is a common feature along certain portions of the Pacific coast and in Alaska. It is one of the most important of the seaweeds encountered on a hydrographic survey, one of its principal characteristics being that it generally grows in rocky bottom and therefore indicates a possible danger to navigation. The usual practice where the beds were extensive was to show a fringe of kelp (by symbol in black ink at the outer limit and to mark it "outer limit of kelp" (Register No. H–1508 (1881)).[96] But sometimes the full extent from shore outward was shown by symbol in green ink, as on Register No. H–1340*a* (1876).

(*b*) *Oil Well.*—It is a matter of interest that on a survey of Santa Monica Bay, Calif., made in 1876, at a point about 3 miles north of Point Vicente and about 1 mile from shore, an area 1 mile long and ½ mile wide was outlined and marked "oil well" (*see* Register No. H–1340*b*).

(*c*) *Salt Domes.*—In the Gulf of Mexico, submerged formations were located near the edge of the continental shelf on the hydrographic surveys made in 1937 (Register No. H–6293) and in 1939 (Register No. H–6501), and other surveys in the area of the 100-fathom curve. These formations resemble some of the buried salt domes along the coastal plains of Louisiana and Texas, where many oil reserves are located.

(*d*) *Notes on Hydrographic Surveys.*—Notes are sometimes found on the hydrographic survey which often have an important bearing on a collateral use of the survey. In deducing the probable method of drawing the boundary between the United States and Mexico in the Gulf of Mexico, a note on the survey sheet, regarding the non-discernibility of the entrance to the Rio Grande until "it bears per compass W ½ N" shed considerable light on the matter (*see* Register No. H–377 (1853)).[97]

96. This was also the practice called for in the 1942 Hydrographic Manual. ADAMS (1942), *op. cit. supra* note 1, at 744. The present practice (in 1963) is not to use the symbol except for small, detached areas of kelp (*see* fig. 62). Instead, a dashed, black line is used to mark the limits and the notation "kelp" added. JEFFERS (1960), *op. cit. supra* note 22, at 212.

97. This was part of a study made in response to a request from the State Department for information on the precise location of the U.S.-Mexican boundary in the Gulf. The result of the study was embodied in a Memorandum dated Aug. 29, 1957.