Hydrographic Manual
Fourth Edition

By Melvin J. Umbach

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U.S. DEPARTMENT OF COMMERCE
Elliot L. Richardson, Secretary

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Foreword

Continual and unrelenting demands and pressures on the National Ocean Survey for accurate nautical charts of the coastal waters of the United States and her possessions have led to the development of new concepts and techniques in surveying, innovations in cartography, and the introduction and use of sophisticated automated data acquisition and processing methods. Acquisition, analysis, and dissemination of related basic oceanographic, hydrographic, and littoral zone data for coastal engineering and scientific research are charting by-products nearly equal in importance to our nautical charting mission. Exploitation of the Nation's submerged lands and natural resources and man's increased concern for his environment, wetland area, flood plains, and ecosystems have altered many of our traditional priorities and have encouraged the development of new techniques to meet these new responsibilities.

This edition of the *Hydrographic Manual*, a revision of *Coast and Geodetic Survey Publication 20-2* (Jeffers 1960), was compiled to meet these demands and to define the applications of the latest available technology. It describes current National Ocean Survey methods of planning, executing, and processing a hydrographic survey. No claims are made for originality nor do we propose that the techniques described become universally adopted.

This new *Hydrographic Manual* is designed so that revisions, additions, and extractions of the material can be made to maintain currency with the state of the art. Our attitudes, approaches, and applications to meet our Nation's ever-changing needs are not stagnant; thus, we cannot allow this instruction manual, that defines the standards and methods through which we meet these needs, to become stagnant. It is incumbent upon the readers and users of this publication to ensure vitality in the information by constant review, evaluation, and improvement of the contents.

Allen L. Powell

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(Foreword; July, 1976)

Preface

This *Hydrographic Manual, Fourth Edition,* by the National Ocean Survey was prepared under the able direction of Captain Robert C. Munson, Associate Director, Office of Marine Surveys and Maps, and represents the culmination of more than 160 years of experience in nautical surveying and marine charting. These contemporary instructions for hydrographic and related data surveys that define the applications of the most modern available technology will allow the second and third editions to be retired.

In this fourth edition, extensive changes have been introduced in both format and content; the major changes are, of course, based on the use of modern automatic data collection and processing techniques. Few of the basic requirements of hydrography have been altered. An attempt has been made to identify stringent specifications for hydrographic surveys and to describe survey methods and techniques of accomplishment that result in the most effective utilization of manpower and equipment. I hope each salty old hydrographer who looks askance at what he considers to be radical departures from tradition is offset by one of our dedicated young crusaders from the binary generation who is convinced we are moving too slowly. If this is the case, then I believe a satisfactory balance has been achieved; thus this edition will retain the tradition of usefulness characterizing the previous editions.

Recent streamlining of procedures between the completion of a hydrographic survey and the production of a nautical chart has added responsibility upon both commanding officers and those engaged in survey verification. In many areas, increased emphasis is placed on quality control, completeness, and cohesiveness of field survey data. *Quality of our data is as important as quantity.* The shopworn adage that "miles bring smiles" can no longer be considered a hydrographic commandment.

New ideas and information were received and added continually throughout the preparation period. Ultimately, however, editorial deadlines neared, causing the manuscript to be sent to the presses. Because the technology and state of the art of hydrographic surveying are dynamic, the National Ocean Survey will make a constant effort to keep this manual current by issuing periodic amendments and supplements. Readers are urged to make suggestions and advise us on improvements. Through your written comments, the manual can reflect changes in the state of the art.

The many improvements in this edition stem directly from the enthusiastic response received from personnel throughout the NOAA fleet and at the Marine Centers and Headquarters. Space does not permit one to credit each person who contributed in a technical sense, although their efforts are sincerely appreciated; but special thanks must go to those who made major outstanding contributions: Betty V. Arozian, Gabriel J. Bren, Raymond H. Carstens, Donald R. Engle,I.Y.Fitzgerald, Walter F. Forster II, Wayne L. Mobley, William J. Monteith, Robert K. Norris, Hugh L. Proffitt, Jack WALLACE, and Dale E. Westbrook.

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Introduction

The "Survey of the Coast," the earliest forerunner of the National Ocean Survey (a major element of the National Oceanic and Atmospheric Administration), conducted its first hydrographic surveys in 1834. In that year, the U.S. Naval schooners *Jersey* and *Experiment*, under the respective commands of Lieutenant Thomas R. Gedney and Lieutenant George S. Blake, initiated field operations for nautical charting in the vicinity of Long Island, N.Y.

On February 10, 1807, an Act of Congress authorized the President ". . . to cause a survey to be taken of the coasts of the United States. . . . " As it happened, 27 frustrating years passed before Lieutenant Gedney's *Jersey* would run that first line of soundings on the south coast of Long Island between Conklins Point and Green Point. This first hydrographic survey eventually was registered and achieved in 1837 (Wraight and Roberts 1957).

Hydrographic surveying and the cartographic representation thereof in the form of nautical charts were not unknown mysteries in 1807 when President Jefferson appointed Ferdinand Hassler as the first Superintendent of the "Survey." Over 4,000 years ago, Cretan warships and merchantmen plied the Mediterranean. Seagoing junks had spread Chinese trade throughout the Indian Ocean well before the time of Marco Polo's explorations. These early navigators neither relied entirely upon memory in familiar waters nor did they entrust the safety of their commands to chance in uncharted or strange waters. While the instruments and methods used by these ancient mariners are considered crude and unreliable by today's standards, water depths were measured, shoals and channels delineated, landmarks and aids to navigation established, and hazards identified; all were recorded and charted to the best of their ability. By the 19th century, hydrography was accepted as a scientifically based surveying element capable of meeting rigorous engineering standards. Unrelenting pressures and demands for surveys to make maritime commerce safe resulted in placing responsibility on the newer "Coast Survey" for the publication and maintenance of nautical charts of the coastal waters of the United States and her possessions. Upon the arrival of the 20th century, the achievement of this mission by what was then the Coast and Geodetic Survey required the execution of surveys and the continual updating of charts that included a water area in excess of 2 million square nautical miles.

Since the end of World War II, the demand for hydrographic surveys to update nautical charts has increased tremendously because of expanded development in coastal areas, an enormous boom in the popularity of recreational boating, and a sustained growth in waterborne commerce. The more than 9,000 hydrographic surveys filed in the archives of the National Ocean Survey are the basis for an assemblance of about 970 nautical charts regularly updated and published. Each survey represents a unique and comprehensive record of the coastline and adjacent waters. A detailed record of changes brought about by natural and cultural causes can be compiled from a review of contemporary and prior surveys of the same area. These surveys, conducted primarily for nautical charting, are used extensively for engineering, research, and various legal purposes. Only selected important details and soundings from the surveys are shown on published nautical charts.

The hydrographer is engaged in a unique and unusually complex arena within the field of surveying. Unique because, unlike topographic surveying, hydrographic surveying is essentially inferential and deductive since the hydrographer cannot directly view the sea bottom features and so must rely upon discrete sampling methods to construct a continuum of the bottom configuration. And complex in that hydrographic surveying includes consideration of and direct dealing with geodetic control networks, nautical datums based upon an analysis of water level conditions, submarine topography, shoreline delineation, and foreshore detail (e.g., the precise location of navigational aids and landmarks), the total requiring a legion of surveying methods and instrumentation to bring about the desired results.

Tools and techniques used in hydrographic surveying have improved continuously at varying rates. In the early days of hydrography, water depths were measured and bottom characteristics determined solely by lead lines, sounding poles, and wire sounding machines. Positions of the sounding vessel were determined by three-point sextant fixes or, if the shore was not visible, by astronomic observations or dead reckoning. All data were recorded manually for subsequent manual calculation, reduction, correction, and, eventually, plotting. During the past four decades, considerable advances in the science of hydrography have been achieved through the development of echo sounders and electronic navigation systems. With these instruments, the hydrographer acquired much more information for detailed charting of submarine relief than ever before. Although these instruments enabled a substantial increase in the rate and volumes of data acquisition and greatly improved the accuracy and completeness of the hydrographic survey, the volume of manual labor in recording, processing, and plotting the data was not reduced.

More recently, computer assisted data acquisition, machine plotting, and information processing systems have materially increased the speed and efficiency of producing a hydrographic survey. Automated data acquisition and treatment permits the hydrographer to select the optimum sounding line direction without being constrained by the geometry of the electronic positioning system. Time, depth, and position are recorded automatically at a much higher rate than was possible manually and with minimal possibility of recording error.Automatically entered data correctors have speeded the development of new instruments and techniques, such as the real-time telemetering tide gage. The shipboard computer has opened new possibilities for the future; among these are digital electronic sextants, which may result in more efficient surveys in areas where visual control must be used, and heave correctors that compensate for vertical motion of the sounding vessel.

Other technological advances are beginning to tear away the veil of water that obscures the configuration of the sea bed. Photobathymetry-underwater mapping with aerial photography — is showing its operational usefulness. A family of swath mapping instruments is being developed, refined, and tested operationally to provide complete sonar records analogous to aerial photography. Remote-sensing measurement devices, such as laser depth scanners and air gap echo sounders, are around the corner. Worldwide high precision positioning systems are in sight. All of these, together with computer analysis and processing that is replacing the inefficient drudgery of processing data manually, promise to make the hydrographer more efficient and effective.

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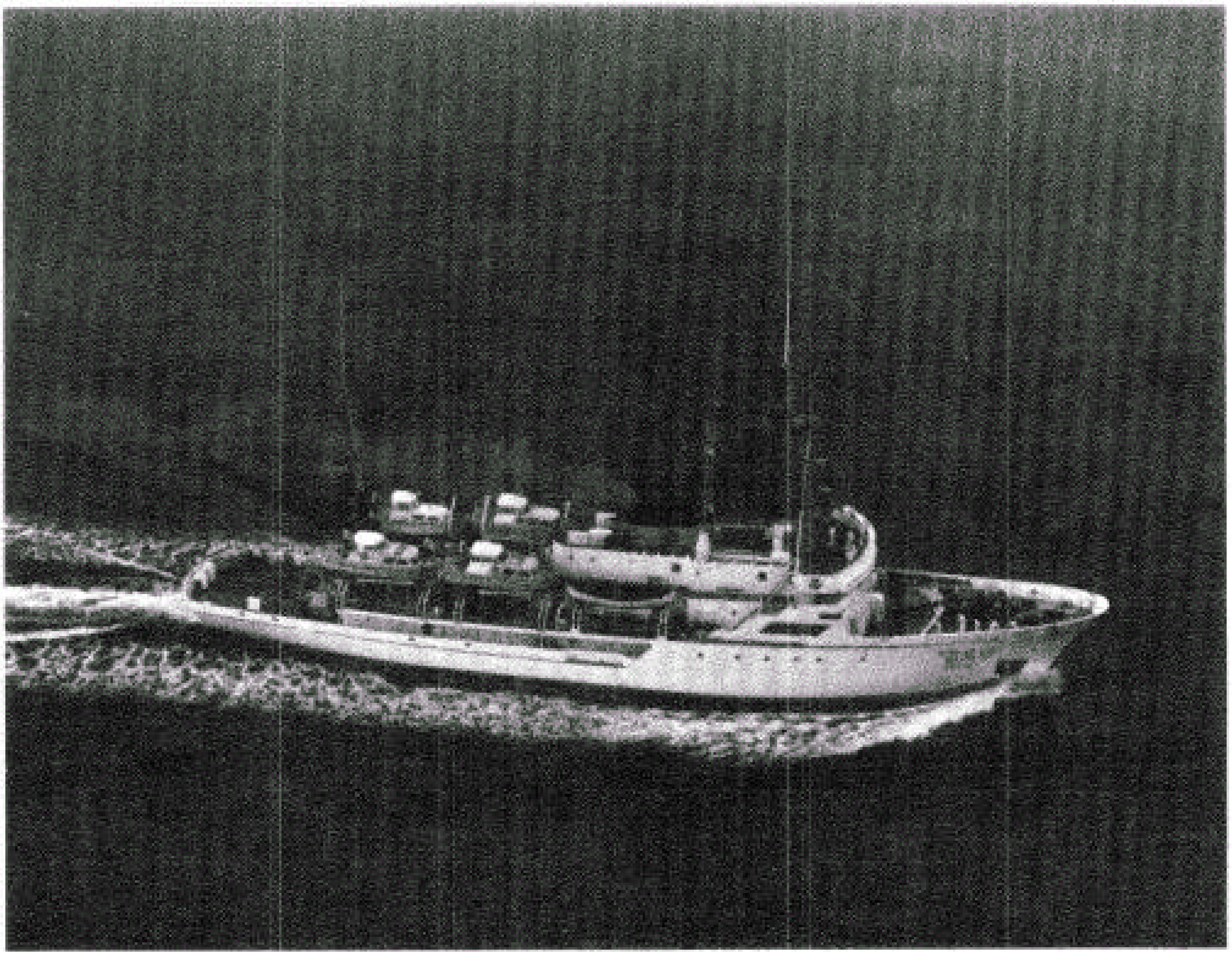
PART ONE

Hydrographic Field Operations



• FIGURE 1.1. — NOAA ship *fairweather* a class-II hydrographic survey vessel •

1. SPECIFICATIONS AND GENERAL REQUIREMENTS

1. 1. HYDROGRAPHIC SURVEYING

1.1.1. Definition and Purpose

Hydrography is that branch of physical oceanography dealing with the measurement and definition of the configuration of the bottoms and adjacent land areas of oceans, lakes, rivers, harbors, and other water forms on Earth. Hydrographic surveying in the strict sense is defined merely as the surveying of a water area; however, in modern usage it may include a wide variety of other objectives such as measurements of tides, currents, gravity, Earth magnetism, and determinations of the physical and chemical properties of water.

The principal objective of most hydrographic surveys conducted by the National Ocean Survey is to obtain basic data for the compilation of nautical charts with emphasis on the features that may affect safe navigation. Other objectives include acquiring the information necessary for related marine navigational products and for coastal zone management, engineering, and science.

Most mariners rarely attempt to evaluate a nautical chart. They have unquestioning faith in its accuracy; and where no dangers are shown, they believe that none exist. The accuracy and adequacy of a nautical chart depend on the quality of the hydrographic surveys from which it is compiled.

1.1.2. International Accuracy Standards for Hydrographic Surveys

Accuracies attained for all hydrographic surveys conducted by the National Ocean Survey shall equal or exceed the specifications stated in International Hydrographic Bureau (1968) *Special Publication* 44, "Accuracy Standards Recommended for Hydrographic Surveys." Significant deviations from these standards, other than those defined in this manual, must be expressly approved by the Director, National Ocean Survey.

The following are pertinent extracts from *Special Publication* 44.

"The standards were drawn up in April-May 1967 by a working group that met at the IHB before and after the 9th I.H. Conference to complete a study which had previously been the subject of a long exchange of views by correspondence between the Bureau and Member States. This group was made up of the following experts:

Chairman:

Mr. M.R. ULLOM (U.S.A.: NAVOCEANO)

Members:

*Rear Admiral **D.A. JONES, USESSA** (U.S.A.: C.&G.S.), Commander **F. MENDONCA DA COSTA FREITAS** (Brazil); **Mr. H. TUORI** (Finland)*

In preparation of these accuracy standards, hydrographic surveys were classified as those conducted for the purpose of compiling nautical charts generally used by ships. Special surveys for engineering and research projects were not considered. The study confined itself to determining the density and precision of measurements necessary to portray the sea bottom and other features sufficiently accurate for navigational purposes.

The planning for each hydrographic survey and the preparation of appropriate specifications is a unique task, and it is not possible to prepare a treatise on accuracy standards for hydrographic surveys which would be applicable for any area to be surveyed. The density of sounding and the precision of measurements depend on several factors; the depth of water, the composition and configuration of the bottom, and the type of ships which will navigate in the area all need to be considered.

Certain degrees of accuracy are, nevertheless, commonly acceptable for hydrographic operations, and it is reasonable that such standards should be stated in order that they may serve as a guide for planning an adequate hydrographic survey.

PART A. —GENERAL STANDARDS

Section I.—Scale of survey

1. The scale adopted for a survey of a particular area should not be smaller than the scale of the existing or proposed chart of the area and preferably should be at least twice as large as that of the largest scale of the published or proposed chart of the area.

2. Ports, harbours, channels and pilotage waters should be surveyed on a scale of 1/10 000 or larger.

3. Other waters used by shipping with possible shoals or other dangers to navigation should be sounded on a scale of 1/20 000 or larger.

4. Surveys of coastal and harbour approach areas to a depth of at least 20 m (11 fm) should be conducted on a scale of 1/50 000 or larger.

5. Offshore hydrographic surveys in depths greater than 20 m (11 fm) may be plotted on a scale smaller than 1/50000 dependent on the importance of the area covered, the depth, and bottom configuration. The scale of the offshore plotting sheet should not be smaller than is necessary to provide a sheet of convenient size that will extend a short distance beyond the offshore limit of the survey and will, where feasible, include the stations necessary for control of the survey.

Section II.—Interval of sounding lines at the scale of the survey

1. Spacing of principal sounding lines:

1.0 cm (0.4 in) or less, as may be needed to thoroughly develop the area at the scale of the survey, except where depth and character of the bottom will permit wider spacing.

2. Spacing of cross-check lines:

7.5 cm (3.0 in) or less.

Section III.—Interval of plotted soundings

Frequency along sounding lines:

Spacing should be less than the interval between lines, preferably one-half of the interval with peak and deep soundings shown, but this interval may be increased in areas of even bottom, and where the soundings are recorded on an echogram.

Section IV.—Sampling of bottom characteristics

In general, sufficient sampling should be done to demarcate the limits where one general type of bottom changes to another.

In waters that may be used for anchoring, samples should be taken at regular intervals not to exceed 5 cm (2 in) at the scale of the survey. In other areas, shoaler or deeper, a spacing of 8 cm (3 in) is sufficient depending on the regularity of the bottom. Deep-water bottom samples, over 100 m (55 fm), are classed as oceanographic observations requiring special equipment and samples will be taken as required.

Section V.—Spacing of position fixes

The spacing of position fixes on the survey sheets shall be from 2- 4 cm (1-1.5 in).

Section VI.—Current observations

When velocity is expected to exceed 0.2 knot, both velocity and direction of currents shall be observed at entrances to harbours or channels, at any change in direction of channels, in anchorages, and adjacent to a pier or wharf area. It is also desirable to measure coastal and offshore currents when they are of sufficient strength to affect shipping.

PART B.-SPECIFIC STANDARDS

Section I.—Horizontal control

1. Primary shore stations

The location of primary shore control stations and electronic positioning stations shall be within the limits of accuracy for third-order control when the geodetic survey extends no more than 50 km (27 M) from the point of origin or from stations of a geodetic net of higher order used as the origin. When the extent of the geodetic survey is in excess of 50 km the use of second-order control methods is desirable, and if the stations of an electronic positioning system are separated by distances in excess of 200 km (110 M) ties shall be made to basic first-order control whenever possible.

2. Hydrographic signals

The error in location of hydrographic signals used for visual fixing, with relation to the primary shore control should not exceed 1 mm (0.03 in) at the scale of the survey.

3. Position fixes and floating aids

(a) The indicated repeatability of a fix (accuracy of location referred to shore control) in the operating area, whether observed by visual or electronic methods, combined with the plotting error, shall seldom exceed 1.5 mm (0.05 in) at the scale of the survey.

(b) Ocean surveys for nautical charts (shoal searches, investigation of doubtful soundings, etc.): acceptable error when fixing a reference beacon by astronomic or electronic means: 1 km (0.5 M).

4. Aids to navigation

(a) Fixed aids to navigation shall be located within the same limits of accuracy as primary shore stations stated in para 1.

(b) Floating aids to navigation shall be located within the same limits of accuracy as position fixes stated in para 3.

5. Offshore installations dangerous to navigation

Location of offshore installations dangerous *to navigation should, when feasible, meet the requirements for third-order control.*

Section II.— Vertical control

1. Measurements of depth

Allowable errors:

(a) 0 - 20 m (0 - 11 fm): 0.3 m (1.0 ft)

(b) 20 - 100 m (11 - 55 fm): 1.0 m (0.5 fm)

(c) Deeper than 100 m (55 fm): 1% of depth.

Normally, a disagreement of cross check lines with principle sounding lines of three times or more the allowable error stated above indicates error in either position, depth, or both, and should be further investigated.

2. Sweeping over wrecks, obstructions, and shoals

The same accuracy as that specified for the measurement of depths (Section II, paragraph 1) to a depth of 30 m (16 fm). In depths greater than 30 m (16 fm) the same accuracies as for measurement of depth (Section II, para 1) where the depth and equipment available permit these accuracies.

3. Reference of sounding to vertical datum

Location and duration of tidal observations to be such that each sounding can be referred to the sounding datum with an error no greater than one-half that specified in Section II, para 1 above. Tidal reductions are not usually applied to oceanic soundings over 200 m (110 fm)."

1.2 HYDROGRAPHIC SHEETS

1.2.1. Field Sheet

The field sheet (formerly called the boat sheet) is a worksheet that graphically displays the hydrographer's most accurate representation of all required surface and subsurface features in the area being surveyed. (See 4.2.) The sheet is an indispensable aid to the hydrographer for visualizing the progress and adequacy of the work accomplished and for planning future operations. Field sheets may be the composite product of several plotter sheets, overlays, insets, or rough preliminary launch or skiff worksheets on which most of the errors have been detected, corrected, and eliminated by replotting the data. Under ideal conditions, the field sheet may be the direct product of an on-line real-time machine or manual plot of hydrographic data.

1.2.2. Smooth Sheet

The smooth sheet is the final carefully made plot of a hydrographic survey. In contrast to the field sheet, which is plotted from preliminary unverified field data, the smooth sheet is plotted from checked and corrected data and conforms with rigid cartographic standards of the highest quality. (See chapters 6 and 7.)

The smooth sheet is ultimately archived as the official permanent record of the survey and is the principal source and authority for charted hydrographic data.

1.2.3. Scale of Survey

The basic scale for hydrographic surveys performed by the National Ocean Survey is 1:20,000; almost all other survey scales used will have a simple ratio relationship. The criteria for scale selection are based on the area to be covered and the amount of hydrographic detail necessary to depict adequately the bottom topography and portray the least depths over critical features. (See 4.10 and 7.2.2.) A cardinal rule of nautical chart construction is data from a hydrographic survey should always be plotted at a scale ratio larger than that of the chart to be compiled. The survey scale is generally at least twice as large as that of the largest scale chart published or proposed for the area. For example, the scale of a survey should be 1:20,000 or larger for a chart that will be published at a scale of 1:40,000.

Inshore surveys, defined as those conducted adjacent to the shoreline and in general depths of 20 fm or less, shall be plotted at scales of 1:20,000 or larger, unless smaller scales are authorized specifically in the project instructions. In contrast, *offshore surveys* are those conducted in waters of general depths between 20 and 110 fm not adjacent to the shoreline. As the survey progresses in an offshore direction and the depths and required sounding line spacing intervals increase, smaller scales are applicable (usually decreasing to 1:40,000 and 1:80,000).

Surveys at scales of 1:30,000 and 1:50,000 may be authorized if their use would result in a more efficient sheet layout (2.4) or would permit a clearer portrayal of the bottom configuration.

Basic hydrographic and navigable area surveys of all important harbors, anchorages, restricted navigable waterways, and areas where dangers to navigation are numerous shall be plotted at scales of 1-10,000 or larger. Larger scales shall be even multiples of 1-10,000, with each scale double that of the preceding scale (e.g., 1:5,000 and 1:2,500). Scales larger than 1:2,500 may be in even multiples of 1,000. Scales for chart evaluation, reconnaissance, and special project surveys will be specified in the project instructions.

Ocean surveys are conducted in waters deeper than 110 fm in areas that generally lie seaward of the Continental Shelf. (See F.4.1.) The small scales at which ocean surveys are plotted depend on the purpose of the survey and will be specified in the project instructions.

1.2.4. Sheet Size

The standard size for hydrographic survey sheets, whether plotted manually or machine plotted, is 91 by 137 cm, with the hydrography limited to an area 76 by 122 cm. The Chief of Party may include a request with the sheet layout when it is submitted for approval (see 2.4) to increase the sheet size to a maximum of 91 by 152 cm, with hydrography limited to an area of 76 by 137 cm. Such requests should be submitted only in cases where failure to extend the survey area from 122 to 137 cm would necessitate an additional, undersized, sheet to provide complete coverage of the project area.

Sheets larger than 106 by 152 cm, with hydrography limited to an area of 91 by 137 cm, shall not be used under any circumstances. Should a situation arise where data already acquired will not plot within the maximum 76- by 122-cm area, Hydrographic Surveys Division (OA/C35) shall be advised. These data may be reformatted into two separate surveys and an additional registry number assigned upon approval of Hydrographic Surveys Division (OA/C35).

Sheets should be the standard size except when larger size sheets have been approved as above or when the standard size would result in a margin in excess of 20 cm. (The margin is defined as that area between the limits of hydrographic data and the edge of the sheet.) When an excessive margin exists, the sheet shall be trimmed during Marine Center processing so that the margin is reduced to no more than 20 cm or less than 7 cm. However, the sheet shall not be trimmed any smaller than 76 by 76 cm.

Regardless of the sheet size, a minimum margin of 7 cm is required on all edges of a smooth sheet. The latitude-longitude annotations and grid lines normally will extend to within 4 cm of the edge of the sheet, but should be no closer than 2 cm to the edge of the sheet. The hydrographic data should seldom, if ever, extend into the 7-cm margin area.

1.2.5. Sheet Material

Field sheets shall be prepared on grained or emulsion coated transparent polyester base drafting film, on transparent paper designed specifically for automatic plotter use, or on suitable material easily reproduced and convenient for making comparisons with other plotted data. Material on which hydrographic data will be plotted must be relatively distortion free. (See 7.2.1 for smooth sheet requirements.)

1.2.6. Sheet Projections

Hydrographic survey data shall be plotted either on the modified transverse Mercator or on a polyconic projection. At the relatively large scales required for hydrographic surveys, the two projections are essentially equivalent and may be used interchangeably for comparisons and transfer of hydrographic data.

Field parties equipped with fully automated systems normally plot hydrographic data on the modified transverse Mercator projection because of the simpler calculations involved. Subsequent computer plotting at the Marine Centers during the survey verification phases and for the smooth sheet shall be on the polyconic projection.

Hydrographic parties not equipped with an automated system shall request field sheets and electronic control calibration sheets from the Marine Centers. Extra base sheets with ruled projections and electronic control arcs should be requested as necessary for display and comparison of junctional soundings, presurvey review items, bottom sample data, and other pertinent hydrographic information.

The polyconic projection should generally be used if machine-drafted projections are not available. The manual construction of a polyconic projection is a relatively simple task although extreme accuracy and care are required. All necessary instructions and data for the manual construction are contained in the U.S. Coast and Geodetic Survey (1935) *Special Publication* No. 5, "Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridians and Parallels, Based Upon Clarke's Reference Spheroid of 1866." (See 4.2.2.)

Rubber stamp 1, "Hydrographic Survey," shall be impressed or machine drafted near the lower right corner of each sheet and on each overlay used. (See figure 4-1 in section 4.2.2.) Appropriate entries shall be made in all applicable spaces of the title block stamp. Projection lettering and numerals shall be oriented to read from the south. Refer to 2.4.1 for instructions on the orientation of the projection with respect to the edges of the field sheet. Projection line intervals between meridians and parallels depend on the scale of the sheet and are specified in 4.2.2.

1.3 CONTROL

1.3.1 Horizontal Control

For National Ocean Survey hydrographic surveys, horizontal control shall be based on triangulation, traverse, or trilateration of Third-order, Class 1, or higher accuracy. (See 3.1.1, Federal Geodetic Control Committee (1974) *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys,* and (1975) *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys.)* The project instructions may require control surveys that meet the standards for Second-order, Class II accuracy if additional main-scheme stations are needed to supplement the National Horizontal Control Network or a hiatus exceeding 20 km exists between established geodetic control stations along the coastline.

Third-order, Class I accuracy is generally the minimum acceptable criteria for the location of electronic positioning system antenna sites and calibration signals, theodolite intersection instrument (cutoff) stations, and supplemental control schemes from which hydrographic signals will be located by conventional survey methods. (See 3.1.2.) Third-order control stations when established for the hydrographic survey shall be described, monumented, and marked with standard National Ocean Survey disks at intervals of 4 to 8 km along the coastline for future survey use. (See 3.1.2.1.2.)

Hydrographic signals for sextant-controlled hydrography may be located by sextant fixes or by sextant cuts. Less than third-order traverse methods may be used if the distance from a basic or supplemental control station does not exceed 4 km for hydrographic surveys at scales of 1: 10,000 or smaller or 2 km for larger scale surveys. (See 3.1.3.)

Photogrammetric methods may be used to position hydrographic stations for visually controlled surveys (photo-hydro stations) if these two conditions are met:

The compilation scale of the shoreline manuscript is larger than or equal to the scale of the hydrographic survey sheet.

The photo-hydro support data have been prepared and provided to the field party. (See 1.3.2 and 3.2.)

Electronic positioning system antenna sites and calibration stations may be located photogram- nl metrically, provided that the stations have been marked with targets prior to aerial photography, the positions have been determined by analytic aerotriangulation, and the method is approved in the project instructions.

A thorough search shall be made for all previously established horizontal control stations, reference marks, and azimuth marks in the general vicinity of the shoreline throughout the project area. Recovery notes shall be prepared and submitted in accordance with *Input Formats and Specifications for the National Geodetic Survey Data Base.*

1.3.2. Photogrammetric Surveys

Mapping of planimetric features such as shoreline, buildings, and landmarks for most inshore hydrographic surveys is accomplished through the use of modern photogrammetric techniques. The principal products supplied the hydrographer are copies of appropriate shoreline maps and other related support data. Signals for visual control of hydrography may be located by photogrammetric procedures utilizing the support data. (See 3.2.4.) Although photogrammetry has largely replaced the plane table for planimetric mapping, there occasionally are limited areas where use of the latter is far more practical because of cost, time available, or need to supplement or verify the photogrammetric data.

Photogrammetric and hydrographic surveys are conducted jointly as a part of combined operations in areas where land transportation systems and other facilities are inadequate for shore-based parties. Photogrammetric field work may consist of any or all of the following operations in addition to those required to directly support hydrography: recovering or establishing horizontal control, placing targets on control stations prior to aerial photography, observing tides in support of tide-coordinated infrared photography, and field editing. Experienced photogrammetrists are generally assigned to perform these operations and to give advice, assistance, and training in their execution.

Pending publication of a revised topographic manual, a series of Photogrammetric Instructions has been issued to provide specifications for standard field and office procedures for photogrammetric surveys. [For a current list, consult chapter 76, section 27, of *NOS Manual No. 1,* "Operations Manual" (National Ocean Survey 1971)*a*).] The applicable instruction is cited herein as appropriate.

1.3.3. Hydrographic Positioning Control

1.3.3.1. VISUAL POSITION CONTROL

1.3.3.1.1. *Sextant three-point fix.* The positions of a sounding vessel when conducting an inshore survey may be determined by three-point sextant fixes if precise electronic positioning control systems are not available or are inadequate for the survey. (See 4.4.2.) Hydrographic sextants are used to measure two angles between three points of known geographic position. The middle point of the three should be common to both angles. The visual three-point fix shall be plotted using a three-arm protractor if the field party is not equipped with an automated system for computing and plotting the fix location. (See A.7.)

Sextant angles shall be observed simultaneously and recorded to the nearest minute of arc. Hydrographic sextants must be checked for adjustment before the start of each day's work, and the index error determined and recorded in the survey records. (See A. 5.3.) The adjustments are verified periodically throughout the day and on completion of each day's work. (See 4.8.3.3.)

A check angle shall be observed on each visually determined detached position to verify the fix. A detached position is a recorded fix taken to position an object that does not lie on a continuous sounding line (e.g., a bottom sample, least depth over a shoal, and floating aid to navigation).

1.3.3.1.2. *Theodolite intersection.* Positions of the sounding vessel may be determined by the theodolite intersection method (also called transit cutoff). This method of visual control may be advantageous in harbors, rivers, and other restrictive areas where electronic positioning or sextant fixing is impractical. (See 4.4.2.2.)

Directions to the vessel are observed from at least two and preferably three shore-based theodolite stations of Third-order, Class I, or better accuracy. Directions shall be observed and recorded to the nearest minute of arc. True azimuths accurate to within ± 30 s of arc are required for absolute orientation of the observed directions.

If a computer system is not available for a real-time automated plot of the sounding line, the vessel positions are plotted using a standard drafting machine. The angle of intersection at the vessel shall be such that a directional error of 1 min from a theodolite station will not cause the position of the vessel to be in error by more than 1.0 mm at the scale of the survey.

1.3.3.2. ELECTRONIC POSITIONING.

Electronic positioning systems currently used by the National Ocean Survey for hydrographic surveys may be grouped into the following categories:

Short range, effective over distances ranging from a few meters to about 80 km.

Medium range, effective over distances ranging from a few hundred meters to about 250 km.

Long range, effective over distances ranging from a few kilometers to over 8000 km.

1.3.3.2.1. *Short range systems.* Short range electronic positioning systems operate in the two-station range-range mode either in the ultrahigh frequencies (300 to 3000 MHz) or in the superhigh frequencies (3000 to 30,000 MHz). At these frequencies, the systems are limited to line-of-sight measurements (4.4.3.2.2 and A.4.1) and shall never be used where intervening objects obstruct the line of sight between the survey vessel and either shore station or where the distance from the sounding vessel antenna to either shore station antenna exceeds the line-of-sight condition. Refer to section 4.4.3 for detailed discussions of line-of-sight limitations and requirements for siting shore stations, pattern geometry, and system calibration.

1.3.3.2.2. *Medium range systems.* Medium range electronic positioning systems operate in the two-station range-range mode or in a three-or four-station hyperbolic mode. These systems operate either in the ranges of medium frequency (300 to 3000 kHz) or high frequency (3 to 30 MHz) and, therefore, are not limited to line-of-sight restrictions.

Caution must be exercised when using medium range positioning systems to control inshore hydrography because of the potential adverse effects of land mass-induced signal attenuation. The presence of severe attenuation is usually manifested by relatively large and unexplainable variations in the series of calibrations within a survey area. Refer to section 4.4.3 for detailed discussions on shore station requirements, calibration procedures, system geometry, and the effects of signal attenuation.

1.3.3.2.3. *Long range systems.* Currently available long range systems that are acceptable for controlling ocean surveys operate in both the three-station hyperbolic mode and in the range-range mode (See 4.4.3 and A.4.) These systems operate in either the very low frequency (less than 30 kHz) or the low frequency (30- to 300-kHz) ranges. Long range systems shall be used to control surveys only in those areas that fall beyond the effective ranges of short or medium range systems unless otherwise authorized in the project instructions.

1.3.3.2.4. *Electronics systems calibration.* For use in this manual, "calibration" is defined as the comparison of one or more positions determined by an electronic positioning system with corresponding known positions. Corrections to be applied to observed electronic values are computed from these comparisons. Recommended minimum system calibration requirements follow. Chiefs of party shall make additional calibrations when necessary. (See 4.4.3.3.)

Short range navigation systems used to control inshore surveys shall, at the minimum, be calibrated at the beginning and at the end of each workday and at such times when the hydrographer is uncertain of the validity of the previous calibration. When used for smaller scale offshore surveys, calibrations should be made at least once each day. Two or more three-point sextant fixes with check angles or positions of equivalent accuracy shall be observed simultaneously with the electronic position value. Corrections to the observed electronic values are then determined for each fix, and the mean correction is computed. (See 4.4.3.3.) Corrections that differ from the mean value by more than 0.5 mm at the scale of the survey shall be rejected and redetermined. Calibrations shall be made in or as close as possible to the area being surveyed.

Medium range positioning systems used to control inshore surveys shall be calibrated using the same criteria as prescribed for the short range systems. Calibration corrections for medium range systems occasionally have a tendency to vary significantly in different areas of the survey, particularly close inshore. (See 4.4.3.4.) The hydrographer must be continually alert for this phenomenon and shall make additional calibrations at his discretion. When used for smaller scale offshore surveys, medium range systems shall, at a minimum, be calibrated at the beginning and at the end of each cruise. Medium range systems may also be calibrated using short range systems that have been properly calibrated.

Refer to section 4.4.3.3 for a detailed discussion on calibration procedures and requirements.

Long range navigation systems used to control small-scale offshore surveys shall be calibrated as frequently as practical by the most accurate means available. (See 4. 10. 1)

1.3.3.3. HYBRID CONTROL SYSTEMS. These systems combine line-of-position data from two or more different types of positioning systems. The most commonly used hybrid systems include combinations of electronic positioning data with visual observations. (See 4.4.4.) During sounding operations controlled by hybrid methods, the vessel is generally maneuvered along electronic line-of-position arcs.

Visual observations may be sextant angles between hydrographic signals observed from the vessel or may be theodolite azimuths observed from a shore station. The objects used for sextant observations must straddle the electronic line of position. Calibration requirements for short and medium range positioning systems also apply to hybrid systems.

1.3.4. Plotting Control

Each control station used during the survey that lies within the hydrographic sheet limits shall be shown in ink by the appropriate symbol (appendix B) and shall be identified by a three-digit number. (See 4.2.5.) Identification numbers begin with 001, are consecutive, and must not be repeated on any one hydrographic sheet. Recoverable control stations shall, in addition, be identified on the sheets by name and year of establishment. (Refer to 4.2.5 for manual plotting of control.) Station names and numbers are entered in ink using vertical numerals and upper case letters approximately 3 mm high in colors matching the symbol. Names and numbers should not be placed in areas where they may be confused with soundings or other hydrographic data.

Electronic control lattices shall be plotted in ink on the hydrographic sheets using a distinctive color for each family of arcs. Lattices are not necessary on the final field sheet. (See 4.2.6.) Plotted arcs should be spaced approximately 8 to 10 cm apart on the sheets. Each arc shall be identified in an appropriate matching color by its distance or lane value and its control station number or numbers of origin. The name, identification number, and year of establishment shall be indicated on at least one arc for each station.

Hydrographic parties not equipped with automatic plotters should request field and calibration sheets from their Marine Center to avoid manual plotting. Control stations and electronic control arcs will be plotted on the sheets if the necessary data are furnished. Geographic positions of these stations must be logged, tabulated, and submitted in accordance with the individual Marine Center requirements. The class or type of each station has to be clearly indicated to assure that the correct color and symbolization are shown on the plotted sheet.

Photogrammetrically located hydrographic control stations may be transferred directly from stable base copies of the shoreline manuscripts (at compilation scale) to hydrographic sheets of equal scale. If the scales vary or if photo-hydro station positions are needed for computer input, geographic coordinates must be carefully scaled from the manuscript copy. All control computations, scaled distances and conversions, plots, and direct transfers shall be checked carefully as the work progresses.

1.4 SOUNDING LINES

Hydrography is begun by sounding along a predetermined system of lines that will delineate the submarine relief in the most thorough and economic manner. (See 4.3.5.) A series of evenly spaced parallel sounding lines is usually the best method to accomplish this objective. In general, the sounding lines should be run normal to the depth contours, but frequently it is more advantageous to adopt another system. For the development of steep features, such as ridges or submarine valleys, the system of lines should cross the depth contours at an angle of approximately 45°. A restricted channel may be developed by a series of lines parallel to the axis of the channel if the sounding vessel cannot safely and effectively maneuver on lines that cross the depth contours at a sharper angle. (See 4.3.5.4.)

When hydrography is controlled by an electronic positioning system and positions are plotted by hand, sounding lines may be run along equidistant or hyperbolic line-of-position arcs to gain positive control of the vessel on the sounding line. Vessels equipped with modern computers and automatic plotters have the flexibility of running arcs or straight lines with equal positive control. Straight lines are generally used because of greater flexibility in the selection of direction. Regardless of the system selected for a hydrographic project, the lines or arcs followed shall permit the most effective development of the bottom topography.

Shoreline manuscripts at the required scale are the source of the charted low water or other datum line provided that the line has been compiled using tide-coordinated aerial photography taken after an accurate datum of reference has been established. The low water line shall be determined hydrographically only when so directed by the project instructions. (See 1.6.) The safety of the personnel and equipment, however, shall not be jeopardized under any circumstances. Sounding lines are not required over extensive tidal flats or in other areas shown by the survey to uncover at low water.

1.4.1. Line Spacing

The spacing of sounding lines required to develop an area properly depends upon the depth of the water, the topographic configuration of the bottom, the general nature of the area, and the purpose of the survey. (See 4.3.4.) The bottoms of harbors, channels, anchorages, and shoal areas that may present dangers to navigation should be developed by a system of closely spaced lines (e.g., lines spaced from 50 to 100 m apart on a 1:10,000 scale survey). As depths increase and survey scales decrease, the line spacing increases (up to 8 km for ocean surveys in depths over 1,000 fm). Project instructions specify the maximum allowable sounding line spacing for the various survey depths anticipated. (See 2.3. 1.) It may be necessary, however, for the hydrographer to reduce the line spacing and increase the survey scale to delineate the bottom configuration adequately.

Least depths over pinnacles or other significant sharp features usually cannot be determined adequately merely by decreasing line spacing. Supplemental observations such as direct depth measurements by divers or drift soundings supplemented with lead-line depths over these features shall be obtained. (See 4.5.9.) Frequently, these features can be located by wire sweeps or pipe drags.

1.4.2. Crosslines

The regular system of sounding lines shall be supplemented by a series of crosslines (4.3.6) for verifying and evaluating the accuracy and reliability of surveyed depths and plotted locations. The following procedures are used:

1. All launch and small boat hydrography shall be verified by crosslines to the extent of 8 to 10% of the principal system of sounding lines (exclusive of development).

2. All ship hydrography in areas of fairly regular bottom shall be verified by crosslines to the extent of 5 to 6% of the regular system of lines (exclusive of development). In areas where the principal system of sounding lines is generally parallel to the depth contours, the crosslines shall be 8 to 10% of the regular system.

3. Crosslines shall be run at angles of 45 to 90° with the regular system.

Crosslines are generally of little value for checking in areas of very irregular submarine relief.

(See 4.3.6.) The hydrographer should exercise judgment and seek areas of regular relief where meaningful Crosslines can be run.

In areas of regular bottom, a framework of Crosslines should be run first as an aid in planning the regular system of lines and to provide a running check on the soundings and their positions. The Crosslines should be very accurately controlled, and the sounding equipment should be in excellent operating condition. The lines should be run near the times of predicted low water if practical. The soundings should be reduced to the actual reference datum if possible. Soundings observed on the regular system of lines shall be checked with crossline soundings on a daily basis. Serious discrepancies are evidence of errors in control, vessel positioning, faulty operation of the echo sounder, or use of incorrect values for the reduction of soundings. (See 4.6.1.)

1.4.3. Development of Shoals and Other Hazards

A basic hydrographic survey is not complete and adequate until there is reasonable assurance that all obstructions, shoals, and other dangers to navigation in the survey area have been found and the least depths over them determined. Every sounding slightly less than the general, surrounding depths must be regarded as an indication of a possible shoal or potential hazard to navigation. (See 4.5.9 through 4.5.11.) In many localities where the bottom is extremely irregular, however, it is not practical to examine every shoal indication. When selecting soundings to be further exmined, the importance of the locality and the types of shoals or dangers to be expected must be carefully evaluated. Hydrographers, should be guided by the following considerations:

1. In general depths of 20 fm or less in a navigable area, all indications of shoaling should be investigated.

2. At any depth in excess of 20 fm, all shoal indications rising more than 10% above the general surrounding depths should be investigated.

3. The nature of the bottom must be considered. If it is rocky, there is more likelihood of dangerous pinnacles being present. If the bottom is composed of sand or mud, there is less chance that a natural danger exists.

4. The importance of the region should be considered from the point of view of navigation. All shoal indications in channels and harbors must be examined. In areas of lesser importance, the number of examinations may be reduced; however, the least depth over detached features surrounded by navigable waters shall be determined regardless of the importance of the area.

The development of shoal indications revealed by the general system of fines is the most important part of hydrography, and frequently the most extensive. The line spacing shall be reduced by running intermediate "split" lines to develop these indications. (See 4.5.9.) A second pattern of closely spaced lines, usually parallel to the axis of the feature, should be run to provide greater detail in critical areas. In some instances, radiating lines crossing at the center of a small shoal may better develop the feature. (See 4.3.5.)

After the feature has been developed by closely spaced lines, each critical area thereon must be thoroughly examined to determine the least depth. Pinnacles, rocky shoals, and other sharply rising features hazardous to navigation should be detected by wire sweeping or pipe dragging; their depths should be measured by a diver. (See 1.4.1.) As an alternative, extensive drift soundings should be taken over the feature using both depth recorder and lead line.

The development of a shoal and search for the least depth frequently result in the running of lines that cannot be smooth plotted at the planned scale of the survey. Lines not adding to the data already recorded should be marked "not to be smooth plotted" in the sounding records. Excess data of this nature should be deleted from the master data tapes transmitted for processing at the Marine Centers. Raw field data tapes must not be altered or destroyed.

1.4.4. Survey Overlap at Junctions

An overlap of at least one sounding line or equivalent distance shall be made with each adjacent survey, except as specified below. If the depths at the junction do not agree, sounding lines of the new survey should be extended into the older survey until a satisfactory agreement has been reached. (See 4.3.2.) If a reasonable extension into the other survey fails to reach agreement, an investigation should be made, conclusions and recommendation developed, and a report submitted to the appropriate Marine Center with a request for further instructions.

The overlap specified herein shall apply to the following classes of surveys:

1. All noncontemporary surveys (4.3.2).
2. Contemporary surveys conducted by a different survey party.
3. Contemporary surveys conducted by the same field party in different years, by different methods, or by different vessels.
4. Surveys conducted by other organizations.

If the hydrographic survey is continuous in the same year, by the same method, and by the same survey vessel, junctions between adjacent sheets may be made by spacing the sounding lines as they would have been spaced had the two surveys been combined on one sheet.

1.4.5. Positions

1.4.5.1. POSITION FREQUENCY. The position of the vessel shall be determined and recorded at intervals that permit an accurate plot of the sounding line. (See 4.4.5.) The length of time interval between successive fixes along a line is dependent on the scale of the survey, speed of the vessel, and type of positional control. All information necessary to plot the position accurately, such as time, course, speed, and fix data, must be included in the hydrographic records.

The maximum distance between consecutively numbered positions along a line shall not exceed 5 cm at the scale of the survey provided that a position is determined and recorded for each sounding. Otherwise, the maximum distance shall not exceed 4 cm on the hydrographic sheet regardless of the type of position control or the scale of the survey. If the survey is controlled visually and the vessel is not steered along electronic line-of-position arcs, the interval between plotted positions shall not exceed 3.5 cm. If the vessel is steered on an arc of small radius, the interval shall be reduced as necessary to permit accurate plotting of the soundings between recorded fixes.

Additional position fixes should be taken and recorded for each of the following occurrences:

1. At the beginning and end of each sounding line.
2. At each change of course greater than 10º.
3. At each appreciable change in the speed of the sounding vessel.
4. At each detached position for a sounding, bottom sample, aid to navigation, or other similar purpose.

On automated electronically controlled surveys where a position fix is obtained for each recorded sounding, occurrences 2 and 3 may be omitted, provided the event and time of occurrence are noted in the hydrographic records.

1.4.5.2. POSITION NUMBERING. Hydrographic survey positions are numbered consecutively over the range I through 9999. When more than one vessel is used on the same survey, this range or block of numbers should be proportioned to correspond to the amount of hydrography expected to be accomplished by each vessel. Table 1-1 is an example.

1.4.6. Sounding Interval

Soundings shall be recorded and plotted at regular intervals close enough to provide a realistic representation of the bottom configuration. (See 4.5.6.) Regular spacing intervals should neither be less than 4 mm nor exceed 6 mm at the scale of the survey. Maximum depths over depressions and minimum depths over shoals or dangers to navigation shall be recorded as they occur or be inserted in the records when the hydrographic data are field checked. Recording excessive soundings, however, results in wasted effort when the data are processed and shall be avoided. The time that each sounding was taken shall be noted. When echo soundings are supplemented with depths measured by lead line, by sounding pole, or by a diver, the records shall indicate clearly the method used.

1.5 DEPTHS

1.5.1. Sounding Equipment

Shoal water echo sounders (A.6.3) shall be used to the limit of their capability to record depths accurately. Shoal water digital echo sounders are

TABLE 1-1,-*Position numbering of Hydrographic Survey MI 20-3-74*

Vessel	Assigned position nos.
Mt. Mitchell	1-4000
Launch 1	4001-6000
Launch 3	6001-9000

preferred over sounding instruments limited to analog output. Graphic records of the sounding profiles, however, must be obtained in conjunction with digital records as supporting information for the hydrographer and for survey verification.

The project instructions may authorize the use of deep water echo sounders for surveys in waters deeper than 150 fm to preclude frequent switching between shoal water and deep water instruments.

A sounding pole or lead line (A.6.1) shall be used to measure depths that are too shoal for echo sounders, to supplement and verify echo soundings in areas containing kelp or grass, to verify least depths over shoals, obstructions, and other dangers to navigation, and as a calibration standard for echo sounders. (See A.6 for a discussion of depth-measuring equipment.)

1.5.2. Echo Sounder Calibrations

Digital and analog echo sounders used by the National Ocean Survey (A.6.2) for hydrographic surveys are normally calibrated at 800 fm/s for the assumed velocity of sound in water. Periodic field calibrations of the sounding equipment shall be made to determine the corrections to observed soundings caused by variations in the velocity and for other instrumental errors. When the summation of calibration and datum corrections to an echo sounding is less than half of 1% of the depth, the corrections may be disregarded; the corrections shall be applied in all other cases.

On small vessels, bar checks shall be made twice daily and at other times when necessary, such as when equipment is changed or adjusted. Routine bar checks should be made only when sea conditions permit accurate observations. (See 4.9.) On larger vessels where bar checks cannot be taken, echo soundings are compared with depths observed by lead line (vertical cast) at selected intervals. The simultaneous comparisons are recorded for use in compiling instrument corrections. All vertical cast comparisons should be made in shoal water when the sea conditions are calm and the bottom is relatively smooth and hard. Lead-line comparisons should be made in the areas where junctions are effected with launch hydrography or where soundings were taken by another vessel. If digital soundings are used for the survey, bar check or lead-line values are compared with both the digital readings and the graphic record.

Actual velocities of sound through the waters to be surveyed shall be determined, computed, applied, and reported in accordance with section 4.9.

1.5.3. Graphic Depth Records

Echo sounders used by the National Ocean Survey for hydrographic surveying produce a permanent graphic or analog record of the bottom profile. The graphic record, also known as an echogram or fathogram, shall be used for:

Scanning and checking soundings recorded manually or digitally.

Scaling the depths over peaks, deeps, and other significant hydrographic features found between regularly spaced interval soundings. (See section 1.4.3.)

Adjusting digital soundings for the effects of wave action on the vessel (heave) or, if uncompensated wave action is excessive, serving as the primary record.

Reconciling erroneous soundings caused by kelp beds, fish, or unaccountable strays.

Pertinent information shall be annotated accurately and neatly on the graphic records during the course of the survey for use by the hydrographer and others in the later verification and use of the survey data. (See 4.8.) This information shall include:

1. Dates, times, vessel, and survey and sheet numbers.
2. Sounding apparatus.
3. Weather and sea conditions.
4. Calibrations and operational checks.
5. Position marks and numbers.
6. Brief notes defining the beginnings and endings of lines, turns of the vessel, and changes in speed while sounding.
7. Other descriptive information relating to or confirming more detailed notes in the survey record that pertain to detached positions for aids to navigation, obstructions, and for references to other significant features passed on sounding lines.
8. A definitive statement as to whether undulations on the graphic record were caused by wave action on the vessel.

Every record shall be thoroughly, carefully, and conscientiously scanned and checked by experienced field personnel to ensure completeness and accuracy of all field data. A mere cursory inspection of peaks and deeps is not sufficient. (See 4.8.5 and 4.9.8.)

Many of the problems experienced during the processing of hydrographic data can be traced to improper calibration and operation of the sounding equipment or to incorrect interpretation of the graphic depth record. Knowledgeable interpretation of indications on the graphic records can lead to the detection and correction of faulty data. During the scanning process, the hydrographer should be able to interpret and reconcile most spurious traces caused by stray returns, side echoes, fish, and grass. (See 4.9.8.2.) The actual bottom trace on the graphic record shall be scanned and interpreted to the best of the hydrographer's capability. The graphic record is the key source for indications of the presence of shoals that may have been missed by the regular sounding line system. Variations in initial or other applicable corrections shall be applied as necessary to correct the observed soundings to true water depths.

Under favorable sounding conditions, the graphic depth record should agree with digital or manually recorded depths to within ± 0.5 ft or ± 0.2 fm (except on steep slopes). Because electronic depth digitizers; are programed to record soundings at fixed intervals only and cannot distinguish wave action from undulations in the bottom, adjustments must frequently be made to the recorded digital soundings. Additional soundings must be scaled from the analog depth record to depict the bottom configuration adequately. (See 4.9.8.1.)

Rigid specifications cannot be defined for acceptable differences between digital depths and depths scaled from a graphic record. Close agreement, however, is essential as depths are scaled from the graphic record to supplement the digital data. The hydrographer must continually exercise sound judgment as acceptable differences vary with the depth of the water, the relative importance of the area, and the irregularity of the bottom. (See 4.9.8.1.)

Where size permits, graphic depth records and raw sounding data printouts shall be folded in 10-in (25-cm) lengths and forwarded to the appropriate Marine Center in letter size accordian folders with the other survey records. Data for each sounding day shall be filed in a separate section and labeled, using tabs to show the first and last position numbers, Julian date, and the name and identification number of the sounding vessel.

1.5.4. Reduction of Soundings

Recorded soundings on hydrographic surveys shall be corrected for any departure from true depths attributable to the method of sounding or to a fault in the measuring apparatus and for the elevation of the tide or water level above or below the chart datum (tidal or stage correction). Corrections shall be applied in the same unit in which the soundings have been recorded. Fractions of correction units are entered in the records as decimals.

Required corrections to soundings include any or all of the following:

Corrections for erroneously scaled values.
Heave error (wave effects).
Transducer draft.
Settlement and squat (or lift).
Velocity of sound through water.
Reduction to datums of reference.

Compensation for the following errors, if present, in the graphic depth recording equipment:

Variation of the initial from the adopted index, speed, and radius of rotation of the recording stylus arm.

Corrections for phase errors between scale settings, misalignment of recording paper, and other instrumental errors caused by variations in signal strength and time lags in the circuitry.

Periodic measurements of temperature and salinity shall be made to compute velocity corrections to echo soundings (4.9.5) except in areas where satisfactory bar checks can be obtained down to at least 75% of the range of depths sounded. If oceanographic data are used to determine velocity corrections for soundings, at least one temperature and salinity cast should be taken each month in an area representative of the deepest waters surveyed. The specific frequency for observing velocity data is a matter of judgment and is dependent upon the complexity of variations in the area. Special instructions for velocity corrections will be issued for surveys in areas requiring unusual methods, such as those conducted in the Gulf Stream.

1.5.4.1. DATUMS OF REFERENCE. The daturns of reference adopted for the reduction of soundings on hydrographic surveys and for depths on charts published by the National Ocean Survey are:

1. For the Atlantic Ocean and Caribbean areas, mean low water (MLW). See figure B- 1.

2. For the Gulf of Mexico, Gulf Coast Low Water Datum (GCLWD). See figure B-1. (For datum limits see chart 11462.)

3. For the Pacific Ocean, mean lower low water (MLLW). See figure B-2.

4. For the Great Lakes and connecting channels, low water datum (LWD). See figure B-3.

5. For most other larger navigable rivers and lakes, special datums. In such cases, the project instructions will specify the datum of reference.

1.5.4.2. TIDE OR WATER LEVELS OBSERVATIONS. If there is no tide or water level gage located in or near the project area that can serve as a control station, an automatic tide or water level recording gage shall be installed at a central point and operated during the entire period of the survey. Secondary tide and water level stations may also be required at other sites throughout the survey area. Sites for the gages to be used for the datum determination. and corrections to soundings will be designated in the project instructions. The number and distribution of stations depend on the character of the area and the anticipated changes in the times and ranges of tides and water level fluctuations.

If it is impractical or impossible to install tide or water level gages at the designated sites, the chief of party shall initiate a proposal for alternate locations. Major changes in gage locations must be approved at National Ocean Survey Headquarters unless stated otherwise in the project instructions.

Instructions for installation, maintenance, and removal of tide and water level gages are contained in appendix A and in U.S. Coast and Geodetic Survey (1965a) *Publication* 30-1, "Manual of Tide Observations." Unless stated otherwise in the project instructions, continuous observations at each secondary station shall be continued for a minimum period of 30 days to permit a datum determination of sufficient accuracy. If necessary, the hourly heights of the tide or water levels required for reduction of soundings shall be tabulated prior to sending the records to Headquarters. (See 4.9.3.) However, tide and water level records from automatic digital recording (ADR) gages generally are not tabulated in the field unless the data are required for resolving discrepancies. Knowledge of the binary code and format of the ADR gage punched paper tapes (A.8.1.2) is necessary to extract these data. Verified hourly heights [Greenwich Mean Time (GMT)] for control and secondary stations will be furnished by Headquarters on request.

The time meridian used shall be clearly marked on each tide or water level record. When the observations at any station are terminated, a notation of the hour and date of discontinuance shall be entered on the last record removed from the gage. The location of each gage shall be shown on the hydrographic sheets. (See 4.9.3.)

1.5.5. Depth Units

The depth unit for hydrographic surveys in the Great Lakes, the Atlantic Ocean, the Gulf of Mexico, and bodies of water tributary thereto is integral feet. Offshore areas that lie entirely beyond the limits of charts where the depth unit is feet are surveyed and charted in fathoms. In certain areas such as the coast of New England where echo sounders are operated on the fathom scale for most of the survey, the field sheets may be plotted in fathoms, but the smooth sheet shall be plotted in feet unless other units are designated in the project instructions.

The depth unit of hydrographic surveys in the Pacific Ocean and bodies of water tributary thereto shall be fathoms; but when the major part of the survey is within the limits of a chart with depths in feet, the smooth sheet shall be plotted in feet.

Although the recorded depths may change from one unit to another within the area of a survey, all measurements shall be corrected and reduced to the unit to be plotted on the smooth sheet. Only one unit of depth shall be used on any hydrographic sheet.

Regardless of the methods used for determining depths during a survey, soundings shall be recorded in whole numbers or to the nearest decimal part (4.5.7.1) and in accordance with the following rules:

1. Echo soundings for a hydrographic survey that will be plotted in feet shall be recorded in feet and decimals unless the methods in rules 2 and 3 are employed.

2. When depth recorders are used that can readily be switched to record feet or fathoms in areas of irregular bottom, the first phase in feet shall be used to its maximum depth limit. Where numerous changes in phase would be required on the foot scale, fathoms shall be used for greater depths.

3. Depth recorders that cannot be switched quickly from feet to fathoms shall be operated on the foot scale to the maximum extent practical in those areas which will be charted in feet. In areas where depths exceed the limit of the foot scale or if the submarine features are very irregular, the instrument may be operated on the fathom scale.

4. All depths measured by echo sounders for a hydrographic survey that will be smooth plotted in fathoms shall be recorded in fathoms and decimals except for rule 5.

5. The project instructions may specify that shoal water soundings be obtained in feet and tenths for surveys that will be smooth plotted in fathoms.

6. Lead-line soundings that are interspersed with echo soundings shall be recorded in the same unit as the echo soundings.

1.5.6. Field Sheet Soundings

Soundings should be plotted on the field sheet in black ink as the survey progresses. Sounding numerals shall be of uniform size and clearly legible. (See 4.5.7.2.) Position and sounding numbers shall be plotted at a density and intensity to permit adequate photographic reproduction of the field sheet. Least depths over shoals are inked in slightly larger and heavier numerals. A note and leader may be used to emphasize an important feature. Rock symbols must not be obliterated by soundings or other symbols.

Copies of the field sheet are often used to revise and update nautical charts before smooth sheets of the survey are completed. It is critical, therefore, that soundings and other hydrographic data on the field sheets be clearly shown and easily interpreted.

1.5.7. Depth Contours

These shall be drawn by the hydrographer on the field sheet in pencil as the work progresses. A careful study of both the soundings and closely spaced contours will disclose:

Areas where additional hydrographic development is needed to delineate the bottom configuration adequately.

Where errors have been made or where there are discrepancies that require further investigation.

Whether or not the survey in an area has been properly controlled and soundings have been plotted correctly.

The adequacy of junctions with adjacent surveys or between those areas of a survey controlled or sounded by different methods.

No single requirement for the spacing of depth contours can be prescribed that will apply to all types of terrain. (See 4.5.7.3 and 4.5.7.4.) The contour lines must be spaced at an interval to depict the submarine relief as completely and accurately as possible and to permit the hydrographer to visually inspect every sounding shown on the sheet. A good general rule is that the depth contour on field sheets should be drawn, if practical, at the following intervals:

1. At l-fm intervals to 20 fm.
2. At 5-fm intervals between 20 and 50 fm.
3. At 10-fm intervals between 50 and 100 fm.
4. At 25-fm intervals in depths greater than 100 fm.

Standard depth contours required on smooth sheets are drawn on the field sheet in the colors prescribed for smooth sheets prior to submitting the survey for smooth sheet processing. (See 4.5.7.4.) Supplemental contour lines shall be shown to emphasize relief as necessary.

In those areas where the bottom is relatively flat and featureless, nonstandard depth contours are shown at a spacing of 3 to 4 cm at the scale of the survey.

1.6. OTHER SURVEY REQUIREMENTS

1.6.1. Transfer of Topographic and Planimetric Detail

The shoreline and alongshore detail shall be carefully transferred from the shoreline manuscripts to the field sheets. If shown on the manuscripts, the low water line will also be transferred to the sheets (except for surveys in the Great Lakes).

Shoreline shall be shown on hydrographic survey sheets in accordance with the following:

Great Lakes, the line formed by the intersection of the land with the water surface at the time of the survey.

Tidal waters, the line formed by the intersection of the land with the water surface at mean high water (MHW).

All other waters, as defined in the project instructions.

If the actual shoreline is obscured from the mariner by vegetation such as in marsh and swamp, the apparent shoreline is shown. The apparent shoreline is the intersection of the shoreline datum with the outer edge of vegetation.

The *low water line* shall be shown as follows:

Tidal waters of the Atlantic Ocean and Caribbean Sea, the line formed by the intersection of the land with the water surface at mean low water.

Tidal waters of the Gulf of Mexico, the line formed by the intersection of the land with the water surface at Gulf Coast Low Water Datum.

Tidal waters of the Pacific Ocean including Alaska, the line formed by the intersection of the land with the water surface at mean lower low water.

Great Lakes, the line formed by the intersection of the land with the water surface at the elevation of the low water datum. This line is generally not shown on surveys of the Great Lakes.

Rocks, limits of marine growth or foul areas, and similar detail lying seaward of the shoreline are shown in blue except that offshore islets and rocks with positions definitely established are shown in black ink. Shoreline manuscripts often delineate the approximate limits of shoals and channels. These limits are transferred to the field sheet and indicated by fine dashed blue lines. (See 4.2.7.)

After the transfer has been field verified, the shoreline and other details are inked in black with an unbroken line 0.4 mm wide. (See 1.6.2.)

1.6.2. Verification of Alongshore Detail

The hydrographer and field editor share the responsibility of verifying features seaward of the shoreline that are shown on photogrammetric manuscripts. [See "Provisional Photogrammetry Instructions for Field Edit Surveys" (National Ocean Survey 1974).] These details may include the existence, positions, and heights or depths of rocks, ledges and reefs, limits of foul areas, wrecks, and other similar objects. (See 4.5.8.) Questionable features below the water surface such as reef limits, rocks, pilings, and similar objects must be investigated thoroughly by the hydrographer.

Symbols inked in blue on the field sheet are re-inked in black when field verified. If the position of an offshore rock is changed by the hydrographer or if there is no rock at the position shown, appropriate notes must be made in the hydrographic records, on the field sheets, and on the field edit sheet. Failure to reconcile and explain differences between a shoreline manuscript and a hydrographic survey may cause errors, result in unnecessary delays and difficulties during verification, and in some cases require a field unit to return to the area to resolve a major discrepancy.

Changes to shoreline delineation, rock locations, or other details shown on photogrammetric manuscripts are made in red ink on the hydrographic field sheet with explanatory notes and references to revisory location data. Both hydrographer and field editor must be kept informed of all such changes to avoid discrepancies between the manuscripts and hydrographic sheets. (See "Provisional Photogrammetry Instructions for Field Edit Surveys.") A dashed red line is used to show an approximate or estimated shoreline on the field sheet. (See appendix B.)

Each isolated bare rock, rock awash, or other hazard seaward of the shoreline must be located by hydrographic or photogrammetric methods. Each such feature shall be described definitively on the field sheet. The height or depth of the feature with respect to the water surface and the date and time of the observation shall be recorded for subsequent reduction to the chart datum. Rocks of a group or of a rocky area that are important from a navigational standpoint also shall be located and their elevations determined. If predicted tides were used by the field editor for the determination of elevations, the hydrographer shall verify the elevation when observed tides are available.

Areas in which sounding operations cannot be conducted safely or in which individual features are too numerous to be located economically should be delimited by a surveyed line and appropriate descriptive notes entered on the field sheet and in the hydrographic records.

Close coordination of the activities of the hydrographer and field editor is essential throughout all phases of the survey. The chief of party shall review and evaluate all such data to ensure that errors of omission were not made and all discrepancies were resolved satisfactorily.

1.6.3. Bottom Characteristics

The character of the bottom shall be determined by sampling with corers, clamshell bottom grabbers, or similar grab samplers that produce a recognizable sample. Bottom descriptions are shown on nautical-charts for the mariner as a guide to the holding characteristics of a potential anchorage. The descriptions are also useful for fishermen in locating good fishing areas and in avoiding foul or rocky areas where equipment may be damaged or lost.

In anchorages, the distance between bottom samples should not exceed 5 cm at the scale of the survey. The distance between samples in other areas on inshore surveys should not exceed 6 cm. In depths less than 100 fm in offshore survey areas, the distance should not exceed 12 cm. For ocean surveys conducted between the 100- and 1,000-fm depth contours, the character of the bottom is determined at intervals of about 8 to 16 km. In greater depths, bottom samples are obtained at all oceanographic stations and at such other places as the project instructions may specify. In harbors and anchorages, enough information should be obtained to permit the delineation of the approximate limits of each type of bottom. (See 4.7.1.)

All bottom samples shall be classified, properly recorded, labeled, stored, and transmitted. (See 4.7.2.) The abbreviations shown in table B-7 in appendix B are used to record bottom characteristics.

Extensive bottom sampling is not required if the project area has been surveyed previously and the characteristics have been determined adequately. Sufficient samples, however, must be taken to verify that changes have not occurred or to indicate areas of change where additional sampling is necessary to describe the present characteristics adequately. Where the general trend of the newly surveyed depths has changed significantly since the prior survey, one should assume that the charted bottom characteristics are no longer accurate. In such areas, sampling should be conducted at the prescribed intervals.

1.6.4. Dangers to Navigation

All shoals, rocks, wrecks, and other dangers to navigation discovered during the course of a survey shall be reported immediately by radio, telegraph, or telephone to the commander of the nearest U.S. Coast Guard District and to the appropriate Marine Center. A copy of the message and a tracing from the field sheet or from a large-scale chart showing the exact location of the danger shall be sent to National Ocean Survey Headquarters for disposition and to ensure proper dissemination of information to the public. (See 5.9.)

1.6.5. Aids to Navigation

Locations of all floating and nonfloating aids to navigation shall be provided to the chart compiler to enable him to produce accurate nautical charts for safe navigation. The azimuths of all navigational ranges must also be accurately determined.

Responsibility for the determination of the positions of nonfloating aids to navigation and of the azimuths of navigational ranges is generally assigned to the field editor for inshore hydrographic surveys that include photogrammetric support. Positions of aids and range azimuths are normally determined as part of the photogrammetric mapping operations. [See Photogrammetry Instructions No. 64 and "Provisional Photogrammetry Instructions for Field Edit Surveys" (National Ocean Survey 1971*b* and 1974).]

The hydrographer is responsible for locating nonfloating aids and determining the azimuths of navigational ranges on projects conducted without photogrammetric support. In such cases, positions and azimuths shall be determined by conventional ground survey methods that meet the accuracy standards prescribed for Third-order, Class I horizontal control.

The hydrographer has the responsibility for describing the salient features of each floating aid and for determining its position and the depth of water in which it is located. (See 4.5.13.) The most accurate means of positional control available should be employed for this purpose, and check observations should be taken if practical. On visually controlled surveys, floating aids are located by three-point sextant fixes with one or more check angles or by theodolite intersection with a check cut. Sextant cuts alone shall not be used.

When a floating aid to navigation is off station, as shown on the largest scale chart of the area, the facts should be reported promptly to the commander of the nearest U.S. Coast Guard District. If the aid is off station to an extent that it constitutes a danger to navigation, the facts shall be reported immediately. Recommendations based on new hydrographic surveys for additional aids or for more desirable locations of existing aids are submitted to the U.S. Coast Guard in writing through the appropriate Marine Center as soon as practical; a copy or tracing of the field sheet shall accompany the report.

1.7. REPORTS AND RECORDS

1.7.1. Field Reports

Copies of reports listed in table 1-2 shall be submitted to the indicated addressee, through the appropriate Marine Center, as supporting documentation for hydrographic surveys and to meet other requirements of the National Ocean Survey Nautical Charting Program. The original of each report will be sent by the Marine Center to National Ocean Survey Headquarters for official archiving. (See chapter 5 for details on the required content and preparation of these reports.)

In addition to the reports listed in table 1-2, special reports shall be prepared on items or matters of unique interest or historical documentation. Topics for special reports include but are not limited to innovative operational procedures, trial equipment evaluation, and additional observations not generally associated with hydrographic surveying. (See section 5.12.)

1.7.2. Inspection of Field Sheets and Records

The chief of party shall inspect the field sheets, shoreline manuscripts, and records at regular intervals, daily if possible, to assure himself that all operations are in accordance with the requirements contained in applicable manuals and project instructions. When making his examinations, particular attention must be given to the adequacy and completeness of the survey with special emphasis on indications of shoals and dangers; determination of least depths over submerged rocks, shoals, bars, and wrecks; verification of charted features; and the development of navigable channels. He should ascertain that junctions with adjacent surveys are satisfactory and no unsurveyed gaps (holidays) remain in the area. (See 4.3.2.) Following this review, the chief of party shall indicate to the hydrographer and field editor where additional work is required and ensure that satisfactory methods and procedures are used.

After the survey is completed and prior to departure from the project area, the chief of party shall make a final inspection of all sheets. All questions of adequacy or completeness of the survey must be resolved before leaving the area. The field sheet should also be thoroughly examined for clarity.

1.7.3. Forwarding Field Sheets

Within 6 weeks of the termination of field operations, field sheets and data for surveys shall be forwarded to the appropriate Marine Center for processing. Surveys are then forwarded to NOS Headquarters for quality control evaluation and final acceptance. Ordinarily, field sheets need not be submitted to headquarters following a satisfactory evaluation; however, commanding officers and Marine Centers have an inherent responsibility to en-

TABLE 1.2 — *Field reports*

Schedule	Report title	Section	Addressee
Routine during operations	Monthly Ship Accomplishment Report	5.1	OA/C7
	Monthly Progress Sketch	5.1.1	OA/C351
	Monthly Survey Status Report	5.1	OA/C35x1
	Monthly Activities Report	5.1	OA/C3
As required during operations	Dangers to Navigation	5.9	OA/C322
	Photogrammetric Precompilation Field Report	5.2	OA/C34
As appropriate during or immediately following operations	Chart Inspection	5.10	OA/C322
	Visit to Authorized Chart Sales Agent	5.11	OA/C44
	Coast Pilot	5.8	OA/C324
	Landmarks and Nonfloating Aids to Navigation	5.5	OA/C322
	Tide and Water Level Station Report and Records	5.6	OA/C23
	Photographs	5.12	OA/C5131
	Geodetic	5.12	OA/Cl8x2
	Magnetics	5.12	OA/D62
	special	5.12	OA/C5131
Routine and as appropriate immediately following operations	Descriptive Report	5.3	OA/C353
	Geographic Names	5.7	OA/C3x5
	Field Edit	5.4	OA/C3415
Immediately after close of field season	Season's Report	5.1.	OA/C5131
	Season's Progress Sketch	5.1.2	OA/C5131

sure timely publication of unreported survey data that could affect the safety of marine navigation. If a Marine Center evaluation reveals such critical information, the survey or pertinent portion thereof shall be sent immediately to National Ocean Survey Headquarters with specific recommendations for chart application.

2. PLANS AND PREPARATIONS

2.1 HYDROGRAPHIC SURVEY PLANNING

Requirements for hydrographic surveys arise as the result of policy decisions, product user reports or requests, national defense needs, and other demands. The inception of a specific hydrographic survey project follows an evaluation of all known requirements and the establishment of priorities. Among the many objective and subjective factors that influence the establishment of priorities are national and agency goals, quantitative and qualitative measures of shipping and boating in an area, the adequacy of existing surveys in the area, and the rate of change of the submarine topography in the area.

Priorities are under constant review and are subject to change as a result of the dynamic characteristics of some of these factors.

At least once each year, schedules for hydrographic survey projects are prepared. Among the factors that influence project scheduling are the relative priorities, the resources available including time, and the predominant climatic conditions in the subject areas. After project schedules are approved, detailed project instructions are issued to field units through the appropriate Marine Center.

2.2 HYDROGRAPHIC PROJECT

The field operation of a survey party in a specified geographic area is defined as a project and is assigned a unique project designation.

Project designations include a four-character alphanumeric identification number which sequentially defines:

1. The general project area,
2. The type of survey or project task performed, and
3. The issue number of the project instructions.

The four-character code consists of a letter to identify the project area, a single digit number to identify the type of survey or task performed, and two digits to identify the order of issue (sequence) of the instructions.

The code letters for the specific geographic areas of National Ocean Survey operations are listed in table 2- 1, with these areas geographically defined in figures 2- 1 and 2-2.

The following code designations have been selected for the major survey or project tasks generally performed:

Task Code	Task
1	Basic Hydrographic Survey - Ship
2	Basic Hydrographic Survey - Field Party
3	Navigable Area Survey (NAS)
4	Chart Evaluation Survey (CES)
5	Ocean Dumping Operations (ODO)
6	Wire-Drag Survey (WDS)
7	Track Line Survey (TLS)
8	Tides and Currents Project (T&C)
9	Other

Each set of project instructions written will be assigned two digits beginning with "00" which shall identify the sequence of issue of those instructions. Once begun, this numbering system will be applied continuously through the digits "99" after which the sequence will revert to "00" and begin again. The issue numbers for a given project shall remain unchanged for the duration of a designated project within a given area.

Examples of project designations are:

OPR-X 115-PE-78, a basic hydrographic survey project assigned by National Ocean Survey Headquarters for a ship survey in Lake Huron to be conducted by the NOAA Ship *Peirce*, the project to be performed during calendar year 1978.

OPR-P820-AR-77, a tides and currents survey project assigned by Headquarters for a survey in Prince William Sound, Alaska, to be conducted by the NOAA Ship *McArthur*, the project to be performed during calendar year 1977.

Special projects are field examinations or surveys of very limited extent or scope and frequently require unique survey or data collection procedures. They characteristically are recognized and conducted with much less preparation time than is provided for general projects. Special projects are designated similarly to general projects with the exception of an initial "S" indicator added which precedes the normal four-character code. The issue numbers for special projects revert to "01" at the beginning of each calendar year.

Examples of special projects designations are:

S-L906-RA-77, a special project requiring LORAN-C comparisons assigned by the Marine Center or by Headquarters for a project off the California coast to be conducted by the NOAA Ship *Rainier,* the project to be performed during calendar year 1977.

S-C524-MI-78, a special project requiring operations at Deepwater Dumpsite 106 assigned by the Marine Center or by Headquarters for a project off the New Jersey coast to be conducted by the NOAA ship *Mt. Mitchell,* the project to be performed during calendar year 1978.

All correspondence, reports, and messages relating to the project shall be referenced to the project designation.

2.3 OFFICE PLANNING

2.3.1. Project Instructions

These instructions to supplement the general instructions in this and other manuals are prepared at National Ocean Survey Headquarters for each project. The details of the project instructions vary from specific to general depending on the nature, the locality, and the unique requirements of the survey. Draft copies. of project instructions shall be prepared at least 4 mo prior to sailing to permit revision comments by the appropriate Marine Center, the chief of party, and other interested organizational elements. Final instructions are usually issued 3 mo prior to the start of the project. Amendments or supplements shall be recommended in the interest of safety of personnel or property, for reasons of real economy, or for valid engineering reasons. Ordinarily, the project instructions for hydrographic surveys will be divided into discussions of some or all of the following subjects: general, control, photogrammetry or topography, hydrography, tides or water levels, currents, magnetics, oceanography or limnology, and miscellaneous.

Copies of charts of the project area will be furnished with the project instructions. Project limits, limits of prior surveys, and proposed current, magnetic, and oceanographic stations will be shown on these charts.

2.3.1.1. GENERAL INSTRUCTIONS. The general part of the instructions shall clearly and specifically state the classification and the purpose of the survey to provide the chief of party with all pertinent background information. Limits of the area to be surveyed shall be specified. General instructions will include a plan indicating the priorities of survey operations by areas, sheets, or activities, and the desired or required direction of progress. When two or more chiefs of party are assigned to operate in the same area on the same project, their respective areas of operation and authority shall be defined.

2.3.1.2. CONTROL INSTRUCTIONS. Copies of the latest geodetic control diagrams, lists of geographic positions, and descriptions of control stations will be furnished for the project area. A horizontal control index will also be included with the data. The project instructions will state whether new control surveys are necessary and, if so, will also specify junction requirements and the order of accuracy.

2.3.1.3. PHOTOGRAMMETRIC INSTRUCTIONS. The photogrammetric portion of the project instructions indicate:

The tentative schedule for the delivery of copies of the shoreline map manuscripts.

Areas where photo-hydro support data will be available.

Requirements for horizontal and vertical control identification.

Areas where field edit is necessary.

2.3.1.4. HYDROGRAPHIC INSTRUCTIONS. The instructions for hydrography will ordinarily specify:

Scales to be used for the survey. (The chief of party is authorized to use larger scales in small harbors as necessary.)

Maximum spacing of sounding lines that are referenced to certain areas or depths.

Guidance on bottom sample spacing.

Project limits and junctions to be made with other surveys.

Wire drag or sweeping investigations required.

Charted features that will require special investigation. (See 2.3.3.)

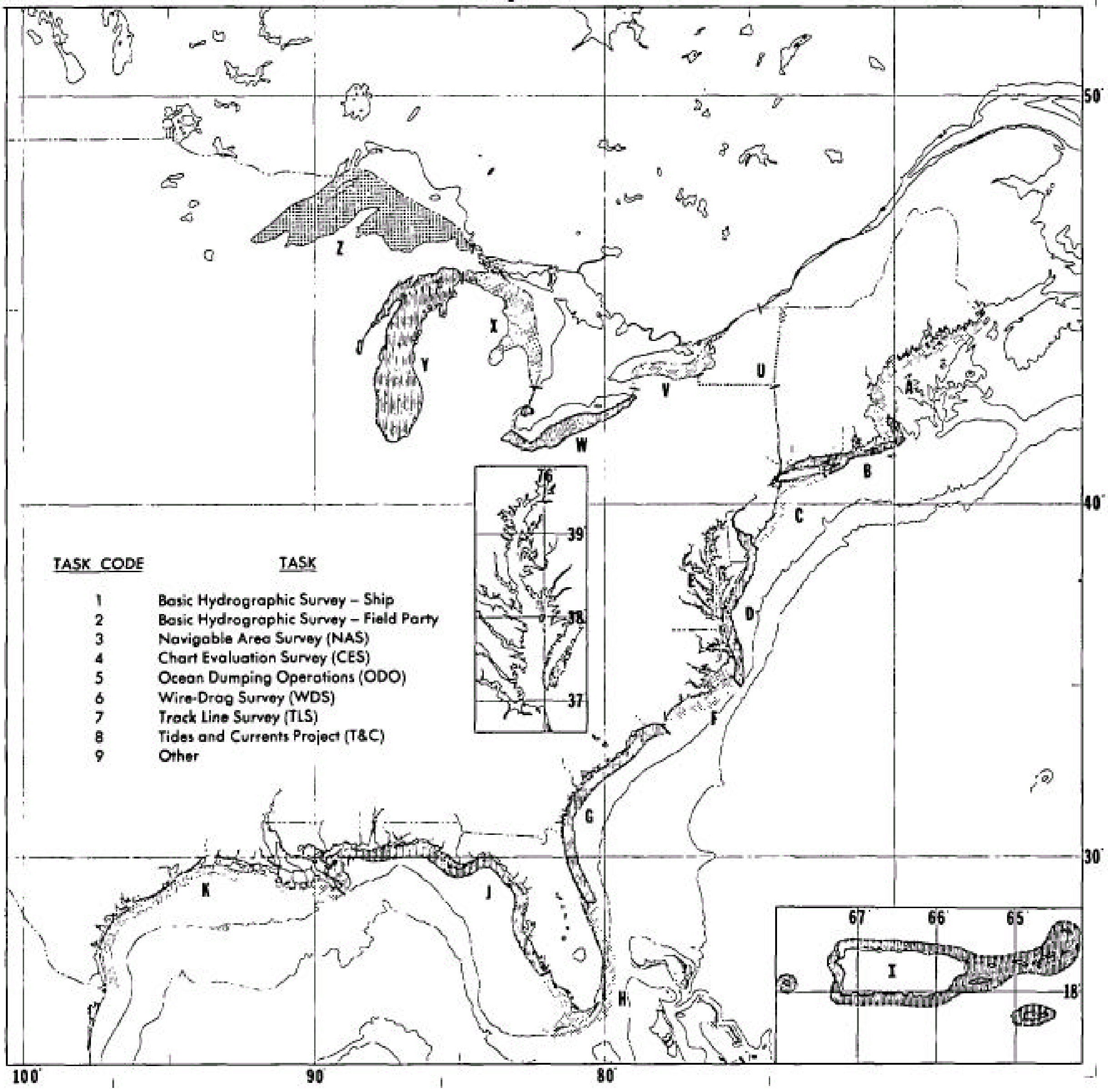
2.3.1.5. TIDES OR WATER LEVELS INSTRUCTIONS. This section of the instructions shall specify which tide or water level gages are to be used as reference control stations for the project. An inspection of an existing station and a report on the in-

TABLE 2-1. — *Area limit designations for project numbering*

PROJECT AREA CODE	GEOGRAPHIC AREA	
	GENERAL	SPECIFIC
A	Atlantic Coast	-Canadian Border to Cape Cod
B		-Cape Cod to Sandy Hook (includes Long Island Sound, New York Harbor, and the Hudson River below Troy)
C		-Sandy Hook to Cape May (includes south shore of Long Island)
D		-Cape May to Cape Hatteras (Includes Delaware Bay)
E		-Chesapeake Bay (includes all charted tributary waters)
F		-Cape Hatteras to Cape Fear
G		-Cape Fear to Cape Canaveral (Including St. Johns River)
H		-Cape Canaveral to Fort Meyers
I		-Puerto Rico and Virgin Islands
J	Gulf of Mexico	-Fort Myers to Mississippi River
K		-Mississippi River to Mexican Border
L	Pacific Coast	-Mexican Border to Point Reyes
M		-Point Reyes to Yaquina Head
N		-Yaquina Head to Canadian Border
O	Alaska	-Canadian Border to Point Manby
P		-Point Manby to Unimak Pass
Q		-Aleutian Islands
R		-Unimak Pass to Seward Peninsula
S		-Seward Peninsula to Canadian Border
T	Pacific Ocean	-Pacific Islands (Hawaii, Samoa, Guam, Marianas, etc.)
U	Inland Waters	-Lake Champlain & New York State Barge Canal System
V		-St. Lawrence River, Lake Ontario, & Lower Niagara River
W		-Upper Niagara River, Lake Erie, Detroit River, Lake St. Clair, & St. Clair River
X		-Lake Huron & St. Marys River
Y		-Lake Michigan, Lower Fox River, & Lake Winnebago
z		-Lake Superior, Lake of the Woods, Rainy Lake, & Minnesota-Ontario Border Lakes

spection may be required. Supplemental tide or water level gages are often required, and the instructions will specify the desired locations. (See 1.5.4.2.) All tide or water level stations shall be established in accordance with instructions contained in U.S. Coast and Geodetic Survey (1965a) *Publication No.* 30-1, "Manual of Tide Observations," except as amended by project instructions.

Figure 1



TASK CODE	TASK
1	Basic Hydrographic Survey – Ship
2	Basic Hydrographic Survey – Field Party
3	Navigable Area Survey (NAS)
4	Chart Evaluation Survey (CES)
5	Ocean Dumping Operations (ODO)
6	Wire-Drag Survey (WDS)
7	Track Line Survey (TLS)
8	Tides and Currents Project (T&C)
9	Other

Fic;URE 2-1-Geographic designations for project numbering for the Atlantic and Gulf of Mexico Coasts and the Great Lakes.

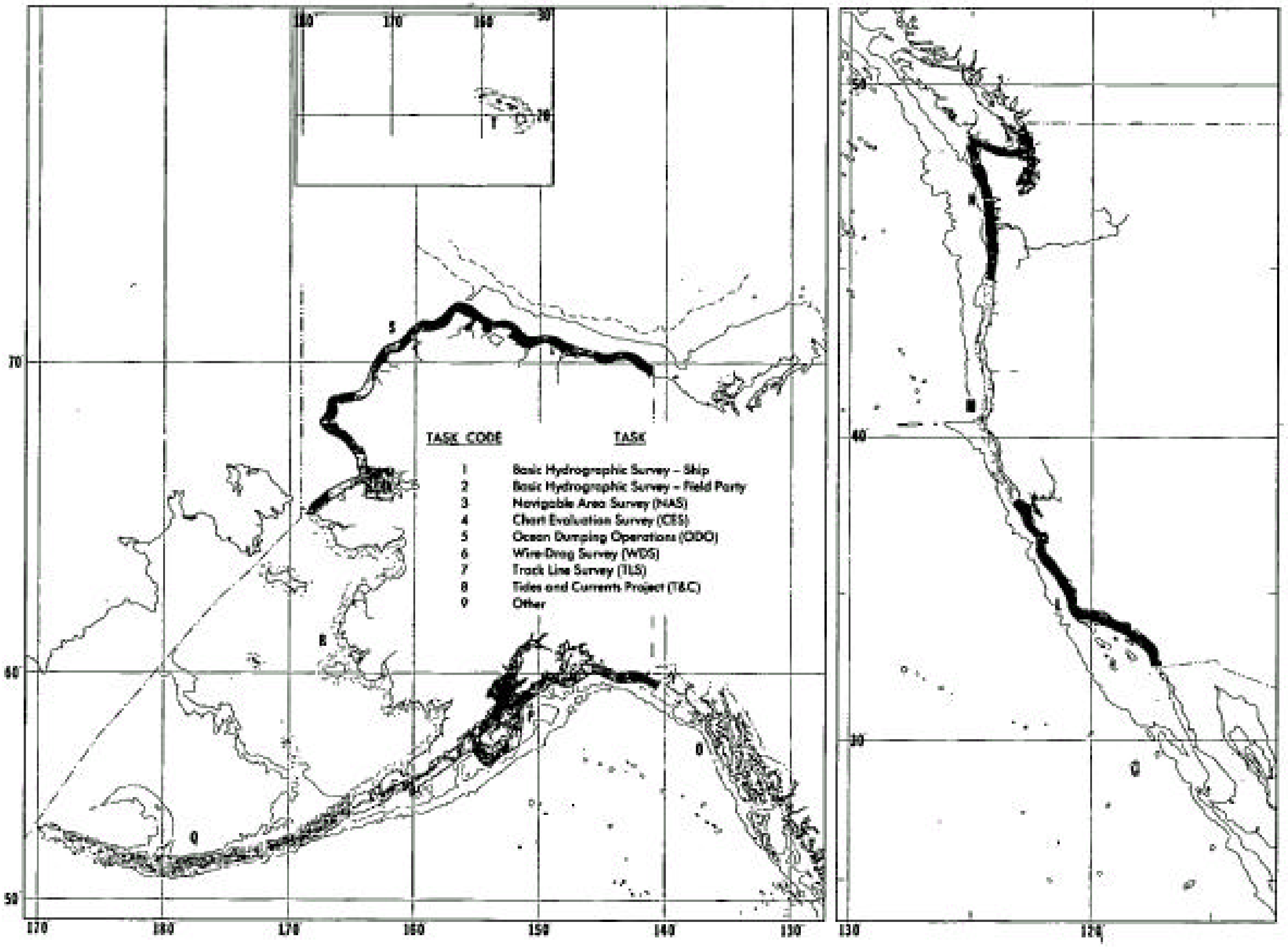


FIGURE 2-2 — Geographic designations for project numbering for the Pacific Coast, Alaska, and the Pacific Islands.

2.3.1.6. OCEANOGRAPHIC OR LIMNOLOGICAL INSTRUCTIONS. When oceanographic or limnological observations are to be made in addition to the standard temperature and salinity determinations required for correction of echo soundings, the project instructions will specify:

Station locations.

Types of observations to be made.

Frequency of observations.

Instruments to be used, sample analysis and preservation requirements, and disposition of the sample.

Observations shall be made in accordance with instructions contained in U.S. Naval Oceanographic Office (1968) *Publication* No. 607, "Instruction Manual for Obtaining Oceanographic Data," except as modified by the project instructions.

2.3.1.7. ANCILLARY TASKS. Hydrographic project instructions may require any or all of the following ancillary tasks: 1. bottom samples, 2. current observations, 3. water characteristics, 4. verification of floating aids, 5. call attention to special or unique requirements for Coast Pilot notes (5.8) and chart inspection reports (5. 10), and 6. magnetics for anomaly detection, in which case the project instructions will specify locations where magnetic observations are required. Magnetic observations shall be made in accordance with Office of Marine Surveys and Maps (1959) letter instructions File DO-T-3 (revised), "Directions for Using a Transit Magnetometer."

2.3.1.8. REPORTS. 1. Reports shall be submitted in accordance with chapter 5 of this manual, 2. project instructions will specify the scale of the chart to be used for the progress sketch to be submitted each month (5.11), 3. the instructions will state the requirement for submission of the monthly Activities Report.

2.3.1.9. MISCELLANEOUS. The miscellaneous section of the project instructions will cover any requirements for 1. public affairs, 2. dump sites, 3. drill rig location, 4. Loran-C chart verification, 5. clearance for research in foreign waters, 6. notification of project operations to U.S. Coast Guard for inclusion in Notice to Mariners, and 7. support data which may include copies of prior surveys, presurvey review, chart blowups, and fixed and floating aids listing.

The Chief of Party shall acknowledge receipt of project instructions and amendments thereto in writing.

2.3.2. Data To Start Surveys

Copies of all prior survey data and other supporting information considered necessary to accomplish the survey project will be furnished to the hydrographic field party or vessel with the project instructions. These data will include:

Descriptions and geographic positions of recoverable horizontal control stations in the project area.

Copies of prior hydrographic and topographic surveys for comparison and junction purposes.

Reports on tide or water level stations previously established in the area, together with the descriptions and elevations of bench marks and the names and addresses of contract observers at primary stations.

Information on reported dangers to navigation.

Prints of the most recent aerial photography and copies of the shoreline manuscripts.

U.S. Geological Survey (U.S. Department of Interior, Washington, D.C.) topographic maps of the area.

Historical oceanographic data, if needed, to correct echo soundings.

2.3.3. Presurvey Review

A presurvey review shall be conducted at National Ocean Survey Headquarters in advance of each hydrographic survey project. Although the hydrographer will have copies of the latest large-scale charts and will be furnished copies of pertinent prior surveys, an office review of all survey records and chart information received from other sources is invaluable during all phases of hydrographic survey operations. The presurvey review is updated each year for continuing projects to provide the hydrographer with the most recent information.

Prior records, surveys, and the largest scale charts of the project area are carefully examined for critical soundings and unverified or questionable charted data. Specific items selected for examination during the survey are described and marked on nautical charts covering the project area. Copies of these charts are furnished to the hydrographic field party.

A brief report is placed as an inset on the first chart of a series. Accompanying charts contain, as insets, pertinent portions of the report. The report shall include a general statement on the extent of the review and the character of the area. Either a statement or legend shall be included to explain chart markings. Charted items requiring complete investigation shall be encircled and designated by a number or letter. The feature shall be described under the same number or letter in the report, unless a brief notation beside the circle can furnish adequate information. The description of the item should include all available information that may be of interest or assistance to the hydrographer. Each presurvey review shall be dated, inspected by the Chief, Requirements Branch, and approved by the Chief, Hydrographic Surveys Division. The original presurvey review is filed for use during the review of the new survey.

All fully circled items identified for investigation in the presurvey review shall, unless noted otherwise, be thoroughly examined during the field survey to prove or disprove their existence. Each item shall be mentioned specifically in the Descriptive Report that accompanies the survey. [See 5.3.4(K).] The hydrographer shall make a definite recommendation as to the disposition or existence of each item for charting.

Charted items and depths that have not been adequately developed during the prior survey may be enclosed by dashed circles. Such items are not numbered or lettered and do not require specific disposal or discussion in the Descriptive Report; they provide additional guidance to the hydrographer on features that require special attention during the field survey.

Information contained in the presurvey review is provided to ensure a more complete, definitive hydrographic survey. The review is neither intended to relieve the hydrographer of the responsibility to compare the results of the new survey with the features shown on the largest scale charts of the area or with prior surveys nor does it preclude the required development of shoals and indications of shoals discovered during the progress of the survey.

Field parties engaged in Chart Evaluation Surveys shall be furnished copies of nautical charts of the project area on which specific items selected for examination are marked. Copies of the source document(s) from which each item originated are also furnished. Each numbered item on a Chart Evaluation Survey is of critical importance and must be specifically investigated and disposed of by definite statements in the reports that accompany the survey.

2.4 HYDROGRAPHIC SHEET PLANNING

2.4.1. Sheet Layout

For complete coverage of the survey area, a smooth sheet layout shall be prepared prior to beginning the project. The number of sheets required and their orientation and coverage shall be delineated on a chart of appropriate scale — preferably on the largest scale chart covering the entire project area. A tracing of the layout at chart scale shall be sent to the Requirements Branch (C351) in NOS Headquarters for approval. Figure 2-3 is an example of a sheet layout.

Each smooth sheet should be laid out so it includes as large a water area as practical, allows the proper overlap with adjacent sheets and space for the sheet title, and provides room for plotting all necessary control stations. Handling and aging cause smooth sheets to crack or crumple along the edges; soundings or other data plotted too near the edge may become illegible. For this reason, the sheets should be laid out so that no data will be plotted closer than 8 cm (about 3 in) from the edge of any sheet. Smooth sheets containing small or detached areas of hydrography shall be avoided if possible. This can generally be accomplished by using subplans or insets. (See 2.4.2.)

Smooth sheets should be laid out so that the projection lines are approximately parallel to the edges of the sheet, with north toward the top. Skewed projections may be used when a nonskewed layout is extremely uneconomical or impractical. The use of skewed projections, however, will be the exception rather than the rule.

Hydrographic field sheets may be laid out in any convenient manner to suit the area being surveyed and the plotting equipment available. A final smooth sheet may be the composite of a group of field sheets, overlays, and insets. (See 1.2.2 and 4.2.1.) To maintain orderly survey records and simplify the data-processing tasks, the hydrography contained on any one field sheet or overlay should lie entirely within the limits of a single smooth sheet. It is usually convenient to adopt identical field sheet and smooth sheet layouts if the survey is to be manually plotted in the field.

A convenient method for making the sheet layouts is to construct, on tracing cloth or clear plastic, one or more models of each standard size sheet (1.2.4) according to the scale of the chart on which the layout is to be made. The models may then be shifted on the chart, giving major consideration to required overlap, until the best position for each sheet is determined. If the area is complex, it is frequently necessary to try various layouts of sheets before the most practical layout is found.

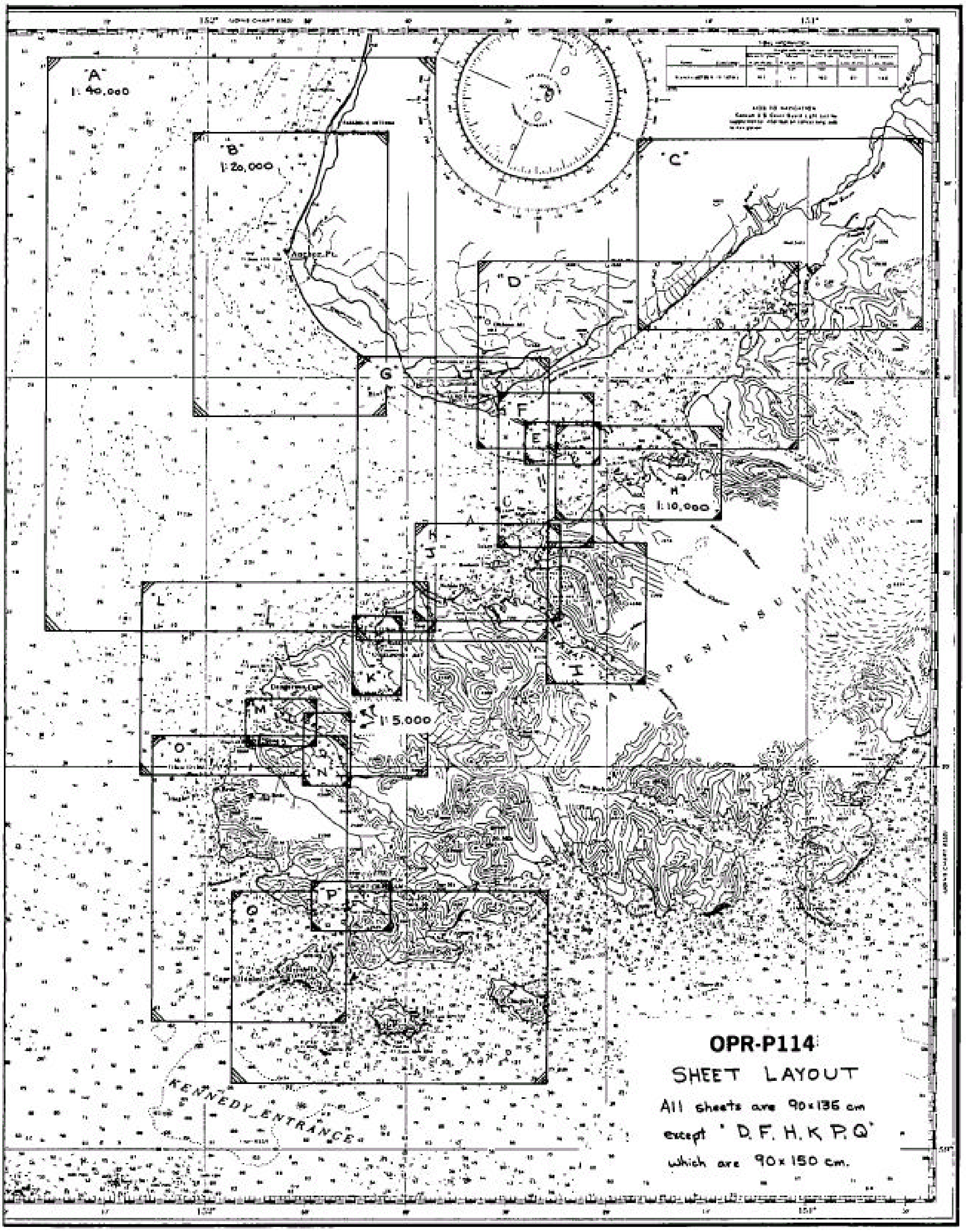


FIGURE 2.3 — Typical layout of hydrographic survey sheets showing reference letters, scales, and dimensions

The area of coverage on a sheet of given dimensions may be readily determined by

$$D = (d) \times (\text{sheet scale})^{-1} \times C$$

where

D = dimension of sheet (nmi),
d = dimension of sheet (cm),

and

C = 1/185,200, conversion factor (cm to nmi).

For example, to compute the area of coverage for a sheet with the dimensions of 90 by 135 cm at a survey scale of 1:20,000, use

$$D = 90 \times 20{,}000 \times (1/185{,}200) = 9.7 \text{ nmi}$$

and

$$D = 135 \times 20{,}000 \times (1/185{,}200) = 14.6 \text{ nmi.}$$

Although a 1:20,000 scale sheet 90 × 135 cm in size would cover an approximate area of 9.7 x 14.6 nmi, the hydrographer should be aware that, because of overlay constraints, hydrography must be limited to an area approximately 8.1 × 13.0 nmi.

2.4.2. Subplans and Insets

Hydrographic sheets containing small detached areas of a survey shall be avoided whenever possible. This problem can often be resolved by placing an inset on an unused portion of a sheet near the area. Insets should always be included on the sheet of comparable scale closest to the area. (See 7.2.4.)

Where a small harbor, anchorage, or other area will be surveyed at a larger scale than the remainder of the inshore coastal waters, it may frequently be included as a subplan on the sheet that includes the area. (See figure 7-7.) Soundings taken in small docks and along the sides and ends of small piers, which are located by reference distances to or along the piers, are most conveniently displayed by a subplan. Such plans need not contain a scale, but shall be adequately referenced to the proper area of the hydrographic sheet. Principal dimensions of piers and docks shall be shown.

Intensive development of certain features of limited extent is often better depicted by using overlays showing successive series of sounding lines. Where specific features have been surveyed in greater detail than can be shown satisfactorily At the scale of the survey, the soundings should be plotted on a subplan at a larger scale.

2.4.3. Sheet Numbers

2.4.3.1. FIELD NUMBERS. For a convenient reference while a survey is in progress, each hydrographic field sheet shall be assigned a field number. A permanent field number shall not be assigned to any sheet until hydrography is started on the sheet; the number shall not thereafter be changed although the survey is completed by another unit. Unused field sheets constructed by or for one survey unit and subsequently transferred to another unit prior to the start of survey operations shall be assigned a field number by the latter when the survey is started. The final two digits of the field number that represent the calendar year in which the survey was initiated are not changed if the survey extends into the following calendar year.

Field numbers shall be a dashed combination of letters (identifying the vessel or field party starting the survey) and numerals (defining the scale, the sequence, and the calendar year in which the survey was started). Sequence numbers assigned shall be consecutive for a specific scale throughout the calendar year regardless of changing project numbers. Composite overlays that will eventually make up an entire smooth sheet are assigned letter designations following the sequence number.

Examples are:

WH 2.5-IA-75 NOAA ship *Whiting* (WH) — scale 1:2,500 (2.5) — first sheet (1) in the series of that scale; first overlay or first in the sequence of plotter sheets (A) that will be grouped into a composite smooth sheet — survey started in 1975 (75).

DA 25 - 4B - 74 NOAA ship *Davidson* (DA) — scale 1:25,000 (25) — fourth sheet (4) at that scale; second overlay or plotter sheet (B) of a composite smooth sheet — 1974 (74).

HFP 10 - 6 -75 Hydrographic Field Party (HFP) — scale 1:10,000 (10) — sixth sheet at that scale (6) — 1975 (75).

2.4.3.2. REGISTRY NUMBERS. When field work has begun on a hydrographic survey, the Chief of Party shall promptly request the assignment of a registry number from the Hydrographic Surveys Division (OA/C353), through the Director of the appropriate Marine Center. The project number, the field number, and the locality of the survey must be included in the request. Requested registry numbers will be forwarded from the Hydrographic Surveys Division to the field unit through the Marine Center. All field survey records, reports, and correspondence associated with that sheet shall be referenced by the registry number.

Sheets for field examinations shall be given registry numbers. The registration for a field examination shall be changed to an alpha-numeric format (e.g., FE-219 WD) from the previously used format (e.g., F.E. No. 2 1979 W.D.). Accordingly all future field examinations will be assigned a sequential registration number similar to the present practice for basic hydrographic ("H") surveys. The letters "WD" are added when applicable to indicate that the field investigation is a wire drag investigation. When referring to a field investigation, the year of the field work is usually added to the registry number and is shown in the format FE-xxx (19xx) WD.

Requests for field examination registry numbers will be submitted to the Hydrographic Surveys Division, OA/C353, by the Marine Center at the time the Marine Center processing begins. (See 4.1.2 and 7.4)

2.4.4. Dog-Ears

The exact limits of a hydrographic sheet cannot always be planned accurately. Unexpected developments occasionally arise during the progress of a visually controlled manually plotted survey that make it desirable or necessary to use a control station which falls beyond the original limits of the sheet.

The preferred method for showing such stations is to plot them on a separate overlay that will accompany the hydrographic survey sheet. A less desirable but acceptable method is to add a small section of stable base drafting film to the field sheet and plot the station thereon. This addition is called a "dog-ear." (See 7.2.3.) If a dog-ear is needed on a field sheet, the sheet layout should be re-examined; and revisions should be made to eliminate the dog-ear from the smooth sheet.

2.5 OPERATIONS PLANNING

2.5.1. Project Study

The chief of party shall make a careful study of the project instructions and accompanying data to assure himself that all necessary data have been received. If omissions are discovered or the data forwarded are considered insufficient, he should request additional data that may be required from the appropriate Marine Center. He should also report immediately his recommendations for revisions to the instructions, request clarification on any parts of the instructions that are not clearly understood, and ask for more complete information which he believes necessary on any subject relative to the project.

2.5.2. Plan of Operation

The project instructions may call for work priorities in certain phases of the operations; accomplishment of this work must be planned in the order of precedence established. In the absence of priorities, the work should be planned to provide uniform and parallel progress of the various operations. To plan and carry out extensive combined operations effectively and systematically, one generally must plot on a chart of suitable scale the project limits, the limits of previously surveyed areas with which junctions must be made, all geodetic control stations in the area, and all other data that can be used in developing the plan. Operations shall be divided between the various units of the field party to attain maximum progress consistent with economy, safety, and maximum use of all available resources.

Any general plan of operations is subject to change as field work progresses. The Chief of Party shall alter the original plan as necessary and notify the Marine Center of significant deviations.

3. HORIZONTAL CONTROL AND SHORELINE SURVEYS

3.1 HORIZONTAL CONTROL

3.1.1. Basic Control

Hydrographic surveys shall be based on a reference system of geodetic control upon which the coordinates of the survey can be established in a systematic manner. Hydrographic surveys conducted by the National Ocean Survey are controlled by a coordinate system referenced to the National Geodetic Datum — currently the 1927 North American Datum (NAD— 1927) — unless specified otherwise in the project instructions. Surveys conducted in the Caribbean Sea, South Pacific, and in the waters of Alaska may be referenced to local datums. NOS geodetic control surveys are classified by order of accuracy for definition purposes. *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (Federal Geodetic Control Committee 1974) and *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (FGCC 1975) specify the details and criteria for the different orders.

Where existing geodetic control is inadequate for a hydrographic survey, the field party may be required to establish supplemental control as necessary. If needed, supplemental control shall be established with an accuracy not less than that prescribed for Third-order, Class I control. (See 1.3.1 and 3.1.2.) Basically, first- or second-order control surveys are the responsibility of the NOS National Geodetic Survey (NGS); hydrographic field parties are generally responsible for third-order surveys to establish needed supplemental control.

First- or second-order control surveys are usually not required for hydrography. Second-order accuracy surveys, however, may be assigned to hydrographic field units where additional main-scheme stations are urgently needed to supplement the National Geodetic Network or if a hiatus of 20 km exists between established geodetic control stations along the coastline. In this case, NGS shall assist in the preparation of the control survey specifications and instructions. Thus, unless second-order control is specified in the project instructions, Third-order, Class I surveys are generally acceptable to control hydrographic and shoreline surveys and to position aids to navigation, landmarks, theodolite intersection stations, and electronic control system antenna sites. (See 3.1.2 and 3.1.3.)

When supplemental control surveys are connected to the national network, field techniques specified for Second-order, Class 11 surveys should be used although Third-order, Class I positional accuracy may be acceptable.

3.1.1.1. SPACING OF MAIN SCHEME CONTROL STATIONS. These stations must be spaced at intervals sufficiently close to provide basic control for the project at hand. The use of photogrammetric and electronic methods for controlling hydrographic surveys has reduced the required density for main-scheme control; however, a certain minimum spacing should be established and maintained for future use. The required density of control depends on the scale of the survey, the configuration of the coastal area, and the requirements for photogrammetric mapping. Control stations are used in survey work by other engineers, public and private, so their density should be adequate to meet anticipated needs for control in the area. Generally, main-scheme stations should be established at intervals of 5 to 10 km along the coastline. See section 3.1.2 for supplemental control spacing requirements.

3.1.1.2. RECOVERY OF EXISTING STATIONS. A thorough search shall be conducted for all previously established horizontal control stations, reference marks, and azimuth marks in the vicinity of the shoreline throughout the project area. A report shall be made on NOAA form 75-82 (5-76) or 75-82A (4-78) to conform with the *Input Formats and Specifications for the National Geodetic Survey Data Base* for each station searched for, including lost and destroyed stations. A station shall not be reported as lost unless there is conclusive evidence to establish the fact beyond a reasonable doubt. Old descriptions must be verified in detail or corrected as necessary to conform with circumstances at the time of recovery. Damaged stations or reference marks should be repaired. All control stations shall be marked or re-marked and the disks stamped in accordance with *ESSA Technical Memorandum* C&GSTM-4, "Specifications for Horizontal Control Marks" (Baker 1968).

When new control surveys are connected to previously established control stations, positive recovery of the old stations must be verified by checking distances and directions to existing reference marks to ensure that none of the monuments have been moved. This check will ordinarily be considered adequate proof of recovery of a third-order station. Reference marks are required at all NOS-monumented third-order stations. More rigorous checking procedures are required when connecting higher order surveys to established control stations (e.g., reobserving original angles, remeasuring old lines, and connecting to more than one existing station). A listing of previous observations at anticipated control stations should be requested from the National Geodetic Survey prior to beginning the survey. If specific methods for connecting required first- or second-order control surveys are not included in the project instructions, refer to *U.S. Coast and Geodetic Survey Special Publication* No. 247 (Gossett 1959) for guidance.

Objects (e.g., flagpoles, chimneys, smokestacks, beacons, and signal towers) with previously determined positions shall not be used for control until they have been positively identified and their positions verified by an onsite inspection and local inquiry. A recovery note is required for these stations.

3.1.1.3. STATION MARKS AND DESCRIPTIONS. Each new main-scheme station shall be marked with a standard National Geodetic Survey disk and two standard reference mark disks — except that well-defined natural or cultural objects of substantial construction (e.g., lighthouses and water tanks) are generally located by intersection methods and are not marked with disks. Subsurface marks, set below the frostline or in bedrock, shall be established at first- and second-order main scheme stations where practical. Azimuth marks set at least 400 meters from the station are established at all control stations unless another station or at least two other objects such as lighthouses, tanks, church spires, or similar features are visible from the ground at the station. Instructions for naming and marking stations and for stamping the disks are contained in *U.S. Coast and Geodetic Survey Special Publication* No. 247 (Gossett 1959) and *ESSA Technical Memorandum* C&GSTM—4 (Baker 1968).

Each newly established control station shall be described on NOAA form 75-82 (5-76) or 75-82A (4 -78) and conform to the *Input Formats and Specifications for the National Geodetic Survey Data Base*. Descriptions must be clear, concise, and complete narratives. They should enable a person to proceed with certainty to the immediate vicinity of the mark and, by measured distances to permanent reference points, inform the searcher of the exact location of the station. Monumented stations of other organizations included in the control scheme should also be described on one of these NOAA forms.

Spires, tanks, and similar objects located by intersection are also described on either NOAA form 75-82 or 75-82A, following the same procedure as outlined above. An observer shall visit such stations and identify the objects by a descriptive name, the name of the property owner, the year of construction, and the type of construction. Lighthouses and other fixed aids are identified by the name as shown in the most recent edition of the U.S. Coast Guard (1976) *Light List.* If possible, the appropriate U.S. Coast Guard District, Aids to Navigation Branch, should be consulted for outdated entries in the *Light List.*

3.1.1.4. CONNECTIONS TO GEODETIC CONTROL ESTABLISHED BY OTHER ORGANIZATIONS. Independent schemes of horizontal control established in the project area by other organizations shall, when feasible, be connected to the National Horizontal Control Network so their positions may be reliably and accurately computed and adjusted on the appropriate datum (NAD-1927 in the contiguous United States and Alaska). Before establishing new control from independent schemes, two stations at the connection should be reobserved as a check. (See 3.1.1.2.) Federal, State, and local agencies should be contacted by the field party to ascertain what control exists in the project area and to obtain copies of descriptions and positions of marks and diagrams of the control schemes.

If practical, positions of stations established by other organizations should be determined instead of establishing new stations nearby, provided the station marks are in good condition and suitably located. Two standard reference marks should be established if none exist. Under no circumstances shall survey station monuments or disks established by other organizations be altered or amended. These marks must not be moved, replaced, or reset unless specified in the project instructions. When needed, such marks should be reinforced to prolong their existence but must not be disturbed or moved. The establishing agency must be notified prior to taking any action.

3.1.1.5. SECOND-ORDER TRAVERSE. When additional main scheme control stations are needed along the coastline, traverse methods are generally recommended over triangulation and trilateration. The ready availability of modem electronic distance measuring (EDM) equipment, the ease and speed with which distance observations can be made, and the use of digital computers for reducing data in the field greatly simplify the work. Requirements for Second-order, Class II traverse described in 3.1.1.5.1 and 3.1.1.5.2 are to be used as guidance to ensure that field survey data will meet specified accuracies. The information is intended to augment existing geodetic manuals.

3.1.1.5.1. *Second-order traverse distances.* Requirements for Electronic Distance Measurements (EDM) are given in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (FGCC 1974); *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (FGCC 1975); and the Technical Monograph CS-2, *Electronic Distance Measuring Instruments* (American Congress on Surveying and Mapping—ACSM 1971).

3.1.1.5.2. *Second-order directions and azimuths.* Direction and azimuth observations for second-order traverses shall be made using theodolites capable of measuring horizontal angles to the nearest second of arc. Each observation shall be recorded to the nearest second.

Horizontal traverse angles may be observed by either one of these methods:

1. Measure the traverse angle not less than eight times using different positions of the horizontal circle. See *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* for proper circle settings.

2. Measure the traverse angle four times, and the explement of the traverse angle four times using different horizontal circle positions when there is only one object for a foresight and one object for a backsight.

Angles differing by more than 5 s from the mean of the set shall be reobserved before leaving the station. When method 2 is used, the sum of the means of the traverse angle and its explement must agree to within ± 5 s of 360° 00' 00".

Recording and computing procedures specified in US. *Coast and Geodetic Survey Special Publication* No. 247 (Gossett 1959), pages 111-112 and 131-137, are to be followed.

Astronomical azimuth stations are selected in accordance with various factors such as the length of the traverse and the availability of existing azimuth control in the vicinity of the initial and terminal stations. The use of azimuth marks and intersection stations at starting and ending stations for azimuth control is not adequate for second order control surveys. We therefore recommend that Polaris observations be made at these stations if an acceptable azimuth check cannot be obtained. The number of intermediate stations between azimuth stations should rarely exceed 15 and should never exceed 20. Observational procedures and checks shall conform to the specifications for first-order azimuths (outlined in chapter 4 of Special Publication No. 247) except that only 12 positions and 1 night's observations are required. If Polaris observations are needed for azimuth control, at least two main-scheme stations shall be observed. Stride levels must be used on theodolites when observing Polaris for azimuth because of the increased sensitivity of their bubbles.

All second-order field data shall be submitted to the National Geodetic Survey for processing, verification, adjustment, and inclusion in the National Horizontal Control Network. Data shall be assembled and submitted in accordance with the *Input Formats and Specifications for the National Geodetic Survey Data Base.*

3.1.2. Supplemental Control

Third-order, Class I accuracies are generally the minimum acceptable criteria for the location of electronic position control antenna sites, calibration signals (1.3.1), and theodolite intersection stations (1.3.3.1.2), and for supplemental traverses or control schemes from which hydrographic signals will be subsequently located using ground survey methods. Since it is frequently impractical to include every hydrographic signal in a third-order traverse or control scheme, less accurate traverses may be run to locate the signals. (See 3.1.3.) The principles discussed throughout 3.1.1 for basic control are also generally applicable to third-order horizontal control surveys. Exceptions to these principles are outlined in 3.1.2.2.

Traverse methods are generally recommended over triangulation and trilateration; however, depending on the nature of the terrain, available existing control, and number of new stations required, other methods may prove advantageous (e.g., a theodolite three-point fix with a check angle or a two-point fix from both ends of a measured base line). Regardless of the method used, there must be a geometric check on the positions of new stations. Side check and closure criteria are listed in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (Federal Geodetic Control Committee 1974).

3.1.2.1. THIRD-ORDER CONTROL SPECIFICATIONS. Procedures and instrumentation discussed in the following sections should produce control surveys with an anticipated minimum accuracy of one part in 10,000 (Third-order, Class I).

3.1.2.1.1. *Station spacing.* Traverse stations should be spaced at 2- to 5-km intervals, but closer spacing is permitted where the terrain limits the line of sight. The minimum length of line should seldom be less than 200 m for lines measured by electro-optical instruments and 500 m for lines measured by microwave instruments. "Wing" or "spur" stations not included in the regular traverse must have a position check. One of the methods described in 3.1.2.1.8 should be used.

For use during future surveys, supplemental control stations of third-order accuracy established for the current survey shall be monumented (3.1.2.1.2) and described at intervals of 4 to 8 km along the traverse line. Stations located for electronic control antenna sites and calibration purposes and for theodolite intersection instrument stations shall also be monumented and described if practical and if there is reasonable assurance of permanence for future recovery.

3.1.2.1.2. *Monumentation.* Marks of the type described in US. *Coast and Geodetic Survey Special Publication* No. 247, "Manual of Geodetic Triangulation" (Gossett 1959) are considered the most suitable for monumenting recoverable stations; but rod or pipe marks with a disk attached on occasion may be utilized where there is reasonable assurance of permanency. The primary consideration is to establish a described monument that surveyors can find and use in the future. National Ocean Survey disks shall be used on all third-order stations.

Station names, if used, are assigned as described in the *Input Formats and Specifications for the National Geodetic Survey Data Base;* however, traverse parties may use different designations such as TRAV-1, PT1, and Al. In any case, the year of establishment of the mark must be indicated on the disk. Mark designators must be selected carefully to avoid duplicate names. (This can be accomplished by the yearly sequential numbering of traverse points.)

3.1.2.1.3. *Instruments.* Distance-measuring instruments include light wave, infrared, or microwave (e.g., Geodimeter, Model 76; Hewlitt-Packard, Model 3800; and Tellurometer, Model MRA- 101).

Angulation instruments include a 1-s or better theodolite (e.g., Wild T-2 and Kern DKM-2).

Leveling instruments include geodetic levels and rods (e.g., Zeiss Ni2 Level and a Kern Rod). A good quality Philadelphia or Chicago Rod may be used if a geodetic rod is not available.

3.1.2.1.4. *Connections to existing control.* Third-order traverses for hydrographic survey control shall begin and end at existing first- or second-order stations. If excessive traverse distances over difficult terrain would be required to tie into a control survey of higher accuracy, connections to existing third-order stations are acceptable as a less desirable alternative.

Check-angle observations and distance measurements shall be made to existing reference and azimuth marks to provide assurance that the stations have not been disturbed.

Observed angles between azimuth marks, intersection stations, and other established geodetic control at the starting and ending stations of the traverse are acceptable for azimuth control, provided the observed angle checks with the angle previously observed or computed from published data to within 10 s of arc. If the observed angle does not check within 10 s, two sets of Polaris azimuths (3.1.2.1.6) shall be observed for azimuth control.

3.1.2.1.5. *Horizontal angles.* A minimum of four positions of the circle must be observed with a 1-s theodolite on 1 day. Angles at any position of the circle that differ by more than 5 s from the mean of the set shall be reobserved before leaving the station. The procedures and circle settings are given on pages 111-112, 131-137, and 141-144 of *U.S. Coast and Geodetic Survey Special Publication* No. 247 (Gossett 1959) and in *Technical Monograph* No. CS-1 (Dracup 1973).

3.1.2.1.6. *Azimuths and astronomic observations.* Astronomic azimuth stations are selected in accordance with various factors such as the availability of existing azimuth control in the vicinity of the initial and terminal stations and the length of the traverse. In addition to the requirements in 3.1.2.1.4, the number of intermediate traverse stations between azimuth stations should rarely exceed 20 and never exceed 25. Polaris, when necessary, shall be observed according to the procedures for Third-order, Class I azimuths as specified in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (Federal Geodetic Control Committee 1974). Two main-scheme stations are observed in conjunction with the Polaris observations. Most 1-s theodolites require a stride level on the telescope when performing these observations because of the increased bubble sensitivity.

Azimuth closures between astronomic azimuths should not exceed 3.0 s per angle station or $10^{n}\sqrt{N}$, whichever is smaller (N = number of angle points), following the most direct route of the traverse. For example, if there are nine angle stations between azimuths, the closure should not exceed *27 s.*

If the traverse forms a closed loop, the position closure will generally be at least *1:20,000* between control stations. Angle closures should not exceed *3 s* per angle station or $10^{n}\sqrt{N}$, whichever is smaller.

3.1.2.1.7. *Distance measurements.* Accuracy for distance measurement shall conform with the standards cited in *Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (Federal Geodetic Control Committee *1974).* EDM procedures for Third-order, Class I surveys are given in *Specifications to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys* (FGCC 1975). Meteorological observations required for determining atmospheric corrections are identical to those specified for second-order distance measurements. (See *3.1.1-5. 1 -)*

Third-order measurements with microwave instruments consist of a full set of coarse and fine readings, as recommended by the manufacturer, taken at both the master and remote units. Measurements should be completed at one end of the line before beginning observations at the other. The difference between the two measurements should seldom be greater than 10 cm and never exceed *15* cm before applying the meteorological corrections.

A complete set of measurements using an electro-optical device that does not have a direct readout consists of observations for internal calibration for each of the three operating frequencies. The spread between the measurements as determined for each of the three frequencies should not exceed 6 cm. When two complete measurements are made, the spread between the two should seldom exceed *3* cm. When using EDM instruments that have direct readout, one measurement from each end of the line is made, or two readings are taken from one end of the line with the prism or instrument offset on the second reading. Measurements with a Ranger 11, III, or AGA Model *76* Geodimeter should consist of five measurements read in meters and five read in feet. The means of each set should agree to within 15 mm.

Slope correction procedures and reduction of distances to sea level are as specified for second-order measurements in *3.1 1.5. 1.*

3.1.2.1.8. *Design of traverse.* This is determined by the terrain and the purpose for which the work is being performed. In general, it is designed as shown in figure *3-1* and follows the surveyor's line of least resistance.

To reduce the number of angle stations through which the azimuth is carried, observe directions directly between points *A* and C, A and A or B and D when possible. Also, distance measurements over these lines provide internal checks on the observational data.

Third order control stations not included in the main traverse scheme, or "spur points," that may be established for a variety of purposes must include a geometric check on the position of the point to avoid blunders. Depending upon the terrain and conditions of point intervisibilities, several methods or variations thereof are suggested to provide a position check.

1. (See figure 3-1.) *ABCD* is the main traverse route. Spur point *B' is* to be located. In addition to measuring the main traverse distances and angles:

a. Locate point *B'* by observing the angle *ABB'* and measuring the distance *BB'.*

b. Observe the angle *B'AB* at traverse point *A.*

c. The angle at *B' is* concluded by subtracting the sum of the angles at points *A* and *B* from 180*.

d. Distance *BB' is* computed using the law of sines,

$$(BB') = \frac{(AB)\sin A,}{\sin B'}$$

and compared with the measured distance.

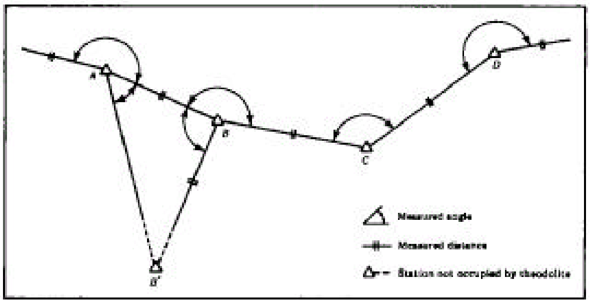


FIGURE 3-1. — Traverse with a checked spur point.

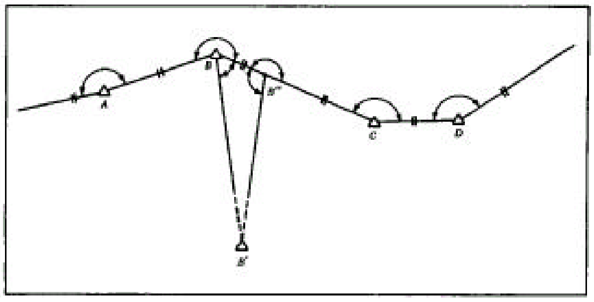


FIGURE 3-2. — Short base method for checking a traverse spur point.

The check observation could have been made from traverse point *C* or from other points along the traverse as well.

2. (See figure 3–2.) As before, *ABCD is* the main traverse route; spur point *B'* is to be located. The following method will provide a check on the location of point *B'* that is determined initially by azimuth and distance from traverse point *B;*

a. Establish auxiliary point *B''* on line with *B* and *C*. Distance *BB''* should be about one-tenth of distance *BB'* but not less than one-twentieth.

b. Distance *BB''* is measured using EDM equipment or a steel tape.

c. Angle *BB'' B'* is observed at auxiliary point *B''*.

d. The angle at *B'* is concluded by subtracting the sum of the angles at points *B* and *B''* from 180º.

e. Distance *BB'* is computed using the law of sines and compared with the measured distance as a check.

3. (See figure 3—3.) The following method is useful where spur point *B'* can be seen only from traverse station *B:*

a. Locate spur point by observing angle *ABB'* and measuring distance *BB'*.

b. Establish auxiliary point *B''* on line with *B* and *B'*.

c. Observe angles *B'' AB* and *AB'' B'*.

d. Measure the distance *BB'' using* EDM equipment or standardized steel tape.

e. Compute distance *AB''* using the law of sines. In this computation,

angle *BB'' A* = 180º — angle *AB'' B'*.

f. The position of spur point *B'* as computed by distance and azimuth from traverse point *B* is checked by the independent traverse route *A* to *B''* to *B'*. Distance *B''B'* is determined by subtracting *BB''* from *BB'*.

4. (See figure 3-4.) In this method:

a. Locate spur point *B'* by azimuth and distance from traverse station *B*.

b. Wing point *B''* is established within easy taping distance from *B'* and is intervisible with both *B* and *B'*.

c. Measure distance *B'B''*.

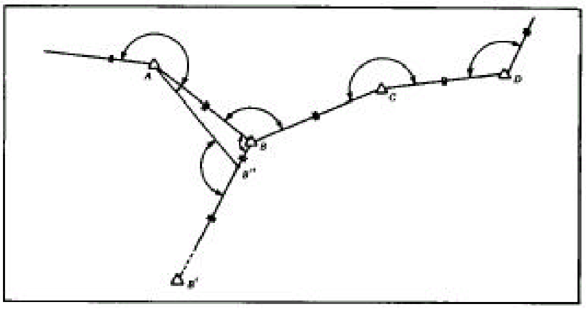


FIGURE 3-3. — Offset method for checking a traverse spur point

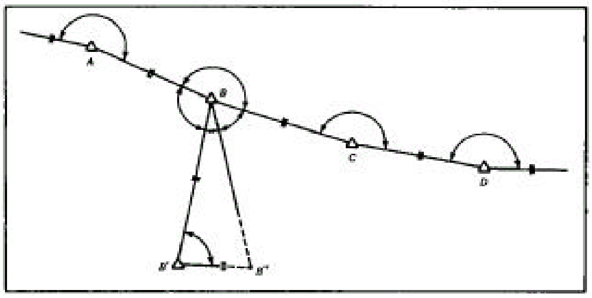


FIGURE 3-4. — Wing point method for checking a traverse spur point

d. While occupying traverse station B, observe all four angles as shown.

e. Observe angle *B"B'B.*

f. Compute distance *BB"* using the law of sines. Angle *BB"B'* is concluded for use in the computation.

g. The position of spur point *B'* is checked through the independent traverse route *B* to B" to *B'*.

There are many acceptable variations of the four methods described that can be used to provide adequate geometric checks on spur point positions.

3.1.2.1.9. *Third-order control data submission.* Data shall be assembled in the following groups for submission to the National Geodetic Survey:

1. Data submitted to the National Geodetic Survey shall be assembled and transmitted in accordance with the procedures outlined in *Input Formats and Specifications for the National Geodetic Survey Data Base.*

2. A progress sketch showing the work accomplished is prepared for the project. This sketch should be similar to the example shown on page 192 of *U.S. Coast and Geodetic Survey Special Publication* No. 247 (Gossett 1959). Also refer to NGS Action Memo 77-03.

3. A project report describing the work performed is also prepared (page 190 of Special Publication No. 247).

4. Data shall be forwarded to the Director, National Geodetic Survey (Attention: OA/C13 x4). All records are to be submitted in at least two mailings so surveys can be reconstructed from the records that would be available if a package were lost. Record books should be forwarded separately from computer-readable data.

3.1.2.2. EXCEPTIONS. If locations of electronic positioning system antenna sites, calibration signals, or theodolite intersection stations require only one- or two-leg traverses over distances of less than 2 km, the following exceptions to third-order procedures are permitted:

Beginning azimuths may be determined by solar observations, using a Roelofs or equivalent solar prism on the theodolite for increased pointing accuracy. See "Photogrammetric Instruction No. 19, Sun Azimuths — Observations and Computations," Revision 2, June 15, 1973, for detailed instructions on observing and computing solar azimuths (National Ocean Survey 1971 *a*). Solar azimuth errors should rarely exceed 1 min of arc.

When horizontal directions are observed, only one position of the circle, consisting of one direct pointing and one reverse pointing of the telescope, is required; the explement of the angle is also observed, and the sum of the two shall check to within 20 s of 360° 00' 00".

Distances may be taped or measured using EDM equipment. If taped, the distance is to be measured in both directions. Tape corrections may be ignored except for the slope correction. If measured with EDM equipment, an on-line offset may be used to check the original measurement.

3.1.3. Hydrographic Control Stations

3.1.3.1. TRAVERSE METHODS. Stations for signals to be used for visually controlled hydrography may be located by less than third-order traverse methods from existing basic or supplemental control stations provided that the following limitations and procedures are observed:

1. Lengths of open or closed traverses where less than third-order methods are used shall not exceed 2 km in total length.

2. Traverses containing more than two lines shall be closed to within one part in 2,500.

3. These traverses should start from stations of Third-order, Class II accuracy or better (3.1.3.2).

4. Initial azimuths may be determined by any method accurate to within 1 min of arc.

5. Traverse angles and their explements may be measured by one pointing of the instrument and shall "close the horizon" to within 1 min of arc.

6. Traverse distances may be measured using a nonstandardized steel tape. Stadia distances should not be used except as a last resort when terrain conditions prevent the use of a steel tape; distances should be kept short (less than 500 m). If stadia distances are used, readings on each of the three wires shall be observed and recorded.

7. Slope corrections to taped distances need not be applied unless the slope exceeds 2°

8. Hydrographic stations used for visual control need not be permanently monumented.

9. Position computations and field notes for work of less than third-order accuracy shall be retained by the field party for inclusion with the transmitted hydrographic records upon completion

of the survey. They are not to be transmitted to the National Geodetic Survey.

3.1.3.2. PHOTOGRAMMETRIC METHODS. Hydrographic control stations for visual fixes may be located by photogrammetric techniques (photo-hydro stations) when traverse or other ground survey methods are impractical or uneconomical. Two basic methods of field photogrammetric locations are approved:

1. Location by transfer. Field identified photo-hydro stations can be transferred directly from a photograph to a transparent stable-base copy of a shoreline manuscript by holding to adjacent shoreline pass points shown on the photographs and on the manuscript.

2. Location by radial intersection. Stations can be positioned graphically on shoreline manuscripts using classical radial intersection techniques for points with images on at least two overlapping photographs.

Once points have been plotted on shoreline manuscripts, coordinates may be scaled (to the nearest 0.25 mm) for use as input for machine drafting of horizontal control and automated hydrographic operations. For manually plotted field surveys, points may be transferred directly to field sheets provided the field sheets and the shoreline manuscripts are of equal scale. Photo-hydro stations shall be established in accordance with "Photogrammetric Instruction No. 22, Field Recovery and Identification of Horizontal and Vertical Control," Revision 2, September 30, 1965, and "Photogrammetric Instruction No. 45, Photogrammetric Location of Hydrographic Control in the Field," Revision 1, March 15, 1954 (National Ocean Survey 1971*a*).

Locations of photo-hydro stations should be pricked on the photographs as accurately as possible. Prick marks shall be within 0.2 mm of the correct positions of the points. Errors in the final geographic positions of photo-hydro stations should not exceed 0.5 mm at the scale of the shoreline manuscript. Field photogrammetric methods shall not be used to locate stations for hydrographic surveys conducted at scales larger than those of the shoreline manuscripts without the prior approval of the Director, NOS.

Traverses starting and closing on photogrammetrically located points may be used to determine positions of photo-hydro stations — provided that the traverse length is less than 2 km and the closure does not exceed 0.25 mm at the scale of the hydrographic survey. If photogrammetrically lorated points are used for azimuth control on these traverses, at least two points must be sighted on to provide a check.

Three sextant cuts from points located on the photogrammetric plot may be observed to locate hydrographic stations. Such cuts must intersect at geometrically strong angles. Azimuth orientation stations used for these cuts should be as distant as possible. Identification of photogrammetric points must be positive.

Identifiable points (such as images of small rocks, corners of buildings or piers, and forks of streams) may be selected as hydrographic signals. When using forks of streams or other similar objects subject to change, extreme caution must be exercised because of the time difference in the current field work and date of photography. Supplemental stations may be located by reference measurements to such details if the objects themselves are not convenient for use as signals or as sites for the erection of signals. (See Photogrammetric Instruction No. 22.)

3.1.3.3. SEXTANT METHODS. Hydrographic stations are occasionally located by sextant angles to supplement existing control. Such stations may be located by observing strong three-point fixes at the stations. (See 4.4.2.) Check angles to a fourth station should always be measured. Navigation sextants should be used and, wherever possible, angles observed to control stations of third-order accuracy or better and read to the nearest 0.5 min. New station positions may be computed and machine plotted or be plotted on the field sheet using a three-arm protractor.

Stations may also be located by fixing the position of the survey vessel by strong three-point sextant fixes with sextant cuts to the station simultaneously observed. At least three well-intersected cuts are required. The vessel should be stationary when cuts are observed. Accurate results cannot be obtained from vessels making way.

Hydrographic stations may also be located by sextant cuts observed from three or more existing control stations. Angles are measured from other control stations to the new stations. The cuts should be observed from stations as close as possible to the new station and provide strong geometric intersections. Stations located by sextant angles shall not be used for locating other stations.

3.1.3.4. PLANE TABLE METHODS. Although largely replaced by photogrammetric techniques, the plane table remains a useful instrument in hydrographic surveying. Graphic triangulation or traverse occasionally provides the most economically effective means for locating hydrographic control stations.

When hydrographic surveys of small but important areas are required at scales larger than those of available shoreline manuscripts, plane table methods may be used to locate additional control. If points located by analytical aerotriangulation are not available to control the graphic survey, stations meeting Third-order, Class II accuracy should be used.

Methods and instruments used shall be such that 90% of the control stations located will be within 0.5 mm of their correct geographic position at the scale of the plane table sheet. No stations shall be in error by more than 0.8 mm. Closing errors of plane table traverses prior to adjustment shall not exceed 0.25 mm/km at the scale of the sheet; and in no case shall the total closing error (which shall be adjusted) exceed 2.0 mm.

Suitably grained, dimensionally stable polyester drafting film is preferred for plotting plane table surveys. Each graphic control sheet is designated by a capital letter assigned in alphabetical order during the season. A new series, beginning with the letter "A," shall be started each season. The complete designation is composed of the first two letters of the name of the survey vessel, or other assigned designator, followed by the capital letter, followed by the last two digits of the calendar year. For example, SU -C-75 is the third plane table sheet started by the NOAA ship *Surveyor* in 1975. The location of each sheet shall be shown on the sheet layout sketch for the project.

Graphic control surveys are retained throughout the processes of hydrographic verification, final inspection, and final quality control analysis, after which they may be destroyed if there is no further use for them. Registry numbers are never assigned to these sheets.

A separate Descriptive Report shall be written to accompany each plane table sheet. Descriptive Reports supplement the plane table surveys with information that cannot be conveniently shown on the sheets. Reports must be written concisely and arranged in a systematic manner with each class of information shown under separate paragraphs with underlined headings. Reports shall not be prepared in the form of a letter or a journal of the field work. Headings shall be "Descriptive Report to Accompany Sheet ____." Dates of project instructions under which the work was done must be stated.

Particular attention must be given in Descriptive Reports to the following subjects:

General description of the area, reason(s) for making a plane table survey, field and registry numbers of hydrographic survey sheets affected, and dates when the work was done.

Horizontal control used.

Closing errors of traverses and method of adjustment.

Descriptions of any work that is incomplete, unreliable, or requires further examination.

Inadequate junctions with adjacent surveys (include recommendations for adjusting discrepancies).

3.1.3.5. UNCONVENTIONAL METHODS. Waterways with sufficient depth of water and considered important enough to be useful for navigation require accurate detailed surveys. Control in such waterways must be established by conventional methods. In sloughs through swamps and mangrove, in minor tributaries, or in extensive shallow and featureless areas, less accurate methods can be tolerated. Hydrographic control for these areas may be established by sextant triangulation.

Traverses may be run using sextant angles to carry azimuths; distances may be measured by stadia or by sextant angles using a subtense bar or its equivalent. Hydrographers should exercise ingenuity and devise methods appropriate to the instruments available — such as range finders, floating wire marked at intervals, or other fast convenient methods. Traverse angles measured by sextant are read to the nearest 0.5 min. Traverses and graphic triangulation should be plotted on a low-distortion polyester base drafting film, preferably at a scale at least twice as large as that of the hydrographic sheet. Such traverses should seldom be more than 2 km in length, and the end of the traverse should be firmly positioned by connecting to established control of a higher order (if possible without undue expense).

On certain Chart Evaluation, reconnaissance, or some special project surveys, the project instructions may specify that landmarks and other details shown on the nautical chart of the area may be used to control sounding lines. In such cases, the identity and position of each object shall be positively verified before use.

3.1.4. Hydrographic Signals

3.1.4. 1. NATURAL AND CULTURAL OBJECTS. The term "signal" designates any type of object, either natural or cultural, observed when measuring angles to locate the positions of a survey vessel engaged in sounding. Signals may be of any size or shape although very large signals should not be used when the observer is close. The measurement of angles is simplified when the objects at the control station are sufficiently conspicuous to be seen easily. For this reason and for economy and durability, natural objects such as prominent boulders, pinnacle rocks, waterfalls, and lone trees, and cultural objects (such as beacons, lighthouses, tanks, spires, and building gables) are used wherever available.

3.1.4.2. CONSTRUCTION OF SIGNALS. Those appropriately located and erected are a critical prelude to successful sextant-con trolled launch hydrography. The ease and smoothness with which a hydrographic team operates depends to a large extent on the competency of the signal building party. When stations are located and spaced so that strong fixes are available at any point in the area and they are varied in size, shape, or color for quick and unmistakable identification, the control will be adequate for hydrographic surveying.

Stations established along sandy beaches or low flat areas should, if possible, be placed well back from the beach to provide strong sextant fixes with fewer signals (4.4.2.1.3). In all cases, signals must be set far enough back from the beach to avoid destruction by wave action during storms.

Where signals are built along an irregular coast, one signal should always be located at the head of each inlet or small cove. Stations high above the water on cliffs or bluffs are generally unsatisfactory for fixes close inshore. (See 4.4.2. L) Signals must be designed to remain intact until the hydrographic survey is completed,

Care must be taken to vary the sizes, shapes, heights, and colors of the signals to prevent confusion. The largest and most conspicuous signals should be sited where they can be readily seen from the offshore areas and where strong fixes will result. Smaller signals should be appropriately spaced for inshore work. If the signals can be built well back from the shoreline, a spacing of approximately one signal every kilometer may be sufficient. Where the beach is irregular and signals must be built close to the shoreline, spacings of 300 to 400 m are usually necessary.

3.1.4.2.1. *Signal building materials.* Where natural objects are not available, the most satisfactory and economical signals are constructed using white cloth or a highly reflective, plasticized cloth. (See figure 3-5.)

The nature of the project and the availability of electronic positioning equipment for offshore hydrography are the determining factors that influence the siting of large signals. There should be enough large signals to provide control for calibration of electronic positioning systems at maximum distances. For inshore launch work signals constructed of white, red, or orange cloth in various shapes should be used. Cross banners, flags on stumps, or cloth wrapped on trees or poles are generally adequate. Black cloth may show well if the signal is skylined. Most signals made of cloth show best if they reflect sunlight and will reflect most efficiently if set at an angle of about 30* from the vertical. While plain red or orange cloth can be seen only from relatively

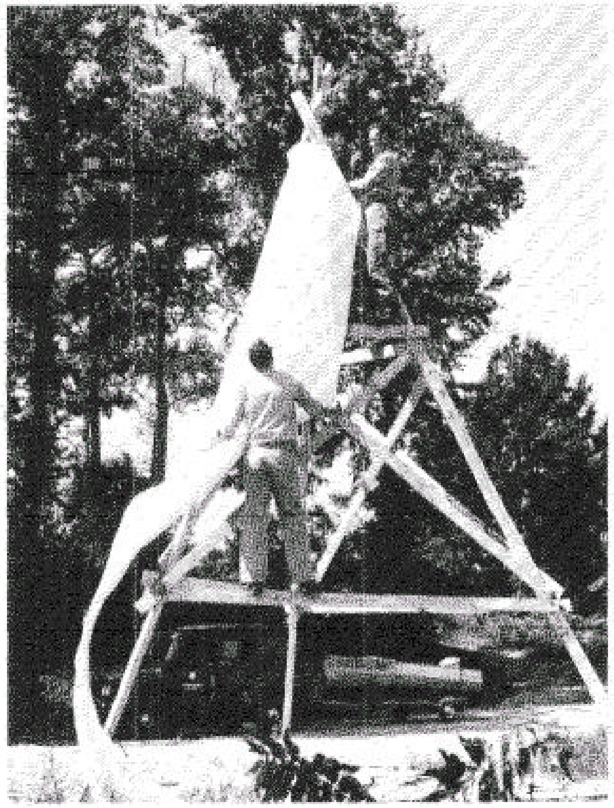


FIGURE 3 - 5. Construction of a large tripod signal

short distances, it can provide the break in a series of white signals necessary to reduce confusion.

When cloth is used to construct a signal, it should be securely fastened with a stapling gun or lacks. U-shaped slits should be cut in the material to relieve wind pressure and discourage vandalism.

3.1.4.2.2. *Entrance on private property.* If stations and signals are to be established on private property, permission must be obtained from the owner. Property shall not be damaged or defaced under any circumstances without the owner's prior written consent. When surveys are made along the shores of publicly owned areas (such as parks, national or state forests, or reservations), the superintendent or other official in charge should be contacted. This requirement is particularly important if vegetation must be cleared.

Nothing arouses the ire of a property owner so much as unauthorized entrance on his property. When the nature of the work is explained, there will seldom be any difficulty in obtaining permission to establish a station. Use of NOAA Form 76-163, "Form Letter to Property Owners," is often helpful in gaining access to private property. If crops, shrubs, or trees must be damaged, a written agreement must be secured beforehand that states the amount of damages, if any, to be paid. When the survey has been completed, all signals shall be removed and the site restored to its original condition unless other arrangements have been made with the owners or officials.

3.2 SHORELINE SURVEYS

3.2.1. Coastal Mapping

Topographic features shown on nautical charts are of nearly equal importance to the water depths. The mariner operating in sight of land is guided primarily by aids to navigation and prominent landmarks on shore. An adequate nautical chart must include some planimetric detail along the adjacent coast, especially salient landmarks visible from a ship at sea and features identifiable on radar. (See 1.6.5 and 4.5.13.)

Topographic surveys made to support hydrography include determinations of the positions of natural and cultural features in a locality and their delineation on a plane surface. These surveys were made solely by plane table methods until about 1930. Aerial photogrammetry is now used almost exclusively to supply topography and related data in support of hydrography and nautical charting. Plane table and topographic survey methods are still used occasionally to locate control for hydrography and to map changes in shoreline and alongshore features that do not warrant supplemental photography. (See 3.1.3.4 and 3.2.5.)

The basic coastal mapping products are shoreline maps, coastal zone maps, and photogrammetric bathymetry. Related data, consisting of landmarks for nautical charts, nonfloating aids to navigation, rocks, ledges, reefs, and other obstructions and dangers to navigation, are included on these maps. The shoreline (1.6.1) is shown to within 0.5 mm of its true position at the scale of the survey.

Shoreline maps portray complete interior planimetry in an area approximately parallel to the shoreline and generally not more than 1 km wide; these areas include both shoreline and alongshore features. Modern photogrammetric techniques and conventional cartographic practices are used to produce these maps. They are not published and are usually compiled at the scale of the hydrographic survey. Under certain conditions, specially prepared photographs and copies of the map manuscripts on stable base plastic material are furnished for locating signals for visually controlled hydrography. If photogrammetric positioning of hydrographic stations is anticipated, photograph centers and shoreline pass points are shown on the manuscript copies sent to the field.

Coastal zone maps are prepared to support nautical charting and to provide data for the determination of coastal boundaries and other information essential for coastal zone management. Orthophoto mosaics made from black-and-white rectified prints of natural color or from false color photographs are used for these maps in flat terrain, usually at 1:10,000 scale. The shoreline, low water line (1.6. 1), alongshore features, nonfloating aids to navigation, and landmarks for charts are compiled. There is no representation of relief. Photographic images of objects on these maps are in true horizontal position in relation to each other and to the reference datum. Objects therefore may be selected for use as hydrographic signals their images identified on aerial photographs, transferred to stable base copies of the manuscript, and the positions of the objects scaled. Good judgment must be exercised in selecting objects and identifying their images to avoid introduction of errors because of relief displacement.

Photogrammetric bathymetry (photobathymetry), consisting of depth contours and discrete depths, may be compiled from color aerial photography in selected waters wherever turbidity and bottom reflectance characteristics permit sufficient penetration. These operations are restricted to areas of relatively shallow water where the bottom is light colored and the water is nearly free of suspended particulates. Photobathymetry can often relieve the hydrographer of the need to sound in hazardous surf zones. Unfortunately, water in the surf zone may carry a heavy load of suspended sediments making photobathymetry impractical. Bathymetry is usually compiled and furnished at the scale of the contemporary hydrographic survey. Field edit and field completion of the compiled sheets are assigned to the hydrographic unit by the project instructions.

Photogrammetric office procedures are described in *U.S. Coast and Geodetic Survey Special Publication No.* 249, "Topographic Manual, Part II" (Swanson 1949). The series of Photogrammetric Instructions (National Ocean Survey 1971*a*) are continually being revised, modernized, and expanded to complement the outdated manual (now out of print but being revised). Complete instructions and specifications for topographic surveying by plane table methods are contained in U.S. *Coast and Geodetic Survey Special Publication* No. 144, "Topographic Manual" (Swainson 1928). Special Publication No. 144, an earlier version of 249, is also out of print but will be replaced by one or more of the series of Photogrammetric Instructions. Except as modified in project instructions, the requirements stated in the Photogrammetric Instructions shall be adhered to by hydrographic parties engaged in topographic surveys.

Shoreline and mean low water (MLW) or mean lower low water (MLLW) lines (1.6.1) on coastal zone maps are generally compiled using tide-coordinated black-and-white infrared aerial photography. These maps are prepared only for areas where adequate tidal datums are available on the date of photography. The same technique is used to delineate these lines on shoreline maps when planning leadtime is sufficient. The primary objective is to provide data for nautical charting and marine boundary determination; a secondary benefit is the elimination of the need for the hydrographer to develop the low water line. Complete and accurate location of the low water line is desirable because it may be used as the base line from which offshore boundaries are determined. Hydrographic survey instructions shall state additional requirements for field verification if there is any doubt as to the validity of the compiled line.

Photogrammetric operations are scheduled as priorities permit to provide support data that conform with planned operating schedules of the assigned hydrographic unit. In general, aerial photography must be obtained at least 1 and preferably 2 yr before hydrographic operations are scheduled in areas such as Alaska, Hawaii, or other locations where transportation facilities and accessibility are limited or difficult. Field support is essential in most of these areas, starting with the recovery or the establishment of horizontal control and the placement of targets on stations required for aerotriangulation in advance of photography. Hydrographic survey instructions may provide for one or more tide observers for tide-coordinated infrared photography. Field operations for areas in the Great Lakes, along the Atlantic Ocean and Gulf of Mexico Coasts, and in the Caribbean Sea will normally be performed by photogrammetric field parties, usually with 12-mo leadtime.

3.2.2. Control Identification

Horizontal control requirements for aerotriangulation are furnished to field units on a specially prepared copy of the large-scale diagram for the mapping job involved. "Photogrammetric Instruction No. 22, Field Recovery and Identification of Horizontal and Vertical Control," Revision 2, dated September 30, 1965 (National Ocean Survey 1971*a*) contains specifications and procedures for marking control for aerotriangulation prior to aerial photography (premarking) and for photo-identification of the control after photography is available. Analog and analytical aerotriangulation techniques developed by the National Ocean Survey have replaced the graphic methods previously in use. The new techniques permit increased production, require less basic control, and yield more accurate results; however, control for aerotriangulation by either technique, particularly by the latter method, must be identified with greater accuracy and reliability. Current practice is to place targets, prior to aerial photography, on all horizontal control stations for aerotriangulation. Photo-identification of aerotriangulation control in the field after photography using the substitute station method has consistently proven to be less than satisfactory with small-scale photographs and has largely been discontinued for coastal mapping operations. The substitute station method may still be used occasionally to identify a station where the target image is not identifiable.

3.2.3. Photogrammetric Support Data

When needed, photogrammetric support data will be furnished for all hydrographic surveys except for surveys of areas completely offshore and for surveys not classified as basic. These data include prints of aerial photographs, copies of photogrammetric map manuscripts, flight line photo center index, and other related support data.

If necessary, the hydrographer is furnished contact color prints of compilation photography, usually at 1:30,000 scale for 1:10,000 scale mapping and at 1:40,000 or 1:60,000 scale for 1:20,000 scale mapping. Color ratio prints of selected exposures will be supplied when special circumstances make their use desirable. Prints of tide-coordinated infrared photographs are not furnished routinely because special experience and knowledge of the spectral response of the emulsion and filter combination are needed for accurate interpretation.

Specially prepared support data will be furnished for all assignments where photogrammetric locations of hydrographic stations are anticipated. In some selected areas, specially prepared support data will be provided to establish the positions of electronic positioning system antenna sites. The data normally will consist of:

1. Contact prints of compilation photography (1 set).
2. Specially prepared ratio prints at specific ratios to the shoreline manuscript scale (1 set).
3. Positive copies of each shoreline manuscript on a dimensionally stable plastic base (2 each).
4. Diazo (ozalid) prints of each shoreline manuscript, to be used as specified in the project instructions (2 each).
5. "Notes to the Hydrographer," which are similar to the field edit questions prepared by the compiler to provide information to supplement the accompanying manuscript (1 set).

Shoreline pass points and photo centers are located and shown on the manuscripts, then transferred and inked on specially prepared prints by the compiler to aid in the location of hydrographic stations and signals in the field. [See "Photogrammetric Instruction No. 45, Revision 1, Photogrammetric Location of Hydrographic Control in the Field," dated March 15, 1954 (National Ocean Survey 1971*a*).] Such prints are normally made on dimensionally stable plastic base film either in black and white or in color; they are costly to prepare and should never be subjected to rough handling or exposed to excessive dampness.

Manuscript copies (support data 3) are made after the manuscript is complete except for field edit. One copy is for use with the ratio prints to locate hydrographic signals; the other is for use when transferring shoreline and alongshore detail to the hydrographic field sheet.

The specially prepared ratio prints shall be returned to the compilation activity that originally furnished them immediately after their usefulness in the field has ended. Prompt application of field edit corrections to the shoreline manuscripts prior to furnishing smooth sheet data is facilitated by availability of these prints. Other data are to be included with the hydrographic records and are forwarded by the hydrographer.

Supplemental horizontal control for hydrography that will be controlled electronically may be established using analytical aerotriangulation procedures. In this case, suitable objects are selected and their images photo-identified, or targets are placed and marked semipermanently in advance of aerial photography. This procedure requires sufficient leadtime to permit proper planning, scheduling, and completion of supporting field operations.

Photobathymetric data consist of copies of the compilation on both paper and on a dimensionally stable medium, a copy of all pertinent reports, and the field edit requirements. Copies provided will be at the scale of the contemporary hydrographic field sheets.

3.2.4. Field Edit

This must be completed on every shoreline manuscript prepared to support hydrography before photogrammetric data for smooth sheet processing can be furnished. Consequently, it is essential that field edit be planned and scheduled as an integral part of combined operations. Photogrammetrists experienced in this operation normally will be assigned from a photogrammetric field party for all projects in the Great Lakes, along the Atlantic Ocean and Gulf of Mexico Coasts, and in the Caribbean Sea areas. Experienced photogrammetrists may not be available for most mapping projects on the Pacific Ocean Coast, in Alaska, or in the Hawaiian Islands. Commanding officers of all vessels conducting hydrographic surveys in those areas shall assign an experienced field editor to this duty. Training and assistance shall be requested from the appropriate Marine Center if an experienced editor is not available.

All field edit work shall conform with the specifications and requirements stated in "Provisional Photogrammetry Instructions for Field Edit Surveys" (National Ocean Survey 1974). The Director of each Marine Center shall establish procedures to ensure that field edit is completed on a satisfactory schedule, that completed data conform with specifications, and that data are forwarded promptly upon completion.

Close cooperation and coordination between hydrographers and field editors are necessary to resolve all discrepancies in the field. Each query shown on the ozalid discrepancy prints shall be investigated and answered. Annotated snapshots should be submitted to supplement and clarify field data where the editor cannot adequately describe a feature in a field block or on a discrepancy print. The chief of party must ensure that the necessary coordination is effected. Many discrepancies created by the failure to coordinate activities properly may not be discovered until the later stages of hydrographic verification and inspection when the problem cannot be resolved properly. The hydrographer shall inform the field editor promptly of any changes or corrections that he considers necessary or desirable. Submerged or sunken objects discovered by the hydrographer, which do not appear on the appropriate manuscript(s), need not be reported to the field editor as items to be added to the manuscript(s). Items such as these are within the province of the hydrographic survey and remain the responsibility of the hydrographer.

A positive unequivocal division of responsibilities between the hydrographer and the field editor cannot easily be made. In general, the hydrographer is responsible for features below the sounding datum while the field editor is responsible for features above that datum. (This may vary in the Great Lakes because of the charting datums used. See 1.6.1.) In many cases, their combined efforts are needed for the complete determination of features that uncover; however, duplication is unnecessary and must be avoided. The unique character of the zone between the sounding datum and high water datum (1.6.1) creates a gray area of overlapping responsibilities that requires careful consideration to ensure that all vital charting data are acquired. Data plotted on hydrographic field sheets or in hydrographic records intended only for hydrographic processing should not be duplicated on shoreline manuscripts or on photographs that will be returned for photogrammetric processing. Duplicated efforts of this nature in the field result in duplicated efforts when processing the survey and may cause discrepancies during compilation; however, all features for which location data are entered in the field edit notes or in the hydrographic records must be plotted on the appropriate sheet.

Several hypothetical cases and examples of items frequently left incomplete (the most troublesome discrepancies) are:

1. A field sheet shows an uncharted rock in the vicinity of a rock shown on the contemporary shoreline manuscript of the area. A comparison of the two sheets during hydrographic verification shows clearly that the positions differ. The hydrographer did not delete the rock symbol that was transferred to the field sheet from the shoreline manuscript; and the field editor failed to verify or delete the rock as mapped. The verifier and photogrammetric reviewer now must decide how to resolve the difference. The most logical solution, in the interest of safety, is to show a rock at each of the two positions although large-scale color photography with good water penetration qualities does not show any image that might be the second rock. It seems clear that there is only one rock; however, a satisfactory solution would require a field investigation. This situation would not have occurred if the activities of the hydrographer and field editor had been coordinated properly.

2. A rock shown on a photogrammetric manuscript does not appear on the appropriate field sheet. What happened? Was the rock inadvertently omitted from the sheet by the hydrographer or did the hydrographer find that the rock does not exist and then fail to note the fact? The photogrammetric reviewer examines the compilation photography and confirms the existence of this rock. The discrepancy just discovered now becomes the problem of the office verifier and of the reviewer. In all likelihood, the rock will be added to the chart from the shoreline manuscript only because the reliability of the combination of color aerial photography and the judgment of experienced photogrammetrists justifies this action. Proper execution of field edit or adequate coordination of field edit and hydrographic operation would have prevented the occurrence of this discrepancy.

3. Images of two of a group of six charted piers were not visible on the aerial photography used for compilation and were not shown on the manu-

script; but neither the field editor nor the hydrographer made any reference to them. As a result, these piers would be shown erroneously as ruins on published charts until the next field investigation is made. Adequate coordination of field edit and hydrographic operations would have clarified the status of the missing piers and prevented appearance of nonexistent piers in ruins on published charts.

4. The offshore end of a pier as it appears on the shoreline manuscript includes a removable float. Such objects cannot always be recognized by the pbotogrammetric compiler. The field editor overlooked the float, but the hydrographer deleted it on the field sheet and actually plotted a sounding at the position. He failed, however, to inform the field editor of the float, thus creating another discrepancy.

3.2.5. Plane Table Surveys

The most frequent use of the plane table is to establish graphic control (3.1.3.4) and to delineate changes in the shoreline and alongshore features. Plane table methods should be used in field edit operations to map sections of the shoreline that were obscured on the aerial photography. These methods also may be used to locate certain nonfloating aids and obstructions to navigation, alongshore rocks, reefs, and ledges and to revise alongshore natural and cultural features that reflect changes since the date of aerial photography. [See "Provisional Photogrammetry Instructions for Field Edit Surveys" (National Ocean Survey 1974).]

Plane table methods should be used when shoreline delineation is required in small areas at scales larger than that of supporting shoreline manuscripts. Requirements of this kind normally arise when hydrographic surveys at a larger scale are necessary to develop a specific area (3.2.1) and photogrammetric mapping is not feasible or cannot be completed in a reasonable period of time.

Horizontal control meeting Third-order, Class-I accuracy standards, if available, should be used to control plane table surveys. Otherwise, photogrammetrically determined positions are acceptable; however, stations located photogrammetrically using specially prepared data shall not be used to control plane table surveys at a scale larger than that of the shoreline manuscripts.

Materials to be used for plane table sheets, sheet projections, and positional accuracy of features and objects located by plane table surveys for mapping and charting are specified in "Provisional Photogrammetry Instructions for Field Edit Surveys" (National Ocean Survey 1974).

A Descriptive Report shall be prepared for each plane table survey made to provide data pertaining to the shoreline and alongshore features as part of a large-scale hydrographic survey. Headings are similar to those specified in section 3.1.3.4, but shall include an additional section specifying the tide or water level station used as a reference to identify the shoreline and to determine the heights of rocks, reefs, and ledges above specified charting datums. If a tide or water level station was not used, explain how the appropriate datums were identified. The date of identifying and locating shoreline is essential and must be stated in this report. Separate reports are not required for plane table surveys conducted as part of field edit operations.

4. HYDROGRAPHY

4.1. GENERAL

4.1.1. Hydrographic Field Surveys

The National Ocean Survey conducts hydrographic surveys to obtain the basic detailed information needed to map submarine topography and to compile and publish nautical charts and related aids to mariners. A basic hydrographic field survey is not complete until it meets all of the following requirements:

1. The area has been systematically covered with accurately located depth measurements sufficient to reasonably ensure that all dangers to navigation have been found.

2. The configuration of all underwater features including channels, shoals, banks, and reefs has been determined; and least depths have been determined over all dangers to navigation.

3. Aids to navigation and landmarks have been described and located.

4. Contemporary tidal or water level observations have been made from which soundings may be reduced to the appropriate chart reference datum.

5. Calibration and correction data have been applied to the observed depths and positions.

6. Bottom samples have been obtained with sufficient frequency to reveal the general physical characteristics of the bottom.

7. Charted information and prior survey findings in disagreement with or not supported by present survey data have been thoroughly investigated and resolved.

8. Other miscellaneous operations have been completed. Examples are field editing shoreline manuscripts, accumulating data to be published in the Coast Pilot and measuring magnetic variations if required (e.g., National Ocean Survey 1976*a*).

Sounding is perhaps the most important part of the hydrographer's duties. An accurate knowledge of the depths is essential for safe navigation, particularly in harbors and their approaches where the draft of many vessels is often nearly as great as the depths in which they navigate. It is not practical, however, to measure the depth at every point, although graphically recorded echo soundings do provide a nearly continuous profile along each line. Enough bottom profiles must be obtained to permit the determination of bottom slopes in all areas. The possibility of irregularities and dangers to navigation remaining undiscovered between sounding lines is always present. The greatest responsibility and most difficult task of the hydrographer is to assure reasonably that none of these remain undetected and that, when found, the least depths over shoals and other dangers are determined.

4.1.2. Classification of Surveys

Hydrographic surveys are primarily classified as basic, navigable area, chart evaluation, or special project. The project instructions will specify the classification required. (See 2.3.1.) A basic survey must be so complete that it need not be supplemented by other surveys. It must be adequate to supersede for charting purposes all prior surveys, and it must satisfy the requirements set forth in 4.1.1. In addition, a basic survey shall verify or disprove the existence of all charted or reported features of significance.

Unless specified otherwise by project instructions, a basic survey need not cover channels and other areas that have been surveyed recently with adequate detail and on an acceptable scale by other qualified and authoritative organizations, provided that the survey by the other agency can be correlated with the basic survey and that satisfactory agreement of depths is attained at the junction of the two surveys. (See 4.3.2.)

Navigable Area Surveys (NAS) are basic hydrographic surveys with restricted area coverage. (See F.2.) The coverage is reduced by omitting requirements for: (1) development of the 0-foot depth curve and foul, nearshore areas not considered navigable; and (2) complete field edit of the survey area. Navigable Area Surveys may also be restricted to the main navigable channel or corridor.

Surveys conducted prior to the development of modem electronic positioning and recording echo-sounding equipment are generally considered to be inadequate for modern charting. Submarine topography in many areas is subject to frequent change by storms, currents, or engineering developments and thus must be resurveyed periodically. Chart Evaluation Surveys (CES) are a rapid means of determining the adequacy and accuracy of charted data and of upgrading the general area of the chart through complete resolution of all reported or discovered chart deficiencies. (See F.3.) Chart evaluation projects may include all of the following types of operations: reconnaissance hydrography, Coast Pilot inspection, tide/water level observations, waterfront planimetry, chart deficiency investigation, and user evaluation.

Hydrographic surveys are classified as special if the general requirements or specifications do not logically fall into any of the preceding categories. A special survey may cover small areas for limited purposes such as to prove or disprove the existence of reported dangers or obstructions, to provide data for harbor development, or to supplement prior surveys for construction of a large-scale chart. Other surveys, regardless of size of area, may be classified as special if significant deviations from line spacing or degree of coverage requirements are authorized. Project instructions for this type of survey shall explicitly define variations from established field procedures and data-processing requirements.

Generally, only standard basic surveys will be assigned registry numbers and be archived. Other surveys are normally filed as field investigations.

4.1.3. Survey Operations

Instructions for a survey project (2.3.1) will be issued and the necessary data furnished sufficiently in advance of field work to permit formulation of a general plan of operation. (See 2.3.2.) Plans for day-to-day operations must be coordinated with the general plan as circumstances dictate so that survey operations can be carried on smoothly and efficiently. All survey operations required in an area should be completed as the work progresses. Required magnetic observations, field edit, compilation of Coast Pilot notes, and similar operations must be kept up to date (e.g., National Ocean Survey 1976*a*).

A hydrographic survey has not served its ultimate purpose until the data have been incorporated in a published nautical chart. The data accumulated must be processed as rapidly as possible to keep pace with the field work accomplished. Periods of inclement weather should be devoted to field processing. When a considerable volume of unprocessed records has been accumulated, one should process during periods of marginal weather. (See 4.9.)

4.2. FIELD SHEET

4.2.1. Definition and Use

The field sheet (formerly called the boat sheet) is the hydrographer's work sheet; it presents a graphic display of all surface and subsurface features in the area being surveyed. It is indispensable to the hydrographer for visualizing the progress and adequacy of work accomplished and for planning future investigations and operations. The field sheet itself may be the composite product of several overlays, insets, and rough preliminary launch or skiff work sheets from which gross errors in the raw field data have been corrected; or it may be a final real-time plot of hydrographic survey field data.

Whether plotted by hand or by automation, the field sheet must portray neatly and legibly all position fixes, preliminary field soundings, inked depth contours that adequately delineate the bottom configuration, bottom characteristics, electronic control lattices, shoreline features where applicable, and all aids and hazards to navigation, particularly rocks, shoals, reefs, ledges, wrecks, piling, dolphins, piers, and breakwaters with their elevations or depths as appropriate. A complete field sheet must also show information pertinent to all geographic names recommended for charting, landmarks, tide or water level gage sites, horizontal control stations, uncharted hazards, presurvey review items, junctional soundings, piers, floats, berthing facilities, and all other data required for charting. Overlays and insets should be freely utilized to prevent the field sheet from becoming cluttered and to present the information in the clearest manner possible. Copious explanatory notes are required on every field sheet and in the hydrographic records to clarify any unusual or questionable circumstance that cannot be depicted by routine graphics and to provide a complete understanding of the survey and charted features not otherwise indicated in the field records.

The field sheet also serves as an invaluable guide and aid during the verification and smooth plotting phases of data processing. Frequently, critical information is extracted from the field sheet prior to verification and applied directly to the nautical charts.

4.2.2. Construction of Field Sheets

Hydrographic survey sheets are constructed to cover efficiently the project area as shown on the approved sheet layout. (See 2.4.2.) The recommended sheet size is 36 by 54 in (91 by 137 cm); maximum sheet size is 42 by 60 in (107 by 152 cm). Refer to 1.2.4 for other constraints on sheet size and for sheet margin requirements. For convenience, hydrographic data are recorded, filed, and referenced on a separate sheet-by-sheet basis. The hydrography shown on any field sheet or portion thereof should not be extended in a continuous manner beyond the limits for that sheet as shown on the approved layout.

Projections shall be machine drafted on stable-base transparent materials insofar as practical. Procedures for a hydrographic field party not equipped with an automatic plotter to obtain plotted projections are established by that unit's Marine Center. Units capable of automatic plotting shall use only NOS-approved projection plotting programs.

If one must manually construct a projection on nonstable material, it should be plotted and checked for accuracy the same day. Procedures for the manual construction of a field sheet are detailed in U.S. Coast and Geodetic Survey (1935) *Special Publication* No. 5, "Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridians and Parallels Based Upon Clarke Reference Spheroid of 1866." Control stations should also be plotted and checked as soon as possible to reduce the adverse effects of distortion of the material. (See 4.2.5.) For the same reason, electronic distance arcs should be drawn as soon as the base station positions are known. (See 4.2.6.) Accurate hyperbolic lattices are not easily plotted by hand and should only be machine drafted.

Table 4–1 specifies projection line intervals for various hydrographic sheet scales. The width of inked projection lines shall be 0.15 mm. Hydrographic field sheets shall be labeled on the lower right-hand corner of the sheet in accordance with figure 4-1. The label may be impressed with a stamp or be machine drafted.

4.2.3. Duplicate Sheets

Marine Centers normally provide duplicate or additional field sheets as required by hydrographic field units for manually plotted surveys. If additional sheets cannot be made available, duplicate sheets can be constructed by pricking through the projection intersections with a fine needle. A long steel straightedge should be placed along each meridian line as the points are pricked; care must be taken not to disturb the relation between the two sheets as the straightedge is moved. Field numbers will be assigned in accordance with section 2.4.3.1.

No. 1 **HYDROGRAPHIC SURVEY**

Field no. ____________
Reg no. ____________
Scale ____________
Datum ____________
Projection ____________
Soundings plotted in ____________
Soundings corrected for ____________
  Draft ____________
  Tides ____________
  Velocity ____________
  Instr error ____________
  Set-squat ____________

FIGURE 4–1.—Rubber stamp 1. This hydrographic field sheet title block is to be stamped or machine drafted on the lower right-hand corner of the sheet.

When the area to be surveyed lies entirely within the limits of a photogrammetric manuscript, a duplicate field sheet can be constructed by simply transferring the projection and shoreline directly from a stable-base reproduction of the manuscript. Two or more manuscripts shall not be joined for this purpose.

4.2.4. Calibration Sheets

Projections required for calibrating an electronic positioning system by manual methods shall be constructed on a stable-base plastic material. The scale of the projection should be at least twice that

TABLE 4–1.—*Projection line intervals for various scales*

Scale of survey	Projection line interval
1:2,000 and larger	Every 5 s
1:2,001 to 1:3,000	Every 10 s
1:3,001 to 1:6,000	Every 15 s
1:6,001 to 1:12,500	Every 30 s
1;12,501 to 1:25,000	Every minute
1:25,001 to 1:60,000	Every even minute
1:60,001 to 1:125.000	Every 5th min
1:125,001 to 1:250,000	Every 10th min

of the survey on which the control system will be used. The principles and methods of projection construction and plotting control and line-of-position arcs are identical to those for other hydrographic sheets; extreme precautions and care are required to ensure plotting accuracy. These sheets need not be numbered and may be discarded after the survey has passed final inspection.

4.2.5. Control Stations

Control stations that will be used for the survey which lie within the field sheet limits should be plotted on or transferred to the field sheet using standard symbols. (See appendix B.) All basic and supplemental control stations used for calibration of electronic positioning systems or for visual sounding control shall be assigned a three-digit number. A numbering system such as the following is recommended:

001-100, basic and supplemental control stations (3.1.1 and 3.1.2) used for electronic control antenna sites;

101-200, other control stations (3.1.3 and 3.1.4) on the first field sheet or part of a field sheet of the project;

201-250, other control stations on the second sheet,....

Although use of such a system is not mandatory, grouping of stations in this manner can simplify signal recognition for the observers and the hydrographer during visual sextant surveys. Signals may also be numbered consecutively in the direction of survey progress to further simplify recognition and identification.

Signals constructed over basic or supplemental control stations are identified on the field sheet by name and assigned number. The names and numbers of stations may be lettered by hand provided the lettering is completely legible. These identifiers should not be placed in water areas nor cover up essential detail on the field sheet and must be positioned so they are clearly associated with the correct symbols. Existing names of geodetic control stations must be shown with their exact spelling. If a station such as a beacon or an off-lying rock lies in the water area, the station name should be inked on a land area nearby; in such cases, an arrow or leader is used to indicate the station to which the name refers. Each control station in the water area should be described briefly and a notation made on the field sheet as to whether the feature on which it is erected is permanent or temporary.

When sextant control stations are numerous, as on an inshore hydrographic sheet, identification will be made easier if brief descriptions of the signals are noted on the field sheet. The more prominent signals should be identified as such. Visual control stations of a permanent or semipermanent nature shall be so described; state whether each is conspicuous enough for use as a landmark.

New control stations are plotted by any convenient and accurate method. The plotting of all control stations should be verified and noted on the field sheet before the station symbols are inked.

4.2.5.1. BASIC AND SUPPLEMENTAL CONTROL STATIONS. On manually constructed field sheets, recoverable control stations of third-order or higher accuracy shall be plotted from the computed values of latitude and longitude. The differences along adjacent meridians (dm's) and the differences along adjacent parallels (dp's) are plotted from the south parallel and east meridian, respectively, using a beam compass and metric scale. (See figure 4-2.) Dividers can be used to measure short distances, but they become less accurate when spread appreciably. The dm and dp distances (in meters) shall be marked by fine prick points adjacent to each set of projection lines then connected by fine pencil lines. To check the plotting and to compensate for sheet distortion, plot the back dm's and back dp's from the north parallel and the west meridian. Distortion, if present, shall be proportioned between each set of dm and dp parallel lines. The position of the station at the intersection of the final dm and dp lines is marked by a fine needle hole that may be blackened by rotating a sharp pencil point in the hole. Never use ink to mark the point. The plot of the control station shall be checked either by the same method or with Sylar-Lockerbie latitude and longitude scales before the symbol is drawn in ink.

4.2.5.2. HYDROGRAPHIC CONTROL STATIONS. Additional hydrographic control stations are designated as traverse, photogrammetric, sextant, plane table, or unconventional as specified in section 3.1.3. Standard cartographic symbols to be used on hydrographic sheets for each type of station are shown in appendix B.

4.2.6. Electronic Position Control Lattices

These shall be constructed on all survey sheets (or on suitable overlays) in those areas where

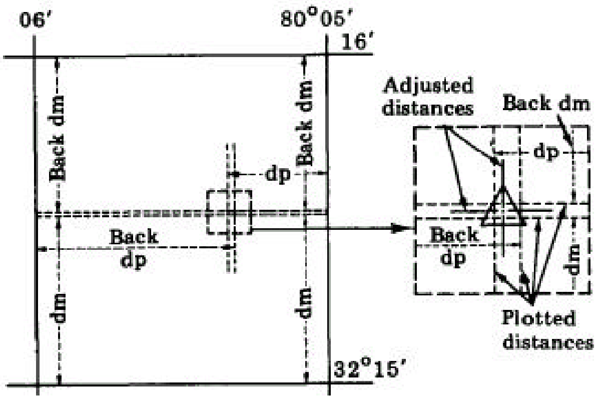


FIGURE 4–2.—Control station plotted by dm's and dp's on a distorted sheet

hydrography is controlled electronically. Lattices are not required on the final field sheet. Lattices serve as a visual check of the geometric strength of the intersecting lines of position, as a convenient reference for plotting or locating plotted data on the sheet, for planning and executing daily work, for positioning the vessel at the desired points, and as an overall aid to the hydrographer for checking lane count or measured distance when the position of the vessel is known. If a large number of position arcs shown on one sheet would result in confusion, lattice overlays should be used.

Whole numbered line-of-position arcs shall be plotted at intervals spaced approximately 7 to 10 cm at the scale of the survey. The lane or distance value and control station number(s) for each arc shall be labeled (in distinctive colors) as follows:

200(126) is a range arc or distance circle with a lane or distance value of 200 units; the transmitting station number is 126.

140(103-211) is a hyperbolic arc with a lane value of 140; the transmitting station numbers are 103 and 211— the left and right stations, respectively, as viewed from the survey area.

If the control station(s) for an electronic lattice do not lie within the sheet limits, the station(s) name and year(s) of establishment shall be shown on at least one of the arcs.

Automated plotting facilities should be utilized for constructing locus arcs on field sheets. If one must plot range arcs on the sheet manually, the following methods are recommended:

Range arcs should be drawn as soon as the projection and control stations have been plotted and checked. An Edmonston Beam Holder or other suitable device should be placed over the station mark to prevent damage to the sheet as the arcs are drawn. If the arcs are drawn later, the projection must be checked for the presence of distortion and significant distortion amounts distributed as subsequently described.

When control stations lie within or near the sheet limits, circular arcs can be drawn using a beam compass and meter bar.

If the control station falls on the sheet, radii for the circles are measured and marked along three radial lines drawn from the station. The lines should be well distributed throughout the survey area. Coordinates of three points on the circle of largest radius are then computed and plotted on the projection. If the measured radii do not check with the corresponding computed and plotted points, the radius measured from the point plotted in the central portion of the survey area is held as correct; the center of the arc system is adjusted so the drawn arcs will pass through each of the computed positions. If the amount of distortion is small, the distance from the plotted arc to the next arc may be scaled along each radial; the new arc may be drawn from the adjusted center. If the distortion is significant, the procedure of computing positions for arc points and adjusting centers must be repeated for each arc.

If the control station lies beyond the sheet limits, the sheet is laid flat and secured firmly at one end of a drafting table. A section of Bristol board or other suitable material is fastened to the table at the approximate plotting location of the control station. The coordinates of three or more well-distributed points on each arc are computed and plotted. The center of the arc system is located by using a beam compass to swing radius arcs from the plotted points for the nearest circle. The arcs should intersect at a point. The relative location of this point with respect to the points plotted for the other arcs must be checked before the arcs are drawn in ink. As before, one may have to adjust the center so the arc passes through each of the computed positions.

If the center of the arc system lies beyond the practical limits of beam compass use, three radii are drawn through points for which coordinates have been computed and drawn. (See figure 4-3.) A sheet layout on a small-scale chart on which the center has been plotted and the arcs drawn is helpful for determining approximate radial azimuths

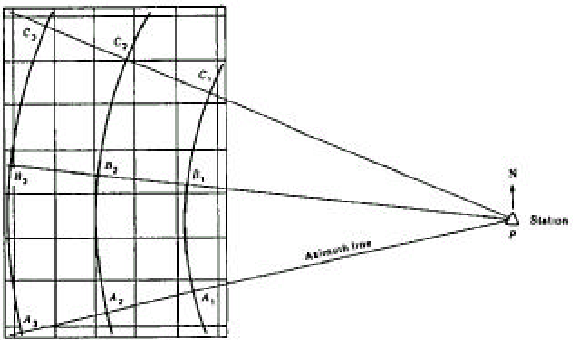


FIGURE 4–3.— Principle of drawing distance-arcs when the station is off the sheet

and distances. Scale the coordinates of a point near the center of the survey area *(B_2*) and compute the inverse between the point and the control station. For convenience, the point may be a plotted projection intersection. From the computed inverse azimuth and distance, a pattern of points on the circles for various radials can be developed. The positions of points A_1, B_2,..., C_3 are computed and plotted. Radial lines should pass through the computed points along each azimuth; a circle should pass through the three points at equal distance. Points on the other circles to be drawn can be located by subdividing the radial lines and compensating for distortion in a proportional manner. Points along additional arcs and radial lines may be necessary, depending on the orientation of the arcs on the sheet. All computations should be retained and included with the survey records.

Plastic templates are available commercially for drawing circles of large radius. If the templates are not long enough to permit drawing a continuous curve across the entire sheet, the coordinates of four or more points should be computed and plotted to permit accurate placement of the template.

Another method of drawing circles is shown in figure 4–4. Two pins are set firmly at positions *A* and *B*. The angle *D* =180º– (*X*/2). This relationship is true for any point along the arc *AB*. The angle *D* is set on a three-arm protractor using the movable arm that can be closed to a zero reading. A pencil is centered in the protractor, and the arc *AB* is drawn by moving it across the sheet with the arms sliding against the pins. The arc *BC* can be drawn in a similar manner using the angular difference in azimuths of the lines *PB* and *PC* as the angle *X*. The portion of the arc that falls beyond *A* or *B* is plotted with the protractor set at the angle *X/2* This method is approved for field sheet plotting only.

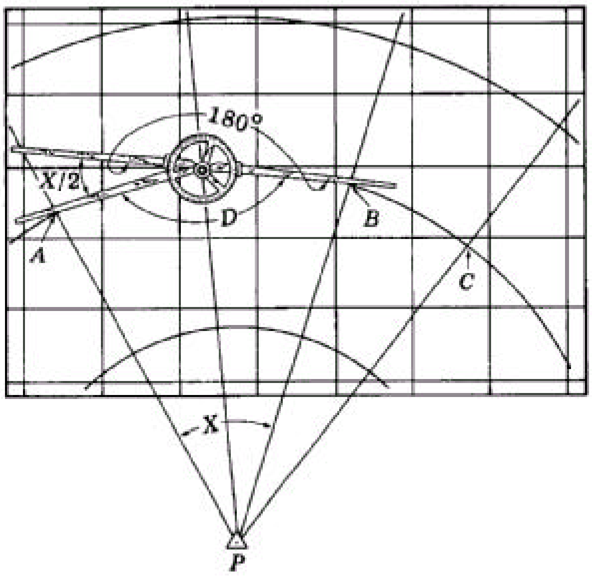


FIGURE 4–4.—Drawing arcs with a metal three-arm protractor

Odessey protractors (A.9.1.3) are generally used to manually plot positions determined by electronic ranging systems.

4.2.7. Transfer of Topographic Detail

Field sheets for all inshore surveys shall show the shoreline (as defined for the particular area (1.6)) and all other available information on alongshore and offshore rocks, aids to navigation, channels, approximate limits of shoal areas, and positions of reported dangers to navigation. The two principal sources of such information are the published charts and shoreline manuscripts. The hydrographic party normally will be furnished copies of the shoreline manuscripts or, if not available, copies of prior topographic surveys. (See 1.6.1 and 3.2.)

The shoreline and important details seaward of the shoreline are transferred from the manuscript copies to the field sheets after the positions of the necessary control stations have been plotted. If the low water line as defined for the particular area (1.6) has been delineated on the shoreline manuscripts, it shall also be transferred to the field sheet. (The low water datum line usually is not shown on Great Lakes surveys.)

If transparent material is used for the field sheet, the important details are carefully traced from the shoreline manuscript. If opaque material is used, the details are transferred by applying "dri-rite" ink or ink from a felt tip marking pen such as "Magic Marker" to the reverse side of the manuscript. The projections are then matched, and the shoreline is traced with a stylus or hard pencil. Shoreline need not be shown on field sheets for offshore surveys.

After the transfer of shoreline and alongshore details has been verified, the shoreline is inked in a fine black line about 0.4 mm wide. (See appendix B.)

Offshore rocks, limits of marine growth or foul areas, and other details (including the low water line transferred from photogrammetric manuscripts) are inked in blue on the field sheet at the time of transfer and then inked in black after verification of position and character by the hydrographic survey. (See 1.6.1.)

4.2.8. Transfer of Data From Prior Surveys

All dangers to navigation, including least depths over shoals, shall be transferred to the field sheet from copies of prior hydrographic surveys and inked in distinctive colors. Representative soundings and sections of depth contours should also be transferred to provide a direct comparison with previous surveys.

The most recent edition of the largest scale nautical chart covering the area must be examined carefully; any additional dangers and significant features must be transferred to the field sheet.

A presurvey review (2.3.3) is usually furnished for each project. Each presurvey review item marked on the chart shall be transferred to a field sheet or overlay for examination during the survey. Discrepancies and questions that arise during the photogrammetric compilation of the shoreline manuscript are also indicated to the field unit as part of the basic data on a copy of the manuscript. Those items seaward of the shoreline shall also be transferred to the field sheet for investigation. (See 1.6.1.)

Each locally reported shoal or hazard to navigation shall be plotted on the field sheet so that its position may be accurately determined or its existence disproved during the survey.

Soundings and other hydrographic data transferred to the field sheet are liable to be obliterated or obscured while surveys are in progress. As an aid to daily inspection of the survey, a transparent overlay may be used to show the data transferred to the field sheet from the charts or prior surveys.

4.3. SOUNDING LINES

4.3.1. Sounding

Equipment and instruments used by the National Ocean Survey for hydrographic depth measurements are described in appendix A. Graphic or analog records of the bottom profile shall be obtained whenever possible. When digital echo sounders are used for a hydrographic survey, corresponding analog depth records shall accompany the digital output and be treated as part of the original survey records.

When sounding in areas where kelp or other varieties of marine vegetation partially or totally obscure the bottom trace, a lead line or sounding pole must be used to supplement or replace echo soundings. Lead-line or pole soundings must be vertical measurements. When bottom samples are being taken, depths should not be recorded if the pole or lead line is sloping. Such erroneous soundings cause confusion in later processing unless such discrepancies are fully explained in the record.

Analog and digital echo sounders record soundings with a consistency and accuracy directly related to the care with which the instruments are calibrated, maintained, and operated. Digital soundings are usually more accurate than soundings scaled from an analog bottom profile because there are no mechanical recorder malfunctions or errors. Differences, however, between digital soundings and soundings from a well maintained and calibrated graphic recorder should not exceed 0.5 ft or 0.2 fm except on steep slopes. If this tolerance is exceeded or if there is doubt as to the accuracy of the soundings or of the control, sounding should be discontinued and not resumed until all uncertainties have been resolved. To continue sounding under such circumstances is usually a waste of time and often introduces processing complications. The hydrographer should remember that the recording of a sounding is only the first operation in a lengthy process of publishing a depth on a nautical chart.

Depths of water shall be measured with the greatest accuracy consistent with efficiency. Depth-measuring instruments or methods used to sound over relatively even bottoms or in critical depths should measure depths less than 20 fm to within 0.5-ft accuracy–greater depths to within 1% accuracy.

In rapidly changing depths and over irregular bottoms, accuracy requirements may be decreased to 1 ft in depths less than 20 fm. Although echo soundings in submarine valleys or on steep slopes may indicate depths less than the true vertical depths under the vessel, corrections for bottom slopes are not usually required.

4.3.2. Junctions and Overlaps

To ensure continuity in survey coverage and depths, one must transfer the soundings from the limits of adjoining surveys to the field sheet or to a suitable overlay prior to beginning a new hydrographic survey. (See 1.4.4.) Transferred soundings are marked on the field sheet in colored ink; use a different color for each survey with which a junction is to be made. Soundings are transferred from prior surveys, contemporary surveys, and new surveys made on adjoining sheets of the same or different scales. In areas where the U.S. Army Corps of Engineers maintains dredged channels, soundings from the most recent Engineer survey may be transferred to the field sheet; if a satisfactory junction is made, a complete survey of the channel need not be repeated unless directed otherwise by the project instructions. (See 4.1.2.) Soundings, however, shall be obtained along mid-channel lines and along other such lines marked by navigational ranges.

Sources of soundings at junctions are referenced on the field sheet by field or registry number of the survey or by identifying number of the U.S. Army Corps of Engineers survey.

An overlap of at least one sounding line or equivalent distance shall be made with an adjoining survey except that, when the survey is continuous in the same year, by the same method, and by the same survey vessel, sounding overlaps are not required.

Junctional soundings from photobathymetric compilations shall be transferred to the field sheet or to a suitable overlay; then a satisfactory junction must be made. Sounding lines shall be run in areas where accurate depths could not be measured on the photobathymetric survey or where the photogrammetric compiler or hydrographer has reason to question measured depths.

Where depths in junctional area do not agree, the new survey shall be extended into the old until agreement is reached. If a reasonable extension fails to reach agreement, a detailed report shall be submitted to the Marine Center with a request for further instructions.

The best evidence of a proper junction of surveys is revealed by the continuity of the depth contours in the overlap area. (See 4.6.)

4.3.3. Inshore Limits of Surveys

Hydrographic surveys shall extend as close to the shoreline as safety and practicality permit, unless the low water line as defined for the area (1.6.1) has been delineated on the shoreline manuscript using tide-coordinated aerial photography. In such cases, the survey need not be extended inshore of the low water line. Otherwise, the low water line must be developed by soundings or other acceptable hydrographic methods wherever conditions permit. Project instructions may require periodic verifications of the compiled line.

In tidal areas, sounding lines close to shore should be run during rising tides (near high) and calm weather. Complete hydrographic development over extensive tidal flats or similar areas is not required, but a few sounding lines spaced at three to four times the maximum spacing in adjacent areas should be run inshore of the sounding datum if practical without jeopardizing the safety of the vessel and personnel. This does not reduce the requirement to fully develop reefs, ledges, or other hazards to navigation.

Streams within the project limits shall be surveyed to the head of navigation for small boats; unless the project instructions specify otherwise, tidal sloughs and estuaries shall be surveyed to the same limit or until the low water line has been delineated adequately.

However desirable it may be to extend a hydrographic survey to the inshore limits stated, the hydrographer shall never subject his boat or personnel to undue risks and avoidable hazardous situations. Along regular sandy beaches, lines should be run parallel to the shore during periods of high tide and calm weather. Risk can often be reduced by running these lines early in the survey to delineate a safe turning zone for terminating sounding lines that are run toward the beach. In areas of small tidal ranges such as the Gulf of Mexico, a wide band of very shoal water difficult and uneconomic to develop often extends offshore from the low water line. In such areas, inshore lines should be run as close as possible to the shoreline; the hydrography should be supplemented by a few widely spaced depths obtamed by sounding from a skiff or by wading at low water.

On rocky coasts, it may be unsafe or impractical to survey any portion of the low water line. Where a rocky area is considered too dangerous for a launch to enter or where kelp is so thick it prevents a sounding boat from passing through, the facts shall be stated in the survey records and the areas delineated on the field sheet as accurately as possible using appropriate notes. The area often can be delineated by estimated distances and bearings from fixed positions observed in safer waters.

If sounding lines are to be run in rocky inshore areas, the hydrographer should examine the area at low water (preferably at a low spring tide) and locate all breakers and exposed rocks by sextant fixes or cuts or equivalent methods. Sounding lines may then be run at high tide with a greater degree of safety.

When the low water line has not been photogrammetrically delineated and a hydrographic determination would be overly hazardous, the areas should be fully described in the descriptive reports; an explanation should be given of the conditions preventing the extension of the survey close inshore. Copious notes must be entered in the sounding records and on the field sheet to show the limits of breakers, kelp, or foul areas that prevented closer approach to shore.

4.3.4. Spacing Sounding Lines

Proper spacing of sounding lines depends on the purpose of the survey, depth of the water, character of the submarine relief, scale of the survey, and importance of the area. (See 1.1, 1.4.1, and 4.1.) Equally important is the accuracy and adequacy of coverage of prior surveys of the area by modern standards and the susceptibility of the submarine topography to change. (See 4.1.2.)

The spacing of sounding lines on basic hydrographic surveys must be such that sufficient information will be provided to satisfy the requirements stated in section 4.1.1. Prominent submarine features and those objects dangerous to navigation must be detected; least depths must be determined to an absolute accuracy of less than 1 ft in water shallower than 20 fm. Depths varying by more than 2 ft from general surrounding depths must be developed in existing or potentially important navigable areas. (See 4.3.1.) Lines must be spaced sufficiently close to permit drawing of accurate depth contours throughout the area and to provide reasonable assurance that all submerged dangers are detected. The general spacing must be reduced as necessary to develop fully all bottom relief and to obtain least depths over shoals, banks, and pinnacles. (See 1.4.3.)

Project instructions will specify the maximum spacing to be used in various depths or areas. The hydrographer or the chief of party shall reduce the line spacing in critical areas as needed for a complete hydrographic survey; but the general spacing specified in the project instructions shall not be increased or decreased over large areas without prior approval of the Director, National Ocean Survey. If the chief of party believes that the general spacing should be changed, a full report to support the request for an amendment to the instructions must be submitted.

There is a practical limit to the number of sounding lines that can be plotted at any given scale. Sounding lines 5 to 6 mm apart can be plotted easily; the soundings can be inked or machine drafted without difficulty. With a little care in plotting and in selecting soundings to be plotted, the line spacing on the sheet can be reduced to about 3.5 mm. Lines plotted in excess of this number seldom. contribute significantly to the survey unless a larger scale inset or overlay is used. After the general bottom configuration has been determined, the hydrographer often finds it necessary to run additional lines to determine least depths over shoals. These additional lines should be plotted on the field sheet or an overlay; but unless revealing information is provided, the data should be marked "not to be smooth plotted" and the reasons stated. (See 1.4.3.) Data from such lines are not rejected; the analog depth records and other data pertinent to these lines shall be forwarded with the records. Bottom profiles of these lines must be carefully studied to ascertain that least depths were not overlooked.

Bottom slopes in mud or sand are usually small (except in areas of large sand waves); areas of shoals in these types of bottoms are generally large in proportion to heights. It is unlikely that a shoal involving any great change in depth could lie wholly between two adjacent lines and remain undetected. Conversely, where the bottom is rocky, sharp irregularities must be expected and every shoal indication examined. Although a shoal is typically indicated by a decrease in depth, abnormally deep soundings must be viewed with suspicion since they often mark the scour caused by the currents near a rock or other obstruction rising steeply from the bottom. In area where the bottom consists of irregular steep features, it is often desirable to record side echoes scanned from the graphic depth record (4.9.8) as they may be indications of shoals or hazards not directly beneath the vessel.

4.3.4.1. LINE SPACING IN HARBORS AND RESTRICTED AREAS. Unless specified otherwise by project instructions, the maximum spacing of sounding lines for basic hydrographic surveys in harbors, bays, passages, channels, and rivers shall not exceed:

100 m in depths less than 20 fm,
200 m in depths from 20 to 30 fm, and
400 m in greater depths.

In dredged or natural narrow channels, the line spacing shall not exceed 50 m. Soundings shall be obtained along the faces of all piers and in adjacent berthing areas. (See 4.5.12.)

If the area is of sufficient navigational importance to warrant a survey at a scale of 1:5,000, the sounding lines are spaced at maximum intervals of 50 m.

In all cases, the sounding line spacing is reduced as needed to develop shoals, to ascertain least depths over them, and to provide enough soundings to permit an accurate portrayal of the bottom configuration.

4.3.4.2. LINE SPACING ON OPEN COASTS. Sounding line intervals along open coasts depend on the type and draft of maritime traffic, water depths, and bottom characteristics. In areas such as the Gulf of Mexico and parts of the Atlantic Coast where bottoms are composed mostly of sand or mud and depths change slowly, sounding lines can often be spaced at twice the interval used in areas of irregular bottom. In areas of smooth bottom along open coasts, line-spacing intervals shall not exceed:

200 m in depths less than 20 fm,
400 m in depths of 20 to 30 fm, and
800 m in depths of 30 to 110 fm.

At entrances to harbors in areas adjacent to spits or rocky points where major changes in bottom contours are expected or found, the fine spacing shall be reduced to half the regular interval.

In areas of irregular bottom on open coasts, the line-spacing interval shall not exceed:

100 m in depths less than 20 fm around rocky points and spits and in entrances to channels,

200 m in all other areas where the depth is less than 20 fm,

400 m in depths of 20 to 30 fm, and
800 m in depths of 30 to 110 fm.

In sea lanes or coastal steaming routes where deep draft vessels are operating or are expected to operate, sounding line spacing is generally decreased; such decreases will be specified in the project instructions.

4.3.4.3. LINE SPACING FOR OFFSHORE SURVEYS. Hydrographic surveys in offshore areas (1.2.3) may be plotted on scales as large as 1:40,000 where they join inshore surveys or on a scale as small as 1:500,000 in ocean areas of great depth. Regardless of the type of bottom, the fine spacing shall not exceed:

1600 m in depths of 110 to 500 fm,
3200 m in depths of 500 to 1500 fm, and
8000 m in greater depths.

Bottom composition, importance of the area, and survey scales will be considered when line-spacing intervals are determined and project instructions written. In areas of rocky or irregular bottom, closer spacing may be required and different breakpoints specified. The spacings specified are maximums that must not be exceeded.

Such wide spacing may not always be adequate to permit detailed contouring of the bottom. The surveyor must study the soundings and analog depth records to detect indications of submerged features that warrant surveys of greater detail. Prescribed line-spacing intervals must be reduced and the survey scale increased as necessary to determine the configuration of submerged mountains, valleys, trenches, and canyons and to determine the limits of escarpments. Smaller features such as mounds, sea knolls, and depressions should also be developed. Breaks in slopes along continental or island shelves should be well defined by soundings.

4.3.5. Systems of Sounding Lines

Because one cannot measure the depth over every point, methodical and systematic examination of each area shall be made. Usually, this is best accomplished by running a system of parallel sounding lines. (See 1.4.) The purposes of this regular system of lines are to (1) provide reconnaissance to the hydrographer for indications of shoals or submerged dangers that subsequently must be investigated for least depths (1.4.3) and (2) furnish a realistic representation of the sea bottom and submarine relief.

Systems of sounding lines normal to the depth contours generally provide the most convenient and economic development of any area; but often it may be advantageous to use a different system. The system ideal for an open coast may not be suitable for bays and harbors. Steep features such as submarine ridges and valleys should be developed by a system of lines that cross the depth contours at angles of approximately 45°. Selection of the most appropriate systems of lines for a particular survey often must be governed by the type of positioning control used and the area configuration and location with respect to an anchorage or base of operations. Three systems in general use are parallel straight lines, radiating lines, and concentric circles or hyperbolic locus arcs.

In the top illustration of figure 4–5, systems of radiating lines and parallel straight lines are used to develop depth contours and delineate hydrographic features. In the bottom illustration, parallel straight lines are combined with electronic line-of-position arcs.

Hydrographers must be continually alert for vessel speed variations that can alter the spacing of soundings between fixes and introduce errors into the survey. Speed variations may occur when sounding lines cross natural or dredged channels and shoals, where landmasses limit sounding lines to two or three positions, during approaches and departures from a beach or shoal water, and where drag or bottom suction suddenly slows the speed of the sounding vessel. If sounding positions are plotted by dead reckoning between fixes (time and course), hydrographers should try to anticipate changes in bottom conditions that affect launch speed and be prepared to take a position on the next sounding interval. (See 4.4.5.) If a speed variation occurred between fixes, soundings are plotted at their most probable position.

4.3.5.1. PARALLEL STRAIGHT LINES. Regularly spaced parallel sounding lines, approximately normal to the depth contours and general trend of the shoreline, are generally used for visually controlled hydrographic surveys or for those surveys electronically controlled and conducted by a vessel equipped with real-time computer plotting capability. Principal advantages of this system are that (1) the best delineation of the depth contours is most frequently obtained with a minimum of sounding lines, (2) three-point fixes are more easily obtained since fewer changes in objects are required, (3) positions close inshore which cannot be fixed by sextant angles may be determined accurately by course and distance from the last fixed position, and (4) natural ranges can be used to keep the vessel on course. Disadvantages are that it may be difficult to control the lines when close to shore (with sextant fixes) and it may be dangerous heading inshore. Variations in speed at the inshore ends often cause erroneous plotting of soundings, making it necessary to run additional lines.

If parallel straight lines are run, two or more lines should be run parallel to the shore during a rising tide when the sea is calm. One line should be run as close to shore as safety and circumstances permit. The second line should be about 50 m offshore from the first (or less on large-scale surveys where depths increase rapidly); additional lines should be run as necessary to determine a safe zone for the launch to turn in when lines are run normal to the shore.

If the coastline has an even trend and a gradually sloping bottom, a system of lines parallel to the shore may be used, whereby the line spacing is gradually increased as the depth increases. If such a system is used, longer lines may be run with less danger to the launch since the inshore lines are run when sea conditions are best. With sextant-controlled hydrography, however, more frequent changes of fix are required; thus the development of depth contours is less accurate. Systems of lines parallel to the coast are impractical if the shoreline is irregular. Unless control stations lie a considerable distance inshore from the shoreline or a dense network of signals has been established, inshore sextant fixes are often weak because one angle is generally very large, the other small, and both change very rapidly.

Straight parallel lines run at an angle of about 45° to the depth contours are advantageous in certain areas. This system often provides better development of long, narrow, steep-sided ridges or troughs.

4.3.5.2. LOCUS ARCS. Systems of parallel or near parallel line-of-position arcs are often used on electronically controlled surveys by nonautomated vessels. Line-of-position arcs are either circular or hyperbolic, depending upon the control system or

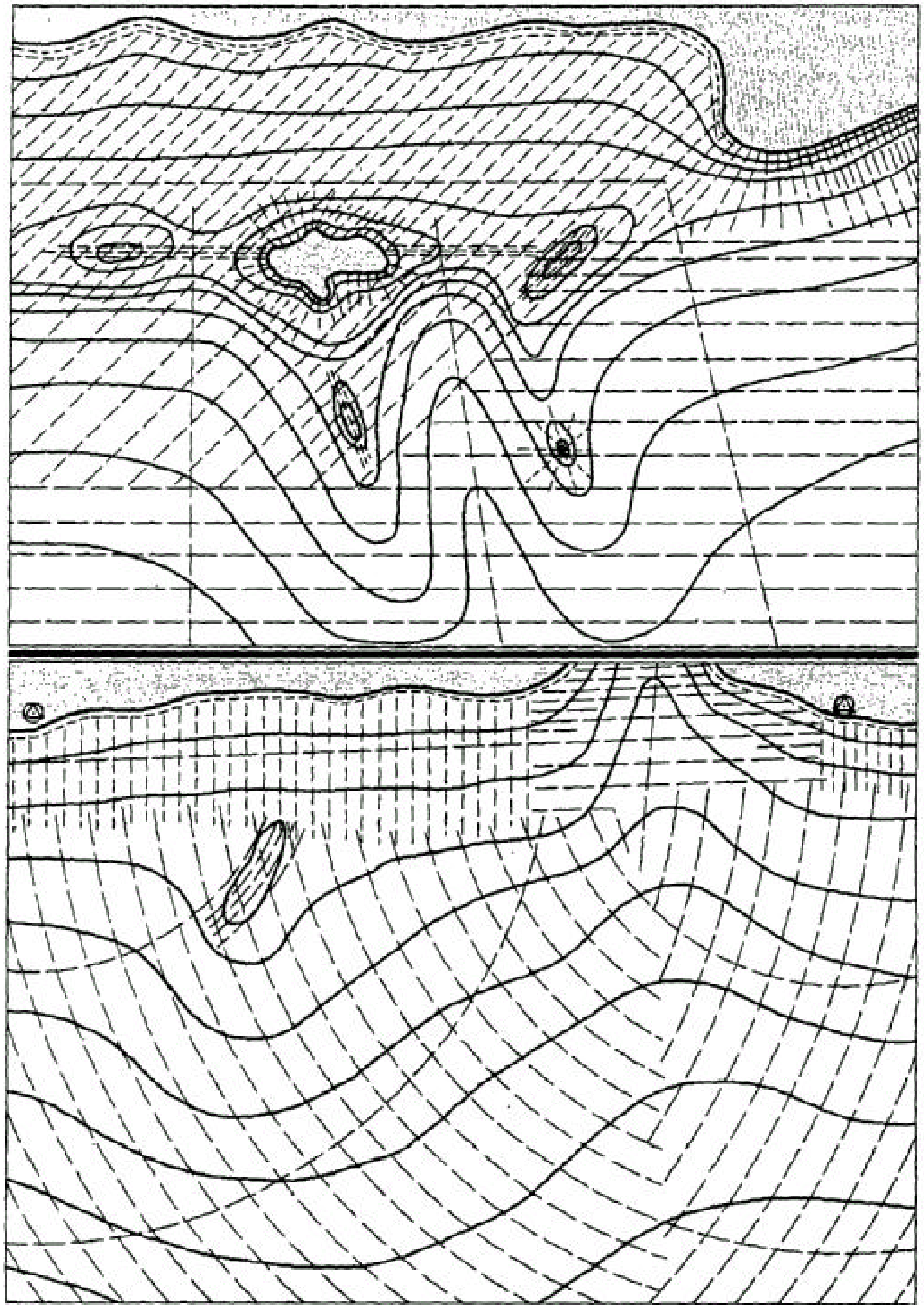


Figure 4-5.—Systems of sounding lines. Solid lines represent depth contours; broken lines show suggested systems of sounding lines for the different conditions encountered

the mode of the system adopted for the survey. Sounding lines are run at the desired spacing by steering the vessel along a preselected arc; deviations from the arc are continually observed, and immediate correctional course changes can be made. The position of the sounding vessel on the arc is fixed by the intersection of another electronic line of position, sextant angle, or theodolite azimuth observed from the beach. (See 4.2.6, 4.4.3, and 4.4.4.)

This system has two important advantages. First, the effects of current are apparent immediately, and timely course corrections can be made to maintain the desired line spacing. Second, sounding line spacing can be reduced by running "splits" at any interval. When this system is used properly, the appropriate maximum line spacing for the depths encountered can be rigorously adhered to because the control along the sounding line is so positive. Because lines are generally run where they are proposed, few are wasted.

When this system is used, the hydrographer has the choice of running lines on either of the paralleling segments of two sets of arcs. He should select the set that provides the most efficient coverage of the area and affords the best development of submerged features. The system is most suitable for inshore hydrography in wide passages, in areas where offshore islands are available for siting shore stations, and in wide bays or estuaries. The system can also be used advantageously for line guidance during visually controlled surveys in areas where the electronic system may not meet survey accuracy requirements or where severe electronic position anomalies exist. Electronic shore stations can be sited to satisfy sounding line directional considerations without concern for strength of fix or accurate positioning of the station.

If electronic control systems are not available and wind or currents make it particularly difficult to stay on a proposed sounding line, concentric circles can be run by steering an arc of a constant sextant angle between two hydrographic signals.

4.3.5.3. RADIATING LINES. Radiating sounding lines often provide the most efficient development of the bottom in small bays, around small off-lying islets, and along shorelines where there is a marked break or change in the trend or where a significant topographic feature occurs. (See figure 4-5.) Radiating lines are a special application; because they diverge on one end, they must be kept comparatively short and not used over an extensive area.

Shoals or sharp submarine features of small extent can sometimes be best developed by running a system of radial lines that cross in the vicinity of a temporary marker buoy planted near the center of the shoal, provided that the position is already reasonably well known.

4.3.5.4. SOUNDING LINES IN CHANNELS AND ALONG PRONOUNCED TOPOGRAPHIC FEATURES. Limits of narrow channels are first defined by a series of crosslines running normal to or diagonally across the channel axis. Extreme care is required to avoid displacement of depth contours on steep slopes. Variations in speed at the beginning and ending of short crosslines can cause errors in sounding positions. Errors of this nature are generally indicated by uncharacteristic depth contours along the edges of the channel.

After the limits of a channel have been established, the channel must be developed by a system of closely spaced lines approximately parallel to its axis. If a channel is marked by a range, a line of soundings shall be run on the range line.

Most dredged channels are maintained by the U.S. Army Corps of Engineers, but some are maintained privately. Nautical charts contain the latest available information on project depths and controlling depths in dredged channels on a stated date. Data on primary channels are usually tabulated on the charts — least depths are listed for the right and left quarters and the center half of the channel (or for each quarter of the channel width). When the hydrographic survey reveals that shoaling of a hazardous nature is occurring in a channel, the Chief of Party should notify the nearest office of the U.S. Army Corps of Engineers and the U.S. Coast Guard. Copies of all correspondence and sketches shall be forwarded to the Hydrographic Surveys Division (OA/C353), through the appropriate Marine Center. (See 5.9)

4.3.6. Crosslines

Regular systems of sounding lines shall be supplemented by crosslines to provide a check and to disclose discrepancies in the main system. (See 1.4.2.) Major sources of discrepancies, such as those indicated by poor comparisons of soundings at the crossings, include the use of an erroneous datum of reference, weak or erroneous control, malfunction of the sounding equipment, or abnormal tides. (See

4.6.1.) Crossline bottom profiles should be scanned thoroughly for indications of shoals or hazards missed by the regular system of lines.

Crosslines need not be run in areas of extremely irregular submarine relief; they are of little value for checking because large vertical differences occur across small horizontal distances. In such cases, the hydrographer should try to find a gently sloping bottom where meaningful crosslines can be run. Regular spacing requirements for crosslines may be varied for this condition.

Shallow water sounds and bays may be subject to unusual tides or water level fluctuations resulting from abnormal meteorological conditions. If crosslines are run first at the predicted chart daturn under normal wind and sea conditions, the occurrence of abnormal tides will be reflected by poor crossings.

If necessary, regular tide or water level observations should be supplemented by a short series of observations in the immediate vicinity. Corrections can often be deduced with reasonable accuracy by comparing soundings at crossings. Until discrepancies are resolved and necessary corrective actions taken, further hydrographic operations may be counterproductive.

4.4 POSITIONING SYSTEMS AND REQUIREMENTS

4.4.1. General

To chart soundings and related data for mariners, one must accurately determine the position of the vessel at frequent intervals along the sounding line and at other discrete points for which the latitude and longitude are needed. If the vessel proceeds at a nearly constant speed along a fixed course, soundings between position fixes can be plotted with reasonable accuracy.

Hydrographic position fixes on sounding lines are almost always determined by the intersection of two lines of position; dead-reckoning positions based on course and speed provide an additional internal check. (See 4.5.5.) Occasionally, a position is expressed as an estimated distance and bearing from the vessel or from a known point or as an estimation of the position directly on the field sheet.

Detached positions are those usually taken at discrete points such as least depths and bottom samples. When conducting visually controlled surveys, a check angle or azimuth shall be observed and recorded for detached positions. If controlled electronically and if practical, a check line of position should be observed and recorded.

4.4.2. Visual Positioning

If electronic positioning systems are not available or adequate for the survey, hydrography may be controlled by three-point sextant fixes taken from the vessel or by the intersection of two or more theodolite directions observed from shore stations. Visual positioning methods are also used to calibrate electronic positioning systems.

4.4.2.1. THREE -POINT SEXTANT FIX. This is a convenient and accurate method for determining the position of a hydrographic survey vessel. Sextants are used to measure two angles between three objects of known geographic position. (See AE.l. for use, care, and calibration of a sextant.) The center object is common to both angles. (See figure 4-6.) The position of the observers taking the angles is fixed by the intersection of three circles. Two of the circles are the loci of the angles observed from the vessel between the left and center objects and between the center and right objects. The third circle is the locus of the sum of the left and right angles. When three-point sextant fixes are used to calibrate an electronic positioning system, the vessel should be stopped; the angle observers should stand as close together as possible.

In figure 4-6, illustration A represents the strongest fix possible where the vessel is at the center of an equilateral triangle; B is the strong fix where the vessel is closer to the center object than to the left and right objects, the observed angles are sufficiently large, and the loci intersect at a large angle; C is the weaker but adequate fix — fixes of this type should be avoided if stronger fixes are available; D is the unacceptable weak fix — note the small loci intersection angles at the vessel where a small error in either of the observed angles causes a large positional error; E is the "swinger," an indeterminate fix, where the sum of the angles ($A + L + R) = 180°$ and the vessel and the three objects lie on a common circle.

4.4.2.1.1. *Selection of objects.* The geometric strength of a three-point fix is greatest when two of the loci intersect at right angles; it is weakest when the three loci approach coincidence. Figure 4-6 shows several configurations of the three-point fix. The relative strength of each fix can be estimated by the intersection angles of the loci.

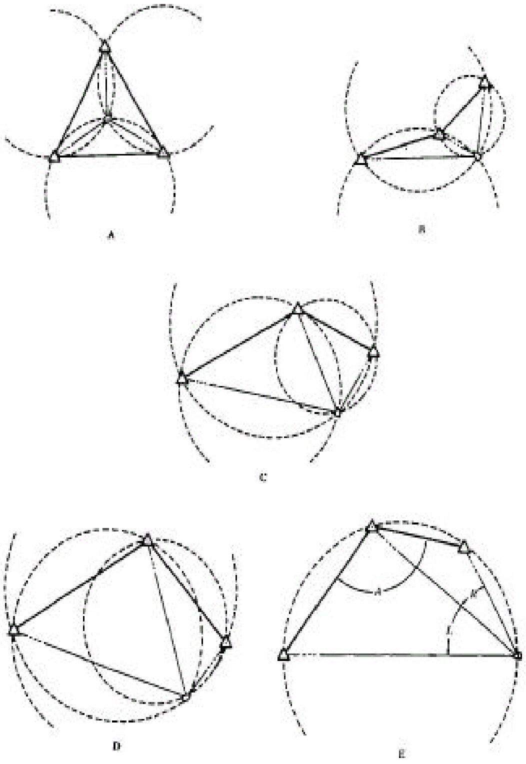


FIGURE 4-6—Various configurations of strong and weak three-point fixes

Figure 4-7 shows, for various arrays of the three points, error contours (in meters) that correspond to errors of 1 min in each of the observed sextant angles and an accuracy of 1:10,000 for the control stations. The observational errors were combined in the direction that resulted in the maximum positional error. These figures may be used to estimate positional errors of varying magnitude because the relationship between the observational errors and the error contours are approximately linear for an angular error and base line lengths. For example, with errors of 2 min in each of the observed angles, the magnitude of the 1-m positional error contour becomes 2 m.

Experienced hydrographers should be able to estimate the relative strength of a fix at a glance and immediately select a strong fix. Beginners may have difficulty in visualizing the problem and often select weak fixes. The following general rules may be helpful when selecting objects to be used:

1. Strong fixes occur when the observer is inside the triangle formed by the three objects; a fix is strongest when three objects form an equilateral triangle, the observer is at the center, and the objects are close to the observer.

2. A fix is strong when the three objects lie in a straight line, the center object lies between the observer and a line joining the other two, and the center object is nearest to the observer.

3. The sum of the two angles generally should not be less than 50º (figure 4-7); better results are usually obtained when neither angle is less than 30º.

4. A fix is strong when two objects that lie a considerable distance apart are alined and the angle to the third is not less than 45º.

5. A fix is strong when at least one of the angles changes rapidly as the survey vessel moves from one location to another (i.e., one of the objects is close to the vessel).

6. Small angles should be avoided since, in most cases, they result in weak fixes difficult to plot by hand. Strong fixes, however, are obtained when two objects are nearly in range and the nearest one is used as the center object.

7. Fixes are always strong if the distance between the center object and the left- and right-hand objects is longer than the distance from the observer to the center.

8. Nearby signals should generally be favored over distant signals. If only one signal is nearby, it should be used as the center object. The use of nearby signals will position the vessel more accurately relative to nearby shoreline and inshore features.

Beginners should demonstrate the validity of these eight rules by plotting examples of each and their opposites. One should note that a fix is strong if a slight movement of the center of a three-arm protractor moves the arms away from one or more of the stations. Conversely, a fix is weak if such movement does not significantly change the relation of the arms to the three points. An appreciation of the accuracy required for measuring angles can be obtained by changing one angle about 5 min in each example and noting the resulting shift in plotted positions. Most automated processing systems use a similar test to determine whether a fix is weak. A "weak fix" message is printed if the addition and subtraction of 1 min to both the left and right angles, respectively, displaces the computed position by more than 8 m. Maximum errors in positions deter-

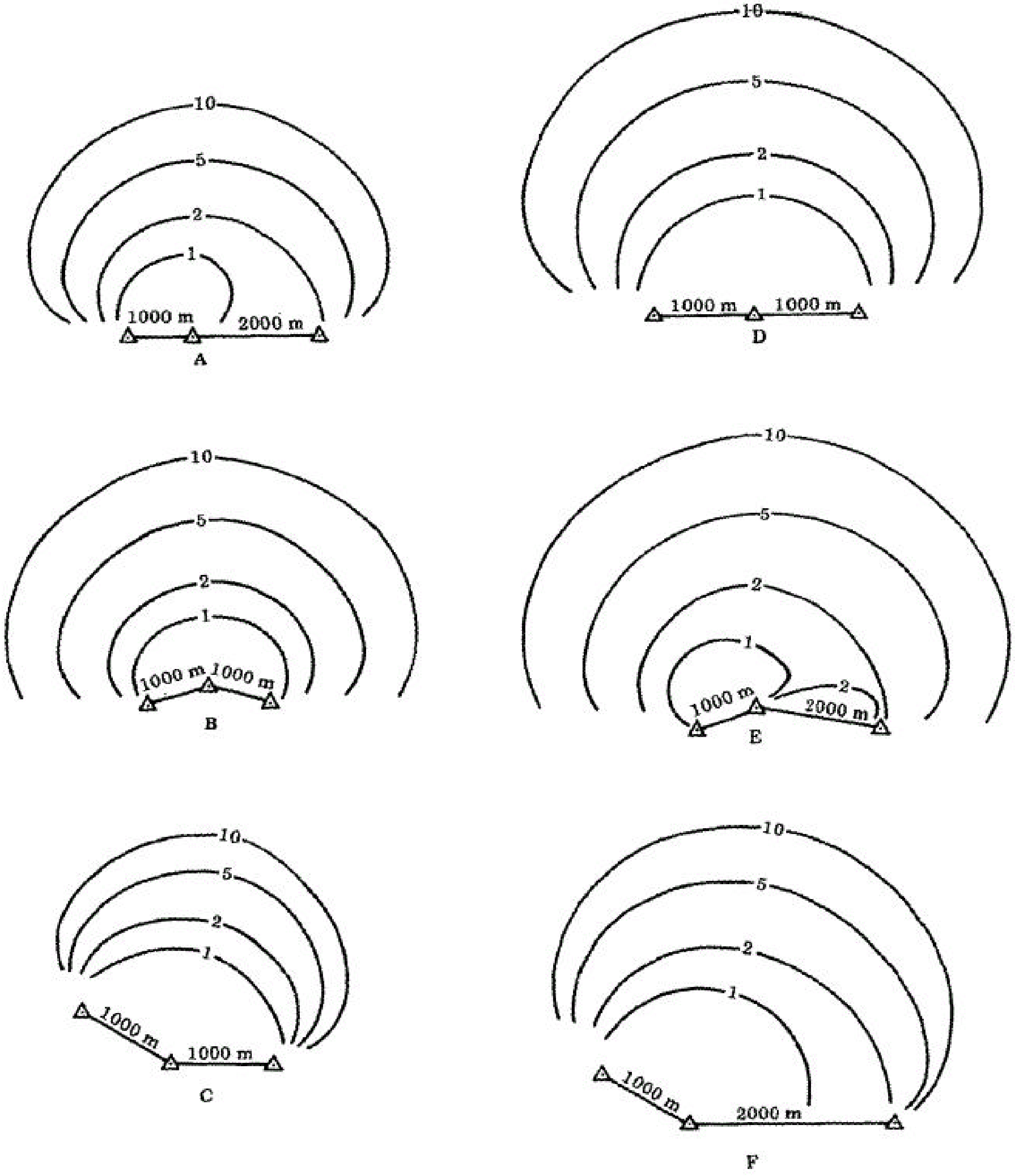


FIGURE 4-7. — Error contours for various configurations of the three-point fix

mined by a weak fix result from a positive error in one angle and a negative error in the other.

Avoid the selection of objects that result in a "revolver" or "swinger." If the vessel ties on or very near the loci circle described by the three objects observed, the fix is indeterminate and defined as a swinger. The hydrographer should estimate his position with respect to the circle passing through the three signals when selecting objects. An easy way to predict a swinger is demonstrated in figure 4 -6E. If the sum of the angles (A + L + R*)* is equal to 180%, the fix is a swinger. The automated system is programmed to reject fixes when the sum of these angles is between 178º and 182º. One can also see that, if the angle *A* is greater than 180º , a swinger cannot result.

Because of observational errors, some theoretically acceptable fixes may prove inadequate if either of the angles is less than 30º(i.e., where the three objects lie on a straight line). See figure 4-6.

Insofar as practical, the objects used for sextant angles should be approximately equal in elevation with the observer. If an angle must be measured between two objects of considerable difference in elevation, the observed angle must be corrected before plotting. When one of the objects is at or near sea level and the other is at an elevation sufficient to cause a horizontal angular error in excess of 2 min, the angular elevation of the elevated object shall be observed and the inclined angle corrected as described in A.5.3.1.5.

4.4.2.1.2. *Change of fix.* Generally, the strongest fix available should be used for each position; but there are other practical limits that may govern selection of a fix. Poor visibility and frequent changes of objects contribute to both observing and recording errors. Signals that can be positively identified often prove to be a better choice than less distinct signals although a slightly stronger fix would be obtained using the less distinct signals. Some observers, however, lack judgment and tend to use the same object long after a change to a stronger fix should have been made.

When angle observers do not have ready access to the field sheet, a rough tracing of the shoreline should be made showing the location, number, and a brief description of each signal in the vicinity. This enables trained observers to select strong fixes and positively identify the stations used.

4.4.2.1.3. *Special problems in sextant fixes.* Sextant fixes at distances approaching the limit of visibility of the signals are likely to be weak because the angles or changes therein are small. In such cases, small errors in the angles induce large positional errors. When signals are far away or are difficult to reflect, a telescope must be used on the sextant. The sextant must be in perfect adjustment, and the angles measured and read with extreme accuracy – to the nearest 30 s of arc if necessary. (See A. 5.3.1.4.)

Strong sextant Fixes often cannot be obtained at the inshore end of each line because the vessel may be nearly on line with shoreline signals. The sum of the two angles frequently approaches 180º with one angle often being very large and the other very small. Under these conditions, angles change rapidly when the vessel is moving; thus, unusual care must be taken to mark angles simultaneously. The effects of errors introduced by failure to mark angles simultaneously is minimized when the signals used are at short distances from the observer.

When one cannot obtain a three-point fix, two angles to four signals may be measured to fix the position. A fix of this type is called a "split fix" because there is no common center object. The locus of each angle must be plotted separately – the position of the vessel is the intersection of the two loci. If the signal and vessel configuration is such that the loci of the observed angles intersect at an angle greater than 45º , the fix is considered strong; however, split fixes are inefficient because of the recording procedure and plotting time involved and should be taken intentionally only when three-point fixes are unavailable. In addition, split fixes are invalid input for the automated processing system. If a split fix is observed, a three-point fix must be "created" by plotting the split fix manually, then scaling a left and right angle between three objects.

4.4.2.2. THEODOLITE INTERSECTION. Positioning a survey vessel by the theodolite intersection method is advantageous in areas where hydrography must be controlled visually, when the entire area can be viewed from several sites, and when a prohibitive number of control stations and signals would be necessary to support three-point sextant fixes. Two or more theodolites are sited (depending on the size of the area, shoreline configuration, and availability of existing geodetic control) to provide a pattern of strong geometric intersections throughout the survey area. Theodolite stations shall meet the accuracy requirements for Third-order, Class I horizontal control. (See 3.1.2.) The angle of intersection at the vessel shall be such that a directional error of 1 min from a theodolite station will not cause the position of the vessel to be in error by more than 1.0 mm at the scale of the survey. Angles greater than 30° and less than 150° will usually ensure meeting this condition.

Generally, depending on the scale of the survey, directions to the vessel are observed and recorded to the nearest minute of arc. (See 4.8.3.1.) Azimuths accurate to within ±30 s of arc are required for absolute orientation of the observed directions. Absolute azimuthal orientation is best achieved by sighting on at least two points of known position. If a geodetic azimuth is not immediately available for absolute orientation and the theodolite stations are intervisible, relative orientation for plotting can still be accomplished (i.e., assume an approximate azimuth for an observed line, then by angulation extend that azimuth to the other control stations). Solar or Polaris observations for azimuth may be used for eventual absolute orientation of the survey or for azimuth checks.

Radios are used to coordinate events, assure that directions are observed simultaneously when a fix is needed, and relay fix data to the hydrographer. Positions are usually plotted by automation or by using a standard drafting machine (AL.1.3) aboard the vessel as the positions are observed. Occasionally, other means such as preconstructed azimuth array sheets are used. Plotting may be accomplished at any convenient location, provided that radio communications with the sounding vessel and theodolite stations are maintained.

Standard drafting machines are portable compact instruments clamped on drafting boards or tables large enough for the field sheet. Machines must be equipped with a full 360° circle; the vernier must be graduated to 1 min of arc. The length of the straightedge attached to the machine depends upon required plotting distances. When plotting positions, the circle of the drafting machine is locked in the orientation parallel to the line joining the theodolite stations being used. An orientation line is drawn and labeled on the field sheet, preferably clear of the working area. Periodic reference to the orientation line with the locked straightedge assures correct orientation of the drafting machine while plotting positions.

Although two observed directions from theodolite stations are adequate for positioning the survey vessel while running routine sounding lines, third directions should be observed as checks on detached positions and when intersecting aids to navigation, landmarks, and similar features. When the survey is progressing rapidly, a third instrument should be used in a "leapfrog" manner to provide continuity of sounding operations and ensure geometrically strong intersections.

In narrow winding sloughs or streams where any form of hydrographic control is difficult, theodolite directions and stadia distances may be used to position the sounding vessel. This method is also a flexible technique for strengthening fixes when directional intersections are weak or if a check on the position is needed.

4.4.3. Electronic Position Control

Electronic position fixing systems currently used by the National Ocean Survey for controlling hydrographic surveys may be classified by their operating ranges (1.3.3.2), and further subclassified by the system mode of operation (i.e., hyperbolic or range-range). Further classifications such as wave timing and pulse matching defining the electronic characteristics of the system can be made; but they are beyond the scope of this manual.

Dutton's Navigation and Piloting (Dunlap and Shufeldt 1969) and International Hydrographic Bureau (1965) *Special Publication* No. 39, "Radio Aids to Maritime Navigation and Hydrography," contain a comprehensive discussion of the principles of electronic positioning. The hydrographer should have all pertinent literature, handbooks, and manuals prepared by the manufacturer for the specific equipment in use. The Decca Hi-Fix Manuals and the Del Norte Operations Manual are especially good references from which much of the following material has been extracted (e.g., Decca Survey Systems 1972 and Del Norte Technology 1974). This section (4.4.3) will not deal with any particular brand name but will outline in general the basic principles of each system and how each system should be used. Refer to AB through AF for more detailed discussions of specific equipment.

Range-range modes of operation with medium range systems are generally preferable to hy-

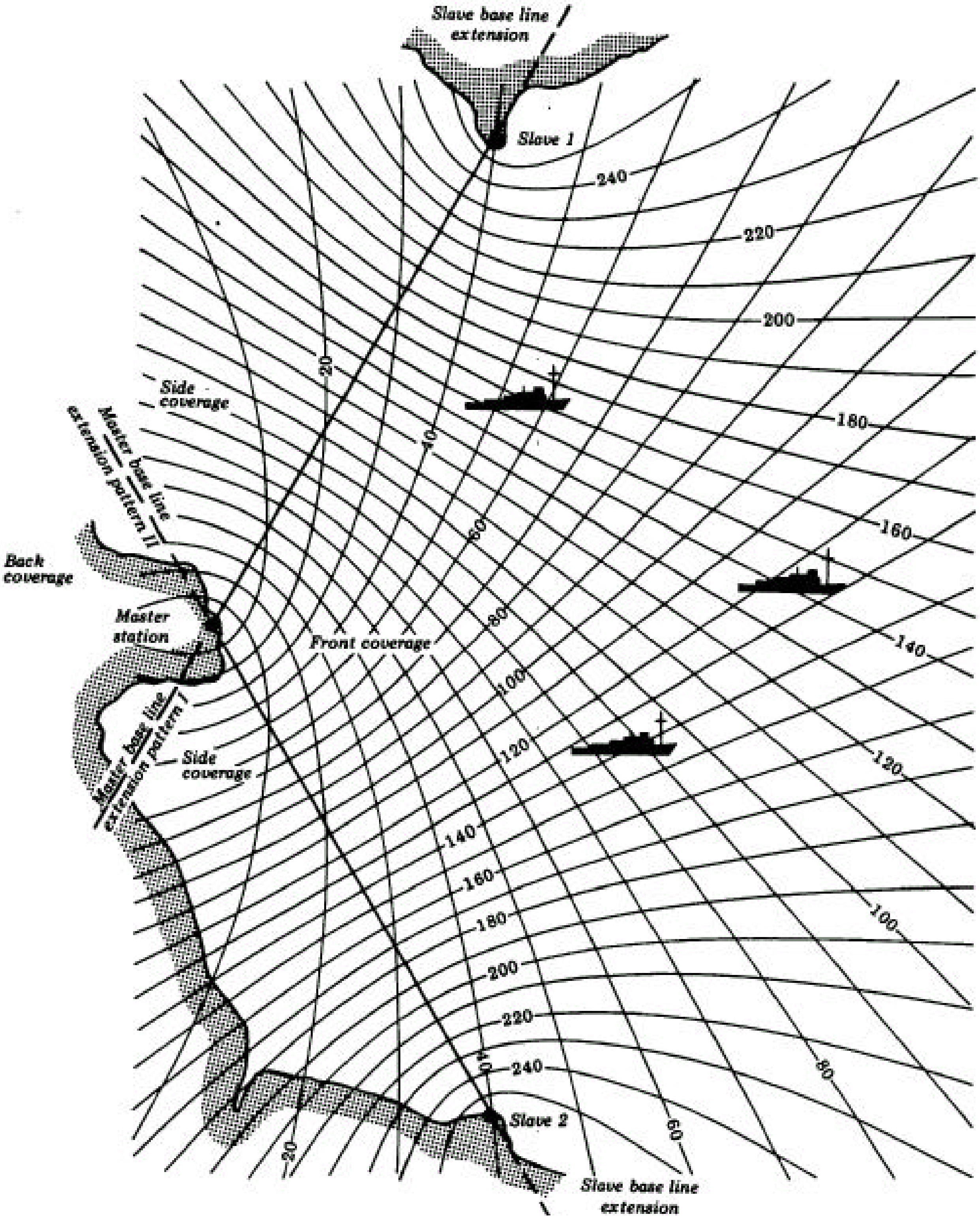


FIGURE 4–8 — Hyperbolic lattice for a hydrographic survey (courtesy of Decca Survey Systems, Inc., Houston, Texas)

perbolic operation because of greater flexibility. Some range-range systems, however, do not permit multivessel time-sharing operations. In table 4–2 are several basic situations that must be considered before the mode of operation is finally selected.

4.4.3.1. HYPERBOLIC POSITIONING SYSTEMS. Arrays of the hyperbolic positioning system consist of one "master" station and two "slave" stations located at known geographic positions (1.3.1), with the receiver aboard the vessels in the work area. Unlimited numbers of vessels can timeshare the system using the same shore stations. (See figure 4-8.)

Each pattern of hyperbolas consists of lines of equal phase difference between the signals received from two transmitting stations. The patterns form lines of position, the intersection of which fixes the position of the vessel. A hyperbolic chain, therefore, needs a minimum of two pairs of transmitting stations to provide a position fix. In practice, one station is common to each pair and is called the "master." The two remaining stations are called "slaves." Each family of hyperbolas has the master station and a slave as its foci.

Lines between the master stations and each slave station are called "base lines." Figures 4–8 and 4–9 show that adjacent hyperbolas diverge as they move away from the base line. On the base line, the distance between these adjacent hyperbolas (a "lane") is equal to half the wavelength at the transmission frequency; it may be computed by

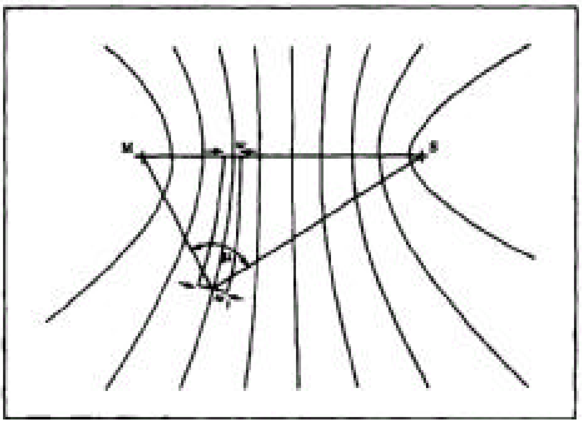


FIGURE 4–9.—Hyperbolic lattice lane expansion (courtesy of Decca Survey Systems, Inc., Houston, Texas)

$$\lambda = v/f$$

where λ is the wavelength in meters; v, the velocity of propogation of an electromagnetic wave (NOS using 299,670 km/s); and f, the system frequency in kilohertz.

The lane width w equals $\lambda/2$. As the dis-

TABLE 4–2.—*Hyperbolic versus range-range system considerations*

Consideration	Three-station hyperbolic	Range-range
Geometric computations, lattice construction, and position plotting	Complex if done manually	Relatively simple
Extent of high-accuracy coverage	Limited by lane expansion and angle of line-of-position intersection	Limited by angle of line-of-position intersection only
Shoreline configuration	Best suited for concave coastlines	Suitable for any coastline configuration
Control surveys for shore station sites	Required for three stations	Required for two stations
Support and logistics	Three shore stations	Two shore stations
Number of time-sharing receivers	Unlimited	Some systems limited to one

tance from the base line increases, the width of a lane expands according to

$$w_1 = w\ (\csc \mu/2)$$

where w is the lane width on the base line; w_1 , the lane width at the point of observation; and μ, the angle subtended by the base line at the point of observation. The position fixing accuracy of a hyperbolic system is inversely proportional to the term csc $\mu/2$, the "lane expansion factor."

In a hyperbolic chain, the master drive unit energizes the transmitter at the master station (M) with the "trigger" and master pulses. Each slave station (S) receives these pulses; the first pulse triggers the electronic timer while the master pulse locks the receiver to the phase and frequency of the master signal. Each of the locked slave receivers then contains a phase datum continually kept in phase with the master transmission. Both slave receivers trigger pulses to their transmitters; the resulting signal is picked up by the vessel's receiver. Vessel receivers "see" two sets of hyperbolas called pattern I and pattern II. Positional values for each pattern are registered (in lanes) on a digital lane counter aboard the vessel. Lane values are usually shown to the nearest one hundredth of a lane. The position is determined by the intersection of the lines of position corresponding to the corrected observed lane values. Most manufacturers provide additional lane and positional displays.

Hyperbolic positioning systems measure only the fractional lane reading (i.e., the relative position of the vessel between two lanes). Whole lane values are not resolved by most of the precise hyperbolic fixing equipment available. Whole lane values must be set manually on the display pattern counter. The observer, therefore, must know the position of the vessel, within an accuracy of ± 0.5 lane. After the lane number has been determined and set, the equipment will automatically keep track of the whole lanes by "lane integration." Losses of signal during operations can cause faulty integration. If the faulty integration cannot be resolved, the hydrographer must return to a point of reference to determine and reset the whole lane value. (See 4.4.3.)

It is difficult and time consuming to manually construct hyperbolic lattices on charts to determine where to locate shore stations when planning a project. The following guidelines and diagrams can be used to determine the coverage and degree of accuracy for various shore station configurations. Shore stations should generally be located to provide a clear water path between the master station and each slave station. (See 4.4.3.)

Typical error propagation contours for various base line intersection angles are shown in figure

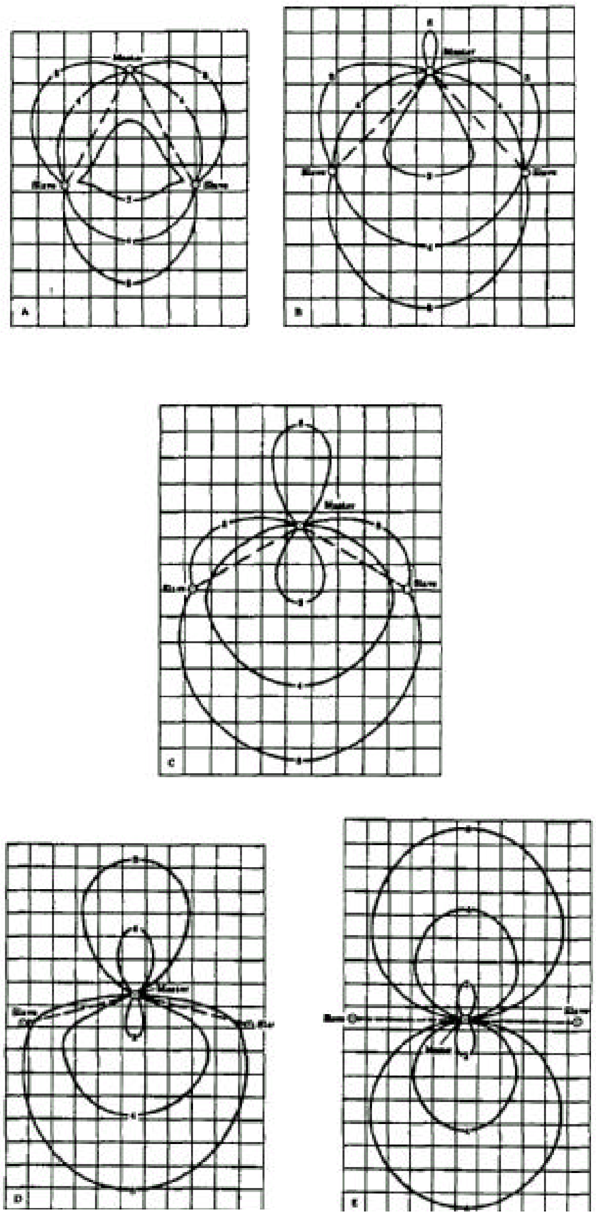


FIGURE 4–10.— Hyperbolic positioning system relative error contours (meters) for a unit standard deviation of 0.01 lanes. The operating frequency used in the computation of the curves is about 1.8 MHz. Illustration A has base lines at 60º; B, 90º; C, 120º; D, 150º; and E, 180º (courtesy of Decca Survey Systems, Inc., Houston, Texas).

4-10. The base lines are shown equal in length for convenience although this may not be typical in practice. On each illustration, the sides of the squares are one-fifth the length of the base lines to permit quick estimation of ranges and areas. Figure 4-11 shows the shape of the contours for chains in which one base line is twice the length of the other. The most accurate positions are obtained within the triangle formed by the three stations at the point where the hyperbolas cross at right angles. The most accurate point in a chain in which stations are placed at the corners of an equilateral triangle lies at the intersection of the perpendicular bisectors of the base lines. Base line angles of 120° to 150° generally give the best compromise between accuracy and area of coverage.

In the following discussion, we assume the transmitting stations have been located accurately and constant displacements or systematic errors in the electronic position coordinates have been eliminated. Random errors result in a variable displacement of position lines about their computed positions. Magnitudes of these errors are defined by the standard deviations of the distribution of such errors. Errors encountered here and in survey observations are best described by the classical normal distribution.

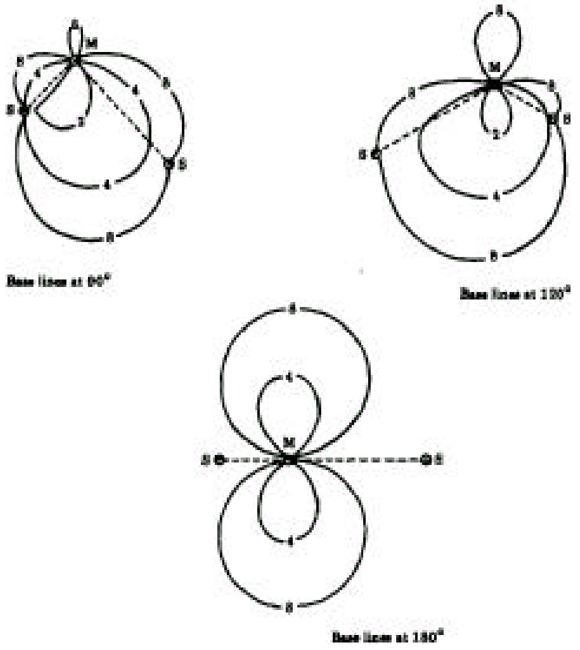


FIGURE 4–11.—Hyperbolic positioning system error contours (meters) for assymetrical base station configurations. The operating frequency used in the computation of the curves is about 1.8 MHz (courtesy of Decca Survey Systems, Inc., Houston, Texas).

A combination of the effects of random movements in the two position lines results in a spread of position plots about the true geographical position of the receiver. To describe the likely degree of uncertainity of a single fix taken at this or at any position covered by the chain, we use the root mean square error (rmse).

In this situation, the rmse is the radius of the symmetrically drawn circle of the fix distribution that encloses approximately 65% of the plotted fixes (i.e., odds against a computed fix falling outside this circle are two to one). This probability level is generally used to estimate hyperbolic system positioning errors for survey purposes. Note that a circle with a radius of 2 rmse (twice the standard deviation) includes approximately 95% of the plotted positions; a circle with a 3 rmse radius includes 99% of the plotted positions.

In figure 4–12, the pattern-I coordinate has a standard deviation of σ_1 m, and the pattern-II coordinate a standard deviation of σ_2 m. Every fix for which the pattern errors are less than its standard deviation will lie within the parallelogram *PQRS*. The *maximum error* of such a fix is the *diagonal* of the parallelogram OP, but the actual error distribution is the ellipse inscribed within and tangent to *PQRS*.

The rmse of a position can be determined from

$$d_{rmse} = \sqrt{a^2 + b^2}$$

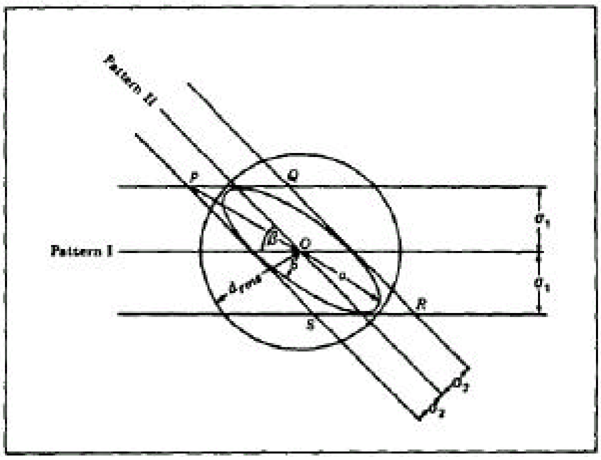


FIGURE 4–12.—Root mean square error (rmse) at an electronically determined position (courtesy of Decca Survey Systems, Inc., Houston, Texas)

where *a* and *b* are the semi-axes of the standard error ellipse, or

$$d_{rmse} = \sqrt{\sigma_1^2 + \sigma_2^2} \csc \beta$$

where ß is the angle of intersection between the lines of position at the vessel; s_1, the standard deviation of the pattern-I coordinate at the vessel, in distance units; and s_2, the standard deviation of the pattern-II coordinate at the vessel in distance units.

In the formula

$$\sigma_{1,2} = \sigma \cdot w_{1,2} \cdot \left(\csc \frac{\mu_{1,2}}{2}\right),$$

σ is the standard deviation (in lanes) of the random errors (generally in lanes of 0.01 to 0.03 for hyperbolic chains); w_1 the lane width on the pattern-I base line; w_2 the lane width on the pattern-II base line; μ_1, the angle subtended by the pattern-I base line at the point of observation (figure 4–9); and μ_2, the angle subtended by the pattern-II base line at the point of observation.

Assuming that both patterns have the same standard deviation (i.e., $\sigma_1 = \sigma w_1$, and $\sigma_2 = \sigma w_2$), one can express the rmse of a position in the areas of front and back hyperbolic coverage as

$$d_{rms} = \sigma w \cdot \csc\left(\frac{\mu_1 + \mu_2}{2}\right) \cdot \sqrt{\csc^2\left(\frac{\mu_1}{2}\right) + \csc^2\left(\frac{\mu_2}{2}\right)} \cdot$$

The corresponding formula for side coverage is

$$d_{rms} = \sigma w \cdot \csc\left(\frac{\mu_1 - \mu_2}{2}\right) \cdot \sqrt{\csc^2\left(\frac{\mu_1}{2}\right) + \csc^2\left(\frac{\mu_2}{2}\right)} \; .$$

Hyperbolic control systems should not be used for surveys in areas where the combined effects of lane expansion and angle of position line intersection cause the rmse of position to exceed 0.5 mm at the scale of the survey. A value for unknown uncompensated systematic errors that may be present must also be assumed and be added to the standard error σ for a meaningful computation. The hydrographer must exercise judgment when estimating a reasonable value for σ. For survey planning, values in lanes of 0.02 to 0.2 should be used depending on equipment make (model, age, and past performance) and anticipated calibration frequency and accuracy. If the equation becomes indeterminate for a particular set of parameters, the system should not be used for the survey.

4.4.3.2. RANGE-RANGE SYSTEMS

4.4.3.2.1. *Phase-matching systems.* When using phase-matching systems in a range-range mode, the master station is installed aboard the vessel. The complement of required radio equipment is the same as that used for hyperbolic operation. As the vessel moves, the base lines vary in length. (See figure 4-13.) Pattern values for circular lines of position centered at the respective slave stations are displayed on the hydrographer's receiver. Positional data are registered by lane counters (as with the hyperbolic system), but the lane count is arranged to increase with distance from the slaves. Lane numbers in the hyperbolic mode increase with distance from the master station.

Lane widths are constant and may be computed by the formulas shown in 4.4.3.1. Without the effects of lane expansion, measured ranges are always coincident with base lines between the master and the slave stations; therefore, phase errors originating at the stations or in the vessel receiver result in distance errors in which magnitudes are independent of range. This is clearly in contrast to the hy-

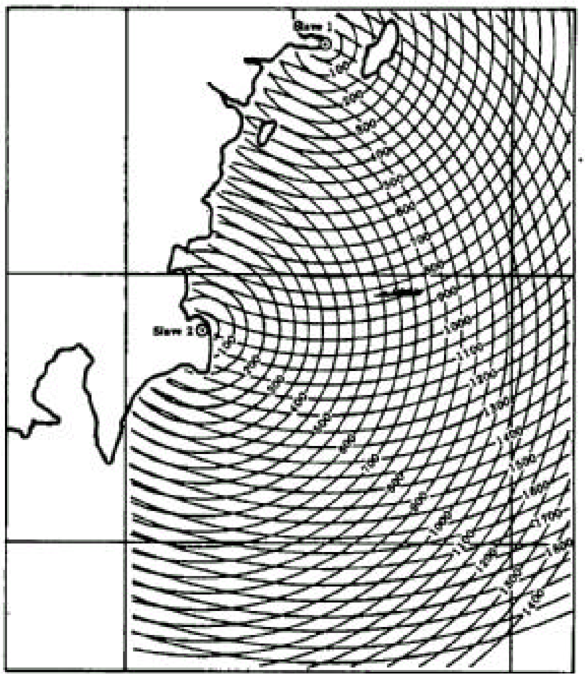


FIGURE 4–13.—Range-range lattice for a hydrographic survey (courtesy of Decca Survey Systems, Inc., Houston, Texas)

perbolic configurations whereby small errors at the base line can propogate substantially (in terms of distance) at the outer limits of the system.

Figure 4-14 shows typical error propogation contours for a set of slave stations located approximately 50 km apart, a reasonably representative distance for hydrographic surveys. The contours are shown in meters for an assumed standard deviation (σ) of 0.015 lane (daylight operation) along the base line. These accuracy contours are circular. The line connecting the two slave stations is straight. High accuracy regions for range-range systems along straight shorelines may be several hundred times larger in area than would be the case if the survey were controlled hyperbolically. The system operating frequency is about 1.8 MHz.

Since there is no lane expansion in range-range operations, the rmse from section 4.4.3.1 simplifies to

$$d_{ms}\ (\mathrm{m}) = \sqrt{(\sigma w)^2 + (\sigma w)^2}\ \csc\mu\ = \sqrt{2}\ \sigma w \csc\mu$$

where μ is the angle at the vessel subtended by the shore stations (and angle at which lines of position intersect); σ, the standard deviation of a coordinate at the vessel (in lanes); and *w*, the lane width.

Figure 4–12 shows graphically the elliptical distribution of the rmse about a point.

Phase comparison systems operating in a range-range mode should not be used in areas where the rmse, as computed by the preceding formula, exceeds 0.5 mm at the scale of the survey. As in hyperbolic operation, judgment must be exercised when estimating a value for σ. Values for σ (generally from lanes of 0.025 to 0.25) should include both the random errors and the unknown uncompensated systematic errors present in the system. If the equation becomes indeterminate for a particular set of parameters, the system should not be used for the survey. Regardless of the computed value, the angle of intersection should generally not be less than 30° or more than 150°.

4.4.3.2.2. *Distance-measuring systems.* Those now in use operate in the ultrahigh frequency range (300 to 3000 MHz) or in the super high frequency range (3000 to 30,000 MHz) and are limited to line-of-sight measurements. Typical characteristics of these systems include:

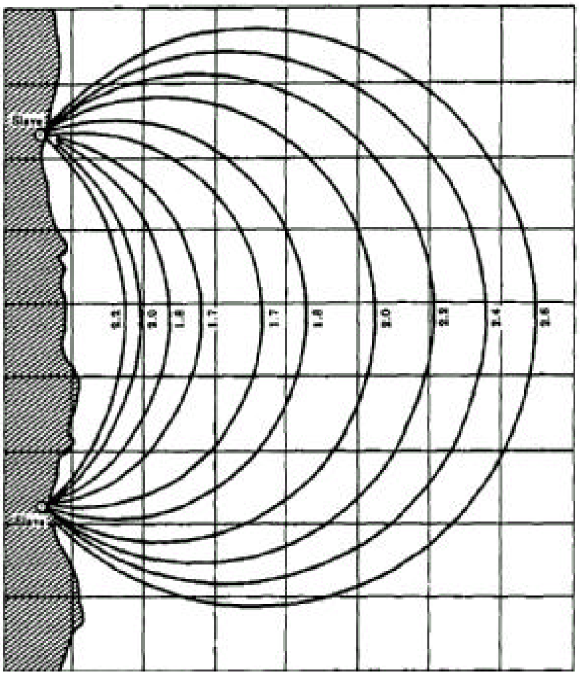


FIGURE 4–14.—Error contours for a typical range-range system (courtesy of Decca Survey Systems, Inc., Houston, Texas)

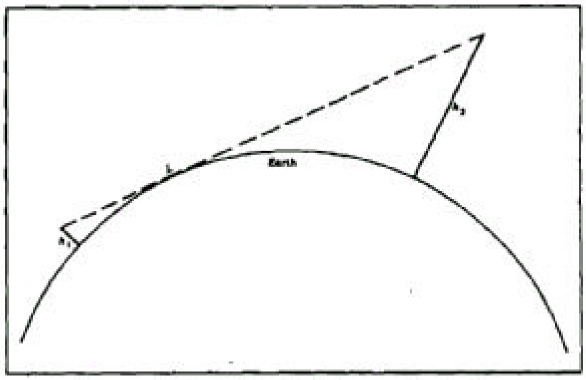


FIGURE 4–15.—Line of sight over the horizon

Light and highly mobile vessel and shore station equipment.

Direct distance readout displays at the master station (usually located aboard the vessel).

Very accurate position fixing at short ranges.

Time-sharing multivessel field operation capability.

Measuring capability of 100 m to 80 km

provided that line-of-sight conditions between the master unit and slave stations are maintained.

The effective microwave line-of-sight distances may be computed by

$$L(\text{km}) = 4.04 \left[\sqrt{h_1(\text{m})} + \sqrt{h_2(\text{m})} \right]$$

or

$$L(\text{nmi}) = 1.23 \left[\sqrt{h_1(\text{ft})} + \sqrt{h_2(\text{ft})} \right]$$

where L is the line-of-sight distance and h_1 and h_2 are the heights of the shore antenna and the vessel antenna. (See figure 4-15.)

For example, if the height of a slave station antenna is 27 m above sea level and the antenna aboard the survey vessel is 12 m above the water surface, the effective microwave line-of-sight distance is

$$L = 4.04 \left(\sqrt{27} + \sqrt{12} \right) \cong 35 \text{ km.}$$

(See tables C-5 and C-6 and figure C-1 for antenna elevations and related line-of-sight distances.)

Conservative values for the heights of shore stations must be used in areas where the tidal range is relatively large and where sea swells may diminish the effective line-of-sight distance to the horizon.

Super high and ultrahigh frequency systems should not be used where any obstruction, however slight, may penetrate the line of sight between the master station and the slave stations. Obstructing objects cause a complete loss of signal or can result in undetected erroneous distance readings. Elevated shore stations should be used as necessary to avoid lower obstructions and attain greater operating ranges. Caution must be exercised when the vessel is working near elevated shore stations since the system measures slant ranges. Slant range measurements shall be corrected to horizontal distance if the magnitude of the correction exceeds 2 m. Refer to section AD for a more detailed discussion of the distance-measuring systems now in use.

Super high frequency direct distance measuring systems shall be used for hydrographic position control only when line-of-sight conditions can be maintained within the maximum operating range limits specified by the manufacturer; they should be used only where the following conditions are met:

$$d_{rms} \leq \begin{cases} \text{0.5 mm at the scale of the survey for scales of 1:20,000 and smaller.} \\ \text{1.0 mm at the scale of the survey for 1-10,000 scale surveys.} \\ \text{1.5 mm at the scale of the survey for scales of 1:5,000 and larger.} \end{cases}$$

Here, $d_{rms} = \sqrt{2}\sigma \csc \mu$; σ, the standard deviation of a distance measurement (meters); and μ, the angle of intersection of the lines of position at the vessel.

As with phase comparison systems, the hydrographer must use judgment when estimating a value of σ for his system. Depending on the system, values of σ can be expected to vary from 3 to 10 m under normal operating conditions.

The preceding formulas can also be expressed in terms of the minimum allowable angle of intersection of the lines of position at the vessel for different survey scales; for example,

$$\mu \geq \csc^{-1} \left[K\sigma^{-1} (\text{survey scale})^{-1} \times 10^{-4} \right]$$

where K is 3.54 for scales of 1:20,000 and smaller; 7.08 for 1 -10,000; and 10.62 for 1:5,000 and larger.

Regardless of the computed value, minimum angles of intersection should not be less than 30°. C-band and X-band positioning systems shall not be used to measure distances less than 100 m because severe accuracy degradations may occur within that range.

4.4.3.3. SYSTEMS CALIBRATION. Electronic positioning systems shall be calibrated in accordance with the specifications in section 1.3.3.2.4 and the following guidelines. The purposes of calibration are:

1. To establish a geographic positional reference (i.e., true lane count or distance).
2. To determine and correct systematic errors in observed electronic positional data.
3. To determine anomalies or variations in the performance of the system throughout the survey area.
4. To serve as a check on the accuracy of the basic chain and the station positions.

The specifications for calibration contained in section 1.3.3.2.4 are the minimum acceptable criteria. Under certain conditions for some hydrographic surveys, it may be desirable or necessary to use more accurate methods, such as locating the vessel by theodolite intersections from known geodetic stations ashore. (See 1.3.3.1.2 and 4.4.2.2.) When necessary, the need for greater calibration accuracies is generally indicated in the project instructions. The hydrographer, however, is not relieved from the responsibility to adopt more rigorous standards if survey conditions warrant.

Requirements for daily or twice daily calibralions are, again, minimal and should be presumed to apply only if the positioning equipment is operating smoothly. Calibration frequency for a particular piece of equipment during a particular survey is a matter of judgment. The hydrographer must maintain and calibrate this equipment with sufficient accuracy to ensure that National Ocean Survey standards will be met.

The importance of calibrating electronic positioning equipment in or as near to the operating area as possible cannot be overemphasized, particularly when using medium range systems. (See 1.3.3.2.2.) Calibration correction values often vary significantly over small areas within the survey area. The degree or magnitude of local calibration variations that may be expected during the course of the survey should be determined prior to beginning hydrography. To accomplish this goal, calibrations are observed throughout the survey area for each shore station configuration. Frequency and spacing of these area calibrations are a matter of judgment, but must be sufficiently dense to give the hydrographer a working perception of the variations. Calibrations taken during the progress of the survey should be compared frequently with those taken previously at the same location to determine system variations with time and under varying meteorological conditions.

A complete calibration consists of at least two independent observations to determine corrections to be applied to the electronic positional values. The recommended procedure is:

1. The vessel is maneuvered as close as possible to the area of survey operations.

2. Simultaneously, a fix is taken, and the electronic line-of-position values are observed and recorded. Three-point Fixes should be observed from a point as near as practical to the receiving antenna of the vessel. Check angles shall be taken—only control of third-order accuracy or better that has been recovered and positively identified may be used. (See 1.3. 1.) When locating the vessel by theodolite intersection methods, the theodolites are pointed on the receiving antenna. The automated system can adjust for an eccentric observation by computing the position of the vessel antenna by azimuth and distance from the observers.

3. The fix position is then converted to electronic positional values graphically or by machine computation. Graphic conversions are made by plotting the fix on a calibration sheet (4.2.4), then scaling the electronic positional values for the fix. Most NOS major survey vessels, however, are equipped for automatic computation of calibration data. Nonautomated launches operating from a major survey ship should transmit the data to the ship by radio for the necessary computations. For calibration, electronic values computed from observed fixes are considered to be true values.

4. True values are then compared with the observed electronic values, and corrections to be applied to the electronic values are computed. (See figure 4-16.)

5. A second set of calibration observations are made as in procedure 2, and a second set of corrections are computed as in 3 and 4.

6. Independent calibrations can best be compared by comparing resultants or vector sums of the line-of-position correctors for each observation. (See figure 4-17.) For this comparison, the line-of-position intersection angle μ is selected for the area of weakest geometric strength in the survey area where the calibration data will be applied. Selection of the proper value of μ is important if calibration is not accomplished in the immediate work area.

7. If the difference in calibrations (i.e., difference in correction vectors) exceeds 10 m or 0.5 mm at the scale of the survey, whichever is less, additional observations shall be made until satisfactory agreement is reached. Refer to figure 4-17 for the following example:

$\overline{C}_1$ is the computed negative correction (in meters) to the P_1 line-of-position arc from the observed position of the vessel, O.

$\overline{C}_2$ is the computed positive correction (in meters) to the P^2 line-of-position arc.

$\overline{R}_1$ is the sum of the C_1 and C_2 corrections.

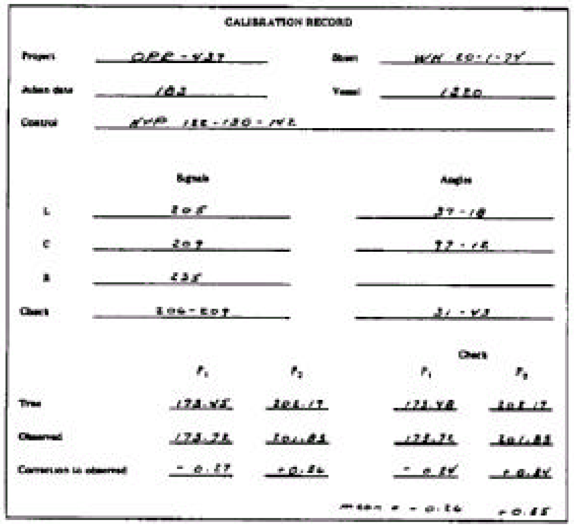
$\overline{R}_2$ is the sum of a second set of similar calibration observations that has been translated to the vessel at O.

The distance between T_1, and T_2, or the difference in correction vectors should not exceed 10 m or 0.5 mm at the scale of the survey, whichever is less.

If the observations fail to agree, calibrations shall be repeated until satisfactory agreement is reached. Mean values of agreeing calibrations are then computed and applied to the electronic positioning values observed during hydrographic operations.

If electronic computers are not available for calculating the calibration data and calibration sheets are needed to determine the correctors (4.2.4), the correctors determined for each observation must agree to within 0.5 mm at the scale of the survey.

Calibration corrections within the same area occasionally vary with time (e.g., the correctors determined in the morning may not agree satisfactorily with those determined at the end of the day). There is no set rule for times between required calibration observations. In addition to regular calibrations, the hydrographer should take every opportunity to check the system calibration against accurately located topographic features. Unless a specific event occurred that the hydrographer believes to be the cause of a variance, a linear interpolation of the correctors is generally advised. The occurrence and treatment of relatively large differences in calibration data over a period of time should be thoroughly discussed in the Descriptive Report. (See 5.3.5.)



CALIBRATION RECORD

Project
Sheet
Julian date
Vessel
Control

Signals
Angles
L
C
R
Check

Check
P_1
P_2
P_1
P_2
True
Observed
Correction to observed

FIGURE 4-16.—Manual record of electronic positioning calibration and computation of corrections (hyperbolic control, three-point fix). Similar formats can be constructed for computer output or other means of calibration and types of control.

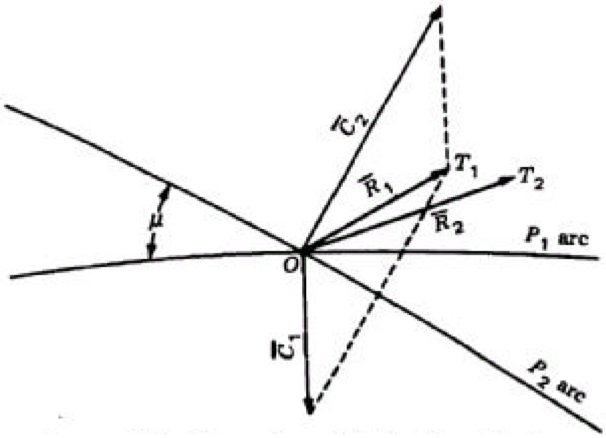


FIGURE 4-17.—Comparison of electronic positioning calibrations

Although the three-point sextant fix is most

equipment, other methods of equivalent or better accuracy are often used. Using the range and angle method, the vessel steers along a sensitive range at slow speed until a predetermined sextant angle to the right or left of the range is closed. Electronic position data are observed at that instant and compared with values that have been computed in ad-

for P_1,... P_4, have been computed beforehand. *A*, *B*, and *C* are stations of at least third-order accuracy, and the angles a have been preselected for each point on the range.

Another acceptable and often preferred method is to bring a launch or small vessel alongside a piling, dolphin, beacon, or other similar object for which a position is accurately known. In practice, a wide variety of acceptable methods of calibration has been devised. The hydrographer should exercise ingenuity in adapting methods for his particular circumstances.

A complete record of all calibrations and calibration data shall be maintained for the Descriptive Report (5.3) and the hydrographic records that accompany the survey.

When using phase comparison systems (i.e., lane counting) in a survey area offshore or relatively distant from an area where good calibrations may be obtained, it is advisable to moor small buoys that can be used to redetermine or check the whole lane

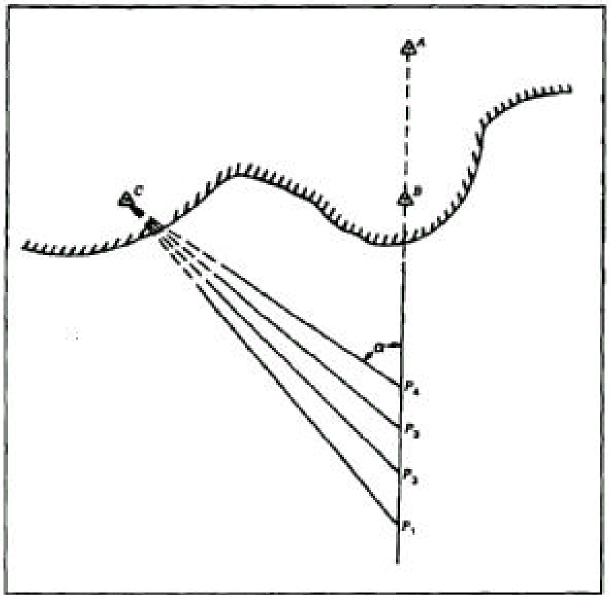


FIGURE 4-18.—Position by range-angle method

count if necessary. The method of determining the position of the vessel by using a buoy shall not be used for calibration — its use is limited to establishing or checking only the whole lane count.

The buoys should be anchored securely with minimum scope of mooring gear. The position of the anchor must be determined and proper account made for the current direction and scope of the anchor cable when used to check the lane count. Buoys used for this purpose should be painted international orange and be lit when moored in areas of likely surface navigation. Radar reflectors are advised in open waters as an aid in finding the buoys. The U.S. Coast Guard must be notified of the presence, position, characteristics, purpose, and anticipated time these buoys will be in position to ensure inclusion of the information in the Notice to Mariners (e.g., Defense Mapping Agency Hydrographic Center et al. 1976).

If it is impractical for the survey vessel to come alongside a buoy for determination of lane count, one of these two methods may be used:

1. If line-of-position arcs are of large radius and curve slowly, the whole lane count may be determined by circling the vessel around the buoy at slow speed. Compute or scale azimuths for the lines of position where the buoy is located. As the vessel circles the buoy, the bearing of the buoy from the vessel is continually observed with a pelorus. When the bearing of the buoy is equal to the azimuth of a line of position for a particular arc, the lane count for that arc aboard the vessel is equal to that of the buoy. (See figure 4—19.) The vessel crosses each arc twice during each full circle. If the values shown on the position display device must be corrected, the setting of the new values must be checked by another circling of the buoy.

2. If the vessel is not equipped with a gyroscope repeater and pelorus from which accurate bearings can be observed, whole lane values may be determined by estimating the bearing from the vessel to the buoy and by obtaining the distance by range finder or depression angle from the horizon. If a graphic solution is necessary, the scale should be sufficiently large to discern tenths of lanes. As a check, at least three comparisons must be made at various positions with respect to the buoy.

C-band and X-band positioning equipment manufacturers recommend calibrating field systems either between known ranges within the survey area or between several points along a measured base line (e.g., at 500, 750, and 1000 m). The range calibration potentiometers are adjusted to make the equipment readout distances agree with the known base line distances. This procedure permits a good initial calibration of the electronic delay circuits under the meteorological conditions at the time and the strength of the signal at the calibration range. Because changes in either the meteorological conditions or the signal strength can cause distance measure-

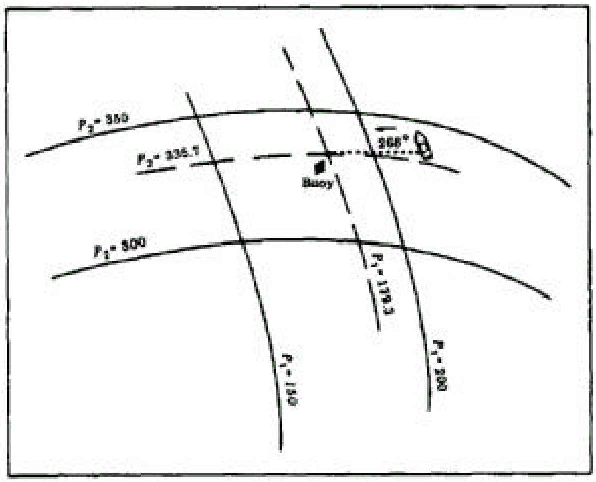


FIGURE 4-19.—Determination of a lane count by buoy circling. When the observed bearing of the buoy from the vessel is 268°, the whole lane value for the line of position P_2 is 335 lanes.

ments to vary considerably, these systems shall also be periodically calibrated or checked in the working area by one of the methods described previously.

4.4.3.4. SHORE STATION SITES. Many factors must be considered when determining good locations for electronic positioning system shore stations. Factors to be carefully weighed include:

1. Size and shape of the area to be surveyed.
2. Topography and configuration of shoreline.
3. Accuracy requirements and lattice orientation.
4. Atmospheric noise levels and external signal interference.
5. Available and acceptable horizontal control.
6. Accessibility to the site, station security, and availability of shore power if needed.
7. Willingness of the property owner to rent or lease.

Medium range position-fixing systems require several additional considerations when selecting shore sites. Velocity of propagation is a fundamental factor in the formulas for the computation of most medium range position-fixing lattices. Any error or variation in the assumed value introduces systematic errors into all position plots or computations. Since the value for velocity varies under different physical conditions, small errors should always be expected throughout large portions of the chain coverage. Atmospheric properties such as temperature, humidity, and pressure have an effect on the velocity of propagation. Major variations in velocity values, however, are caused by differences in the conductivity of the surface over which the wave travels. The effect of surface conductivity is analogous to friction - that is, a poor conductor has an effect similar to that of a rough surface; it absorbs energy and reduces the speed of movement. Thus, a poor conductor results in a low velocity or propagation, high attenuation, and reduction of effective signal range. (See table 4-3.)

The current software package of the HYDROPLOT system employs an electromagnetic propagation velocity of 299,670 km/s in the conversion of lanes to meters and in the computer generation of hyperbolic position lattices, for hydrographic operations conducted over seawater. This value was determined by empirical methods in the late 1950's by the National Bureau of Standards in conjunction with the Coast and Geodetic Survey and Hastings-Raydist, Inc., Hampton, Virginia. For operations over freshwater, it is recognized that the propagation velocity should be less than that derived for operations over seawater. For the Great Lakes, a velocity of 299,350 km/s is recommended.

TABLE 4-3.— *Typical empirically determined velocities of propagation for medium range frequencies*

Medium	Velocity (km/s)
Vacuum	299,792
Over water	
Sea water	299,350-299,670
Great Lakes	299,350
Fresh water	299,250
Over land	
Rich farmland	299,400
Dry sandy flatland	298,900
Rocky mountainous land	298,800

The HYDROPLOT software uses the relationship *v/f* to convert lanes to meters. Since the value for *v* is fixed at 299,670 km/s, the only way to accomodate a different *v* is to modify the relationship *v/f* by changing the value of *f*. This may be accomplished by using

$$\frac{v_1}{f_1} = \frac{v_2}{f_2} \text{ or } f_2 = \frac{v_2}{v_1} \times f_1$$

where: f_2 = pseudo frequency for plotting with a fixed velocity of 299,670 km/s

n_2 = 299,670 km/s

f_1 = true frequency of the electronic positioning system

n_1 = new velocity of propagation

Example: If the true frequency of an electronic positioning system to be used in a hyperbolic mode in the Great Lakes is 1618.65 kHz, and the known velocity of propagation is 299,350 km/s, what frequency should be entered on the HYDROPLOT signal tape to compensate for an erroneously preprogramed propagation velocity of 299,670 km/s?

Ans:

$$f_2 = f_1 \times \frac{V_2}{V_1}$$

$$f_2 = (1618.65) \times \frac{299,670}{299,350}$$

$$f_2 = 1620.38 \text{ kHz}$$

From these facts, it is clear that wave paths over terrain of varying conductivity should be avoided wherever practical. Each shore station site should be located either within 100 m of the water's edge or so that the landmass between the station and the vessel does not change appreciably throughout the survey area. Shore station configurations where base lines are subject to varying conductivities should also be avoided wherever possible (e.g., tidal flats that dry at low water).

If a station must be placed inland, the change of signal instability will be greatly reduced if the antenna is at least 1 km inland of the shoreline. In this case, the requirement to calibrate the system frequently in the vessel's immediate working area must be observed rigorously.

Hydrographers must have a basic understanding of the uncertainties in the velocity of propagation of an electromagnetic wave. There is a common tendency when using medium range systems to "stretch" base line lengths to achieve the largest possible chain of high accuracy coverage. With phase comparison positioning systems, however, it is vital that an uninterrupted signal be transmitted from the master station to each of the slaves. If the signal is lost, even momentarily, the receiver may lose lane integration. If this occurs, the vessel must return to a known point for calibration or for reestablishment of lane count. Although the geometric strength of a control chain may be increased by longer base lines, the pattern stability is usually decreased by random variations in wave propagation conditions.

Base lines that lie entirely over water are highly desirable because of the greater homogeneity of the conducting surface. A homogeneous surface reduces random fluctuations in the velocity of propagation and eliminates excessive signal attenuation. Experience has shown that, under average electronic noise conditions, base lines for most systems should rarely exceed 80 km. When one considers the widely varying conductivity characteristics of most landmasses, base lines in excess of 50 km should be avoided unless knowledge of the area indicates more favorable conditions.

The effects of external noise must also be taken into consideration when selecting shore sites. Natural atmospheric noise generally increases from a minimum at Earth's geographic poles to a maximum in the Tropics. Superimposed upon atmospheric noise is manmade electrical noise reaching its highest level around cities, factories, shipyards, and similar areas. Such local interference is generally "unimportant in the vicinity of the master station but can seriously affect conditions if near a slave station by masking a weak master signal.

Local topography and ground conditions are principal field factors to be considered when selecting station sites. With many systems, a firm connection to a stable electrical ground is essential if the vessel is to receive stable pattern values. Every effort must be made to attain stable electrical grounding by driving ground rods down to the water table or by making a connection to a metallic water supply system. Frequently, large ground planes radiating from an antenna must be constructed for a good ground. Moist soil of good conductivity is preferred over sand where the electrical characteristics of the antenna are subject to variation with rainfall or tidal stage. Variations of this nature cause troublesome pattern shifts.

Medium range stations should be sited where local power is available. Most systems are battery powered with the batteries floating on a 110- or 220-V a.c. power supply through a battery charger. If local power is not available, generators are generally used.

Distances and heights of nearby elevated objects must also be considered. Fixed objects such as trees, cliffs, buildings, cranes, and the like should be at distances at least six times their height away from the antenna. The figure should be doubled if the object is metal and liable to move during station operation. Overhead power cables, telephone wires, and similar objects should be at least 50 m away from the master station and at least 100 m away from the slaves.

Although line-of-sight conditions are not a requirement for medium range position-fixing systems, it is desirable to site shore stations on high ground sloping toward the survey area to attain the greatest effective range. (See 1.3.1 for horizontal control accuracy requirements for station location.)

4.4.4. Hybrid Positioning Systems

For hydrographic surveys, hybrid positioning systems combine positional data of mixed origin to provide accurate fixes. Hybrid systems generally involve the intersection of a visual line of position with an electronic line of position. (See figure 4-20.) Visual data may be sextant angles or azimuths determined by theodolite measurements. Electronic positional data are normally obtained from a short or medium range system.

For example, a launch conducting an inshore hydrographic survey may not be in an area where positional accuracy criteria would be met if an established hyperbolic chain were used. For one reason or another, it would be impractical to alter the existing configuration of the chain. A reasonable alternative under these conditions is to use the "hypervisual" method (i.e., a hyperbolic line of position intersecting a visual line of position). Hydrographic signals along the beach are located and constructed as necessary. During sounding operations, the vessel is maneuvered along the hyperbolic arc; and on the fix, a sextant angle is observed. Objects used for the sextant angles must straddle the electronic arc along which the vessel is steering. The "range-visual" system is similar except that the positioning system operates in a range-range mode.

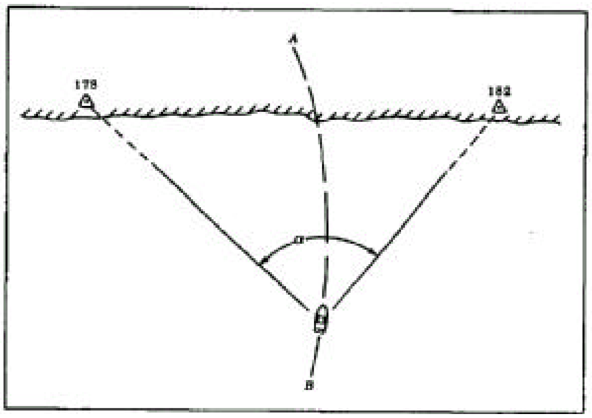


FIGURE 4-20. —Hybrid positioning system. The vessel is maneuvered along electronic line-of-position arc *AB;* sextant angle a is observed between signals 178-182.

The "range-azimuth" method is a convenient system to use in small, restricted, or congested areas where the line-of-sight conditions cannot be met for two short range system lines of position. (See figure 4-21.) Using this method, the sounding vessel maneuvers along a range or circular line-of-position arc; the vessel is fixed along this line by a theodolite azimuth observed from shore. The ideal theodolite site is directly below the electronic control station antenna. This method produces exceptionally strong fixes because the lines of position always intersect at right angles.

Objects sighted on for initial azimuths should be at least 500 in from the theodolite. If a second object is not available for an azimuth check, Polaris or solar observations can be taken to check the initial azimuth.

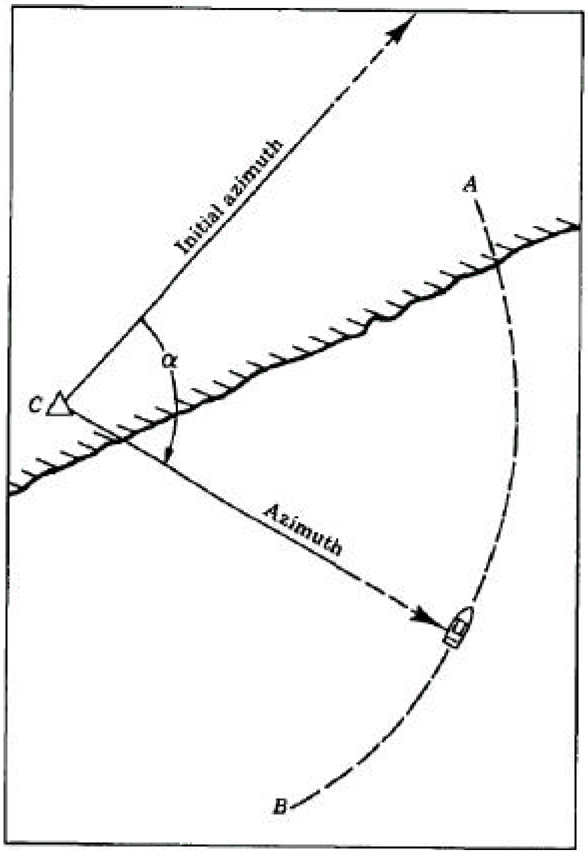


FIGURE 4-21. —Range-azimuth positioning system. The vessel is maneuvered along electronic range arc *AB;* the azimuth from shore station *C* to the vessel is observed using a theodolite.

The azimuth check should not exceed 1 min of arc. Observed azimuths or directions to the sounding vessel for a position fix shall be read to the nearest 1 min of arc or better if necessary to produce a positional accuracy of 0.5 mm at the scale of the survey.

4.4.5. Position Frequency

Frequencies of positions along sounding lines are influenced by several factors:

Scale of the survey.
Line spacing.
Speed of the survey vessel.
Conditions of wind and current.
Type of position control. (See 1.4.5.1.)

The distance between successive numbered positions on sounding lines should be about 40 mm on the hydrographic sheet and shall not exceed 50 mm regardless of the scale of the survey. Positions are taken and numbered at regular intervals to aid in detecting errors. (See 4.5.6 for sounding interval requirements.)

When sextant fixes or theodolite cuts are used for position control, numbered positions should be obtained more frequently—particularly if there is difficulty in keeping the vessel on line because of wind or current or when lines must be closely spaced. Positions may be taken less frequently when steering ranges or when lines are being run along hyperbolic or range arcs. In areas of even bottom, distances between successive fixes along distance arcs may be increased slightly but should never exceed 50 mm on the sheet. Sextant fixes and theodolite cuts can be observed and plotted very rapidly, particularly where the fixes are strong and the signals are nearby. Recording excessive fixes should be avoided to keep the processed data from becoming overly congested. For example, 1.5-min intervals between fixes should not be used if 2-min intervals are adequate.

In most cases, a survey ship or launch sounds at the highest practical speed. If the scale of the survey is small, positions may be taken at intervals of several minutes; however, if the scale is large, the intervals may be so short that it will be necessary to reduce the speed of the vessel to avoid cluttering the sheet.

In addition to evenly spaced positions along sounding lines, numbered positions shall be recorded under each of the following circumstances (whether or not accompanied by control data):

1. At the beginning and end of each line. (Positions must often be plotted by dead reckoning and fixes "created" to ensure accurate smooth plotting.)
2. Whenever the speed of the sounding vessel is changed appreciably.
3. At all changes of course larger than 10º. In such cases, another position should be determined as soon as possible after the vessel is on the new course.
4. At each detached sounding.
5. At each bottom sample.
6. At any other time a position is taken for field edit, aids to navigation, obstructions, or to locate or check a hydrographic signal.

On many automated surveys, position information is obtained and recorded for every recorded sounding. To avoid congestion, position numbers are assigned only at prescribed evenly spaced intervals and for each of the circumstances listed. The maximum allowable spacing of 50 mm between position numbers is generally adopted for these surveys.

4.4.6. Position Identification

Hydrographic positions shall be numbered consecutively with a block of numbers assigned to each sounding vessel. (See 1.4.5.2.) Position numbers continue consecutively from day to day until the survey is completed. Detached positions such as rocks and bottom samples are included in the day-by-day numbering system. A listing of all detached positions must be included in the Descriptive Report. (See 5.3.5.(G.).)

Julian dates are assigned to daily blocks of work for further identification of data. Julian dates begin with 001 every January 1 and run consecutively each day throughout the calendar year.

4.5. RUNNING HYDROGRAPHY

4.5.1. Beginning Survey

When control has been established, field sheets prepared, and the required data plotted on field sheets, the hydrographer is ready to begin. Usually, the first step is to make a satisfactory junction with a prior survey, then progress in the direction specified in the project instructions. It may be prudent, however, to survey an anchorage for the vessel first if there is reason to doubt the charted soundings. The decision on where to begin hydrographic operations may be logically revised by previously unforeseen control problems or by weather and sea conditions.

If the field sheet is to be plotted manually and the sounding line system for the survey is to be parallel straight lines, the proposed lines should be lightly penciled on the sheet to guide the hydrographer. For automated surveys, parameters for the hydrographic line equations are determined as required input for the computer. [See *NOS Technical Manual No.* 2, "HYDROPLOT/HYDROLOG Systems Manual" (Wallace 1971)] On larger scale nonautomated surveys, the proposed line spacing (1.4.1 and 4.3.4) should be approximately 5% less than the maximum spacing authorized as a safeguard against having to run splits later should the maximum allowable spacing be exceeded.

To start a sounding line, one navigates the ship or launch to the beginning of the proposed line. Trial positions are plotted as this point is reached. The course is given to the helmsman; the recorder is told when to take the first position and sounding. For visual surveys, angle observers are advised on which signals to use for the fix or for theodolite azimuthal orientation.

4.5.2. Following Proposed Sounding Lines

The hydrographer should follow the proposed sounding lines as closely as possible for the most efficient and effective coverage of the survey area. Automated vessels normally run straight parallel lines. When the survey is controlled electronically, the position of the vessel is computed every several seconds and displayed relative to the proposed sounding line by an electronic counter or a "left/right" indicator. With this continually updated information, minor course changes can be made easily and quickly to avoid significant departure from the lines.

When electronic control systems are used aboard nonautomated vessels, the easiest method of following proposed sounding lines is by steering hyperbolic or circular loci arcs, the orientation and directions of which vary with the shore station geometric configuration. When steering arcs, the position of the vessel relative to the line can be continually monitored by watching the digital distance or lane counters. Departures from the line can usually be corrected in a timely manner by making small course changes. Steering arcs can be especially effective when strong or erratic currents or wind conditions make it extremely difficult to consistently run properly spaced straight parallel lines.

When visual control is used for the survey, the first position is taken and plotted immediately, either manually or by automation. If necessary, an immediate course correction is given to the helmsman to ease the vessel over to the proposed line. Positions are then taken and plotted at short intervals until a steering course that closely follows the line is established. The time between positions may then be lengthened to the maximum allowable interval corresponding to the scale of the survey and the speed of the vessel.

As a survey vessel approaches the inshore ends of sounding lines or when nearing shoals, breakers, or other dangers, prudent seamanship requires the hydrographer to reduce speed. Fixes are taken at any time the speed is changed for any reason. If the vessel must begin a sounding line near the beach from a standstill, the fact shall be noted in the records and the next fix taken as soon as regular sounding speed is reached.

When visual control is used, the helmsman should be trained to select and steer available natural ranges to stay on the proposed line. Otherwise, the vessel is maintained on the line as closely as possible by steering compass courses - small course changes are made as required. Course changes should not exceed 10° unless a fix is taken when the change is made (or the exact time and new course recorded). Considerable experience is required to gain the knack of making course changes of sufficient amount at the correct time. Changes in the direction or strength of the current are often indicated by "current streaks." These should be observed and recorded for future reference. Changes in the strength of the current may be expected in the vicinity of shoals and banks in offshore areas.

Line spacing is directly related to water depths and widens as depth increases. Maximum spacing for certain depth ranges are generally specified in project instructions. When the maximum spacing is exceeded, split lines should be run as necessary to fill the void — except that wider spacing at the outer limits of depth ranges may be accepted on even slopes. The hydrographer must use good judgment in running splits and should base his decision on the character of the bottom as well as the distance between lines. Generally, splits should be run as soon as possible after line-spacing deficiencies or the needs for additional developments are discovered.

4.5.3. Turns and Changes in Course

Soundings shall be plotted as precisely as possible along the true path of the vessel. Position fixes must be taken on course changes exceeding 10° — except that, when positions are determined for each recorded sounding, additional fixes need be obtained only on course changes of 30° or more. When turns of approximately 90° are made or when the vessel is turned to a reciprocal course to begin a new sounding line, the soundings on the turn may be recorded and plotted if such data are considered useful by the hydrographer. Soundings on turns, however, generally should be omitted unless the vessel is computer equipped and each sounding is positioned uniquely. Whether or not soundings on turns are plotted, the analog depth record must be carefully examined for traces of shoals or hazards that could otherwise go undetected. A fix shall be taken at the beginning and end of each sounding line.

4.5.4. Speed of Sounding Vessel

Within practicality, soundings shall be obtained while the survey vessel is operated at normal cruising speed (i.e., the most efficient speed); however, speed shall be reduced as necessary:

When there is risk of grounding.

When submerged hazards are suspected.

When sounding in heavy seas or reduced visibility.

When necessary to meet requirements for minimum distances between successive positions.

When required to adequately define steep features.

When sounding with lead line or pole to obtain true vertical measurements (A.6.1.1 and A.6.1.2).

At all other such times required by the rules of the road and prudent seamanship.

Vessel speed should be as constant as possible between positions. Each change of speed shall be recorded and a position taken when the change was made or as soon thereafter as practical.

4.5.5. Plotting Sounding Line

When plotting positions by hand, a fine pencil line is drawn lightly between plotted positions to show the track of the vessel. If a course change has been made between fixes, the line drawn shall represent the track as accurately as possible. Sounding lines following circular or hyperbolic arcs may be drawn by using small pieces of clear plastic trimmed to fit arcs of various radii. Positions taken aboard vessels equipped with a HYDROPLOT System (Wallace 1971) are automatically computed and plotted on a real-time basis.

When a line is run parallel to the shoreline, positions often cannot be obtained with sufficient frequency to plot all course changes. In such cases, the hydrographer should draw a line that closely approximates the path of the launch between successive positions. Under these circumstances, a note, "SFS" (1.2.1), should be made in the sounding record to indicate that the field sheet plotting must be used as a guide when processing the data. Positions and soundings taken in narrow winding channels, in streams, and over mudflats are treated in the same manner. When positions of this nature are logged for automatic plotting, a fix must be "created" (i.e., fix values for the approximate position are scaled).

Position numbers for hand-plotted ship hydrography can often be inked when the position is plotted — frequently, on small-scale surveys soundings may also be inked shortly after they are scaled and recorded. During launch or skiff hydrography or on larger scale surveys where data are obtained rapidly, positions and soundings are usually inked later. When the vessel does not steer an arc, the fixes shall be plotted as quickly as possible so that course changes necessary to follow the proposed lines can be made. Hand-plotted positions are numbered in pencil when plotted and are inked in assigned colors as soon as practical, preferably no later than the end of the day. Insofar as possible, position numbers are placed below and to the right of the position. Position numerals should be about half the size of the sounding numerals.

Under certain conditions, it may not be necessary to make an accurate plot of the sounding line when the data are being gathered. If a launch is steering circular or hyperbolic arcs and sounding and position data are being logged on tape for later plotting, rough plots on a field sheet tracing to monitor progress are normally sufficient. During open skiff operations, it may be advisable to plot on a rough worksheet to prevent water damage to the field sheet; then replot or transfer the positions on the field sheet at the end of the day.

4.5.6. Sounding Interval

Although echo sounders produce a nearly continuous graphic record of the bottom profile, soundings are recorded at fixed intervals as the lines are run. Digital sounding equipment is programmed to record soundings at preselected fixed intervals. The hydrographer shall select a time interval for recording soundings that is appropriate to the scale of the survey, depth of water, configuration of the bottom, and speed of the vessel. (See 1.4.6. and figure 4-21b) Where depths of water or slopes of the bottom are uniform, the minimum interval between recorded soundings shall be such that all recorded soundings can be plotted on the smooth sheet without congestion.

While uniform intervals facilitate plotting the smooth sheet, it is more important that recorded soundings give a true representation of the bottom configuration. In areas of irregular bottom, least depths and greatest depths between interval soundings must be recorded with additional intermediate soundings as necessary to define the profile adequately. To ensure that soundings are plotted accurately, record times of observations. Odd interval soundings and times are scaled from the graphic depth record and entered in the sounding records. (See 4.9.8. 1.)

The following guidelines may be used when selecting sounding intervals over fairly regular bottom topography:

1. If the horizontal axis of the sounding numerals is approximately parallel to the direction of the sounding line, one-digit numerals should be spaced about 4 mm apart, two-digit numerals spaced about 6 mm apart, and three- and four-digit numerals about 8 to 10 mm apart. (Rotation of the sounding numeral about the sounding line permits closer spacing.)

2. If the horizontal axis of the numerals is approximately perpendicular to the direction of the sounding line, numerals should be spaced 4 to 8 mm apart, depending on the depth.

3. If numerous soundings are to be shown in decimals, the decimal is considered to be equivalent to a half digit in width.

The final decision as to the sounding interval, however, lies solely with the hydrographer. Selected intervals shall, when the soundings have been

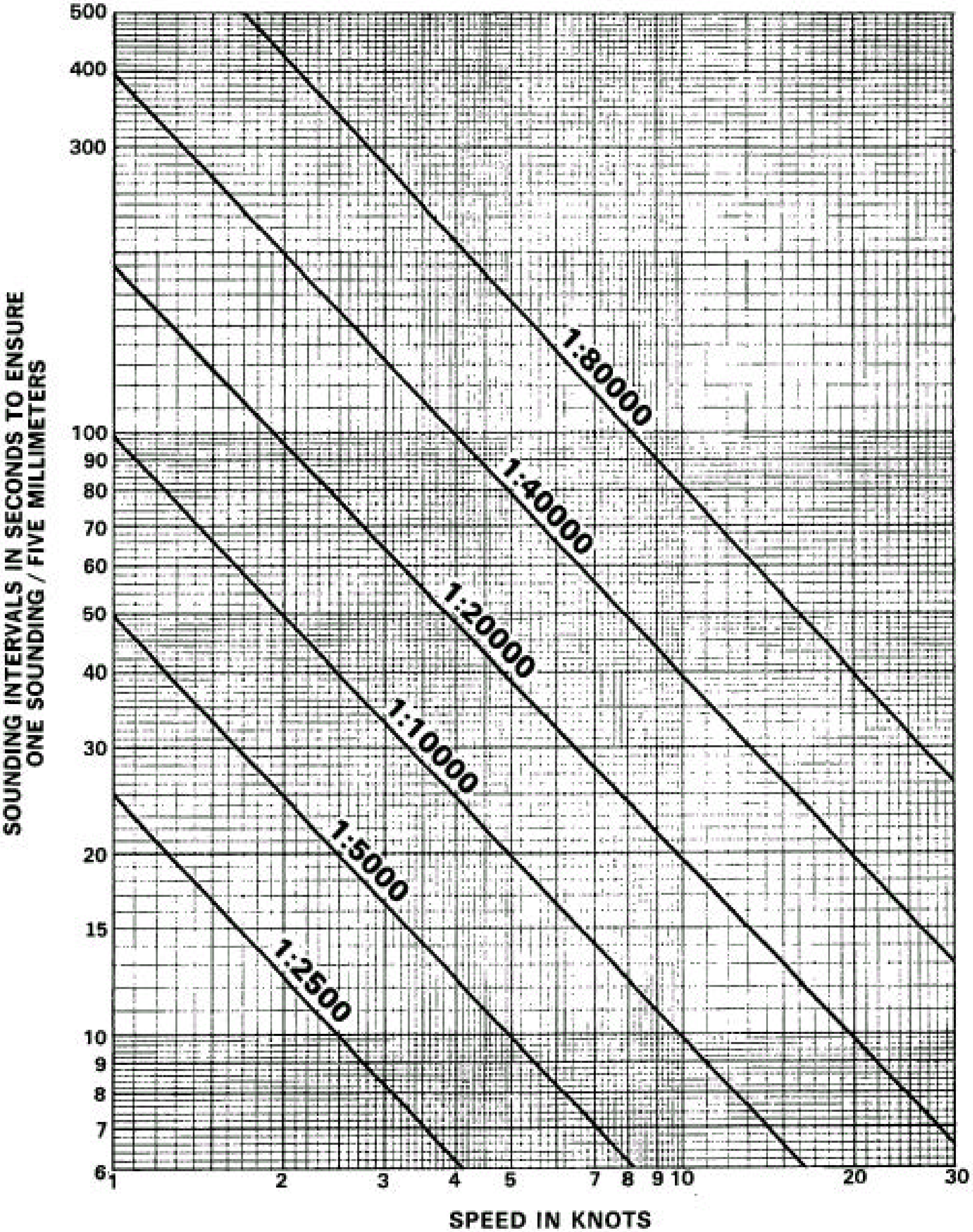


FIGURE 4-21 a. — Sounding Interval vs Speed plotted at the scale of the survey, portray the bottom configuration accurately.

4.5.7. Measuring Depths

4.5.7.1. DEPTH UNITS. These units and rounding limits to be used for various areas and depths ranges are specified in table 4-4. Soundings are always recorded in fathoms and decimals, meters and decimals, or feet and decimals -fractions shall never be used. Occasionally, soundings are recorded in fathoms for part of the area being surveyed and feet for other parts. The records must indicate which unit is being used. (See 4.8.3.5.) Only one sounding unit may be used when plotting, soundings on a field sheet or on a set of field sheets that will ultimately compose one smooth sheet. Special instructions will be issued for surveys on which soundings will be recorded and plotted in metric units.

4.5.7.2. FIELD SHEET SOUNDINGS. On the field sheet, soundings shall be plotted in black ink as soon as possible after all necessary data have been gathered. Soundings shall be reduced to the tidal or lake level datum adopted for the area using either predicted or observed tide or water levels. (See 1.5.4 and 4.9.3.) Significant corrections for phase differences or variation of the initial of the echo sounder should be applied (4.9); small corrections may be ignored for field sheet plotting. Hand-plotted soundings between positions shall be properly located by the use of a spacing divider; odd interval soundings on peaks and deeps must be positioned correctly. Soundings shown on positions must not obscure position dots or position numbers. (See 1.5.6.)

Plotted soundings should be uniform in size and clearly legible. In congested areas, a selection of representative soundings should be shown; however, all soundings necessary to show the bottom configuration adequately must be plotted. Least depths over shoals and dangers may be inked on the sheet in bolder figures than the surrounding soundings; notes are placed in nearby marginal areas on the field sheet giving least depths with references to sounding record position numbers.

Where the depth unit is the fathom and the bottom is generally flat or has a gentle slope, soundings shall be plotted in fathoms and decimals for depths less than 31 fm. This is also applicable for areas where the chart sounding unit is the foot but the survey is in fathoms. In other areas, soundings shall be plotted in whole units. (See 7.3.8.1 for smooth sheet soundings.)

4.5.7.3. DEPTH CURVES ON FIELD SHEETS. These are indispensable for a comprehensive interpretation and examination of a hydrographic survey. The best gage of the survey's completeness, adequacy, and accuracy is to be able to draw closely spaced depth curves for the plotted soundings with an assurance that the submarine relief is depicted accurately. Depth curves must be drawn on the field sheet by the hydrographer as the work progresses. A careful inspection of the depth curves will disclose where sounding lines have not been spaced closely enough, where additional development is required, and where there are errors that require further investigation. (See 1.5.7.)

An adequate representation of submarine relief by depth curves is a problem similar to the representation of land topography by contour lines, except the topographer can examine the area visually while the hydrographer has only measured and plotted depths as his guide. The hydrographer should make a study of characteristic bottom forms, as such forms are common within the same region and in similar regions.

Abnormal or improbable depth curves may be strong evidence of inaccuracies, inadequacies, or possible errors in the hydrographic survey or the plot of the soundings. Raw position and depth data and corrections thereto must be thoroughly examined to resolve possible discrepancies where the curve configuration is questionable.

On extensive coastal shelves, commonly found on the Atlantic Ocean and Gulf of Mexico Coasts of the United States, depth curves are generally smooth and regular because prevailing bottom forms are caused by wave or current action on loose bottom materials. In depths greater than about 100 fm on the continental slopes, bottom forms are generally more like those found on land. Intervals of 25 fm between depth curves are normally adequate on continental slopes and in deeper waters off the Pacific Ocean and Alaskan Coasts.

Drawing closely spaced depth curves accurately requires a careful inspection and consideration of each sounding, not only once but often several times; when sketching depth curves at too wide an interval, many intermediate soundings may not be considered, and important indications may be over-

TABLE 4-4.-*Depth units for scaling soundings and applying corrections.*

Depth range (fm)	Character of area or bottom	For soundings scaled in feet				For soundings scaled in fathoms			
		In protected waters		In exposed waters		In protected waters		In exposed waters	
		Record soundings to the nearest	Apply corrections to the nearest	Record soundings to the nearest	Apply corrections to the nearest	Record soundings to the nearest	Apply corrections to the nearest	Record soundings to the nearest	Apply corrections to the nearest
0-20	Least depths over shoals and dangers	0.2	0.2	0.5	0.2	0.1	0.1	0.1	0.1
	In channels, established sea lanes, and fairways								
	Delinearion of appropriate low water line								
	Elsewhere, over regular bottom	0.5	0.2	1.	0.5	0.1	0.1	0.2	0.1
	Elsewhere, over irregular bottom	1.	0.5	1.	0.5	0.2	0.1	0.5	0.2
20-110	Over regular bottom	1.	1.	1.	1.	0.2	0.1	0.5	0.2
	Over irregular bottom	2.	1.	2.	1.	0.5	0.2	1.	0.5
Greater depths	All bottom types	2.	1.	2.	1.	1.	1.	2.	1.

•Digital soundings are recorded, and computer determined correction are usually applied to the nearest tenth of the sounding unit regardless of depth or bottom character.

If there is double as to which increment to use, select the more accurate.

If soundings are being recorded in meters select the nearest equivalent increment from the fathoms portion of the table.

In areas of depth greater than 500 fm where the slopes are very deep and the echo trace is not sharp and clear, soundings may be sealed to the nearest 5 fm.

looked. (See 7.3.9.) Where interpretation is difficult, intermediate depth curves must be drawn.

Topographic experience is a great asset when drawing depth curves as is the ability to recognize predominating physiographic shapes. The ability to represent submarine relief by means of contouring can be acquired only by intensive training and practice and by studies of similar work done by experienced hydrographers.

Depth curves cannot cross or run abruptly into each other except at cliffs, overhangs, or other extreme topographic features. When approaching one another, they tend to be parallel. Information from sounding lines shall be sufficient to permit the delineation of depth curves. Special care must be' exercised to avoid excessive spacing of the sounding lines — particularly when the direction of the lines is parallel to the depth curves.

An alternate and often preferable way of determining whether sufficient soundings have been plotted on worksheets is to "group" depths. Depth curves are drawn to group numbers into small areas easy to work with, such as:

0-100/101-200/201-300,...,
0-10/11-20/21-30,....,
0-1/2-3/4-5,. . ., or
0-1/2,. . .,

depending on the slope of the bottom. Standard depth curves, however, must still be drawn. (See 4.5.7.4.)

Hydrographic field sheets are preliminary engineering representations of the surveyor's acquired data and findings. Generalization of the depth curves will not accurately portray the results of the field work and may prove to be misleading. Apparent irregularities or anomalies in the depth curve patterns can be key indicators either of erroneous data or of areas requiring additional hydrographic development.

See section 7.3.9 for various conventions adopted by National Ocean Survey for drawing depth curves on hydrographic sheets.

4.5.7.4. DEPTH CURVE INTERVAL. No single requirement for spacing of depth curves can be prescribed that applies to all regions. In areas of steep slopes and irregular submarine relief, all depth curves that the scale of the field sheet permits should be drawn. A good general rule is that depth curves should be drawn according to these intervals:

1-fm intervals in depths between 1 and 20 fm,

5-fm intervals in depths between 20 and 50 fm,

10-fm intervals in depths between 50 and 100 fm, and

25-fm intervals in depths greater than 100 fm.

Where the bottom is relatively flat or slopes gently and is featureless, nonstandard depth curves are drawn at a spacing of 3 to 4 cm at the scale of the survey. Depth curves are drawn first in pencil. Standard depth curves listed in table 4-5 are then drawn in the proper color ink.

Supplemental depth curves listed in table 4-6 shall be shown in ink at the discretion of the hydrographer. Additional depth curves necessary to display the bottom configuration are drawn in brown ink. (See 1.5.7.)

4.5.8. Verification of Alongshore and Offshore Detail

The hydrographer and field editor share the responsibility for verifying map details seaward of the shoreline. These details are shown on the photogrammetrically compiled shoreline manuscripts that

TABLE 4-5. - *Standard depth curves*

Curve (fm)	Curve (ft)		Curve color
0	0	(Datum of reference)	Orange
1	6		Green
2	12		Red
3	18		Blue
5	30		Red
10	60		Orange
20	120		Blue
30	180		Violet
40	240		Green
50	300		Red
100	600		Green
200	-		Orange
300	-		Violet
400	-		Green
500	-		Red
600	-		Blue
700	-		Green
800	-		Red
900	-		Violet
1000	-		Blue
1100	-		Green
1200	-		Orange
1300	-		Violet
1400	-		Green
1500	-		Red
2000	-		Orange
3000	-		Violet

TABLE 4-6. - ***Supplemental depth curves***

Curve (fm)	Curve (ft)	Curve color
0.5	3	Violet
4	24	Orange
4	36	Green
60	360	Blue
70	420	Green
80	480	Red
90	540	Violet

support the hydrographic survey. Normally, the field editor is responsible for the completeness and accuracy of the details above the chart datum. (See section 915 of the *Coast and Geodetic Survey Special Publication No.* 249, "Topographic Manual, Part II, Photogrammetry" (Swanson 1949), and "Provisional Photogrammetry Instructions for Field Edit Surveys" (National Ocean Survey 1974).) Close coordination between the field editor and hydrographer must be firmly established at the start of survey operations and maintained faithfully throughout to avoid duplication of effort, to prevent the occurrence of errors of omission, and to avoid submission of conflicting data. (See 1.6.2. and 3 2.4.)

Field edit operations shall remain current with hydrography to avoid application of obsolete data for smooth sheet use; however, field edit for any individual sheet must be completed although hydrography on that sheet cannot be completed before ending the field season.

Changes discovered in field edited areas where hydrography has been deferred for more than 1 yr are the responsibility of the hydrographer. Such changes shall be shown on the field sheets with records of all observational data entered properly in the hydrographic records. Each change of this nature must be listed and explained in the Descriptive Report. (See "Provisional Photogrammetry Instructions for Field Edit Surveys.")

Pertinent items that must be verified include the existence, the positions, and the elevations or depths of rocks, ledges, and reefs, and the limits of foul areas, wrecks, and similar features. Modern photogrammetric techniques used by the National Ocean Survey produce complete, accurate, and reliable map manuscripts. Use of color aerial photography generally permits an accurate and adequate inventory of rocks and other hazards, except when obscured by breaking waves, turbid water, and marine growth or where floating debris can be mistaken for rocks. Limits of foul areas can usually be delineated with a high degree of confidence. Tide-coordinated infrared aerial photography is routinely obtained for the delineation of the low water line in all areas where tidal datums have been established accurately. These lines must be field edited for accuracy and completeness. Unless specified otherwise in project instructions or the hydrographer doubts the accuracy of the photogrammetrically compiled high or low water line, the lines need not be developed by hydrographic methods.

Symbols and chart details inked in blue when the data were transferred from copies of shoreline manuscripts to the hydrographic field sheet are inked in black immediately after verification of the specific feature. (See 4.2.7.) Changes to the shoreline, rocks, or other details transferred from copies of photogrammetric manuscripts are shown in red ink on the field sheet. Such changes made by the hydrographer must be coordinated with the field editor. Explanatory notes and references to revisory location data shall be included on the field sheet when necessary. Sufficient information is obtained and recorded to permit any needed corrections to be made on the manuscripts and to permit the verifier to reconcile any differences between positions of features shown both on the manuscripts and on the field sheets. For example, if adequate information is not furnished, it may not be possible when verifying a survey to determine whether there is one rock shown at different positions on the field sheet and on the manuscript or whether the positions are for different rocks. (See 6.3.5.) Discrepancies between the existing physical conditions and shoreline manuscripts must be positively resolved in the field.

The field editor shall be notified promptly of actions by the hydrographer that affect details shown on photogrammetric manuscripts. Coordinated effort by both hydrographer and field editor is essential to ensure that changes are properly handled. Failure to reconcile differences between manuscripts and hydrographic sheets results in unnecessary delays during verification of the survey. The hydrographer must continually bear in mind that changes affecting a photogrammetric manuscript which are reported only in the hydrographic records will probably not be seen by a photogrammetrist until the discrepancy created is discovered in the final processing phases.

Each isolated rock and ledge, whether bare or awash, and all other hazards to navigation, including prominent rocks in a group or in a rocky area, shall be located and described accurately and adequately. If the standard symbols shown in appendix B are inadequate to portray a feature, a complete description must be entered on the field sheet. Elevations and depths of such features shall be determined in the field when observed tide or water level data are available. When the height or depth of a feature relative to the water surface is measured, the date and time must be recorded for subsequent reduction of the measurement to the chart datum. (See "Provisional Photogrammetry Instructions for Field Edit Surveys.") The existence of every feature shown seaward of the shoreline on the photogrammetric manuscripts shall be verified by the hydrographer. He shall also check the limits shown for kelp beds and for rocky and foul areas and verify the selection of the most prominent features lying therein. Rocks and other similar features lying along or near the shoreline or other accurately plotted reference point may be verified by visual inspection at the hydrographer's discretion; but off-lying rocks or other similar hazards to navigation, especially those in or near navigable waters, must be verified by more rigorous methods. Estimating distances and bearings to the feature from nearby hydrographic positions is an acceptable method of verification provided that the estimates are of reasonable accuracy. The method of verification is left to the hydrographer's judgment.

Rocks and other dangers not shown or incorrectly positioned on the manuscripts shall be located accurately and, if possible, a check measurement taken. If visual control is available if practical and safe to land on such features, the locations may be determined by strong three-point fixes with check angles; or the feature may be located by a minimum of three cuts from stations ashore or afloat that provide a strong intersections - or by sextant positions with the rock on range with control stations bearing in several directions.

During electronically controlled surveys devoid of visible signals, positions shall be taken alongside or as close to the feature as safety permits. Accurate compass bearings and estimated distances to the feature must be recorded. If the hydrographer has doubt as to the accuracy of the estimated distance, two or three additional positions with bearings and distances to the feature should be obtained as a check.

Heights or depths of rocks must be determined accurately, and the observation time, date, and time zone noted. If a landing can be made and the sea is calm, the height of a rock can be measured by holding the lower end of a rod or staff at the water's edge — then read the rod or staff at the point where the top of the rock and the horizon are in line. Heights must be estimated as accurately as possible from a position nearby if impractical or unsafe to land.

When a rock that has been verified or adequately located during current field edit operations is passed on a sounding line, this fact and the estimated distance to the rock when abeam is entered in the sounding records. These data are not to be used to locate the rock but serve as a verification of its existence and position.

Bare rocks or rocks awash shown on prior surveys or on published charts but which are found to be nonexistent, incorrectly located, or have erroneous elevations shall be fully explained in the Descriptive Report. Recommendations shall be made for the charting procedures to be followed.

4.5.9. Shoals and Dangers

4.5.9.1. INDICATIONS OF SHOALS AND DANGERS. There are several sources of evidence that shoals or submerged dangers exist in the area being surveyed; the hydrographer should be aware of all of them. This information may be obtained from:

1. A study of soundings obtained during the systematic survey.
2. Reports of dangers submitted by pilots, fishermen, and other reliable sources.
3. Sightings of breakers, current swirls and eddies, kelp, or other visible evidence while sounding.
4. An examination of aerial photographs, particularly those in color. These often reveal the location of shoals or rocks. (See 4.5.8.)

The spacing of the systematic sounding lines should provide an indication of dangers and shoals within the area. Such indications normally occur as breaks in the continuity of bottom slopes. More positive evidence of the existence of a shoal is found where two adjacent lines of soundings contain similar indications. Even slight changes from the general surrounding depths should be regarded as a possible indication of a shoal. In many localities, it is not feasible to examine every such indication; furthermore, it is not required. The hydrographer decides which areas need additional development (1.4.3); the Chief of Party makes the final inspection to assure himself that no additional field work is required. Hydrographers and Chiefs of Party should be guided, by the considerations listed in section 1.4.3 and from experience in similar areas when deciding which areas will be developed further.

Pilots, fishermen, yachtsmen, and others with knowledge of the local waters should be consulted for important hydrographic information. Each report of uncharted rocks, shoals, or obstructions must be investigated. U.S. Power Squadrons and U.S. Coast Guard Auxiliary, if active in the area, are particularly valuable sources of information for uncharted hazards. Attempts should be made to verify or cross-check information from several sources. Individuals with local knowledge will often guide hydrographers to uncharted features. Otherwise, approximate locations must be obtained and plotted in pencil on the field sheet. Exact information on the location of rocks or shoals cannot always be obtained. In such cases, extensive examinations are often required to find them.

All members of a hydrographic survey party, when not otherwise engaged, should be alert for visible evidence of submerged dangers. In many tropical waters, coral banks and shoals are usually visible for a considerable distance when the sea is calm, the observer is stationed well above the water, and the sun is high and at the observer's back. Breakers are clear evidence of obstructions or shoals, but current eddies indicating a shoal are less apparent and are not always easily detected. Eddies are caused by disturbance of the current and are always seen down current from isolated shoals — the distance depends on the depth of water and the velocity of the current. Eddies are more prominent when differences in depths between shoals and surrounding bottoms are large, and are most noticeable at the last of the ebb or first of the flood current.

Kelp is one of the better indications of dangers because it generally grows where the bottom is rocky. Each isolated growth of kelp must be investigated. If kelp is growing over a hazard, the fact shall be entered in the hydrographic records. Also note whether the kelp is visible at all stages of the tide or whether it tows under and cannot be seen.

4.5.9.2. DEVELOPMENT AND EXAMINATION OF SHOALS. When shoal indications are to be investigated, limits of the area where the least depth will most probably be found should be delineated by running a series of closely spaced sounding lines. A study of these soundings (plotted at a larger scale if necessary) should reveal the approximate location of the least depth, but may not establish the least depth on the feature. A more intensive examination of the shoalest part of the feature should be made to obtain the least depth. (See 1.4.3.) When the bottom is visible, a lead line or sounding pole can usually be placed on the high points and the depth measured. In other areas, detection and measurement are more difficult.

When divers are unavailable, a short wire drag, wire sweep, or pipe drag should be used. (See AF.1.4 and AF.1.5.) Alternatively, a small buoy may be anchored near the most probable least depth location. The buoy serves as a reference point while the vessel cruises slowly or drifts over the area. (Caution, for currents may carry a drifting boat around the peak of a shoal.) A second marker buoy may be used to mark the shoalest sounding recorded by the echo sounder. The final examination is then made by drifting over the shoalest part taking lead-line soundings. The vessel should be allowed to drift across the feature several times, each time overlapping the previous path by about half the length of the vessel. The echo sounder shall be in continuous operation and the graphic record properly annotated during the investigation. Bottom characteristics should be determined on these features. The lead line aids the hydrographer in resolving echo sounder misinterpretation caused by kelp or by other spurious traces.

When the existence of a pinnacle rock is suspected from the general nature of the visible terrain, a very patient and exhaustive search must be made or the least depth may not be found. If at all possible, divers or a simplified wire sweep or pipe drag should be used to determine the least depth over this type of feature.

Where features are too shoal to sound safely, the limits should be defined by sounding lines run as close to the feature as safety permits — in such cases, estimates of depths covering the feature should be made and entered on the field sheet.

4.5.9.3. RECORD OF SHOAL EXAMINATION. When a shoal is examined by sounding along a series of closely spaced lines (4.3.4), all data shall be recorded in the hydrographic records. If the least depth is found by drift soundings or by another nonsystematic procedure, a full report of the following items must be entered in the sounding record when not otherwise evident:

1. The method of search used.
2. The length of time spent in the examination.
3. A statement as to whether the bottom was visible.
4. A brief description of the feature including the bottom character.
5. A statement as to whether the shoal is marked by kelp, eddies, or other visible evidence.

4.5.10. Detached Breakers

If submerged rocks or other obstructions are evidenced by breakers and it is impractical or dangerous to locate the object and obtain a sounding, they must be located by intersection cuts taken from the sounding vessel or from shore stations. (See 4.5.8.) The cuts should form a strong geometric intersection. The depth over the feature is estimated and the time of observation noted. Conditions under which breakers form in the area must also be included; the stage of the tide or lake level and the sea conditions are also recorded. Submerged rocks inside a generally foul area may be symbolized without an observed position, provided the outline of the foul area is accurately delineated.

Whenever possible, such features should be located during low tides and relatively calm sea when danger of damage to the vessel is least. Small areas around rocky points can often be examined and the limits of foul areas determined from a skiff or other small boat. The hydrographer must be sure that other dangerous rocks lying just outside foul areas are located and shown as detached rocks.

4.5.11. Wrecks and Obstructions

All wrecks and obstructions not afloat should be located and as complete information as possible furnished. (See 1.6.4 and 4.5.9.3.) Whether a wreck is totally submerged, visible at all stages of the tide, or only at some stage of the tide should be stated; when possible, the wreck should be described. The description should include but not be limited to the name, dimensions, construction material, condition, and orientation of the located wreck. Any historical information concerning the wreck should be included. Sunken wrecks are treated as dangers or shoals. (See 4.5.9.2.) Least depths over wrecks are practically impossible to determine without diver observations or wire dragging the area. Masts or other parts of the wreck usually cannot be found using ordinary sounding methods. Qualified divers, if available should determine least depths and describe wrecks.

Large pieces of floating wreckage, logs, or other debris potentially hazardous to navigation that are sighted in areas where such obstructions are not commonly encountered shall be reported immediately to the commander of the nearest U.S. Coast Guard District.

4.5.12. Soundings Along Wharves and in Docks

Sounding lines shall be run close to and along the outer faces of wharves and in docks and slips within the project limits. (See 4.3.4.1.) In addition, soundings shall be taken along the most likely keel line of vessels berthing there. Several depths alongside wharf and pier faces should be measured by lead line or by sounding pole to determine if silting or shoaling is occurring. Soundings need not be taken along small privately owned piers. Soundings in the vicinity of wharves and docks are shown on subplans at an enlarged scale if the scale of the regular survey is too small to show the detail adequately. (See 2.4.4 and 7.2.4.) The project instructions may require that dock and slip areas be surveyed at a larger scale depending on the importance of the area.

4.5.13. Aids to Navigation

All aids to navigation in the project area shall be accurately located and described. (See 1.6.5.)

4.5.13. 1. NONFLOATING AIDS AND LANDMARKS. Data on nonfloating aids to navigation and landmarks are essential for safe navigation in the coastal waters of the United States. If geodetic positions are not available, these aids shall be located photogrammetrically or by ground survey methods meeting the requirements of Third-order, Class I or better accuracy. Where numerous minor day beacons are subject to frequent changes in position, topographic, field photogrammetric, or hydrographic methods may be used. [See "Photogrammetry Instructions No. 64, Requirements and Procedures for Collecting, Processing, and Routing Landmarks and Aids to Navigation Data — Photogrammetric Operations" (National Ocean Survey 1971*b*).]

Positions and descriptions of all nonfloating aids and landmarks shall be submitted in accordance with sections 1.7.1 and 5.5. If the name and description for an aid do not agree with the data published in the most recent edition of the *Light List* (e.g., U.S.

Coast Guard 1976), the differences shall be fully explained in the report.

Azimuths of all light and day beacon ranges maintained by the U.S. Coast Guard for navigational purposes within the project area must be determined. If the ranges were located by photogrammetric methods, the hydrographer must verify the azimuth of each by observing one or more visual fixes with checks observed from a reasonable distance away from the front range — preferably, the effective use of the range. Azimuths of ranges established for use in crossing bars shall be determined or verified by visual fixes observed on or outside the bar.

4.5.13.2. FLOATING AIDS. Positions and depths at all floating aids to navigation in the project area shall be determined during the hydrographic survey. If sextants are used, aids may be located by three-point fixes with check angles. Theodolite intersection methods (4.4.2.2) are acceptable for locating floating aids, but sextant cuts from shore stations are not. Electronic positioning systems used to locate aids must be calibrated carefully before and after the observation at the aid — separate and immediate calibrations are not necessary. If calibrations fail to agree or if unresolvable lane changes occur, the observed fix shall be rejected and a new fix observed. Procedures described in section 4.4.3.3 for determining lane count by circling a buoy can be reversed to locate a buoy. Positions of marker buoys maintained near aids shall also be determined. Location dates are important and must be noted in the hydrographic records because the aid may have been temporarily off station when located and subsequently replaced to its proper station.

Floating aids found to be off station by an amount that makes them unsuited to mark features intended shall be reported immediately to the commander of the nearest U.S. Coast Guard District. Recommendations for additional aids to navigation or for more desirable locations for existing aids should be reported in writing to the U.S. Coast Guard and to the National Ocean Survey Headquarters through the appropriate Marine Center. Reports of this nature shall be accompanied by a reproduction or tracing of the field sheet.

Reference shall be made in the Descriptive Report to reports made to the U.S. Coast Guard relative to floating aids to navigation.

4.5.13.3. NONFEDERAL AIDS TO NAVIGATION. Aids to navigation established and maintained privately or by State or local governments shall be located by the hydrographic party. Positions of such aids shall be shown on both the field and smooth sheets. The status and purpose of these aids must be made clear on the sheets and in the Descriptive Report. The report should state the purpose of each unofficial aid, the date of its establishment, the agency or person who established it, and whether the aid is maintained — if these facts can be ascertained.

4.5.14. Bridges and Cable Crossings

Bridge clearance data shown on nautical charts and in the Coast Pilots (e.g., National Ocean Survey 1976*a*) are usually furnished by the U.S. Coast Guard. Overhead cable clearances are provided by the U.S. Army Corps of Engineers. Field parties shall measure overhead bridge and cable clearances only where charted values are questionable, definitive information is lacking, or there is new construction. When feasible, the nearest U.S. Army Corps of Engineers district office should be visited for a comparison of charted or field clearances with Corps of Engineers' data. Where National Ocean Survey and Corps of Engineers' values differ, the Corps of Engineers shall decide which value to use. [See section 5.8 of the U.S. Coast and Geodetic Survey (1969*a*) *Coast Pilot Manual.*]

Locations of bridges, overhead cables, and shore ends of submarine cables shall be determined and shown on field sheets with descriptive notes.

4.5.15. Verification of Charted Features

Data transferred to the field sheet (4.2.8) must be compared carefully with the results obtained during the new survey. If a transferred sounding is obscured by new soundings, it may be overlooked and not properly investigated. Each charted danger must be surveyed in detail to either verify it or disprove it. If the hydrographer fails to find a reported shoal or danger at its charted position, the survey of the area must be sufficiently complete so that the feature can be removed from the chart with confidence. All indications of shoals in the vicinity must be examined meticulously as the positions of reported dangers are often in error. Soundings or charted dangers cannot be removed from charts unless there is conclusive evidence that the features do not exist.

To merely prove the existence of charted features is insufficient; positions, least depths over submerged features, and elevations of exposed features must be determined. If the new survey reveals a least depth deeper than the charted depth, the discrepancy must be explained in the Descriptive Report with a positive recommendation made as to which depth should be charted and why. (See 5.3.4(L).)

One of the most difficult problems encountered in hydrographic surveying is finding and locating charted piling. Submerged stubs of broken piles are almost impossible to detect by means other than bottom sweeping. When there is no visible evidence of a charted pile or dolphin, the hydrographer should consult with local agencies such as the U.S. Army Corps of Engineers, the U.S. Coast Guard, or the owner of the waterfront property to determine whether the piles have been removed. Without conclusive evidence to this effect, the area should be examined at the lowest tide; it is usually necessary to use a small sweep (A.6.1.4) before meaningful recommendations can be made.

Dangers, shoals, and least depths from adequate wire-drag surveys in relatively stable bottom areas need not be verified unless required by the project instructions. In most areas important to navigation, obstructions and dangers to navigation may have been removed. The hydrographer must consult the U.S. Army Corps of Engineers and the U.S. Coast Guard to learn which obstructions have been removed. In such cases, a new least depth over each feature so affected must be determined by hydrographic examination. Areas containing rocks and obstructions reported to have been removed by blasting should be checked by bottom sweeping.

4.5.16. Inspection of Field Sheet

After the proposed system of lines has been completed in an area and the soundings and depth curves plotted on the field sheet, the results must be studied carefully for indications of submerged features that should be more closely examined. Analog depth records must be viewed while this study is being made (4.9.8) since side echoes (4.9.8.2) are important indications of shoaler depths. The study of the field sheet reveals where additional lines ("splits") must be run to comply with line-spacing requirements and to obtain a better delineation of the bottom configuration. Critical depths transferred to the field sheet from charts or previous surveys must be compared with the new survey. (See 4.2.8.) Additional soundings may be required to prove or disprove the existence of features. Each discrepancy must be positively resolved in the field before the survey is completed.

It is good practice to run splits (4.3.4) as necessary for detailed examinations of shoal indications as soon as possible after the indications have been discovered. The same vessel and depth-recording system used for the basic system of lines should be used for splits. It is especially important that surveys be complete or "squared off" at the end of the season.

4.6. DISCREPANCIES IN HYDROGRAPHY

4.6.1. Discrepancies at Crossings

Crosslines are run to disclose systematic and accidental discrepancies in soundings. (See 1.4.2 and 4.3.6.) Discrepancies at crossings must be recognized as evidence of a fault of the equipment, method, or record that requires further study to discover the source and to indicate the most probable correction.

Allowable differences in depths at crossings in any area should be based on both the amount of horizontal displacement corresponding to the differences in depth and a percentage of the depth. In comparatively even bottom, differences of 2 to 3 ft may be excessive because of extreme lateral displacement of depth contours. In areas of irregular bottom or on steep slopes, differences of several feet or fathoms may be inconsequential since depth contours will not be appreciably affected.

Allowable differences at crossings on the smooth sheet are specified in section 6.3.4.3. Since minor corrections are ignored and predicted tides or water levels are normally used when correcting soundings to be shown on the field sheet, greater differences may be expected. In areas of smooth bottom with depths less than 20 fm, discrepancies should not exceed 2 ft or 0.4 fm. In areas of irregular bottom and in depths greater than 20 fm, discrepancies should not exceed 3% in the lesser depths and should not exceed 1% (or less) in ocean depths.

If discrepancies are consistent at a number of successive crossings and the horizontal control is strong and consistent, it is probable that the echo sounder is at fault or that the datum of reference is incorrect. Vertical cast comparisons must be made in the vicinity of all substandard crossings to support the conclusion of any studies of recorded data. Predicted tides or water levels used to reduce soundings to the appropriate chart datum must be compared with actual data to determine if that is the source of discrepancy. If constant displacements of sounding lines would bring the crossings into agreement, the calibration and stability of the control system, should be carefully checked and evaluated. Surveys with unresolved discrepancies at line crossings are incomplete and as such will not be accepted for verification and smooth plotting.

4.6.2. Discrepancies at Junctions and Overlaps

When inshore hydrography is overlapped by work done by a larger vessel, soundings at the junctions sometime fail to agree. Because bar checks cannot be taken from a large vessel, vertical cast comparisons must be made to determine the instrumental error of the echo sounders. Several comparisons in overlapping areas are required to provide data for reconciliation of possible discrepancies. The field unit must resolve the discrepancies before leaving the area.

Similar situations may arise where hydrography accomplished by different vessels joins on inshore sheets. Where displacements of depth curves occur at junctions, errors probably exist in the work of one or both of the vessels. Magnitudes and sources of errors must be established by comparing both echo sounders with vertical cast soundings.

4.6.3. Other Discrepancies and Sources of Error in Hydrography

Other discrepancies less obvious and more difficult to explain or detect are frequently found. After the regular system of lines has been completed over a wide area, it may be necessary to run "splits" (i.e., reduce the line spacing). If soundings on alternate lines differ by 2 or 3 ft in areas of comparatively flat bottom, the soundings on one system or on both systems of lines are obviously in error. In other instances, a vessel may have used different echo sounders on alternate days — the soundings obtained with each instrument are consistent within themselves but fail to agree with those from the other. Discrepancies of this nature are generally manifested by improbable and inexplicable shifts or anomalies in depth curves.

When discrepancies arise, additional field tests and checks must often be conducted to determine which data set is in error and to detect and eliminate problem sources. Generally, discrepancies are caused either by errors made in horizontal positioning or by errors made when obtaining or reducing depths. The review of potential hydrograhic error sources in tables 4-7 and 4-8 provides a checklist for the investigation of discrepancies found during the progress of the survey. In all instances, the field unit must obtain sufficient and conclusive evidence to resolve all discrepancies.

4.7. CHARACTER OF BOTTOM

4.7.1. General

The character of the bottom shall be determined for nautical charting, particularly in harbors, designated anchorages, and in all other areas where vessels may anchor. (See 1.6.3.) In addition to furnishing data for selecting anchorages, bottom characteristics shown on charts assist fishermen when selecting areas where fish may be found and to avoid places where equipment may be damaged.

For surveys in uncharted waters, in areas where bottom characteristics are subject to frequent change, the most effective means of determining the bottom character is to sample at regular frequent intervals throughout the project area. Extensive bottom sampling is not required if the project area has been surveyed previously, the characteristics have been adequately determined, and there have been no significant changes in charted depths nor reason to believe the charted characteristics are incorrect. Sufficient samples, however, must be taken to verify either that no changes have occurred or to indicate areas of significant change where additional work is necessary to accurately describe the bottom characteristics.

Sampling the surface layer is usually adequate to define bottom characteristics for charting. Clamshell bottom snappers or similar type grab samplers are used to obtain as large a sample as possible. (See AL.2.7.) Bottom samples shall be stored individually in airtight labeled plastic bags recorded on NOAA Form 75-44, "Oceanographic Log Sheet-M, Bottom Sediment Data." The forms are self explanatory. Data sheets and sample labels must include the vessel's name, geographic location, depth, date, field description of material, type of sampler, and pertinent remarks. The bottom sedi-

TABLE 4-7.—*Hydrographic survey horizontal positioning errors*

Station Control

1. Incorrect geodetic datum
2. Use of unadjusted or incorrect geodetic positions
3. Use of survey methods that fail to meet the required accuracy criteria
4. Use of photogrammetric manuscripts that are incorrect because of bridging errors
5. Incorrect identification of photo-hydro signals
6. Incorrect reduction for eccentric placement of electronic control system antennas ashore or afloat
7. Misidentification of control stations
8. Excessive use of hydrographic stations to locate other stations in the survey
9. Incorrectly plotted control

Vessel control -visual

1. Undetected errors in the instrument, initial or index (i.e., when observing theodolite cuts or sextant angles)
2. Geometrically weak fixes
3. Sextant tilt not compensated when using elevated signals
4. Misidentification of signals
5. Sextant angle observers not standing close enough to each other or improperly located relative to the antenna and transducer
6. Poor coordination of the fix event when observing and recording data
7. Angles or directions read or recorded incorrectly

Vessel control— electronic

1. Operation of nonalined or poorly adjusted positioning systems
2. Improper use of calibration or field check data
3. Undetected errors or jumps in distance or lane count
4. Attenuated or reflected signals over portions of the survey area
5. Electronic interferences with the positioning system
6. Failure to correct slant ranges when necessary
7. Geometrically weak fixes
8. Use of improper operating frequencies
9. Failure to reduce the electronic center of the ship to the transducer location

TABLE 4-8.—*Hydrographic survey sounding errors*

Tidal and water level observations

1. Incorrect predicted or real-time tide or water levels
2. Improperly accounted time and height shifts in the records
3. Long periods of missing data
4. Incorrect zoning
5. Incorrect datum determination
6. Incorrect gage, staff, and bench mark elevation relationship
7. Undetected tide or water level anomalies caused by meteorological conditions

Transducer errors

1. Incorrectly measured or applied coffeetions for draft or settlement and squat
2. Failure to apply the eccentricity of the transducer relative to the fix observation point
3. Inadequate or erroneous velocity corrections
4. Unobserved or improperly applied bar check or vertical cast data

Depth recorder errors

1. Analog systems' phase errors, initial errors, incorrect stylus arm or belt length, incorrect stylus or paper speed, fine arc error, recording paper skew, record misinterpretation (i.e., presence of side echoes, silt or mud bottom, kelp or other marine growth, and strays), improperly accounted wave effects (heave), improperly maintained voltage
2. Digital systems' incorrect threshold receiving frequency, incorrect calibration (feet or fathoms), scaling errors caused by not allowing for differences between the digital and analog trace, improperly accounted heave.

Plotting errors

1. Protractor not in adjustment or improperly used.
2. Incorrectly set angles on the manual plot
3. Automated plotter malfunction or improper alinement during the sheet registration
4. Distortion of the plotting material

ment samples and original log sheet "M" shall be mailed to this address.

Curator
Division of Sedimentology
Smithsonian Institution
Washington, D.C. 20560

One copy of the log sheets with a transmittal letter shall be sent to the Data Control Branch, OA/C353, at NOS Headquarters. Bottom descriptions shall also be entered into the sounding records.

Frequencies of bottom samples in various depths of water are specified in section 1.6.3. If a more detailed study of the ocean floor is contemplated, bottom samples are usually obtained by coring or by dredging. In such cases, the project instructions will specify sampling density and the type of sampler to use. Core samples are preserved intact in the sleeve of the corer or are carefully extruded into a suitable container for later analysis. Dredging samples must be preserved in sturdy containers. All samples shall be carefully labeled and cross-referenced to detailed records on the place and time of sampling. Procedures for coring or dredging sample disposal will be included in the project instructions.

4.7.2. Classification of Bottom Materials

A complete description of a bottom sample consists of: one or more adjectives describing size or consistency; one or more adjectives designating color; and one or more nouns naming the class of bottom material.

Descriptions should follow standard classifications listed in table B-5 in appendix B. If more detailed classifications are required by the project instructions, use the standard abbreviations shown in part S of *Chart No. 1, United States of America Nautical Chart Symbols and Abbreviations* (National Ocean Survey and Hydrographic Center 1975). When necessary, descriptive terms not included should be written in full. Descriptions shall be arranged in this order, size or consistency, color, and noun. Bottom characteristics are shown on field sheets in black ink slightly below and to the right of the position dot.

In most cases, a precise classification of bottom materials requires a laboratory analysis; however, this is impractical for hydrographic surveys and is not a charting requirement. Careful inspection of a sample by sight and touch should enable the hydrographer to provide a reasonably accurate description of the material.

Close to shore and on the Continental Shelf, bottoms generally consist of sands, gravels, muds, and the remains of plant and animal life. Ledge rock may be exposed in a few areas close to shore where slopes are steep. Sediments are typed according to the size of their particles. Table 4-9 is a general guide for classification of the sands and coarser particles. It is not intended that the dimensions be measured. A careful estimation by eye is satisfactory.

Sediments larger than sand are easy to recognize and simple to classify by size. Generally, sand is recognizable as even the finer grained sands feel gritty when rubbed between a finger and the palm of the hand. When dry, sand separates into grains visible to the naked eye.

Technically, there are two classes of material finer than sand. These are silt and clay. For practical purposes, silt and clay are classified under the general term, mud.

If the material feels gritty when rubbed between the fingers, between finger and cheek, or between tongue and cheek, it may properly be classified as silt. Clay is a finer grained deposit than silt and normally feels smooth and sticky to the touch. Another simple way to detect very fine sand is to put about a fourth of a teaspoonful of the sample into a large test tube, add water, and shake well. If within less than a minute a portion of the sediment settles out, sand is present. Ooze is not soft mud, as commonly interpreted, but is a pelagic sediment containing more than 30% organic material and is found only in the greater ocean depths off the Continental Shelf on the abyssal plains.

TABLE 4-9. — *Sediments classified by size*

Type	Term	Grain diameter
Clay		(mm)
	Mud	0.02-0.1
Silt		
	Fine	0.1-0.3
Sand	Medium	0.3-0.5
	Coarse	0.5-1.0
	Fine	1-2
Gravel	Medium	2-4
	Coarse	4-6
	Fine	6-10
Pebbles	Medium	10-20
	Coarse	20-50
Stones		50-250
Boulders		≥ 250

4.7.3. Description of Bottom Materials

Natures of bottom materials are indicated by adjectives such as broken, sticky, hard — or by size such as coarse, medium, or fine. Consistencies of bottoms determined by feeling with a lead line or sounding pole (without a visual examination of the material) should usually be described as "hard" or "soft." The term "rocky" may be used only when it is known positively that the bottom is bedrock or consists of material larger than gravel, although a specimen was not obtained for examination. "Rock" is used only when solid rock or a rock ledge is visible to the hydrographer.

The return of an empty sampler is not sufficient reason to label the bottom as "hard" or as "silt". If repeated tries for a grab sample fail, the station should be labeled "no sample" unless additional knowledge is available to the hydrographer.

Colors of specimens should always be noted while still wet. Some sediments change in color when dry. The terms "dark" and "light" should never be used alone; these terms are intended for use in qualifying the intensity of color.

To aid in sample analyses more detailed than usually required for nautical charting purposes, one may obtain sand grain size charts and color charts from this company.

Geophysical Instruments and Supply Co.
900 Broadway
Denver, Colorado 80203

4.8. HYDROGRAPHIC RECORDS

4.8. 1. General

Clear and comprehensive field records and reports are essential for an adequate successful hydrographic survey. Incomplete, unintelligible, or carelessly maintained records can seriously impair the value and validity of the data to the point of rendering a survey worthless. Satisfactory records are the direct reward of constant good judgment, attention, and care.

The chief of party shall ensure proper maintenance, arrangement, and security of hydrographic records, that all necessary records and reports are submitted at the proper time, and that hydrographic data are appropriately cross-referenced for ease of use and complete understanding. AD records and reports pertaining to one hydrographic sheet, and one only, shall be identified by the sheet registry number. (See 2.4.3.2.) Records and reports submitted on a seasonal or project basis should make reference to the registry numbers of all surveys to which they apply.

The records must be sufficiently complete to permit the survey to be plotted accurately and thoroughly at any future date. Explanatory and supplemental notes shall be inserted as necessary in the field records to make the information complete. Modem survey techniques are complex, and the records must by necessity be accompanied and supported by a host of associated data and reports containing information that cannot be shown properly in the records or on the hydrographic sheets. (See chapter 5.)

4.8.2. Use of Abbreviations

The large volume of recorded and annotated field data makes it logical and convenient to abbreviate and symbolize many of the terms and expressions used repeatedly. For emphasis and ease of bandling, these are tabulated in appendixes B and E. Those not tabulated but used during the survey must be defined at the beginning of the sounding records.

4.8.3. Manually Recorded Survey Data

4.8.3.1. GENERAL NOAA Form 77-44, "Soundings," is the basic, permanently archived record book for all nonautomated hydrographic surveys. These Sounding Volumes are the official record of positional data and of special soundings measured by divers, lead line, and sounding pole. Final interpreted and scaled depths entered in the volumes combined with the graphic depth records comprise the official record of echo soundings. Sounding Voles must also be used during automated surveys to record supplemental descriptive information on sounding lines, detached positions, speed and course changes, and to enter notes on the passing of features, shoreline changes, and many other items that cannot be conveniently recorded elsewhere.

Although automated data acquisition systems are used for the majority of NOS hydrographic surveys (4.8.4), it is essential that hydrographers be thoroughly familiar with basic manual data-recording techniques for these reasons:

Automated systems are merely extensions of the manual recording system. The same basic principles apply as to the required volume, type, and detail of field data although the records differ in format.

Many surveys accomplished from small boats, skiffs, and other nonautomated vessels require manual record keeping although the data will be logged for machine plotting at a later date.

Should an automated systems failure occur during the course of a survey, hydrographers must be capable of quickly reverting to manual recording methods.

Information entered in the Sounding Volume shall be as complete and self explanatory as possible; it should be possible to reconstruct the survey and replot all hydrographic data at any future date using only the information in the volume and on the graphic depth record. (Some items such as ledge symbols, however, may be outlined on the field sheet and plotted on the smooth sheet by direct transfer.)

Data observed by each survey vessel shall be recorded chronologically in a separate series of volumes and listings for each hydrographic sheet. Hydrographic data that will be plotted on two or more separate hydrographic sheets shall not be recorded in one volume. Sounding Volumes shall be numbered consecutively as the survey progresses. If more than one vessel surveys an area covered by a single smooth sheet, a temporary series of numbers is assigned to each unit that will use more than one volume. When the survey is completed, the records of each unit are grouped in proper order, the various groups combined, and the complete set of records for the survey area numbered consecutively and permanently. Information required on the cover label of each volume shall be entered in black ink.

Recorded data must be completely legible. Drafting style lettering is not required nor is it necessary to make entries in print; it is essential that every numeral, abbreviation, and word be unmistakable. Data must be recorded systematically and, insofar as possible, in the form prescribed in this manual.

While in use, Sounding Volumes should be protected by a suitable temporary cover. This is especially important during launch hydrography when spray, rain, or other conditions could cause damage to the records.

Sounding records are essentially time records of recurring series of acts and events, with related observations occasionally interspersed. Recorded data must clearly show the relationship between these events and times of occurrence. Generally, each entry appears on the same horizontal line with its respective time. Occasionally, miscellaneous notes must be made at other places, then referred to their corresponding times by distinctive reference notes. Several examples of manually recorded hydrography are shown in figures 4-22 through 4-25. Although space should not be wasted, recorded data should not be crowded. Soundings at irregular intervals must frequently be scaled from analog depth records to protray the bottom configuration properly. When surveying in areas of irregular bottom, soundings at regular intervals are recorded on alternate lines of the record book; when the bottom is smooth and evenly sloped, a sounding may be recorded on each line.

Recorded data must never be erased. Corrections are made by crossing out erroneous entries and making corrections above or to one side; however, this prohibition does not apply to soundings scaled from the analog depth records if congestion or ambiguity would result from using this rule. Entries rejected for any reason are indicated by an "R" written boldly over the entry. Soundings not plotted are indicated by the letters "NP."

Rubber stamps are used to record nearly all of the information required at the beginning, during, and at the end of the day's work. Header tapes can be used instead of stamps to include the necessary information on automated data listings. (See 4.8.4.)

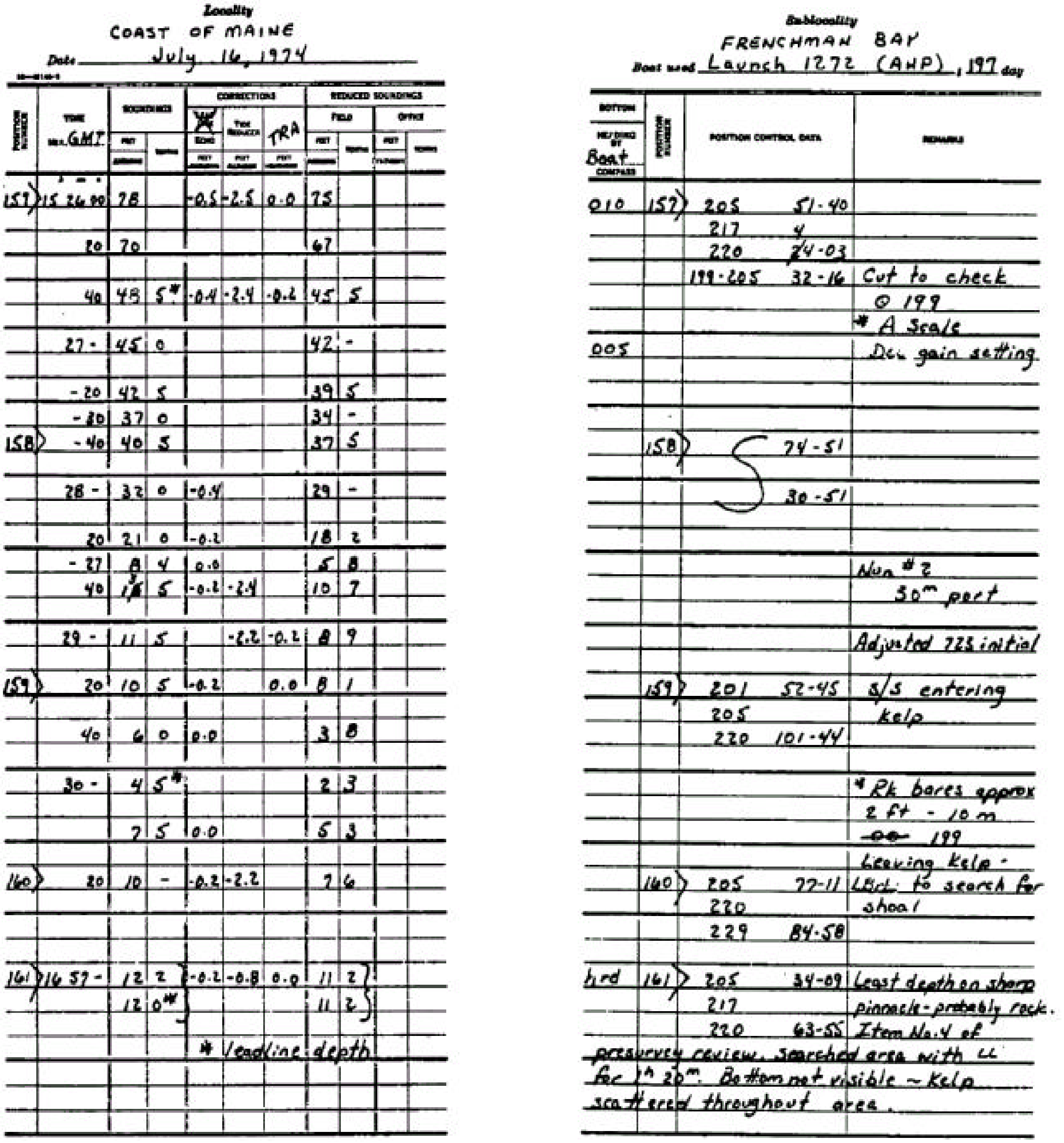
4.8.3.2. PAGE HEADINGS. Appropriate entries are made in full at the top of the first and last record page of a day's work. If the work is divided between two volumes, the entries must also be made on the last page of the first volume and first page of the second volume. The locality, sublocality, Julian date, name, and identification number of the sounding vessel can be entered using rubber stamps. Entries should be made on all pages if it will not interfere with the recording of more important data. Julian dates are entered at the top of each page of the Sounding Volume in the identification color of the vessel.

4.8.3.3. INFORMATION AT BEGINNING OF DAY'S WORK. Certain information about personnel, instruments and their adjustments, weather conditions, and other pertinent facts important for complete records of the survey shall be entered at the beginning of each day's work.

When hydrography is controlled visually, names of key personnel and serial numbers of instruments used shall be recorded in the appropriate spaces of stamp 2A, "Personnel." (See figure 4-26.) Instrument adjustments shall be verified and the fact noted after the number of each instrument. Stamp 2A can be modified slightly for use during theodolite intersection surveys. If hydrography is controlled electronically, use stamp 2B and make entries in all appropriate spaces. Punched paper tapes can be prepared for machine printing of these data on automated survey data listings instead of using a rubber stamp. (See 4.8.4.)

When survey personnel are standing watches or are otherwise rotated at regular intervals, record the changes using stamp 2A or 2B. When relief is temporary or is limited to less than three members of the survey team, the fact may be recorded in the remarks column of the Sounding Volume.

4.8.3.4. ELECTRONIC CONTROL INFORMATION. The information on electronic positioning control systems used is entered on stamp 3 (figure 4-27) at the beginning of each day's work and at all other times changes are made. These data shall include:



Locality COAST OF MAINE

Date July 16, 1974

POSITION NUMBER	TIME GMT	SOUNDINGS FEET	SOUNDINGS TENTHS	CORRECTIONS Echo	CORRECTIONS Tide Reducer	CORRECTIONS TRA	REDUCED SOUNDINGS FIELD FEET	REDUCED SOUNDINGS FIELD TENTHS	REDUCED SOUNDINGS OFFICE FEET	REDUCED SOUNDINGS OFFICE TENTHS
	h m s									
157)	15 26 40	78		-0.5	-2.5	0.0	75			
	20	70					67			
	40	48	5*	-0.4	-2.4	-0.2	45	5		
	27 -	45	0				42	-		
	-20	42	5				39	5		
	-30	37	0				34	-		
158)	-40	40	5				37	5		
	28 -	32	0	-0.4			29	-		
	20	21	0	-0.2			18	2		
	-27	8	4	0.0			5	8		
	40	13	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	0*				11	2		

* leadline depth

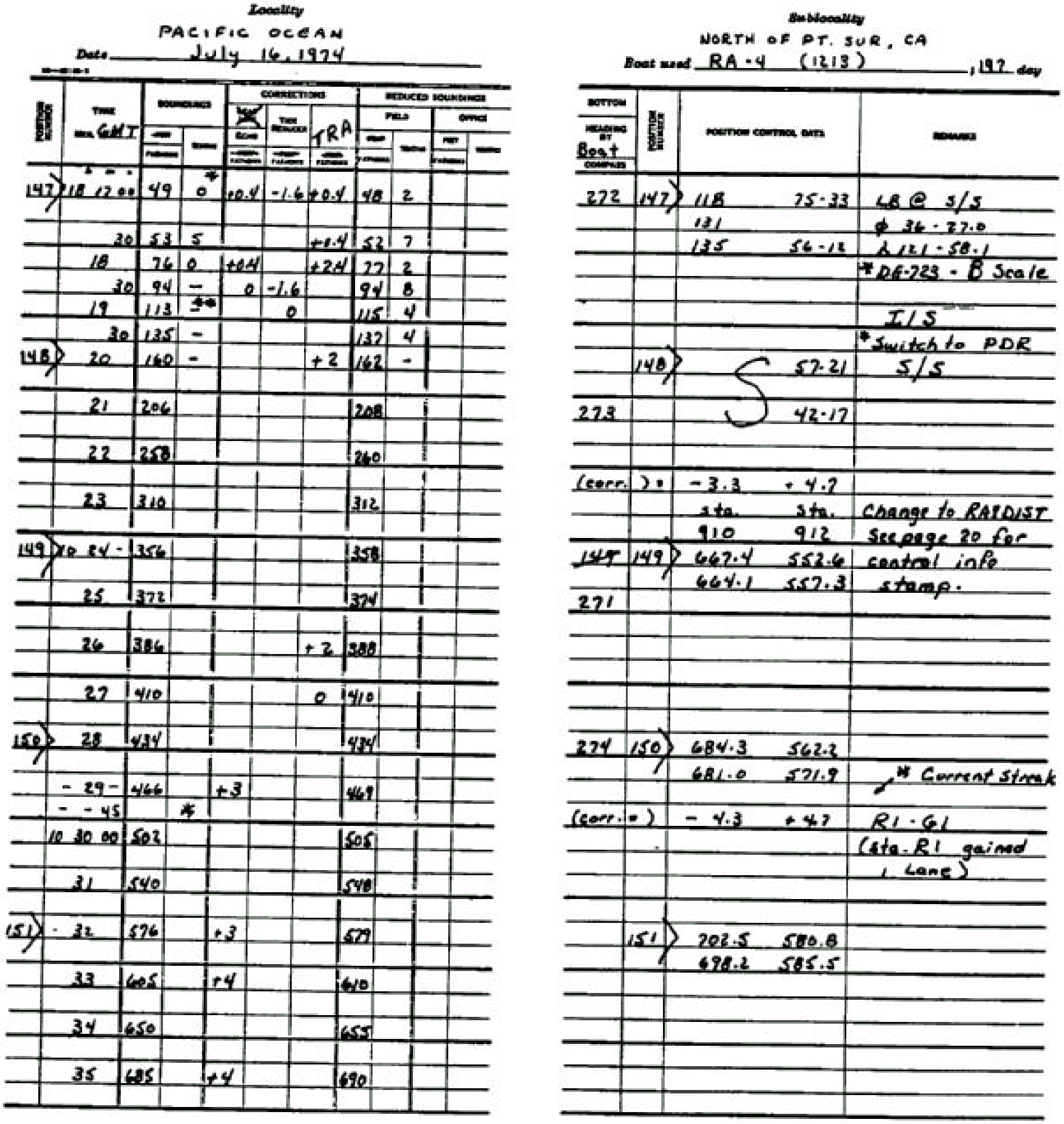
Sublocality FRENCHMAN BAY

Boat used Launch 1272 (AHP), 197 day

BOTTOM HEADING BY Boat COMPASS	POSITION NUMBER	POSITION CONTROL DATA		REMARKS
010	157)	205	51-40	
		217	4	
		220	74-03	
		199-205	32-16	Cut to check
				⊙ 199
				* A Scale
005				Dec. gain setting
	158)		74-51	
			30-51	
				Nun #2
				30m port
				Adjusted 223 initial
	159)	201	52-45	S/S entering
		205		kelp
		220	101-44	
				*Rk bares approx
				2 ft - 10 m
				~~00~~ 199
				Leaving kelp -
	160)	205	77-11	LBd. to search for
		220		shoal
		229	84-58	
hrd	161)	205	34-09	Least depth on sharp
		217		pinnacle-probably rock.
		220	63-55	Item No.4 of

presurvey review. Searched area with LL for 1h 20m. Bottom not visible ~ Kelp scattered throughout area.

FIGURE 4-22.- Manually recorded survey (NOAA From 77-44, "Sounding") using visual sextant control and showing the application of rules for entering corrections and remarks



Locality
PACIFIC OCEAN
Date July 16, 1974

Sublocality
NORTH OF PT. SUR, CA
Boat used RA-4 (1213), 197 day

	TIME GMT	SOUNDINGS		CORRECTIONS			REDUCED SOUNDINGS			
						TRA	FIELD		OFFICE	
	h m s		*							
147	18 12 00	49	0	+0.4	-1.6	+0.4	48	2		
	30	53	5			+0.4	52	7		
	18	76	0	+0.4		+2.4	77	2		
	30	94	—	0	-1.6		94	8		
	19	113	**		0		115	4		
	30	135	-				137	4		
148	20	160	-			+2	162	-		
	21	206					208			
	22	258					260			
	23	310					312			
149	10 24 -	356					358			
	25	372					374			
	26	386				+2	388			
	27	410				0	410			
150	28	434					434			
	- 29 -	466		+3			469			
	- - 45		*							
	10 30 00	502					505			
	31	540					548			
151	· 32	576		+3			579			
	33	605		+4			610			
	34	650					655			
	35	685		+4			690			

Boat				
272	147	118	75-33	48 @ S/S
		131		φ 36 - 27.0
		135	56-12	λ 121 - 58.1
				*DE-723 - B Scale
				I/S
				*Switch to PDR
	148	S	57-21	S/S
273			42-17	
(corr.) =		- 3.3	+ 4.7	
		sta.	sta.	Change to RAYDIST
		910	912	See page 20 for
~~145~~	149	667.4	552.6	control info
		664.1	557.3	stamp.
271				
274	150	684.3	562.2	
		681.0	571.9	* Current Streak
(corr. =)		- 4.3	+ 4.7	R1 - G1
				(sta. R1 gained
				1 Lane)
	151	702.5	580.8	
		698.2	585.5	

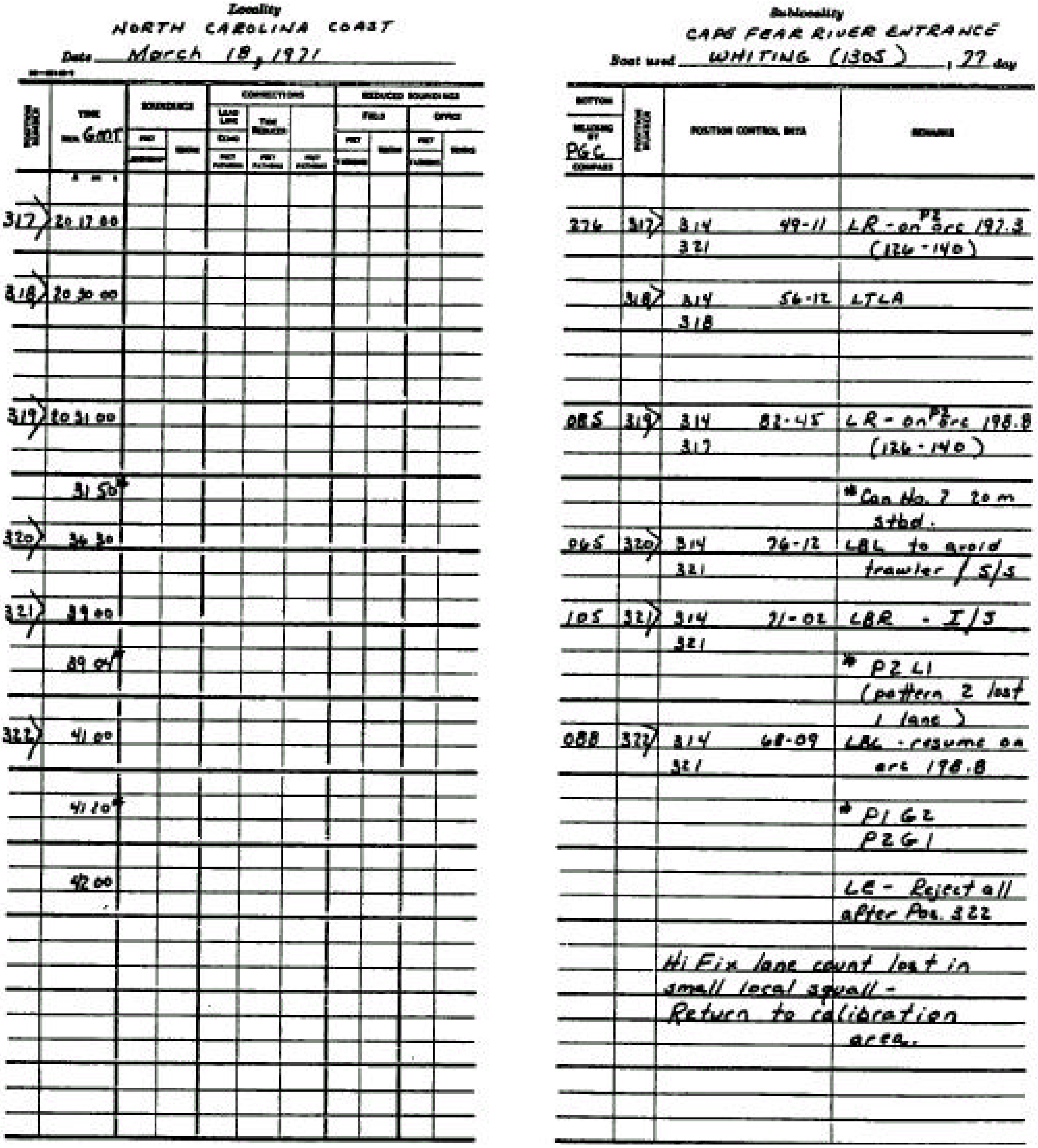
FIGURE 4-23.- Record of hydrography controlled by sextant fixes and Raydist

Method of data acquisition (i.e. manual or automatic recording).

Mode of control (such as visual, range-range, range-azimuth, hyperbolic-visual).

Name of control system.

System operating frequency.



Locality
NORTH CAROLINA COAST
Date March 18, 1971

Sublocality
CAPE FEAR RIVER ENTRANCE
Boat used WHITING (1305), 77 day

	TIME GMT h m s	SOUNDINGS	CORRECTIONS	REDUCED SOUNDINGS
317	20 17 00			
318	20 30 00			
319	20 31 00			
	31 50*			
320	36 30			
321	39 00			
	39 04*			
322	41 00			
	41 10*			
	42 00			

BOTTOM HEADING BY PGC COMPASS		POSITION CONTROL DATA		REMARKS
276	317	314 321	49-11	LR - on P2 arc 197.3 (126-140)
	318	314 318	56-12	LTLA
085	319	314 317	82-45	LR - on P2 arc 198.8 (126-140)
				*Can No. 7 20 m stbd.
065	320	314 321	76-12	LBL to avoid trawler / S/S
105	321	314 321	71-02	LBR - I/S
				* P2 L1 (pattern 2 lost 1 lane)
088	322	314 321	68-09	LBL - resume on arc 198.8
				* P1 G2 P2 G1
				LE - Reject all after Pos. 322

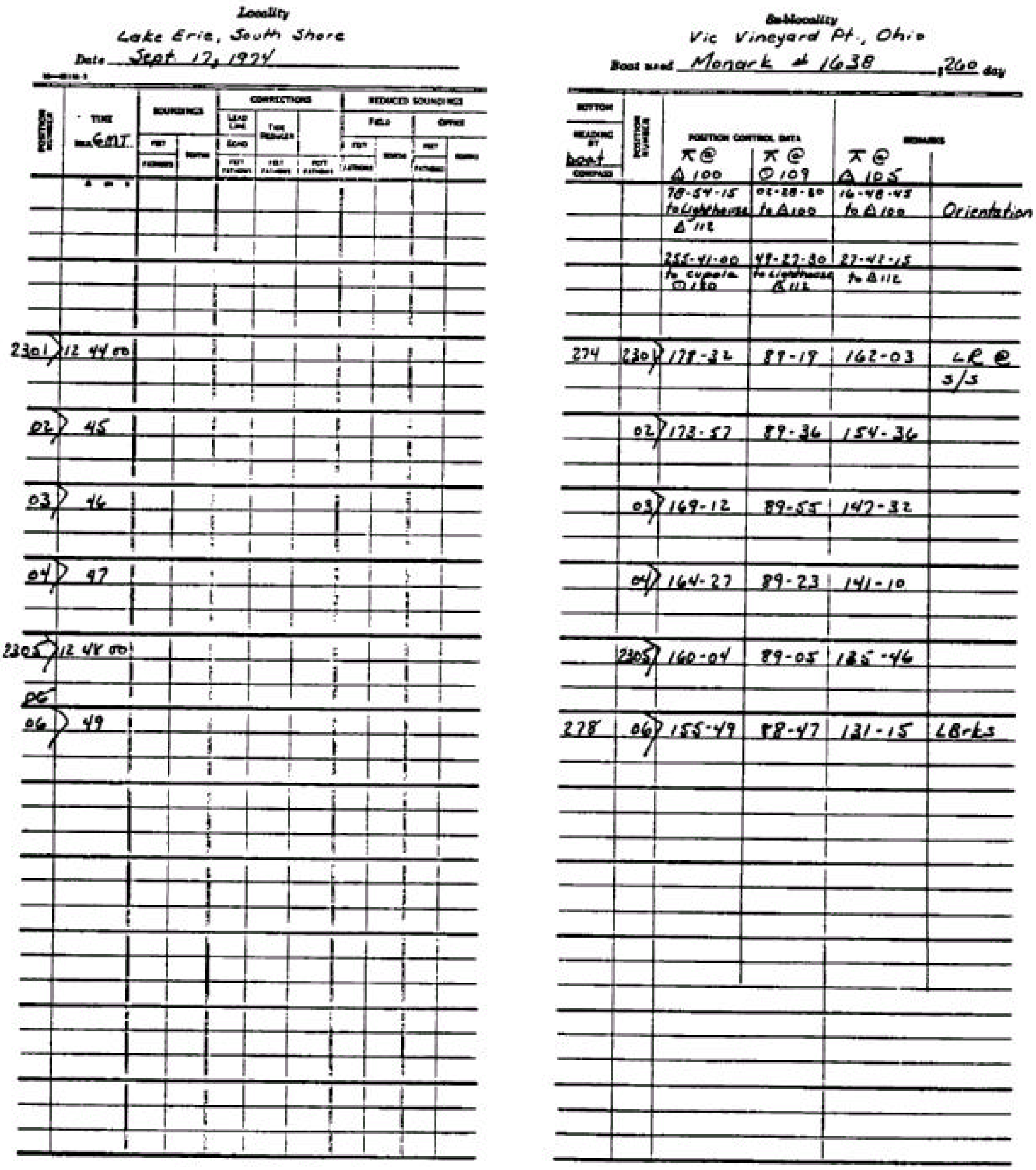
Hi Fix lane count lost in small local squall - Return to calibration area.

FIGURE 4-24.- Recorded hydrographic-visual controlled hydrography (one hyperbolic lane value and one sextant angle). Soundings and hyperbolic lane values recorded automatically through a digital control unit.

Names and number of shore stations.

Modification may be made to stamp 3 to fit the control system used.

4.8.3.5. SOUNDING EQUIPMENT. Names and serial numbers of sounding equipment used shall be entered using stamp 4 (figure 4-28) at the beginning of the day. Equivalent information may be machine printed on automated survey data listings. (See



Locality
Lake Erie, South Shore
Date Sept 17, 1974

POSITION NUMBER	TIME GMT	SOUNDINGS		CORRECTIONS			REDUCED SOUNDINGS			
	h m s	FEET / FATHOMS		LEAD LINE / ECHO	TIDE REDUCER		FIELD		OFFICE	
2301	12 44 00									
02	45									
03	46									
04	47									
2305	12 48 00									
PG										
06	49									

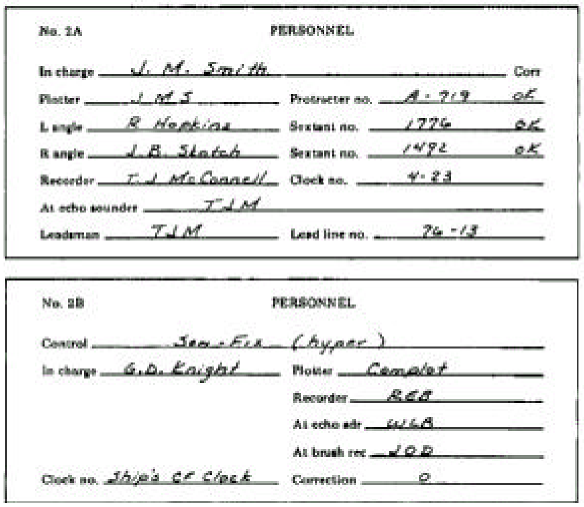
Sublocality
Vic Vineyard Pt., Ohio
Boat used Monark # 1638, 260 day

BOTTOM / HEADING BY boat COMPASS	POSITION NUMBER	POSITION CONTROL DATA			REMARKS
		⊼ @ Δ 100	⊼ @ ⊙ 109	⊼ @ Δ 105	
		78-54-15 to Lighthouse Δ 112	02-28-20 to Δ 100	16-48-45 to Δ 100	Orientation
		255-41-00 to cupola ⊙ 180	49-27-30 to Lighthouse Δ 112	27-42-15 to Δ 112	
274	2301	178-32	89-19	162-03	LR @ 3/5
	02	173-57	89-36	154-36	
	03	169-12	89-55	147-32	
	04	164-27	89-23	141-10	
	2305	160-04	89-05	135-46	
278	06	155-49	88-47	131-15	LBrks

FIGURE 4-25 —Record of positions observed by the theodolite intersection method

4.8.4.) If shoal and deep-water echo sounders are used at various times during the day, each instrument must be identified. The source of the soundings must be shown in the records—times of instrument changes, malfunctions, component changes, and similar occurrences must be noted. If supplemental depth recording equipment [e.g., Precision Depth Recorder (A.6)] is used, the fact is noted immediately below the stamp or machine printed data.

Phase corrections and frequency checks must also be entered. Frequency should be checked weekly by comparing an actual count of stylus revolutions with the manufacturer's specifications or by using an accurate frequency meter that is not part of



No. 2A PERSONNEL

In charge J. M. Smith Corr

Plotter J M S Protractor no. A-719 OK

L angle R Hopkins Sextant no. 1776 OK

R angle J. B. Sketch Sextant no. 1492 OK

Recorder T. J. McConnell Clock no. 4-23

At echo sounder TJM

Leadsman TJM Lead line no. 76-13

No. 2B PERSONNEL

Control Sea-Fix (hyper)

In charge G. D. Knight Plotter Complot

Recorder REB

At echo sdr WLB

At brush rec JOD

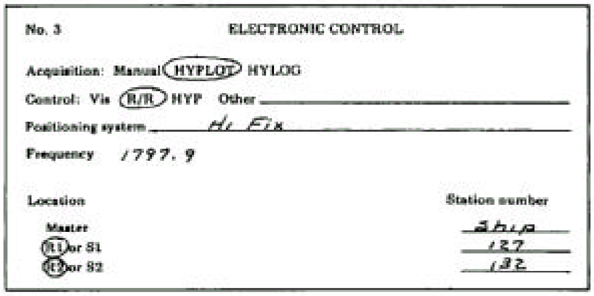
Clock no. Ship's CF Clock Correction 0

FIGURE 4-26—Rubber stamps 2A and 2B, personnel stamps used at the beginning of the day

the recorder. Dial or vibrating reed types of meters built in the recorders may be used to check frequencies throughout the day after the weekly independent check is made.

When lead-line soundings are recorded, the number of the lead-line shall be entered either below the stamp or in the remarks column. A reference shall be made to the volume and page where lead-line graduation comparisons are recorded.

4.8.3.6. COMPARISON OF SOUNDING EQUIPMENT. When graduations on lead lines or on bar check lines are compared with a standard, the results should be recorded on stamp 5. (See figure 4-29.) Calibrated steel tapes or marked distances are used to compare graduated lines for an accuracy check. Stamp 5 is also used to enter echo sounder calibration data obtained by bar check. (See AF.1.3.) Detailed instructions for observing and recording bar checks are found in section 4.9.5—a suggested alternate form for recording these data during automated surveys is also shown.



No. 3 ELECTRONIC CONTROL

Acquisition: Manual [✓ HYPLOT] HYLOG

Control: Via [✓ R/R] HYP Other

Positioning system Hi Fix

Frequency 1797.9

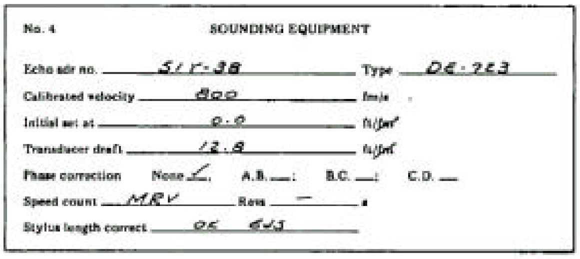
Location Station number

Master ship

[✓ R1] or S1 127

[✓ R2] or S2 132

FIGURE 4-27. - Rubber stamp 3, electronic control information



No. 4 SOUNDING EQUIPMENT

Echo sdr no. 51r-38 Type DE-723

Calibrated velocity 800 fm/s

Initial set at 0.0 ft/fm

Transducer draft 12.8 ft/fm

Phase correction None ✓; A.B. ; B.C. ; C.D.

Speed count MRV Rev — s

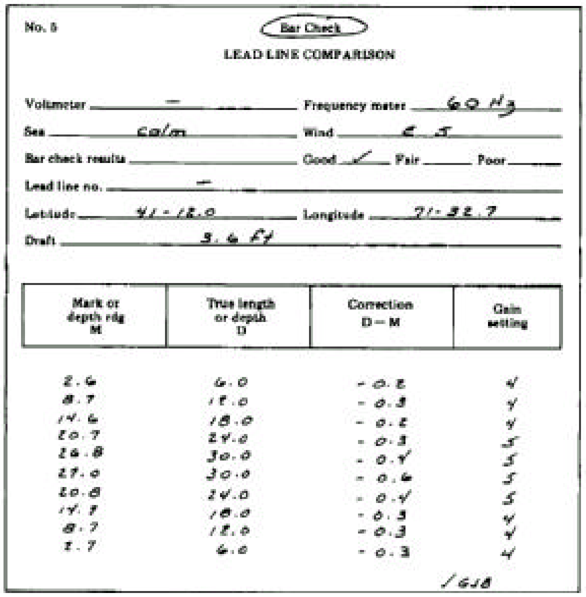
Stylus length correct OK 643

FIGURE 4-28. - Rubber stamp 4, a record of sounding equipment

Comparisons between simultaneous vertical casts and echo soundings are recorded on stamp 5A. (See figure 4-30.) The lead-line number must be entered so the proper correction (from the comparison of the lead line with a standard) can be made to the vertical cast measurement.

Standardizations and comparisons recorded in a Sounding Volume must be indexed in the front of the book for easy reference.

Deviations of the initial from the standard value observed during comparisons shall be noted and the observed data adjusted accordingly. The



No. 5 [✓ Bar Check]

LEAD LINE COMPARISON

Volumeter —

Frequency meter 60 Hz

Sea calm

Wind E 5

Bar check results Good ✓ Fair Poor

Lead line no. —

Latitude 41-12.0

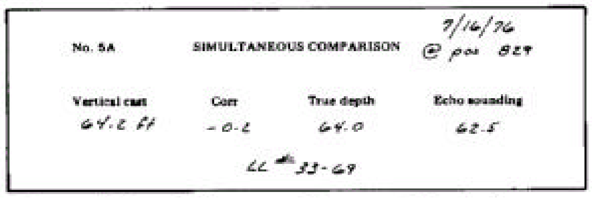
Longitude 71-32.7

Draft 3.6 ft

Mark or depth rdg M	True length or depth D	Correction D − M	Gain setting
2.6	6.0	-0.2	4
8.7	12.0	-0.3	4
14.6	18.0	-0.2	4
20.7	24.0	-0.3	5
26.8	30.0	-0.4	5
27.0	30.0	-0.6	5
20.8	24.0	-0.4	5
14.7	18.0	-0.3	4
8.7	12.0	-0.3	4
2.7	6.0	-0.3	4

1618

FIGURE 4-29. - Rubber stamp 5, a record of a bar check



No. 5A SIMULTANEOUS COMPARISON 7/16/76 @ pos 827

Vertical cast	Corr	True depth	Echo sounding
64.2 ft	-0.2	64.0	62.5

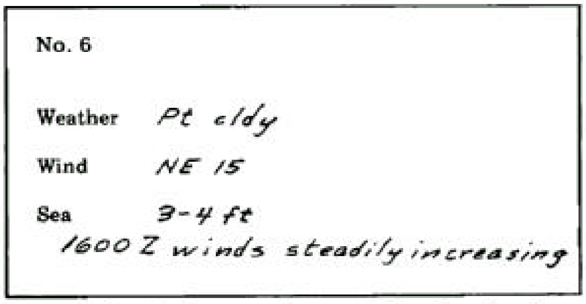
LL # 33-69

FIGURE 4-30.— Rubber stamp 5A, a record of a simultaneous comparison of an echo sounder

draft of the transducer at the time of comparison must be entered.

4.8.3.7. WEATHER AND SEA CONDITIONS. These conditions shall be entered on stamp 6 (figure 4-31) at the beginning and end of the workday and at other such times that significant changes occur. The "weather" entry is a general description of the prevailing conditions. "Wind" is recorded in terms of the direction from which it is blowing combined with an estimate of the force in knots. "Sea" state is recorded as the average estimated height (in feet) of the waves or chop. If the survey continues on a 24-hr basis, the weather, wind, and sea conditions are entered in the records when each watch begins.

4.8.3.8. COLUMN ENTRIES. Figures 4-25 through 4-27 illustrate manually recorded data for a hydrographic survey. Sounding Volume pages are ruled in headed columns. Entries must be made in the correct columns and should not encroach on adjacent columns. All data related to a specific time entry should appear on the same horizontal line to avoid confusion—if more than one line is required, only the first entry is placed on that line. Miscellaneous entries in the remarks column may be referred to their respective times of occurrence by using corresponding reference marks. Asterisks or similar identifiers are used for this purpose.



No. 6

Weather Pt cldy

Wind NE 15

Sea 3-4 ft

1600 Z winds steadily increasing

FIGURE 4-31— Rubber stamp 6, a record of weather throughout the day

Positions shall be numbered consecutively for each hydrographic sheet in accordance with 4.4.6; they are entered in the columns headed "Position Number" (on both left- and right-hand pages and on the same line as the time of observation). Other entries are not made in these columns.

Greenwich Mean Time (GMT) shall be used for hydrographic recording and the fact noted at the head of the time column at the beginning of each day's work. Time is recorded on a 24-hr basis from 0 (midnight) to 23 (11 p.m.). Times are recorded in the "Time" column with corresponding data to which they refer entered on the same horizontal line. The time of each position, each regular interval sounding, and each entry that will be used when plotting data must be recorded. Depths over peaks and deeps occurring between regular interval soundings are also recorded in GMT.

All times shall be recorded using a carefully regulated clock (AL.3) or an electric clock operating on a constant frequency circuit. Echo sounders operate at constant speeds but will not measure elapsed time accurately; they shall not be used for this purpose. Clocks must be set to the correct time at the beginning of the day and shall be compared with a reliable standard at the end of the day. Gains or losses of time shall be recorded.

Soundings shall be entered in the double column headed "Soundings." If the bottom is generally even and few soundings need be recorded at odd intervals, a sounding may be entered on each line except on the line following a position. Where the bottom is irregular and many extra soundings must be scaled from the analog depth record, the soundings at regular intervals are entered on alternate lines.

Soundings shall be entered in whole units and decimals of fathoms or of feet in accordance with table 4-4. (See 4.5.6.) Soundings shall not be entered in mixed units of fathoms and feet (i.e., 6 fm 4 ft; fractions are not used). The depth unit is indicated by striking out the inapplicable subheading at the top of the double column.

Changes in sounding units must be clearly indicated. Because only one unit is used on one hydrographic sheet, it is more convenient to record soundings in the unit to be used in plotting — changes from one unit to another during sounding should be held to the minimum consistent with the accuracy required. (See 4.5.7.2.)

When soundings are obtained simultaneously by two instruments, the source of each sounding must be shown. For example, if most depths are measured using an echo sounder but several lead-line soundings are interspersed, each lead-line sounding is identified by the letters "LL." Similarly, pole soundings shall be identified by the abbreviation "PS." Depths measured by lead line or pole must not be recorded unless they are true vertical measurements of depth.

Bottom characteristics are entered in the first column on the right-hand page using the abbreviations listed in table B-5 in appendix B. Every determination of the character of the bottom must be accompanied by position data.

The heading of the vessel must always be entered. Indicate in the space at the top of the first column on the right-hand page whether a steering (psc), standard magnetic (pmc), or gyro (pgc) compass was used. Course changes are entered on lines corresponding to the time the change was made. Courses are recorded in degrees (clockwise from north).

4.8.3.9. POSITION DATA. If practical, all positional data are to be entered on the right-hand page of the Sounding Volume in the column headed "Position Control Data." The first entry for positional data must be on the same horizontal line as the corresponding time on the left-hand page-the remainder of positional data is entered on following consecutive lines.

Numerical designations of the stations used for sextant three-point fixes are recorded vertically, in the left part of the column. Recorded numbers of signals must agree with those shown on the field sheet. Objects are always recorded in a clockwise direction, that is, left object first, center object next, and right object last. (See figure 4-22.) Observed angles are recorded in the right part of the column-left and right angles are recorded opposite the numbers of the left and right objects, respectively. Station numbers need not be repeated when the same signals are used for successive fixes. The word "same" or a large letter "S" that covers the three spaces usually occupied by fix data may be used to indicate repetitions on the same page; however, signal numbers must be recorded at the top of each new page. All station numbers must be entered if any signal in the fix is changed.

Supplemental angles, cuts, or check angles are entered in the same column and on the next line below the fix data. Signal numbers are entered on the same line. The number of the left object is always recorded first. Detached positions are frequently recorded without a sounding (e.g., when locating rocks or signals). All such positions are assigned numbers and are recorded in the same manner as prescribed for hydrography.

Theodolite intersection location data are recorded in the position control data column. (See figure 4-25.) The listing of the station numbers must be in the same order in which observed directions are radioed to the hydrographer for plotting. Once established, the order need rarely be changed until a theodolite is moved to a new station.

Electronic positioning systems normally display positional data either on two dials or by two digital counters. Readings from these types of displays should be read and recorded from left to right or from top to bottom and the values related correctly to the shore stations. Rubber stamps can be used to enter headings or repetitious electronic positional data in the sounding record. Electronic data are more conveniently recorded in double columns, each column headed by the station(s) designation. Both distances or line values comprising a fix are recorded on the same line (figure 4—23) as read from left to right or top to bottom from the display.

Several spaces should be left between positions for the entry of calibration data and other corrections to electronic positional data. If sextant fixes, theodolite cuts, or bearings are observed at an electronic position, the visual data are recorded in the remarks column and referenced to the position number.

4.8.3.10. REMARKS COLUMN. Additional information is entered in the remarks column as necessary for a thorough understanding and correct processing and plotting of the survey. Abbreviations (appendixes B and E) may be used for many entries. The sequence of recording may be interrupted to enter long notes across the entire width of a page. As a rule, all notes should be entered at the time the event described occurred. The hydrographer should place his initials under explanatory notes entered in the record.

A great number of miscellaneous entries are required: these are too numerous to be discussed individually, but the following entries illustrate the variety of information that should be recorded:

1. Latitudes and longitudes shall be noted for the beginning of the first line of the day's work, for each detached position, and for beginnings of lines in different localities. Rubber stamp 7 (figure 4-32) may be used. Scaled distances and directions from nearby signals may be used instead of latitudes and longitudes.

2. The abbreviation **LTLA** (line turns left about) or **LTRA** (line turns right about) is entered when the line turns 180° to the left or right and reverses direction to begin a new line — **LR** (line resumes) is entered for the first position of the new line.

3. Note changes affecting information recorded at the beginning of the day's work (e.g., personnel, instruments, and weather).

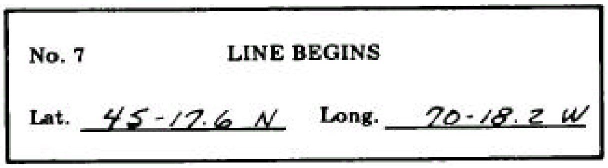
4. Note the times, distances (in meters), and directions when passing important features nearby (e.g., aids to navigation, rocks, breakers, and kelp). Indicate whether the distance is estimated, whether the object has been previously located, or whether the data recorded are to be used to locate the feature.

5. Note estimated distances to the shoreline, low water line, and reef lines from the nearest recorded position.

6. Record significant changes in speed of the sounding vessel. Note each sounding line started from a standstill and the time that normal sounding speed was reached. (See 4.5. 1.)

7. Indicate the scale or phase being used on the analog depth recorder and all changes thereto. When shoal and deep water echo sounders are used alternately, each change shall be recorded.

8. Enter notes concerning the correct operation of the echo sounder or other electronic equipment. Various checks are required periodically to ensure proper operation and accuracy; the fact that these checks were made must be noted. Adjustments to the stylus length of the analog depth recorder must be entered.



No. 7 **LINE BEGINS**

Lat. 45-17.6 N **Long.** 70-18.2 W

FIGURE 4-32.—Rubber stamp 7, the position of a line beginning

9. Pertinent information received from electronic shore stations must be recorded and referenced to time (e.g., time comparisons, changes in equipment, electronic adjustments, and repairs that may affect the results of the survey).

10. Enter measurements or estimates of heights of exposed rocks and estimated depths over submerged features on which soundings cannot be measured safely. Be sure to include the time of observation so that a subsequent reduction to the sounding datum can be made. (See 1.6.2.)

11. Record complete and comprehensive notes regarding the examination of shoals including the method of search used, a statement as to whether the bottom was visible, type of bottom, presence of kelp or grass, least depths found, and any other information that will help the verifier to ascertain whether the investigation is adequate.

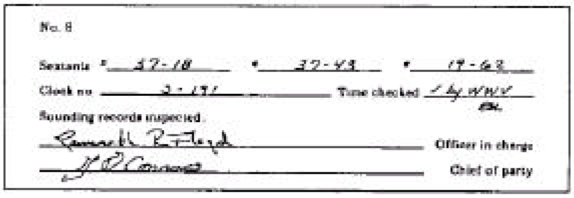
12. Each feature marked in the presurvey review must be examined and the results noted as in entry 11. Items are identified by number or by latitude and longitude. Notes shall include statements as to the amount of time spent in making the investigation. Specific recommendations to delete or retain features on charts shall be made and be accompanied by the reasons for the recommendations. (See 2.3.3.)

13. The beginning and end of charted feature investigations shall be noted, and the feature specifically identified.

14. Note local tidal anomalies that vary significantly from the conditions at established tide stations to assist in zoning the tidal reducers.

4.8.3.11. INFORMATION AT END OF DAY'S WORK. Certain entries are required to complete the records at the end of the day's work. These entries can be made using rubber stamps for hand-recorded surveys or by using machine listings of the stamps for automated surveys. (See 4.8.4.) Bar check or vertical cast data required at the end of the day may be entered in stamp 5 (figure 4-29). Correct adjustment of sextants, theodolites, and clocks must be verified at the end of the day-these facts are entered in stamp 8 (figure 4-33.) The Officer in Charge or the Chief of Party shall certify this verification by entering initials or a signature in the appropriate spaces on the stamp.

Statistics for each day's work are entered at


No. 8

Sextants # 37-18 # 37-43 # 19-63

Clock no 2-171 Time checked ✓ by WWV ok

Sounding records inspected.

Kenneth R Floyd Officer in charge

Chief of party

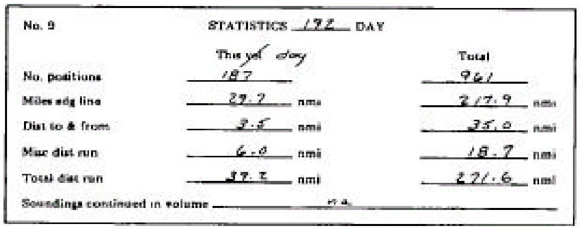
FIGURE 4.33. —Rubber stamp 8, verification of sextants and sounding clock

the end of the day's records using stamp 9 (figure 4-34) or by using an equivalent machine listing. If a day's work is recorded in more than one Sounding Volume, the stamp is used in each volume and the statistics for that volume entered. The totals are entered at the end of the day's work.

Rubber stamp 10, "Processing" (figure 4-35), is used as a checklist to ensure orderly and complete data processing. All applicable data must be entered. Space must be left at the end of each day's work for this stamp or a machine listing.

4.8.3.12. COMPLETION OF SOUNDING RECORDS. Following completion of required field processing and prior to submission of the survey for verification and smooth plotting, the records for each hydrographic sheet must be indexed, cross-referenced, and arranged in a logical orderly manner. Procedures for correction of soundings and reduction to the appropriate datum are described in section 4.9.

All records are grouped in the proper order, the various groups combined, and the complete set numbered consecutively and permanently. Chronological ordering of daily sounding records in accordion-type files is recommended. The hydrographer shall examine each data tape, data listing, abstract, Sounding Volume, analog record, and all other survey records to ensure that each is properly identified and explicit. Field records and computations not part of the daily sounding records must be so identified and grouped in a rational manner. Both field and registry numbers (2.4.3) are entered wherever the hydrographic sheet number is required. Rubber stamps may be used for most of the necessary entries.

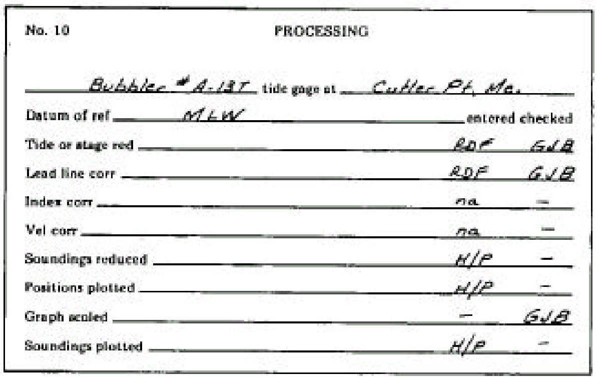

No. 9

STATISTICS 172 DAY

	This yd day	Total
No. positions	187	961
Miles sdg line	29.2 nmi	217.9 nmi
Dist to & from	3.5 nmi	35.0 nmi
Max dist run	6.0 nmi	18.7 nmi
Total dist run	37.7 nmi	271.6 nmi

Soundings continued in volume na

FIGURE 4-34. – Rubber stamp 9, statistics for a day's work


No. 10 PROCESSING

Bubbler # A-13T tide gage at Cutler Pt, Me.

Datum of ref MLW	entered	checked
Tide or stage red	RDF	GJB
Lead line corr	RDF	GJB
Index corr	na	–
Vel corr	na	–
Soundings reduced	H/P	–
Positions plotted	H/P	–
Graph scaled	–	GJB
Soundings plotted	H/P	–

FIGURE 4-35 .— Rubber stamp 10, a processing checklist

On surveys recorded by hand, the entries on the cover labels of the Sounding Volume shall be filled in using black ink. If any ship hydrography was run using a magnetic steering compass, a copy of the deviation table is entered on page 1 of the first volume of each set of records. Deviation tables are not required for launch or small boat hydrography. Location data contained in the Sounding Volumes for objects such as signals, rocks, landmarks, and aids to navigation shall be indexed on page 2 of the volumes. These entries are repeated in volume 1 of the record set with a reference to the appropriate volume number. References to data concerning a presurvey review item (2.3.3) shall include the item number. Calibration data for electronic control systems and for echo sounders (including bar checks, vertical cast and phase comparisons, or references thereto) must also be indexed on page 2 of the appropriate volume. Other significant events or activities not listed shall also be indexed.

For automated survey data, a single index of the events and items listed shall be prepared and inserted in the volume(s) accompanying the survey. References are made to the Julian date and the position number or time of the event.

4.8.4. Automated Survey Records

Most **NOS** hydrographic surveys are conducted and processed using the **HYDROPLOT** Data Acquisition and Processing System. (See A.7.) The system is thoroughly documented in *NOS Technical*

Manual No. 2, "**HYDROPLOT/HYDROLOG** Systems Manual" (Wallace 1971), and need not be discussed in detail here.

The **HYDROPLOT** system acquires, processes, and plots sounding data automatically on a real-time basis. **HYDROPLOT** also permits the survey to be plotted later using corrected and adjusted data. Although a highly sophisticated automatic data acquisition and processing system, the final results are similar to those had the survey been recorded and plotted by hand. **HYDROPLOT** produces an accurate machine drawing of most of the data required for **NOS** hydrographic surveys and provides time, position, and depth records on punched paper tape and on hard copy.

It is frequently difficult to annotate neatly and adequately the hard copy produced by the electric typing devices that are connected to the automated systems. Descriptive notes and information (4.8.3.10) are essential and necessary for understanding and processing the survey. Such information that cannot be recorded accurately and completely in the data tapes or on the data listings shall be entered in **NOAA Form 77-44**, "Soundings," and be referenced by time, position number, or both.

The records stamps described in section 4.8.3 are often inadequate or superfluous for automated survey data. For this reason and to standardize automated records identification, the stamps have been modified and the contents arranged in a format suitable for machine listing. The stamps are available from the Marine Centers on mylar tapes in either **ASCII** or **BCD** form. Nonchanging entries can be added to the tapes for automatic listing (e.g., project number, vessel, and year).

4.8.4.1. DATA IDENTIFICATION. *All* data listings (such as soundings, hourly heights, and velocity corrections) shall be preceded by the **DATA IDENTIFICATION** block (figure 4-36). Every applicable entry must be made. A tape identification stamp is to be impressed on each paper tape. The "**TAPE #**" entries on the **DATA IDENTIFICATION** block and on the tape identification stamp must be the same. Identification numbers or codes are designated in a logical sequential manner by the hydrographer. Each tape and data listing transmitted with the survey records is identified on the transmittal by this number. If a tape or a listing applies to more than one survey (e.g., tidal hourly heights), a copy of the listing must accompany the records of each. The survey data containing the tape is referenced under **"REMARKS."**

4.8.4.2. SURVEY INFORMATION, PROCESSING/STATISTICS, AND PERSONNEL/WEATHER BLOCKS. These blocks (figure 4-37) shall be listed after the **DATA IDENTIFICATION** block on all original sounding record printouts. Position and sounding data listings logged from Sounding Volumes require only the **DATA IDENTIFICATION and SURVEY INFORMATION** blocks provided that the proper personnel, weather, statistics, and processing data have been entered in the volumes.

Nonessential information should be deleted from the **SURVEY INFORMATION and PERSONNEL/WEATHER** blocks as necessary, and additional information, such as instrument serial numbers, entered to improve documentation.

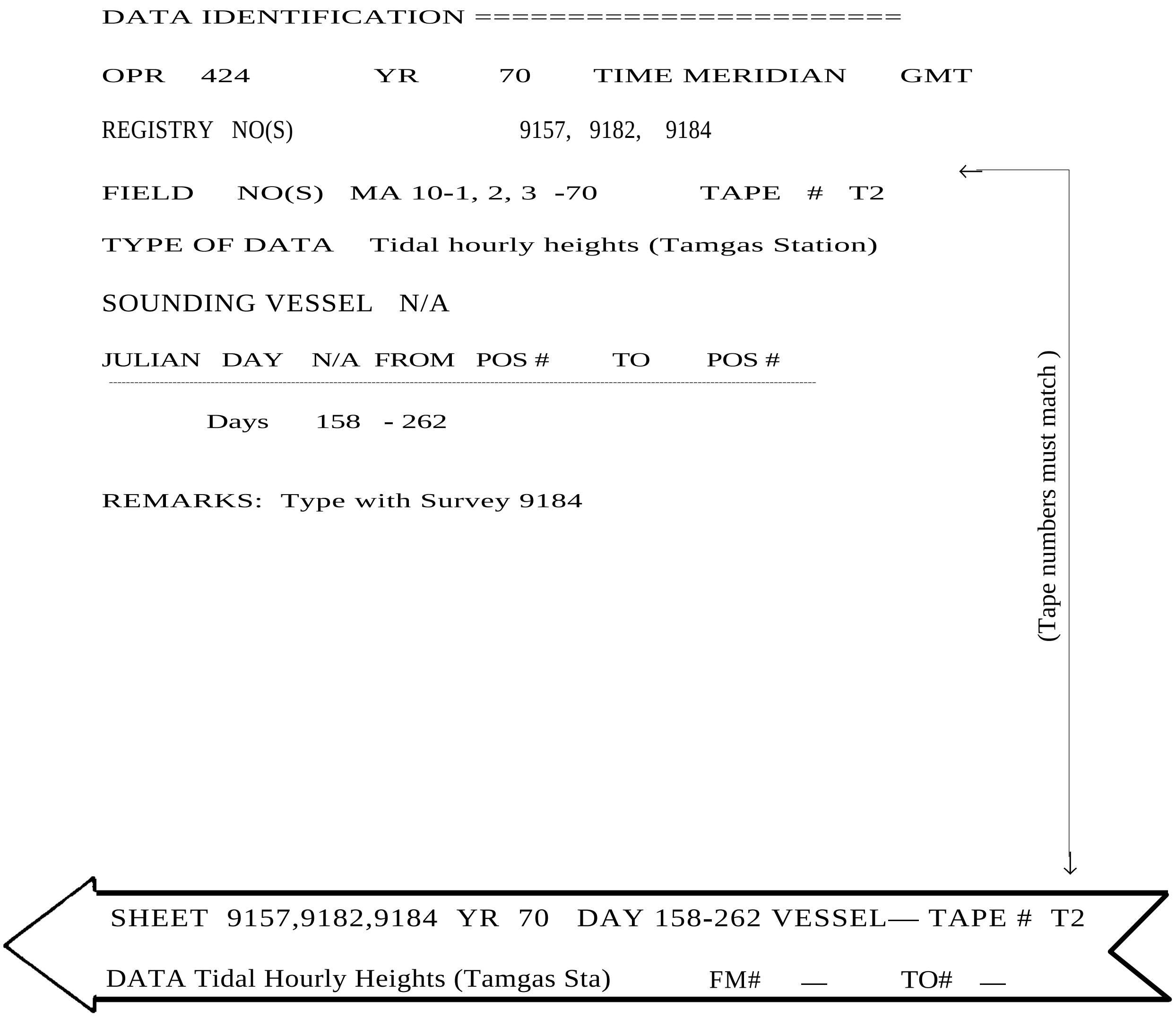
The **PROCESSING /STATISTICS** block should not be modified. The "**SQ MI**" (square nautical miles of hydrography) entry is provided for use when tabulating statistics for Monthly Ship Accomplishment Reports and Descriptive Reports. The chief of party shall sign on the last line after he has examined the records and is satisfied that the data are complete.

4.8.4.3. OTHER DATA. When the data blocks are inadequate, inappropriate, or for other reasons cannot be used, they must be modified or the stamps described in section 4.8.3 used. Additional information the hydrographer believes necessary to record shall be entered by hand.

Stamp 7 (latitude and longitude, figure 4-32) shall be used for all detached positions if necessary to provide a reference to the position. Stamps 5 and 5A, "**BAR CHECK**" and "**SIMULTANEOUS COMPARISON**" (figures 4-29 and 4-30), may be entered on the listings (figure 4-38) or in a supplemental Sounding Volume as appropriate. An alternate method of recording bar checks and simultaneous comparisons is discussed in section 4.9.5.1.1.

4.8.5. Depth Records

4.8.5.1. GRAPHIC DEPTH RECORDS. Graphic or analog records of bottom profiles produced by echo sounders are the official field records of soundings for manually recorded surveys and are used to supplement the generally more accurate digi-



DATA IDENTIFICATION =======================

OPR 424 YR 70 TIME MERIDIAN GMT

REGISTRY NO(S) 9157, 9182, 9184

FIELD NO(S) MA 10-1, 2, 3 -70 TAPE # T2

TYPE OF DATA Tidal hourly heights (Tamgas Station)

SOUNDING VESSEL N/A

JULIAN DAY N/A FROM POS # TO POS #

Days 158 - 262

REMARKS: Type with Survey 9184

(Tape numbers must match)

SHEET 9157,9182,9184 YR 70 DAY 158-262 VESSEL— TAPE # T2

DATA Tidal Hourly Heights (Tamgas Sta) FM# — TO# —

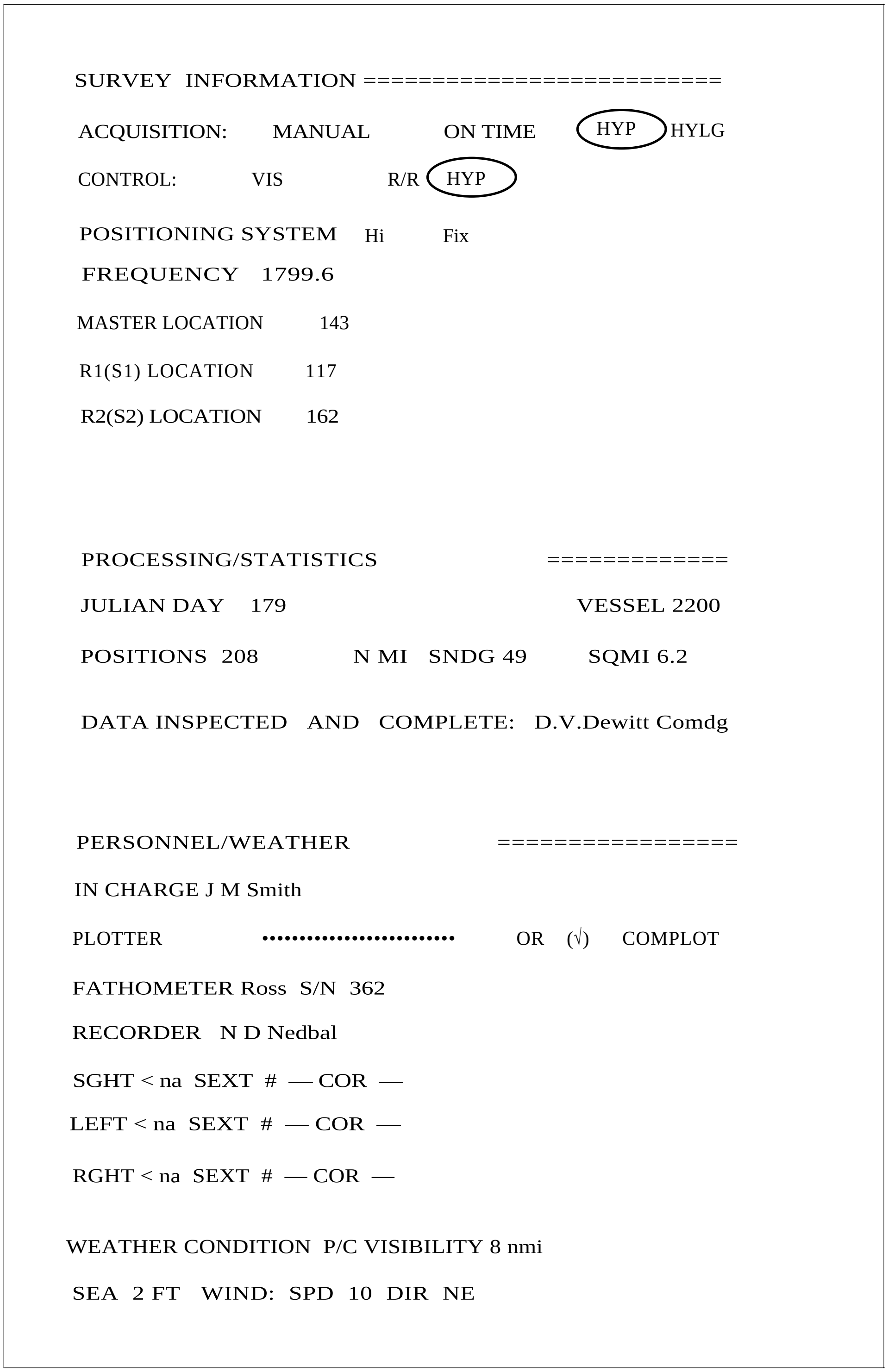
FIGURE 4-36. _ Teletypewriter printout of a data identification block (upper), for listing tidal hourly heights, and tape identification stamp (lower)

tal depth listings. These analog records are frequently referred to as fathograms or echograms.

There must be no ambiguity between bottom profiles and other recorded hydrographic field data. Stamp 11, "**GRAPHIC RECORD**" (figure 4-39), shall be impressed at each end of each analog

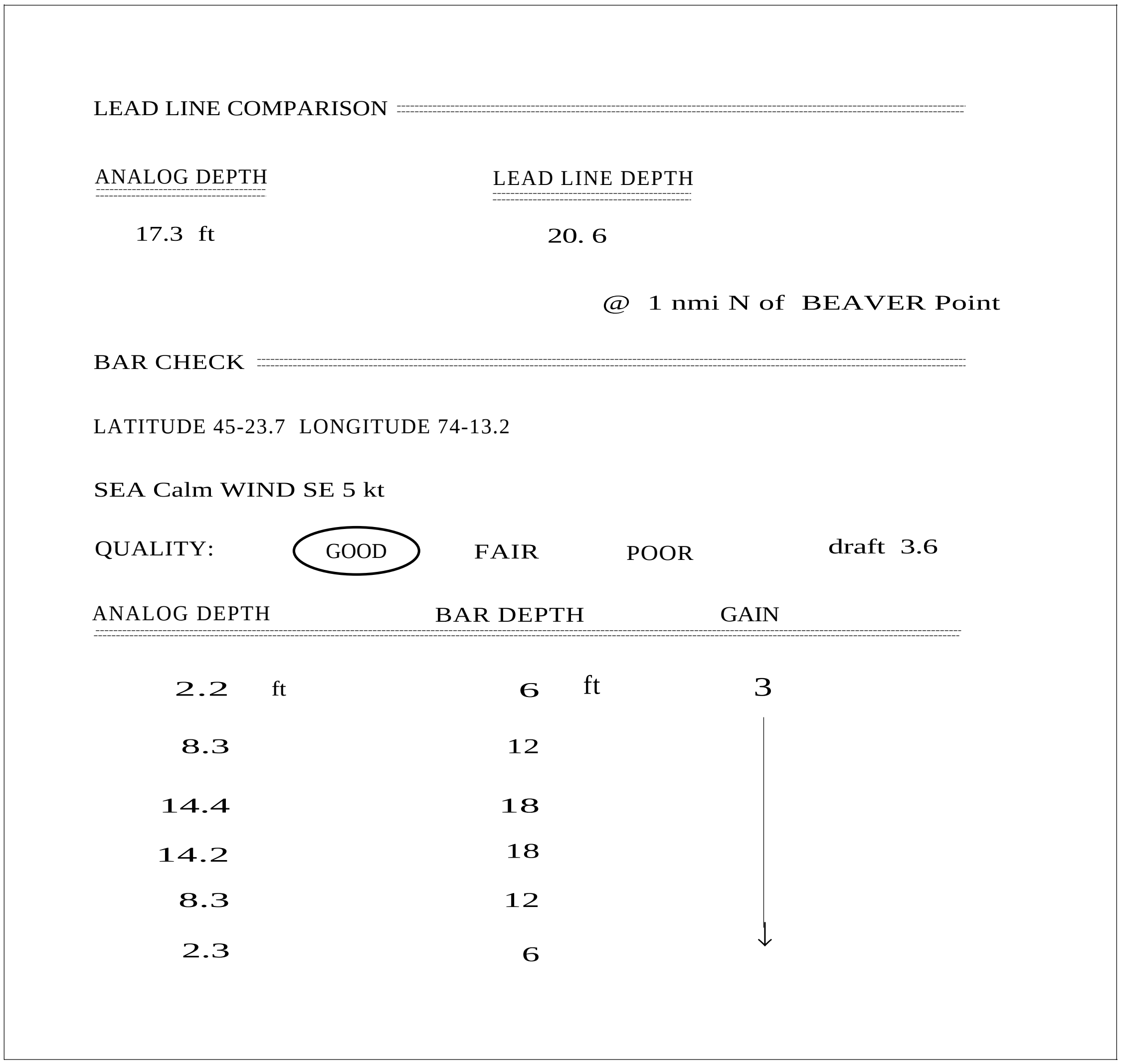
TABLE 4-10.— *Definitions of terms used in figure 4-3 7*

Term	Definition
Manual	Data logged by hand from Sounding Volumes
On time	Data logged by hand as acquired
HYP	Data recorded automatically by the HYDROPLOT system
R1(Sl)	Control station number for the slave number 1 antenna
R2(S2)	Control station number for the slave number 2 antenna
S/N	Serial number
Sght <	Sighting angle for the hybrid control system. (See figure 4-20, angle a.)
Cor	Enter sextant index correction.
Sea	Enter average wave height in feet.



```
SURVEY  INFORMATION =========================

ACQUISITION:     MANUAL       ON TIME    [✓ HYP]  HYLG

CONTROL:         VIS          R/R  [✓ HYP]

POSITIONING SYSTEM   Hi       Fix
FREQUENCY   1799.6

MASTER LOCATION        143

R1(S1) LOCATION        117

R2(S2) LOCATION        162



PROCESSING/STATISTICS                 =============

JULIAN DAY    179                           VESSEL 2200

POSITIONS  208          N MI   SNDG 49      SQMI 6.2

DATA INSPECTED   AND   COMPLETE:  D.V.Dewitt Comdg



PERSONNEL/WEATHER                  =================

IN CHARGE J M Smith

PLOTTER            ••••••••••••••••••••••••      OR   (√)    COMPLOT

FATHOMETER Ross  S/N  362

RECORDER   N D Nedbal

SGHT < na  SEXT  #  — COR  —

LEFT < na  SEXT  #  — COR  —

RGHT < na  SEXT  #  — COR  —

WEATHER CONDITION  P/C VISIBILITY 8 nmi

SEA  2 FT   WIND:  SPD  10  DIR  NE
```

FIGURE 4-37. — Teletypewriter printout of survey information, processing/ statistics, and personnel/ weather blocks for a day's survey work. See also table 4-10.



LEAD LINE COMPARISON

ANALOG DEPTH	LEAD LINE DEPTH
17.3 ft	20. 6

@ 1 nmi N of BEAVER Point

BAR CHECK

LATITUDE 45-23.7 LONGITUDE 74-13.2

SEA Calm WIND SE 5 kt

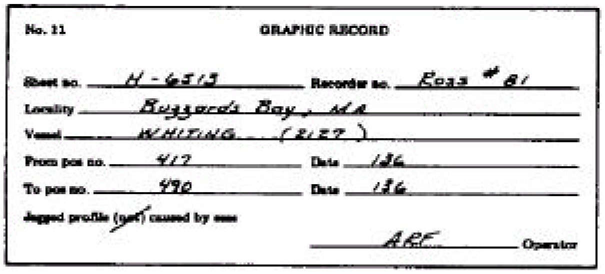
QUALITY: [✓ GOOD] FAIR POOR draft 3.6

ANALOG DEPTH	BAR DEPTH	GAIN
2.2 ft	6 ft	3
8.3	12	
14.4	18	
14.2	18	
8.3	12	
2.3	6	↓

FIGURE 4-38.— Lead -line comparison and bar check machine listings. Other data normally required are found in figure 4-37.

record, and the required information entered in all applicable spaces. Fine-tipped felt pens are recommended for annotating graphic records.

Each echo sounder is provided with a fix marker that, when pressed or activated electronically, causes the stylus to draw a line across the width of the recording paper. At each fixed position, the echo sounder operator shall make a fix mark; the position number is entered beside it. When a fix is rejected or missed, the fact is indicated by two or three "X's" made on the fix mark.



No. 11

GRAPHIC RECORD

Sheet no. H-6513 Recorder no. Ross #81

Locality Buzzards Bay, MA

Vessel WHITING (2127)

From pos no. 417 Date 136

To pos no. 490 Date 136

Jagged profile (~~not~~) caused by sea

ARE Operator

FIGURE 4-39.— Rubber stamp 11, a graphic record for identifying bottom profiles

To properly relate the graphic depth record to the other records, the operator shall make notes to indicate where lines begin, turn, end, or break, using the standard abbreviations listed in appendixes B and E. In addition, notes are added regarding interpretation, wrecks, and marine growth; entries are made to identify all actions taken. The time of day

(GMT) shall be entered periodically on graphic records where it is not evident.

Echo sounders generally record depths in more than one phase or scale depending upon the instrument. The first phase (A scale) is usually identified by an initial trace indicating the relative depth of the transducer. Other phases must be accurately and positively identified by the operator on the record. On some models, a circle can be drawn around the scale being used on the preprinted recording paper; on others, it is necessary to enter notes on the record. See appendix A for a complete discussion of the various echo sounders and depth-recording equipment currently in use by **NOS**.

Graphic profiles of record shall be accordion folded into flat 10-in (25-cm) panels and filed in manila envelopes or bellows-type files that are properly labeled for sheet number, sounding vessel, and dates and year day numbers.

See section 4.9.8 for field scanning and record interpretation procedures. Graphic depth records shall be carefully packaged and forwarded by registered or certified mail for final processing upon completion of work on the hydrographic sheet. These records shall be sent in separate shipments from the sheet and other sounding records.

4.8.5.2. DIGTAL DEPTHS. Most echo sounders used by NOS display depths in both digital and analog form. Generally, digital soundings are inherently more accurate than those extracted from a graphic record because digital depths are free of scaling and mechanically induced errors; therefore, digital soundings are considered as primary data that are supplemented by analog records for these purposes:

1. To scale and record peaks, deeps, and other critical or revealing soundings that may have been missed on the regular sounding interval.
2. To correct digital soundings obviously in error because of returns from kelp beds, fish, side echoes, or spurious strays.
3. To adjust the effects of excessive wave action on digital soundings.

See section 4.8.4 for a discussion of the hydrographic records acquired by automated methods and figure 4-40 for an example of the hard copy format. On the digital record:

From the top, line 1 provides the "day record" (i.e., the vessel identification number, year, Julian day, sounding unit indicator, and the control mode code.

Line 2 provides the corrections [i.e., time, tide reducer, **TRA** (transducer) correction (4.9.7), electronic position value corrections, and electronic control station numbers].

Line 3 lists time, depth, position number, electronic position values, and vessel heading.

Line 4 shows a depth record similar to line 3 but without a position number attached to the sounding. Refer to the "**HYDROPLOT/HYDROLOG** Systems Manual" (WALLACE 1971) for interpretation of the codes and other automated formats for sounding data. (See section A.7 for detailed descriptions of digital sounding equipment now in use.)

4.8.6. Analog Position Data

Analog records of the vessel's movements shall be obtained, when possible, during all surveys controlled by phase comparison type position-fixing systems. Instruments available for this purpose produce a graphic record similar to that shown in figure 4-41, which is a continuous record of lane changes recorded as the vessel maneuvers . The line drawn by the stylus, commonly referred to as a "sawtooth record," shows whether lane values are increasing or decreasing; the slope of the line indicates the rate of change. This record is particularly useful for reconstructing accurate lane counts, when electrical interference or weak signals cause the phasemeters to operate erratically, and for recognizing recording blunders. Lane gains and losses are easily recognized by using spacing dividers to check lane change rates and to verify the annotated lane count. Frequent comparisons between the graphic record and lane count displays are essential for detection of losses or gains in lane count.

Analog position records shall be annotated as follows:

1. Lane count must be entered when calibrations or lane checks are obtained.
2. Positions shall be marked and numbered.
3. Every 5th or 10th lane is numbered depending upon the rate of lane change.
4. Lane count is recorded on both sides of a direction reversal (i.e., when an increasing lane count changes to a decreasing lane count).

```
2220 71 269  1  041

010201 1004 0023 100022  100025  100 000  200

010201 00228 20455 067155 073060  091

010301 00232             067415 073369 091

010401 00228             067677 073675  090

010501 00221             067946 073987  090

010601 00232             068183 074303 089

010701 00242             068432 074599  089

010801 00249             069695 074903  089

010901 00259             068945 075214  089

011001 00259             069204 075517  088

011101 00264             069471 075830 089
011201 00264 00456 069743  076141  090

011301 00252             069983 076459 090

011401 00248             070249 076768 090

011501 0025l             070515  077079 092

01160l  00000            070795  077377 092

011701 00271             071051  077692 093

011801 00286             071313  078003 091

011901 00289             071588 078305 090

012001 00289             071852 078622 089

012101 00255             072123  078929 089
012201 00300  00457   072377  079244  090
```

FIGURE 4—40.—Raw data printout of an automated record of hydrography

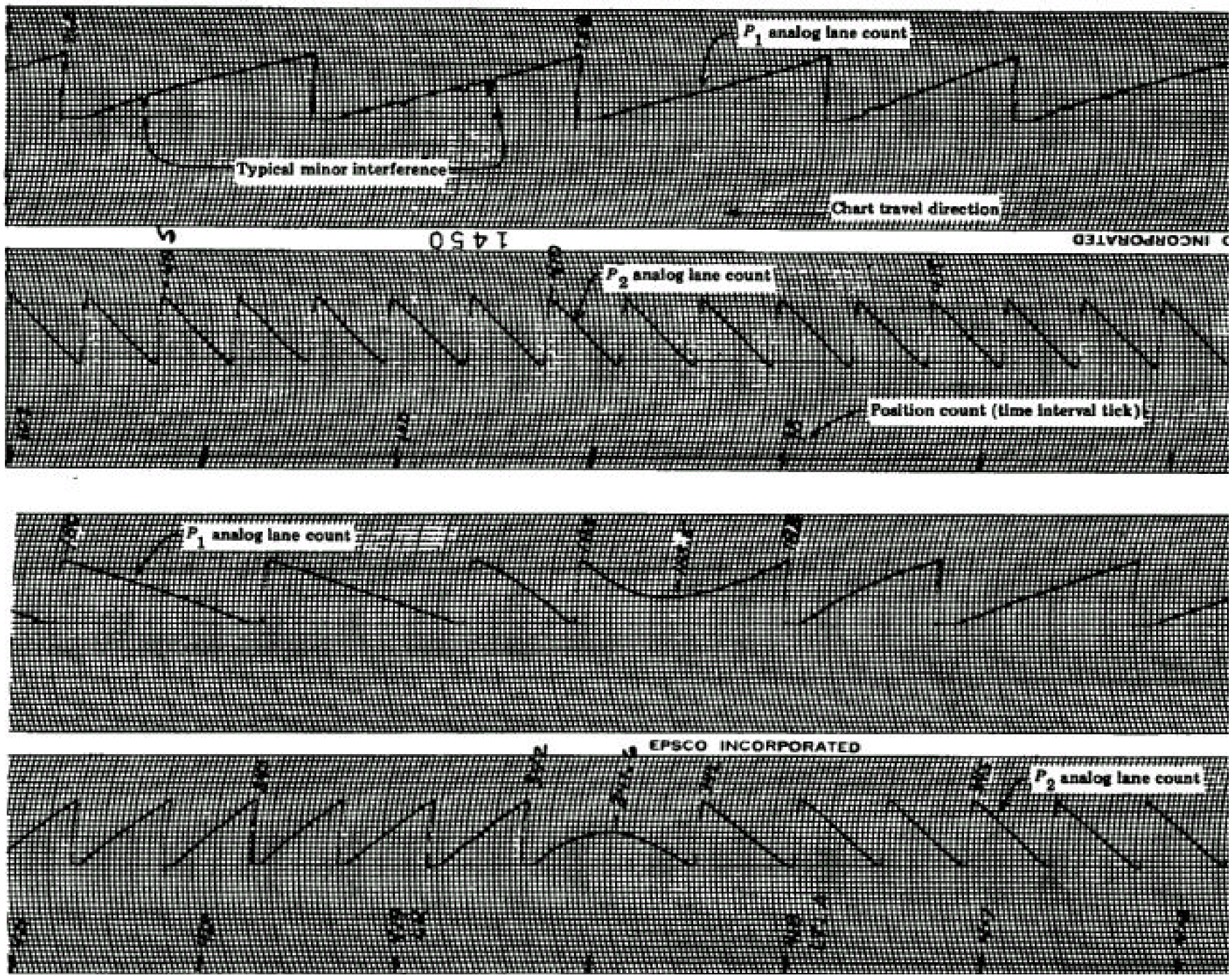


FIGURE 4-41- "Sawtooth: or analog record of a vessel position

5. Detectable lane gains and losses are marked on the record.

6. Stamp 11 (figure 4-39) is impressed on each graphic record and the appropriate entries made. Analog position records are maintained daily and filed with the graphic depth records.

4.9. CORRECTIONS TO SOUNDINGS

4.9.1. General

Observed soundings must be corrected for all departures from true depths attributable to the method of sounding or to faults in measuring apparatus and must be corrected for heights of the water surface above or below the datum of reference when soundings were taken. When sounding operations are in progress, hydrographers occasionally become so engrossed with measurements in the horizontal plane that depth measurement problems are neglected. An echo sounder appearing to be operating correctly is not always sufficient evidence that recorded soundings are correct. Detection of errors in both positioning and sounding data and the accumulation of information necessary to correct these errors can often present real challenges. The final measure of the quality of a hydrographic survey may depend on these factors.

Occasionally, discrepancies are not discovered until the survey is verified. Available data must be sufficiently adequate to permit reasonable solutions of any problems and proper adjustments of discrepancies.

Corrections to soundings, often called "reducers," are determined and tabulated in the same units in which soundings are recorded. Fractional parts of sounding units shall be recorded as decimals.

In those rare instances when soundings are recorded on NOAA Form 77-44, "Sounding," then plotted by hand, vertical columns are provided in the volumes for entering various corrections and corrected soundings. Each correction, with its algebraic sign, is entered on the horizontal line opposite the first sounding to which it applies—correctors need not be repeated on each line, except opposite the first sounding on each page and when they change. (See figures 4-22 through 4-25.) Corrections once entered are considered applicable to all following soundings until different corrections or signs are entered.

4.9.1.1. Standard Nomenclature. In discussing the various corrections to echo soundings, standard nomenclature as defined in this section and shown on figure 4-42 will be used.

Chart depths are the actual water depths below the datum of reference and are the depths shown on hydrographic smooth sheets. Chart depths are determined by applying algebraically the following corrections and reductions to observed soundings:

Heave correction for wave action.

Echo sounding instrument correction.

Velocity of sound correction.

Transducer dynamic draft correction.

Datum of reference reduction for tide or water level stage.

Observed depths are raw uncorrected echo soundings obtained digitally or by scaling depths from graphic depth records. Graphic depth records provide a nearly continuous profile of the bottom below the sounding line. Depths scaled from the re-

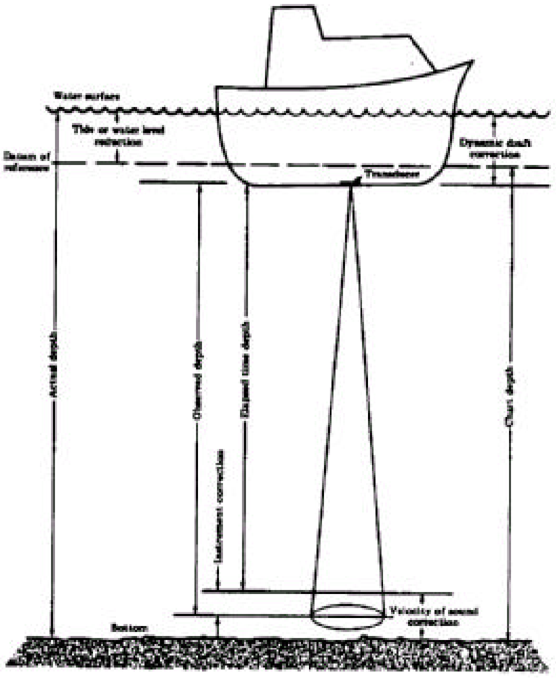


FIGURE 4-42—Corrections to echo soundings

cords are subject to human error and inaccuracies inherent in the mechanical recording devices.

Digital depths are the more accurate of the two because they are determined electronically by multiplying the velocity of sound through water by half the time taken by a pulse to travel from the transducer to the bottom and back; however, the effectiveness of digital depths is often lessened by the inability of the system to compensate for wave action on the vessel and to select peaks and deeps between the programmed sounding interval.

Heave correction (not shown) is applied to observed soundings to compensate for the vertical displacement of the sounding vessel from the mean water surface because of sea conditions. When soundings over regular bottom are being scaled or checked from graphic depth records, heave effects are compensated by visually averaging the undulating depth profile in the vicinity of the sounding. (See 4.9.8.1.)

Correcting heave errors in either digital or scaled soundings over rough and irregular bottom is a more complex problem because authentic depth changes often cannot be distinguished from heave. Soundings should not be taken in rough sea conditions when critical depths are required.

When seas are rough and recorded digital soundings are measured instantaneously and not corrected for the effects of heave, an excessive number of soundings will be in error; therefore, to avoid extensive hand corrections when the records are checked, one should discontinue digital sounding and soundings should be scaled from the graphic depth record when the effects of heave exceed 2 ft or 1% of the depth, whichever is greater.

Instrument corrections are applied to observed depths to compensate for the errors introduced by the echo sounder and depth recorder. (See 4.9.6.) Soundings obtained by digital methods are generally free of these errors and do not require significant corrections. Instrument errors in graphic or analog depths may be attributable to one or more of the following sources:

Incorrect setting of initial pulse.

Scale or phase error.

Incorrect frequency (affects paper speed and stylus arm rotation speed).

Stylus belt improperly adjusted.

Stylus arm length error.

Fine arc error.

Variations in signal strength and time lags in the circuitry.

As a general rule, the accuracy of depths measured by echo sounders is related directly to the competence and reliability of the technicians who operate and maintain these instruments. Each type of echo sounder has its unique characteristic features that must be closely watched. Failure to maintain proper adjustments results in erratic observations and unresolvable discrepancies.

Elapsed time depth is not widely used in hydrographic terminology; but it identifies a specific entity for visualizing the sounding correction scheme. Elapsed time depth is the observed depth corrected for instrument errors—it is equal to half the time taken by a sound wave to travel from the transducer to the bottom and back multiplied by the calibration sound velocity of the instrument.

Velocity corrections must be applied to soundings because both digital and analog echo sounders display depths based on a calibrated constant value for the velocity of sound through water. National Ocean Survey echo sounders are calibrated to record depths based on a velocity of 800 fm/s, which closely approximates most actual values. During hydrographic surveys, field measurements are made for the determination of true sound velocities throughout the water column. (See 4.9.5.) Corrections are then computed and applied to the soundings to compensate for the differences between calibrated and true values of sound velocity. Elapsed time depth when corrected for velocity variations results in the actual depth of the water below the echo sounder transducer.

Dynamic draft is the algebraic sum of the static draft (4.9.4.1) and the effect of vessel settlement and squat (4.9.4.2). Static draft is the depth of the transducer below the water surface and is measured when the vessel is not underway. Settlement and squat corrections are determined for various vessel speeds to compensate for vertical displacements and changes in attitude when underway. NOS echo sounders shall be adjusted to record initial sound pulses at zero depths; therefore, the dynamic draft of the transducer must be added to the actual depth below the transducer (elapsed time depth plus velocity correction) to obtain the actual depth from the water surface.

Transducers should be installed and

shimmed as necessary to ensure verticality of the sound wave cone for the average operating attitude of the vessel.

Datum reduction is applied after all other corrections have been made to reduce each actual depth to the datum of reference (chart datum) for the particular area. (See 1.6.1 and 4.9.3.) This reduction is made by applying the difference in elevation of the water surface (tide or water level stage) and the datum of reference at the time the sounding was observed.

4.9.1.2. STANDARD PRACTICES. Three standard practices concerning echo-sounding corrections have been adopted by the National Ocean Survey:

1. NOS depth recorders are calibrated for an assumed velocity of sound in water of 800 fm/s (1463.43 m/s). This value is reasonably close to the velocity of sound in most waters surveyed.

2. The synchronous motor that drives the stylus arm shaft or belt shall be operated at the proper frequency recommended by the manufacturer. Changing frequencies to cause agreement between bar checks and analog records is not permitted. By prohibiting this practice, the hydrographer can better determine the magnitude of other types of errors.

3.The initial setting on all depth recorders shall be zero rather than the assumed transducer depth.

4.9.2. Correction Units

Corrections to soundings are computed and applied according to the specifications listed in table 4-4, section 4.5.7. 1. Corrections are generally determined to the nearest decimal that is half that required for recording soundings (e.g., use 0.2 where the requirement for recording is 0.5); however, corrections in fathoms need not be closer than 0.1 fm. For soundings in feet, except on shoals, banks, and other critical areas, corrections need be entered only to the nearest foot in depths greater than 20 fm.

In ocean depths over 110 fm, corrections may be omitted where the algebraic sum of the tide correction and other corrections, excluding velocity corrections (4.9.5), is less than half of 1% of the depth. Water level stage corrections are applied to all soundings in the Great Lakes regardless of the depth.

4.9.3. Tide and Water Levels Reductions

Except as stated in section 4.9.2, all soundings must be corrected for the height of the tide or water level above or below the datum of reference for the area. (See 1.5.4.1.) Predicted tides or forecast water levels are often used to reduce soundings in the field. Final reducers are generally derived from tide or water level automatic recording gages (1.5.4.2) located at primary stations or from supplemental gages established in the project area especially for this purpose. (See 2.3.1.5 and AK.) Occasionally, these reducers may be determined from tide or water level values observed visually on a tide staff (AK.2) for limited amounts of hydrography. See *Publication* No. 30-1, "Manual of Tide Observations" (U.S. Coast and Geodetic Survey 1965*a*), for detailed instructions concerning annotation and transmittal of tidal records.

Chiefs of Party are responsible for the proper field monitoring of all gages established to support the project. When contract observers are hired, a reliable line of communication shall be established to ensure prompt notification of any gage malfunction or change in the staff-gage relationship. Tidal heights and times can often be interpolated during short interruptions or breaks in the gage records. Accurate interpolations cannot be made for interruption or invalid data periods in excess of 3 days. In such cases, tidal control may be damaged to the extent that a resurvey of affected areas is necessary. Water level records cannot be mathematically reconstructed; however, straight-line interpretation may be acceptable for short periods when nearby gages record steady levels during the same period.

Predicted values for tide stages and forecast values for water level stages are usually essential to almost all operations of a hydrographic field party. In addition to their possible use as preliminary reductions to soundings for Field sheets, knowledge of predicted tides may be necessary for planning beach landings, for conducting inshore and shoal water soundings operations, and for certain hydrographic feature developments and investigations. Predicted tide or forecast water level values may be used to reduce soundings shown on field sheets, but the final reducers applied to determine chart depths shall reflect actual tide or water level stages as accurately as possible.

Although predicted times and heights of high and low tides may be sufficient for some operations, values for the intermediate stages are often necessary. The Marine Environmental Services Division, Office of Oceanography, NOS, will, upon request, provide predicted hourly tidal heights for reference tide stations cited in the project instructions. Corrections for subordinate supplemental stations may also be computed by the Marine Environmental Services Division.

If these resources are not available, predicted hourly heights of sufficient accuracy can be determined graphically using values extracted from the NOS Tide Tables published annually. The procedure is as follows:

1. From table 2 of the Tide Tables, look up the tide differences applicable to the area being surveyed. Apply these differences to the tide predictions for the reference station and obtain corresponding times and heights of the high and low waters for the required period.
2. Plot the low and high water time and height coordinates, A and E, on cross-section paper. (See figure 4-43.)
3. Divide the connecting line *AE* into four equal parts, points *B, C,* and *D.*
4. Plot point *B* vertically below *B*, and plot *D* vertically above *D*, making each equal to one-tenth the range of tide.
5. Draw an approximate sinusoidal or parabolic curve through points *A*, *B*, *C*, *D*, and *E*. This curve closely approximates the actual tide curve permitting the required data to be readily scaled. The falling stage of the predicted tide curve is plotted and drawn similarly.

On the tide curve thus constructed, points can be marked where changes in corrections occur. A tabulation of corrections and times of change can then be extracted from the curve.

In some areas, one must establish zones between adjacent stations because of significant differences in times and ranges. Procedures for making tidal time and height interpolations are described in *Publication* No. 30-1, "Manual of Tide Observations" (U.S. Coast and Geodetic Survey 1965*a*). Correct zoning is critical in estuaries and in long narrow bays. Improper zoning in such areas will be reflected in the junctions with adjacent surveys and may cause excessive differences in depths at crossings within the survey.

The Office of Oceanography, NOS, will provide preliminary tidal or water level zoning to the hydrographic field unit for survey areas where the tidal or water level dynamics are complex and difficult junctions are anticipated. Final zoning based on real observations will also be determined by the Office of Oceanography prior to verification and smooth plotting of the survey. (See chapter 5 for tide and water levels report requirements.)

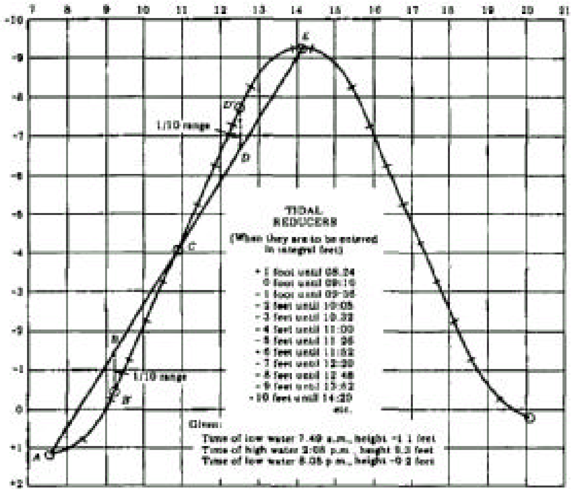


FIGURE 4-43—Construction of a predicted tide curve

When unusual tidal or water level conditions are observed and the stages are expected to vary significantly from those at the preselected gage sites, the chief of party is responsible for establishing additional gages as necessary or obtaining series of staff observations (AK.2.1) in the problem area. Such additional observations shall be made for the duration of hydrography in that area, and the nearest preselected gage must be in operation. Tide gages or tide staffs shall be established and monitored at the upper reaches of rivers and creeks in the vicinity of the survey if gage sites were not designated for the area.

Tidal and water level reducers for soundings on projects where several gages are operating may be computed by interpolation or linear regression techniques, provided there is evidence that time and height variations are similar throughout the area.

4.9.4. Dynamic Draft Correction

The static draft of the hydrographic vessel combined with the effects of settlement and squat when underway are factors that must be taken into account when soundings are corrected. Static draft and the combined effects of settlement and squat are determined individually, then combined algebraically for the total dynamic draft correction.

4.9.4.1. STATIC DRAFT. Depths of water measured by echo sounders aboard NOS vessels are depths below the transducer—not depths below the surface. Draft, as an echo-sounding correction, refers to the depth of the transducer below the surface of the water when the vessel is not underway. Adjustments to echo sounder initial settings to compensate for the draft and variations thereof shall not be made while engaged in hydrography.

Provision must be made or special instruments installed to measure the draft of the transducers permanently mounted in the hull. Internal draft gages may be installed on which the draft of the units can be read directly.

The method most commonly used to measure draft is to mark points on the rail or deck above and abeam of the transducers. By measuring the vertical distance of these marks above the transducers, their drafts can be determined at any time by measuring the vertical distance of the reference marks above the water surface, then taking the difference between the vertical distances. Reference marks should be established on both port and starboard rails—measurements to the water surface are made from both points and averaged to compensate for list of the vessel. Elevations of the reference marks above the acoustical units are determined while the vessel is in drydock using an engineer's level and steel tape.

Variations in ship's draft and depths of the water are the two factors that determine the proper frequency of draft measurements. For soundings of 20 fm or less, the draft should be observed and recorded to the nearest 0.2 ft. Measurements and record entries shall be made with sufficient frequency to meet this criteria. When sounding in waters deeper than 20 fin, the draft should be observed and recorded to the nearest 0.5 ft. In depths greater than 110 fm where errors caused by improper draft adjustments result in a small percentage of the total depth, an estimated average value for draft may be used to correct soundings. Draft values for small vessels shall be observed and entered in the records at the beginning and end of each workday and at other such times when significant changes occur.

4.9.4.2. SETTLEMENT AND SQUAT. Transducers are generally displaced vertically, relative to their positions at rest, when a vessel is underway. Depth measurements are affected by these vertical displacements. Such displacements may be of sufficient magnitude to warrant compensation, especially when accurate soundings in shoal water are measured from a vessel running at moderate to high speeds. The factors accountable for this vertical displacement are termed "settlement" and "squat."

Settlement is the general difference between the elevations of a vessel when underway and when at rest. For lower speed nonplaning vessels, settlement is caused by a local depression of the water surface. Settlement is not an increase in vessel displacement and, therefore, cannot be determined by reference to the water surface in the immediate vicinity. Vessels surveying at higher speeds may experience a negative settlement or lift when planing.

Squat refers to changes in the trim of the vessel when underway and is generally manifested by a lowering of the stern and a rise of the bow. Occasionally, the bow lowers on smaller vessels. This change in attitude can cause significant errors when soundings are measured on steep slopes and the lines are normal to the depth contours.

Major factors that influence settlement and squat are bull shape, speed, and depth of water beneath the vessel. Squat does not appreciably affect transducer depth if mounted amidships (or a little forward of amidships as they generally are). Conversely, settlement is generally significant at normal sounding speeds. In depths approximately seven times the draft, settlement for a larger survey ship often amounts to about 0.5 ft, and in extreme cases may be as much as 1 ft; this amount increases slightly as the depth lessens.

Combined effects of settlement and squat at various sounding speeds shall be determined to the nearest 0.2 ft at the beginning of each season for each vessel, including auxiliaries and launches used for hydrographic surveying in shoal or moderate depths. When the measurements are made, each vessel should be carrying an average load and be in average trim. Derived values may be assumed to be constant throughout the season. Settlement and squat corrections of less than 0.2 ft may be ignored when correcting soundings. Sounding vessel speeds must be entered in the hydrographic records during survey operations to permit accurate corrections for settlement and squat.

Either of two methods may be used to determine the combined effect of settlement and squat. Regardless of the method used, the tide should be either high or low when the level is varying slowly. Tidal changes that occur during settlement and squat determinations must be measured and applied accordingly.

Measurements for settlement and squat should be made over a smooth, level, and firm bottom in depths of at least seven times the draft of the vessel. If the vessel will be used to survey in shoaler depths, additional measurements should be made at those depths.

The preferred method is to set up a leveling instrument ashore— if possible, on the end of a pier off which are found the conditions for ideal depth and bottom type and past which the vessel can run at normal sounding speeds. A marker buoy with the shortest possible mooring scope is anchored at the point where the measurements will be made. The vessel is brought alongside the marker buoy and stopped. A level rod is held over the echo sounder's transmitting and receiving units (or over the midpoint if one is forward of the other), and the elevation read from the instrument a shore. The height of the tide must be noted. The vessel is then sailed past the marker buoy at normal sounding speed. With the rod on the same spot, the elevation is read again from the same instrument setup. The difference between the two readings after correction for tidal changes is the combined effect of settlement and squat at the location of the transducers. Several measurements of reasonable agreement shall be made and averaged for a final value.

An alternate method is to select an area that satisfies depth and bottom-type requirements, then anchor a marker buoy with a short mooring scope. The vessel is stopped alongside the marker buoy, and the depth of water measured as accurately as possible with an echo-sounding instrument. The vessel is then sailed past the marker buoy at normal sounding speed, taking another accurate sounding when in the same position relative to the buoy. Again, provisions must be made to record tidal changes during the observations. The difference between the echo soundings underway and stopped as corrected for tidal changes is the value of settlement and squat. Observations are repeated several times, and the average value determined.

4.9.5. Velocity Corrections

When echo sounding, sound waves travel from the transducer vertically downward to the bottom and return through a column of water in which the velocity of sound varies at different depths. (See A.6.2.) Because depth is the product of velocity and elapsed time, the average velocity of the sound wave from surface to bottom must be known. Velocity of sound in water varies with density, which is a function of temperature, pressure, and (in salt water) salinity. Velocities used for echo-sounding corrections are calculated from these characteristics using Wilson's equation. (See 4.9.5.2.2.)

Hydrostatic pressure increases in a nearly direct proportion to depth; temperature decreases with depth, but not uniformly; and salinity usually increases with depth. The result is that the velocity of sound is seldom uniform from top to bottom, and seasonal changes within any region will change the average velocity.

Echo sounders used by the National Ocean Survey are calibrated to record soundings for an assumed uniform velocity of 800 fm/s. The actual velocity of sound through water must be determined for all hydrographic surveys except those in shoal areas. In such areas, bar checks (A.6.1.3), supplemented by velocity determinations, are generally used to determine corrections throughout the full depth range. In deeper waters, velocity corrections may be ignored when they are less than 0.5% of the depth.

For use in correcting echo soundings, the velocity of sound must be known with sufficient accuracy to ensure that no sounding will be in error by as much as 0.25% of the depth from this cause alone. Therefore, the mean velocity must be known to within ± 4 m/s. Temperature is the characteristic of water that most affects the velocity of sound. To satisfy these accuracy requirements, one must know the mean temperature of the water to an accuracy of ± l°C and the salinity to within ± 1‰. (ppt). A sufficient number of salinity and temperature observations must be made so that the velocity can be determined within the specified accuracy over the entire area sounded.

The number of observations required depends on the physical characteristics of the water and the physiography of the area. A minimum of one serial temperature shall be observed each month in the deepest part of the area surveyed. It is the responsibility of the chief of party to make additional observations as needed to meet the accuracy requirements.

Two standard NOS methods for determining velocity corrections are described in detail in the following sections. The first method is by direct comparison with a standard [i.e., by comparing digital and analog echo soundings with known depths at which a bar is suspended below the transducer (bar check)]. Because the equipment is manhandled over the side, bar check usage is limited to smaller survey vessels. Larger vessels make direct comparisons by comparing echo soundings with vertical lead-line casts. The effects of both instrument error and velocity variations are included in direct comparison results. The effectiveness of direct comparisons is generally greatly reduced as the depths of the observations increase because of nonverticality of the calibrated lines on the bar or lead line when the measurement is made.

The second method entails combining direct comparison results with velocity corrections determined from oceanographic or limnologic observations for density throughout the water column. This method is always used by larger vessels and by other vessels at such times when bar checks are impractical.

See section A.9.2 for a description and discussion of the various water samplers, instruments, and electronic sensors used by NOS for the determination of velocity corrections.

Velocity corrections are tabulated so they can be applied to the soundings by a straightforward table look-up procedure in which the entering argument is the observed depth (uncorrected for velocity) plus the dynamic draft; the output is the velocity correction value for that observed depth. (See 4.9.5.2.5.)

4.9.5. 1. DIRECT COMPARISONS. Simultaneous direct comparisons are made between actual depths and observed echo soundings to determine corrections to the observed values. The two methods most commonly used are bar checks and vertical casts. Bar checks are the more accurate of the two and should be used when possible. Observed differences between actual and observed depths include the effects of sound velocity variations, instrumental errors, and the static draft of the vessel.

4.9.5. 1. 1. *Bar checks*. Reliable and accurate bar checks can be made only under the most favorable conditions. When the sea is calm and there is little differential current or wind effect causing the bar to be displaced from a position vertically below the transducer, bar checks can be obtained in depths as great as 15 fm. Under less favorable conditions, effective bar check depths may be reduced to 2 fm. In moderate depths where bar checks can be obtained over the full depth range of the survey, corrections to soundings can be determined that compensate both for the difference between the calibrated velocity of the instrument and the actual velocity of sound in the water and for instrumental errors.

Launches and small boats using echo sounders for hydroghraphic surveying shall make bar checks and record the results as follows:

I. In protected waters where bar check results are considered dependable and the survey depths lie within the bar check range, bar checks shall be made at least *twice* daily—prior to beginning hydrography and again at the end of the day. Comparisons are recorded during both descent and ascent of the bar at each 10 or 12 ft below the surface throughout the depth range of the survey. Additional observations are made at a depth of 5 or 6 ft—if the sounding can be recorded.

2. Where all or some of the project area depths are beyond bar check range, bar check data must be supplemented with oceanographic observations to determine velocity corrections. In such cases, bar checks consisting of four observations are taken at twice daily. Two comparisons are made at the shoalest depth below the transducer at which the echo sounder can record. The remaining two comparisons are made at approximately 2 fm below the transducer.

Bar checks should always be made when and where the water conditions are the calmest; observations taken during rough sea conditions are subject to unacceptable magnitudes of error. A small vessel operating in exposed rough water should run to a protected area or lie in the lee of the parent ship for the bar check although water densities may vary slightly. Bar checks, however, shall not be made in areas where temperatures or salinities vary significantly from those at the working grounds. Additional bar checks shall be made as considered necessary by the hydrographer to attain the required accuracy of sounding corrections. Changes, variations, or adjustments in the sounding equipment or variations in water properties are reasons for making additional comparisons.

A Direct Comparison Log similar to that shown in figure 4-44 may be used as an alternate method to record bar check data and can be used to abstract the results if recorded in a Sounding Volume. (See 4.8.3.6.) The following are procedures for observing and recording bar check data:

1. The marked lines used to suspend the bar at the comparison depths shall be compared periodically with a standard (i.e., a surveyor's steel tape or equivalent). When used daily, weekly comparisons with a standard are made. When compared, the lines should be wet and under a tension equal to the weight of the attached bar when in water. Comparison data are entered in column B of figure 4-44 and then are added algebraically to column A to obtain the Actual Depth (column C).

2. Direct comparisons should not be made until the echo sounder has warmed up in accordance with the manufacturer's specifications. The vessel must be stopped, the sea relatively calm, the bar vertical beneath the transducer, and the instrument operating at the proper voltage.

3. The depth recorder should be operated at the same gain setting that will be used during normal sounding operations. Gain settings and the analog scale are also recorded on the comparison log (figure 4-44) in columns D and E, respectively.

4. As the bar is lowered through each successive depth, corresponding analog and digital readings are recorded in columns F and K. Recorded digital depths at each stage should be average values of the displayed digital readings.

5. The comparisons are repeated during the scent by stopping the bar at each depth observed during the descent. Observed values are recorded in columns G and L. Mean observed depths are then computed by averaging columns F and G, and K and L—then entering the results in columns H and M.

6. Data entries on the remaining columns for the determination of corrections to observed soundings are self explanatory. (See 4.9.5.1.3.)

4.9.5.1.2. *Vertical casts.* Because bar check observations from larger hydrographic survey vessels are impractical, reliance must be placed on comparing echo soundings with vertical lead-line casts. (See A.6.1.1) Vertical cast comparisons are made to determine or verify instrumental corrections for each echo sounder and depth recorder used on each survey. It is particularly important that vertical casts be made in areas where launch hydrography joins or overlaps ship hydrography. In such areas, soundings and depth contours often fail to agree. A minimum of two sets of comparisons shall be observed at different depths to provide the data necessary to reconcile potential discrepancies. In the field, discrepancies must be resolved—under no circumstances shall surveys with unresolved discrepancies be submitted for smooth processing.

Similar situations frequently arise where sounding lines run by different launches join on m-shore sheets. If a displacement of depth contours occurs at a junction, an error probably exists in the work of one or both launches. The magnitudes of the sounding errors must be established by comparing echo soundings from both vessels with vertical cast observations in the junctional areas.

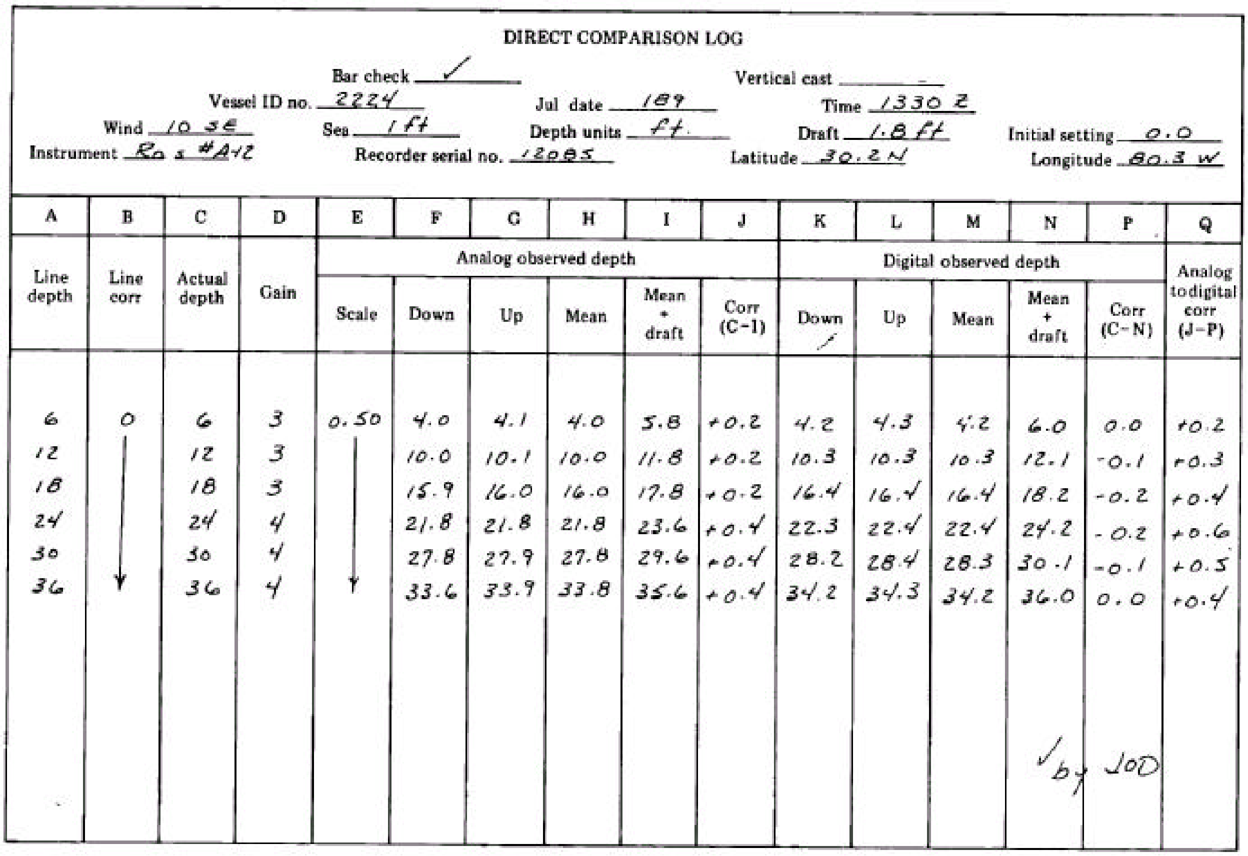
Vertical cast observations may be recorded either on stamp 5A (figure 4-30, section 4.8.3.6) or on the Direct Comparison Log (figure 4-44). Procedures for observing and recording vertical casts are as follows:

1. Lead lines shall be compared with a standard and the results entered in the records each time a direct comparison by. vertical cast is made. (See 4.9.5. 1. 1.)

2. Echo-sounding equipment must be properly warmed up prior to making comparative observations.

3. Because vertical cast measurements are highly susceptible to errors, observational conditions must be better than those required for bar checks. The vessel must be stopped, the sea relatively calm, and the current slack. Ideally, the bottom should be flat with no projections and be comparatively firm for optimal echo soundings. For obtaining the most accurate lead-line measurements and minimizing the effect of variation of sound velocity in the determination of instrument errors, vertical casts are taken in the shoalest water practical.

4. At least five simultaneous comparisons between echo soundings and lead-line depths are observed and recorded from each side of the vessel for a complete vertical cast. Digital and graphic depth records obtained during the comparison series shall be made part of the hydrographic records.



DIRECT COMPARISON LOG

Bar check ✓ Vertical cast -
Vessel ID no. 2224 Jul date 189 Time 1330 Z
Wind 10 SE Sea 1 ft Depth units ft. Draft 1.8 ft Initial setting 0.0
Instrument Ro s #A42 Recorder serial no. 12085 Latitude 30.2 N Longitude 80.3 W

A	B	C	D	E	F	G	H	I	J	K	L	M	N	P	Q
				Analog observed depth						Digital observed depth					
Line depth	Line corr	Actual depth	Gain	Scale	Down	Up	Mean	Mean + draft	Corr (C-I)	Down ✓	Up	Mean	Mean + draft	Corr (C-N)	Analog to digital corr (J-P)
6	0	6	3	0.50	4.0	4.1	4.0	5.8	+0.2	4.2	4.3	4.2	6.0	0.0	+0.2
12	↓	12	3	↓	10.0	10.1	10.0	11.8	+0.2	10.3	10.3	10.3	12.1	-0.1	+0.3
18		18	3		15.9	16.0	16.0	17.8	+0.2	16.4	16.4	16.4	18.2	-0.2	+0.4
24		24	4		21.8	21.8	21.8	23.6	+0.4	22.3	22.4	22.4	24.2	-0.2	+0.6
30		30	4		27.8	27.9	27.8	29.6	+0.4	28.2	28.4	28.3	30.1	-0.1	+0.5
36		36	4		33.6	33.9	33.8	35.6	+0.4	34.2	34.3	34.2	36.0	0.0	+0.4

✓ by JOD

FIGURE 4-44.—Direct Comparison Log for echo-sounding corrections

5. See section A.6.1.1 for instructions on lead-line usage.

6. Original vertical cast observational data shall be entered in the records of each applicable hydrographic survey to substantiate the echo sounding correction values.

4.9.5.1.3. *Corrections to soundings from bar check data.* Computations for echo-sounding corrections from bar check data are relatively simple and straightforward:

1. Remove the effects of draft correction from the bar check data by adding the vessel draft to the mean observed depths before comparing observed depths with actual depths (i.e., add the draft to columns H and M and record the results in columns I and N). See figure 4—44.

2. Total corrections for velocity variations and residual instrument errors are determined by subtracting column I from column C (analog sounding corrections) and column N from column C (digital sounding corrections), then entering the results in columns J and P, respectively.

3. From these data, a sounding correction curve is constructed by plotting corrections versus mean observed depths plus draft in a manner similar to that shown in figure 4-45, section 4.9.5.2.6. When digital echo sounders are used, final correction curves are developed by plotting mean observed depths plus draft listed in column N on the vertical scale against their corresponding digital corrections (column P) on the horizontal scale. A smooth curve is faired through the plotted points. When only analog records are available, the sounding correction curve is plotted in a similar manner—except that the mean observed depths plus draft (column 1) are plotted against the corresponding corrections (column 1).

4. Final incremental sounding corrections are then scaled from the curve and tabulated for application as shown in example 1, section 4.9.5.2.6.

5. Analog errors with respect to digital soundings (column Q) are determined by subtracting the values in column P from those in column J. This correction is applied to intermediate scaled analog depths inserted into digital sounding lists and reflects the instrumental errors. (See section 4.9.6.)

The results of each bar check and vertical cast must be carefully compared with others taken in the same area over a period of time. Series of data can generally be combined and average sounding correction curves used.

4.9.5.2. OCEANOGRAPHIC AND LIMNOLOGIC DETERMINATIONS. Velocity of sound through water for echo-sounding corrections must be determined either by collecting water samples at standard depths for temperature and salinity measurements or by using one of the modern sophisticated electronic sensors designed to measure and display water density parameters. Several of the available sensors are capable of recording continuous measurements throughout the water column. When sampling at discrete depths, the National Ocean Survey normally adheres to the standard observation depths proposed by the International Association of Physical Oceanography (Jeffers 1960); these depths (in meters) are 0, 10, 20, 30, 50, 75, 100, 150, 200, (250), 300, 400, 500, 600, (700), 800, 1000, 1200, 1500, 2000, 2500, 3000, 4000, and thence at 1000-m intervals to the bottom. (Depths in parentheses are optional.) Data for other levels are interpolated from the standard observation depths.

When Nansen bottles and reversing thermometers (AL.2.1, AL.2.2) are used to measure water temperatures and collect samples at various depths, the data are recorded and computed on "Oceanographic Log Sheet-A." U.S. Naval Oceanographic Office (1968) *Publication* No. 607, "Instruction Manual for Obtaining Oceanographic Data," contains detailed instructions on the proper use of Log Sheet-A for computing temperatures versus depths. Log Sheet-A is available through ERL/AOML, RD/RF2. Water sample salinities are generally measured with induction type salinometers (AL.2.3) or by measurements of specific gravity with calibrated hydrometers (AL.2.4).

Most electronic temperature, depth, and conductivity (TDC) or salinity, temperature, and depth (STD) sensors and recorders now available commercially (AL.2.5, AL.2.6) yield precise measurements in excess of accuracy requirements for sound velocity corrections if properly calibrated and maintained. In addition to the laboratory calibration procedures required by NOS and those recommended by the manufacturer, each device shall be field checked for accuracy against Nansen cast or equivalent observations at least once during each hydrographic project and at other times considered necessary by the Chief of Party. Each time a sensor is used, a rough check on the temperature and density shall be made against a surface bucket sample to avoid gross errors. Surface sample values for this check may be determined by using a hydrometer and thermormeter. If differences between sensor values and surface check values exceed 1C° or 1‰ (ppt salinity), corrections shall be computed and applied to all sensor data. Instruments shall also be recalibrated or adjusted as necessary.

Depths can be checked or measured directly by lashing a sensor to a lead line or by similarly marking the sensor conductor cable. Erratic readings often result from bad connections to a sensor from salt deposits on a conductivity sensor or from a faulty sensor. Manufacturer's specifications should be observed rigorously for adjusting, cleaning, and care of equipment.

Once temperatures and salinities have been determined for the proper depths, velocity corrections for the sounded water column are computed using the "summation of layers" method. Velocities of sound at mid-depths of specified layers are computed either by graphical or by numerical methods (described in the following sections). Corrections computed for each layer of depth are then summed algebraically to arrive at total velocity corrections applicable to given depths. A graph of observed depth plus draft versus correction is then plotted and used to scale corrections for even correction intervals (table 4-4, section 4.5.7. 1) according to survey requirements.

Velocity corrections seldom vary appreciably over relatively short periods of time throughout most project areas. It is, therefore, practical to average computed velocities from several casts at layer mid-depths for final corrections; however, under special circumstances such as in areas of upwelling, extensive estuarine discharge of fresh water, or in areas such as the Gulf Stream or Great Lakes where large temperature variations occur, series of regional velocity curves are required. Regional curves must be carefully studied to determine how they can be best grouped by area or time or to permit drawing of average curves. It is also desirable to take frequent temperature observations in such areas with a bathythermograph, thermistor, or similar sensor to disclose the existence of temperature inversions and to assist in the selection of appropriate depths for sampling. Steep temperature or salinity gradients in the water column require closer spacing of Nansen bottles.

Because oceanographic data are assembled from many sources nationally and are processed automatically, International Standard Depths are used; but when serial temperatures and salinities are observed in relatively small project areas and when the winch registering sheave is graduated in fathoms, observations may be taken at the following approximate depths: 0, 2, 5, 11, 16, 27, 41, 55, 82, and 109 fm.

4.9.5.2.1. *Selection of layers.* Layer thicknesses need not always be chosen in a uniform manner. Experience has proven that 10-m layers in the upper 200 m, 40-m layers from 200 to 400 m deep, and 400-m layers in greater depths are usually satisfactory; however, in areas where the changes in temperature are not great and are relatively regular with respect to depth, thicker layers may give sufficient accuracy. When changes in temperature are irregular and are large with respect to depth, smaller layers must be selected to attain the required accuracy. The first layer is irregular and is dependent on the draft of the vessel. (See 4.9.5.2.3.)

4.9.5.2.2. *Determination of velocities at layer mid-depths.* The velocity of sound through water is computed by using the Wilson (1960) equation and the temperature and salinity values observed at each sampling depth:

$$V\mu=1449.14+V\rho+V\phi+V\sigma+V\tau+V\sigma\tau\rho$$

where $V\mu$ *is* the velocity of sound through water in meters per second, $V\rho$ is a correction for pressure (depth), $V\phi$ is a correction for the variation of gravity with latitude, Vs is a correction for salinity, $V\tau$ is a correction for temperature, and $V\sigma\tau\rho$ is a simultaneous correction for the combined effects of temperature, salinity, and depth.

Using this equation, velocities of sound may be determined in one of three ways:

1. By using table 12 in U.S. *Naval Oceanographic Office Special Publication* No. 68, "Handbook of Oceanographic Tables" (Bialek 1967), to look up and sum algebraically the equation variables;

2. By using the "Sound Speed and Structure Form" nomogram also included in table 12; or

3. By using an available program for calculating velocities if the hydrographic party is equipped with a digital computer. (See "HYDRO-

PLOT/HYDROLOG Systems Manual" (Wallace 1971).)

When sampled depths are not equal to preselected layer mid-depths, computed velocities are plotted against their depths. Velocities for layer mid-depths are scaled from a smooth curve faired to the plotted points.

4.9.5.2.3. *Layer corrections***.** When the velocity of sound has been determined for each layer mid-depth, a correction for each layer can be computed. A correction factor based on a calibrated sound velocity of 800 fm/s is then obtained from table C-7. For echo sounders calibrated at other velocities, factors can be calculated by using the formula:

$$\text{factor} = \frac{A-C}{C}$$

where A is the actual velocity at the layer mid-depth and C is the velocity for which the instrument has been calibrated.

Multiply each layer thickness by the factor to derive the layer correction. Exercise caution when computing the first layer correction. If this layer includes the depth from the surface to the transducer, correction factors are multiplied by the layer thickness minus the vessel draft instead of the total layer thickness. Although in many areas the effects of draft may be negligible, it should be considered before ignoring it in the calculations. A draft that results in a layer correction of less than 0.1% of the depth is considered negligible.

4.9.5.2.4. *Corrections versus applicable depths.* Layer corrections are summed algebraically to give the correction applicable to the depth at the bottom of each layer (i.e., when using 10-m intervals, the correction at an actual depth of 70 m is equal to the sum of the first seven layers.)

Up to this point, computations are in metric units. Corrections and applicable actual depths are now converted to the sounding units for the survey. The summed corrections are plotted against applicable actual depths in the proper units and a smooth curve faired through the points.

4.9.5.2.5. *Velocity correction table.* Corrections for the corresponding actual depths are scaled from the correction versus applicable depth curve at specific correction intervals. It should be noted, however, that observed depths to which the corrections apply are not the same as the actual depths. The observed depth is the actual depth minus the correction (figure 4—42), and the velocity correction table for each vessel should be so constructed. Correction intervals are dependent upon the depth of water and character of the area. (See table 4—4 and section 4.9.2.)

4.9.5.2.6. *Sample computation of velocity corrections* The following examples illustrate methods used for computing velocity corrections:

Example 1. Table 4-11 has been computed for a salinity, temperature, depth sensor (STD) cast (AL.2.6) taken at 35° latitude.

In column A, the mid-depths of each layer are entered following the selection of layer thicknesses.

In columns B and C, tabulate the temperatures and salinities observed at each mid-depth from the STD cast data.

In column D, enter the velocities of sound for each mid-depth as computed using one of the methods described in section 4.9.5.2.2.

In column E, the correction factors for each tabulated velocity, relative to the calibrated value of 800 ftn/s, are interpolated from table C-7 (appendix C) or as described in section 4.9.5.2.3.

In column F, each factor tabulated in column E is multiplied by its respective layer thickness and the product entered. Note that the layer thickness for the first layer correction is 6 m for a vessel with a 4-m draft.

In column G, enter the cumulative sums of the layer corrections from column F.

In column H, the maximum depth of each layer is entered as the applicable actual depth for the corresponding computed velocity correction.

If the data were obtained by a temperature, depth, conductivity sensor (TDC) cast (AL.2.5) and conductivities rather than salinities were measured, computations are similar except that the observed conductivity values must be converted to salinity values prior to calculating velocities in column D.

Columns G and H are converted to the sounding unit assigned to the survey, then plotted on NOAA Form 75-21, "Velocity Corrections," as shown in figure 4-45. For the example, soundings are in fathoms. Velocity correction curves for greater depths can be shown on the same graph used for the shoaler water curve by applying an appropriate ratio to the shoal water scales. In this example, the ratio

TABLE 4-11.— *Example of velocity correction computations, STD cast **

A Mid-depth of each layer (m)	B Tempera-ture (C)	C Salinity (‰)	D Mid-depth velocity (m/s)	E Correction factor (m)	F Layer correction (m)	G Accumulative layer Corr (m)	H Applicable actual depth (m)
5	19.6	33.6	1519.4	+0.03855	+0.23	+0.23	10
15	19.2	33.7	1518.7	+0.03807	+0.38	+0.61	20
25	18.5	33.8	1516.8	+0.03677	+0.37	+0.98	30
35	15.9	33.9	1509.5	+0.03179	+0.32	+ 1.30	40
45	10.7	34.0	1492:4	+0.02010	+0.20	+ 1.50	50
55	7.7	34.1	1481.5	+0.01265	+0.13	+ 1.63	60
65	8.4	34.3	1484.5	+0.01470	+0.15	+ 1.78	70
75	9.3	34.4	1488.3	+0.01729	+0.17	+ 1.95	80
85	10.4	34.6	1492.7	+0.02030	+0.20	+2.15	90
95	11.5	34.7	1497.0	+0.02324	+0.23	+2.38	100
105	12.1	34.9	1499. 4	+0.02488	+0.25	+2.63	110
115	12.4	35.0	1500.7	+0.02577	+0.26	+2.89	120
125	12.5	35.2	1501.5	+0.02632	+0.26	+ 3.15	130
135	12.5	35.4	1502.0	+0.02667	+0.27	+3.42	140
145	12.4	35.6	1502.0	+0.02667	+0.27	+ 3.69	150
155	12.3	35.7	1502.0	+0.02667	+0.27	+ 3.96	160
165	12.1	35.8	1501.6	+0.02638	+0.26	+4.22	170
175	11.9	35.9	1501.3	+0.02618	+0.26	+4.48	180
185	11.7	36.0	1500.9	+0.02590	+0.26	+4.74	190
195	11.4	36.1	1500.1	+0.02536	+0.25	+4.99	200
220	11.1	36.1	1499.3	+0.02481	+0.99	+ 5.98	240
260	9.5	36.2	1494.4	+0.02146	+0.86	+6.84	280
300	8.5	36.2	1491.3	+0.01934	+0.77	+7.61	320
340	7.8	36.1	1489.2	+0.01791	+0.72	+ 8.33	360
380	6.7	36.0	1485.5	+0.01538	+0.62	+8.95	400
600	5.4	34.5	1481.9	+0.01292	+ 5.17	+ 14.12	800
1000	4.2	35.2	1494.5	+0.01470	+ 5.88	+20.00	1200
1400	3.9	35.1	1489.8	+0.01832	+7.33	+27.33	1600
1800	3.7	35.1	1495.8	+0.02242	+8.97	+ 36.30	2000
2200	3.5	35.0	1501.5	+0.02632	+ 10.53	+46.83	2400
2600	3.3	35.0	1507.6	+0.03049	+ l2.2O	+ 59.03	2800

* Computed for echo according taken with an instrement calibreated for a velocity of sound of 800 fm/s and taken by a verssd with a draft of 4.0 m or 2.2 fm

or scale factor of 10 as shown on the form was selected. Note that the velocity correction which will be applied is zero at the depth of the transducer.

Velocity corrections are scaled from the Plotted curves at the appropriate correction inter. vals, then tabulated in a Velocity Correction Table (table 4-12):

a. Determine the required sounding correction intervals from table 4-4. (See 4.5.7. 1.)

b. Scale the actual depths from the graph at the points where the curve crosses the cor. rection values for the required correction interval, and enter these depths in column J. (See table 4-12.) In shoaler waters where corrections are applied to the nearest 0.1 unit, the depth range for a discrete correction is from the depth where the curve crosses a correction value 0.05 unit less than the discrete correction to the depth where the curve crosses a correction value 0.05 unit more than the discrete correction value (e.g., a 0.0-fm velocity correction is applied from the depth for which the correction is 0.05 fm to the depth for which the correction is +0.05 fm); a + 0.1 fm velocity correction is applied from the depth for which the correction is + 0.05 fm to the depth for which the correction is +0.15 fm.

c. Tabulate in column L the appropriate velocity correction values for the scaled depths.

d. Subtract the corrections in column L from the actual depths in column J for the applicable depths in column K. The values listed in col. umn K are the entering arguments for determining velocity corrections.

To determine a velocity correction, find the nearest discrete depth in column K that is greater than or equal to the observed sounding plus draft to be corrected; the corresponding entry in col. umn L is the correction to be applied to the sounding. From the example shown in table 4-12, the ve. locity correction is + 2.0 fm for an observed sounding of 77.2 fm and a draft of 2.2 fm.

Example 2. The method used to com. pute velocity corrections from Nansen cast data var. ies slightly from example 1. The Velocity Correction

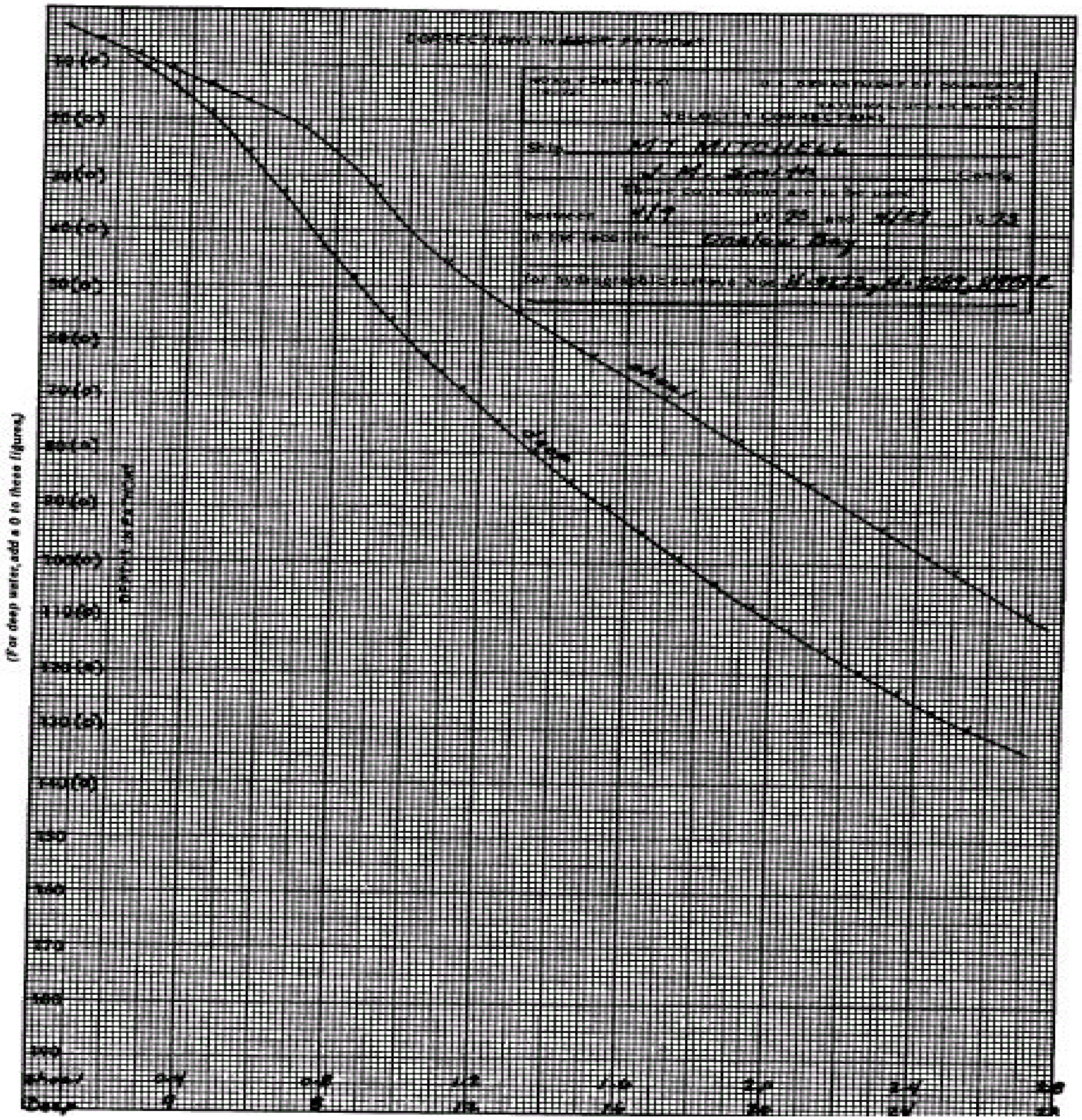


FIGURE-4-45-Velocity correction curve plotted from data in columns G and H in table 4-11

TABLE 4-12.—*Example of a Velocity Correction Table (derived from figure 4-45). The draft is 2.2 fm.*

J To actual depth (fm)	K To applicable depth from surface (fm)	L Velocity correction (fm)
3.2	3.2	0.0
5.6	5.5	+0.1
8.2	8.0	0.2
11.0	10.7	0.3
13.6	13.2	0.4
16.3	15.8	0.5
21.2	20.6	0.6
32.0	31.2	0.8
46.0	45.0	+1.0
55.6	54.4	1.2
62.6	61.2	1.4
70.0	68.4	1.6
78.0	76.2	1.8
85.4	83.6	+2.0
93.4	91.2	2.2
101.0	98.6	2.4
108.0	105.4	2.6
115.0	112.2	2.8
135.0	132.0	+3.0
190.0	186.0	4.0
255.0	250.0	5.0
330.0	324.0	6.0
412.0	405.0	7.0
485.0	278.0	8.0
560.0	551.0	9.0
630.0	620.0	+10.0
690.0	679.0	11.0
745.0	733.0	12.0
800.0	787.0	13.0
852.0	838.0	14.0
900.0	885.0	15.0
945.0	929.0	16.0
990.0	973.0	17.0
1035.0	1017.0	18.0
1080.0	1061.0	19.0
1120.0	1100.0	+20.0
1158.0	1137.0	21.0
1195.0	1173.0	22.0
1232.0	1209.0	23.0
1265.0	1241.0	24.0
1295.0	1270.0	25.0

Computation Table shown in table 4-13 illustrates the method to be used.

In columns AA, BB, and CC enter the oceanographic data determined from the cast.

In column DD, compute the velocity of sound for each Nansen bottle depth by one of the methods described in section 4.9.5.2.2 and enter the results.

In column D, plot the computed velocities in column DD against their respective actual depths (figure 4-46); then fair a smooth curve through the plotted points. Scale the interpolated velocities for the selected layer mid-depths and enter them.

In columns E, F G, and H, derive and tabulate as described in example 1 for the subsequent plotting of the velocity correction curve and compilation of the Velocity Correction Table.

4.9.5.3. Combining Oceanographic Determinations With Direct Comparisons. Generally, in other than shoal waters, the best and most accurate method of determining sounding corrections is to combine oceanographic observations with direct comparisons. Significant information can be obtained by comparing bar check data (if the depth recorder has been adjusted to eliminate major errors) with velocity corrections derived from oceanographic or limnologic observations. The displacement of the bar check velocity correction curve relative to the curve derived from temperature and salinity data (figure 4-47).indicates the sum of the draft and the residual instrument error. The shapes of the curves, in theory, should be identical. Major variations in the shapes or slopes occurring in common depths indicate a malfunction in the sounding system that must be remedied.

Velocity corrections derived by combining direct comparisons with oceanographic data are determined as follows:

1. Plot the correction curve, based on oceanographic data, in accordance with section 4.9.5.2.6. (See figure 4-47.)

2. Plot at the same scale the curve from data obtained by direct comparison. Depths scaled from an analog record for comparison must be corrected for all known instrument errors (i.e., initial error, stylus arm length error, and fine are error). Note that the plotted curves should be based on data averaged from a series of observations.

3. Measure the average displacement (d on figure 4-47) of the bar check curve from the oceanographic curve. The displacement is equal to the combined residual instrument error plus draft and will be applied separately as a sounding correction. (See 4.9.7.) For vessels where the draft varies significantly or bar checks were not taken, draft is determined for each comparison and applied separately. The shapes of the two curves in common depths should be nearly identical if the echo sounder is calibrated properly and the direct comparisons are made carefully and accurately.

4. The Velocity Correction Table is then

TABLE 4-13.—*Example of velocity correction computations, Nansen cast•*

AA Cast-depth (m)	BB Temperature (°C)	CC Salinity (‰)	DD Velocity (m/s)	A Md-depth of layers	D mid-depth velocity	E Correction factor	F Layer correction	G Depth correction	H Actual depth (m)
0	21.36	35.81	1526.7	5	1526.7	+0.04354	+0.26	+0.26	10
9	21.35	35.79	1526.8	15	1526.4	+0.04334	+0.43	+0.69	20
19	21.02	35.77	1526.0	25	1525.9	+ 0.04299	+0.43	+1.12	30
28	20.92	35.75	1525.9	35	1525.6	+0.04279	+0.43	+1.55	40
38	20.59	35.77	1525.3	45	1519.5	+0.03862	+0.39	+1.94	50
47	17.61	35.77	1517.1	55	1513.7	+0.03466	+0.35	+2.29	60
71	15.12	35.77	1509.9	65	1511.1	+0.03288	+0.33	+2.62	70
95	13.86	35.71	1506.0	75	1509.2	+0.03158	+0.36	+2.98	80
142	12.62	35.66	1502.8	85	1507.7	+0.03056	+0.31	+3.29	90
190	12.06	35.61	1501.5	95	1506.2	+0.02953	+0.30	+3.59	100
287	11.38	35.53	1500.7	105	1505.2	+0.02885	+0.29	+3.88	110
385	10.59	35.41	1499.4	115	1504.3	+0.02823	+0.28	+4.16	120
448	10.03	35.30	1498.2	125	1503.6	+0.02775	+0.28	+4.44	130
538	9.12	35.25	1496.3	135	1503.2	+0.02748	+0.27	+4.71	140
719	743	35.16	1492-8	145	1502.7	+0.02714	+0.27	+4.98	150
901	6.02	35.01	1490.2	155	1502.3	+0.02686	+0.27	+ 5.25	160
1086	5.21	34.97	1490.0	165	1502.1	+0.02673	+0.27	+ 5.52	170
1369	4.20	34.96	1490.5	175	1501.8	+0.02652	+0.27	+ 5.79	180
1853	3.68	34.94	1496.4	185	1501.6	+0.02638	+0.26	+6.05	190
2153	3.41	34.94	1500.5	195	1501.3	+0.02618	+0.26	+ 6.31	200
				220	1501.0	+0.02597	+ 1.04	+7.35	240
				260	1500.7	+0.02577	+ 1.03	+ 8.38	280
				300	1500.6	+002570	+ 1.03	+9.41	320
				340	1500. 1	+002536	+1.01	+10.42	360
				380	1499.7	+0.02509	+ 1.00	+ 11.42	400
				600	1495.2	+0.02201	+8.80	+20.22	800
				1000	1490.0	+0.01846	+ 7.38	+27.60	1200
				1400	1490.6	+001887	+7.59	+ 35.19	1600
				1800	1495.4	+0.02215	+8.86	+44.05	2000
				2200	1501.1	+0.02604	+10.42	+54.47	2400
				2600	1506.2	+0.02953	+11.81	+66.28	2800

• Computed for echo sounding with an instrument calibrated for a velocity of sound of 100 fm/s taken by a vessel with a draft of 4.0 fm or 2.2 fm

derived from the oceanographic curve as described in section 4.9.5.2.6.

Translating the bar check curve to the oceanographic curve has several advantages over a translation in the opposite direction:

1. The resulting curve and correction table give a more meaningful profile of the actual velocity of sound correction.

2. Bar check errors are not propagated into the oceanographic velocity correction curve. A slight depth error when observing temperatures and salinities has little effect on the velocity determination because of the slow rate of change in velocity with depth. Depth errors made during a bar check or caused by poor line calibration severely impact the results of that check. For this reason, bar checks are logically grouped and average curves drawn.

3. Several vessels working in close proximity can share a common velocity curve if their drafts are the same or if the difference in corrections caused by neglecting the draft layer of water is insignificant.

4.9.6. Instrument Error Corrections

Soundings shall be corrected for errors introduced by mechanical and electronic faults in the depth recording system. (See 4.9. 1. 1.) Digital depths are nearly free of these errors and generally do not require corrections of this nature; corrections for instrument errors must be applied to depths scaled from analog records.

Although digital depths may comprise the pnmary depth data for a hydrographic survey (4.8.5.1), it is imperative that instrumental errors in analog depth records be kept to an absolute mini. mum. Careful calibration and adjustment procedures must be strictly observed, and continual diligence exercised by hydrographers and recorder operators. The following sections discuss the various types of instrument errors common to most analog recorders. See section A.6 for more details and calibration procedures for specific instruments.

4.9.6.1. INITIAL ERRORS. In the setting of the initial pulse, errors are manifested by noncoincidence of the trace of the leading edge of the transmitted outgoing sound pulse with the zero line on

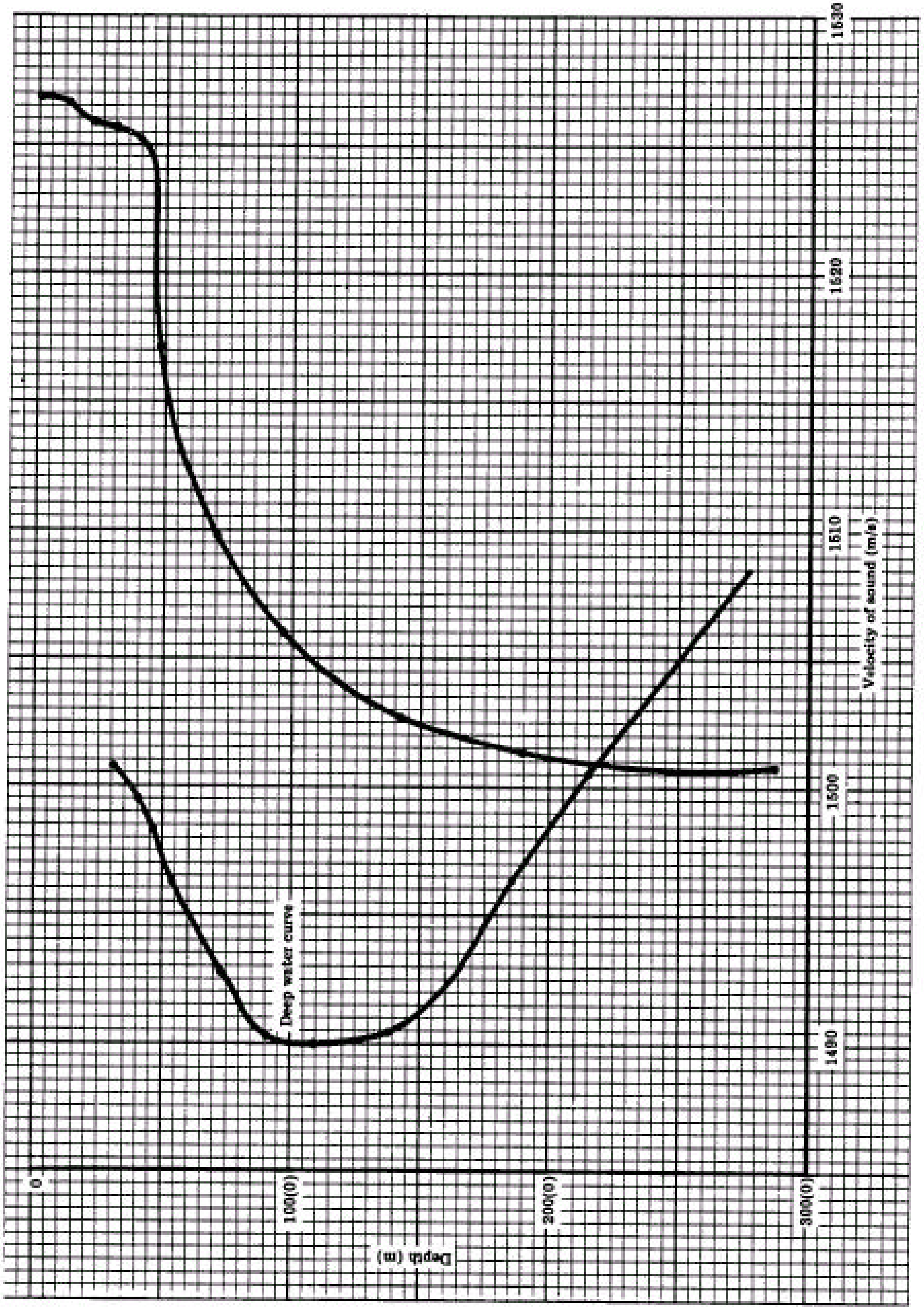
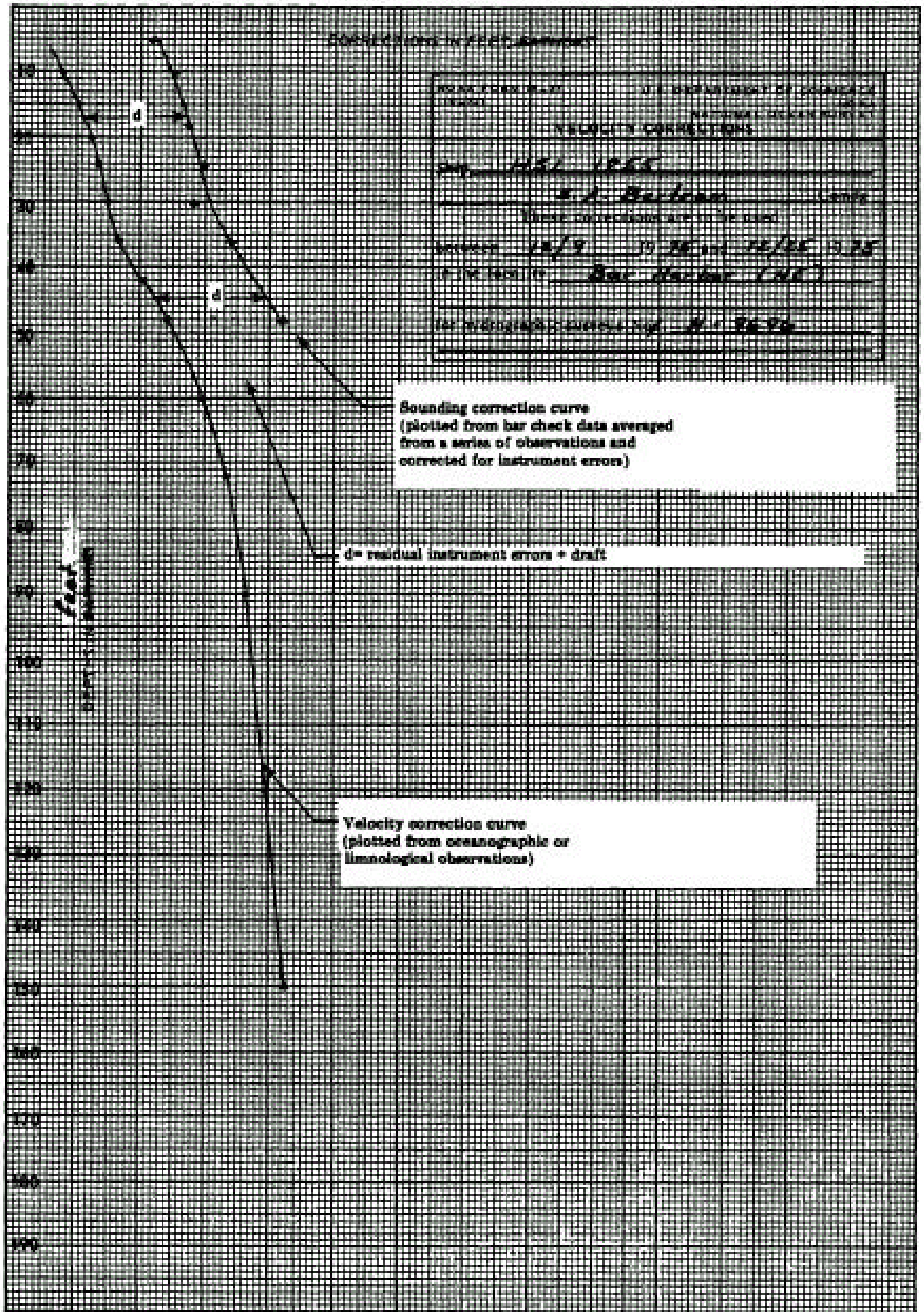


FIGURE 4-46.—Velocity versus a depth curve plotted from columns AA and DD in table 4-13
The depths in parentheses are for the deep water curve.



Sounding correction curve
(plotted from bar check data averaged
from a series of observations and
corrected for instrument errors)

d= residual instrument errors + draft

Velocity correction curve
(plotted from oceanographic or
limnological observations)

(For deep water,add a 0 to these figures)

FIGURE 4–47.—Velocity correction curve with combined observations the chart recording paper. Most analog depth recorders are equipped with an initial setting adjustment that allows the instrument operator to maintain the initial pulse at zero. Nonzero settings are identified easily when scanning analog records. (See 4.9.8.) Corrections for initial errors must be applied to scaled depths of peaks and deeps that occur between interval soundings.

Unfortunately, the initial trace is registered only on the first scale ("A" scale) or depth range of the recorder. When sounding in deeper waters and recording on wales other than the A-scale for extended periods of time, the scale setting shall be frequently switched to the A-scale, momentarily, to check the initial setting. This check is performed as often as necessary to ensure that the initial setting is not fluctuating in a manner that precludes accurate determination of corrections. Digital depths are not .subject to initial setting errors.

4.9.6.2. PHASE ERRORS. These are disagreements between recorded soundings common to more than one phase or scale setting of the analog depth recorder (i.e., soundings in phase overlap depths). Such errors are caused by improper calibration of the instrument. Necessary adjustments should be made only by qualified electronic technicians.

Digital phase checkers . (A.6.3.1.4) provide the best means of detecting and measuring phase error. "True depths" are simulated electronically and recorded on the graphic depth record. The phase error is the difference between the simulated sounding and the recorded value. Otherwise, phase errors can be detected readily by comparing soundings free of other instrumental errors that occur in the overlapping depths between adjoining scales. Although not as accurate, bar checks made at depths common to more than one phase can be used to determine the error. Phase error is compensated by applying a constant correction to all soundings scaled from an analog depth record at a particular scale. Digital depths are not subject to phase error.

4.9.6.3. STYLUS ARM LENGTH ERRORS. On some echo sounders, such as the Raytheon DE-723, depths are determined graphically by the length of the stylus arm and the angle through which it rotates in the interval between the transmitted and received acoustical pulses. Various angular rotation values correspond to fixed depths.

The scale of the depth lines is computed and printed on the recording paper on the assumption that the radius of the rotating stylus arm will be maintained at its constant calibrated length. Errors in the recorded sounding traces occur if the stylus arm radius is too long or too short. (See figure 4-48.) If the arm is too long, scaled analog depths are greater than actual depths; conversely, if the arm is too short, scaled values are less than actual depths. Ile magnitude of the depth error is proportional to the error in the length of the stylus arm. Stylus arm error corrections are applied to scaled soundings as a percentage of the relative depth in each scale and vary from zero at the top of each scale to a maximum at the bottom of each scale (not as a percentage of the entire depth).

Errors caused by incorrect stylus arm lengths can be detected by making a careful visual comparison of a single trace of the stylus with a fine arc that is preprinted on the recording paper. The preferred method of comparison is to transfer a series, of points from a preprinted arc on the recording paper to a mylar or other suitable clear plastic overlay. The overlay is then placed over an actual stylus trace on the graphic depth record to determine if there is a significant deviation between the two. If the two traces conform exactly, the stylus arm is within ± 0.5% of being correct; and the recorded soundings are correspondingly accurate to within ± 0.5% of the depth range within the particular scale or phase used. Deviations between the two traces at the center of the graphic depth record are directly proportional to the errors in stylus arm lengths. A deviation of 0.4 mm at the center of a trace is equivalent to a 1.6-mm error in arm length and causes a 1% error in depth throughout the scale. If the printed fine arc bulges outward from the sty-

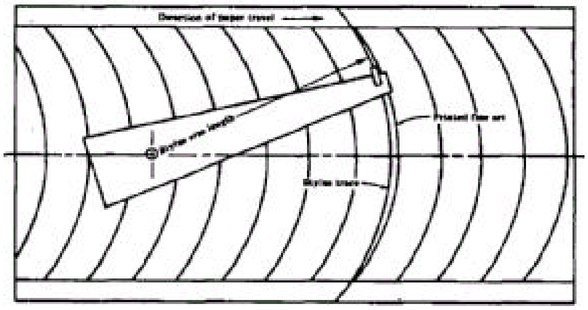


FIGURE 4—48.—Echo sounder stylus arm-length error. The effective length here is too long causing recorded depths to be greater than actual depths.

lus trace as shown in figure 4–48, the arm is too long, the scaled values are greater than the actual depths, and a negative correction is required.

4.9.6.4. STYLUS BELT LENGTH ERRORS. These occur only in soundings scaled from analog recorders equipped with a recording stylus.mounted on an endless moving belt [e.g., Ross Sounding Systern (A.6.3.2)]. These errors are easily detected by generating simulated depths with a digital depth checker, then comparing simulated and recorded values. Most endless belt-type recorders are equipped with the internal circuitry necessary for digital depth checking. Stylus belt length error effects are similar to those of incorrect stylus arm length (4.9.6.3); therefore, when detected they must be corrected immediately.

4.9.6.5. FINE ARC ERRORS. These are revealed by a divergence of the stylus trace from the printed fine arc on the recording paper. A fine arc error may be present even when the stylus arm radius is at the proper length. (See figure 4–49.) This error is generally caused by misalinement of the recording paper and the corresponding displacement of the stylus arc center from the paper axis. Adjustmeats to the analog recorder to elimmate a fine arc error must be made by a qualified electronics technician at its first indication.

4.9.6.6. FREQUENCY ERRORS. Variations in frequency of the recorder power supply (usually 60 Hz) that drives the synchronous motor, which in turn drives the stylus arm shaft or belt, generates errors in scaled soundings. If the operating frequency is too high, the arm or belt moves too fast causing recorded depths to be too deep; conversely, low frequencies result in recorded depths that are too shallow. When available, constant frequency power sources should be used for analog depth recorders. Depending upon the particular instrument in use, various ways by which frequency can be measured or checked include:

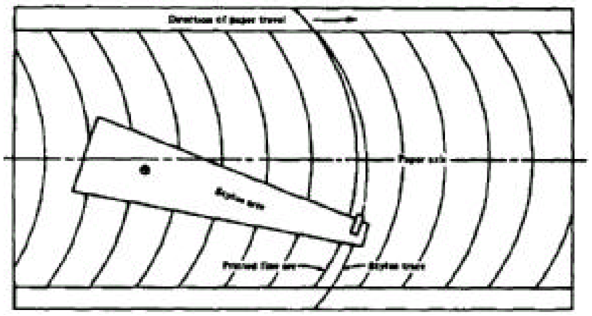


FIGURE 4-49.¾Echo sounder fine-arc error

A dial-type frequency meter.

The position of a vibrating reed on a reed frequency meter.

Counting the- number of stylus revolutions (on the fathoms scale) in a set time interval and comparing the revolutions with the manufacturer's specifications and with the linear measurement of paper travel.

Variations in frequency from the standard 60 Hz shall be noted in the sounding record—such variations must be corrected or adjusted immediately. Recorder frequency shall never be varied in an attempt to compensate other analog recorder errors.

4.9.7. Transducer Correction

The final transducer (TRA) correction is the algebraic sum of the corrections for the combined effects of dynamic draft and instrument errors. The TRA correction is a time, vessel, echo sounder dependent variable that must be applied to all observed analog and digital soundings.

The form shown in figure 5–7 [5.3.5(D)] or a similar version should be used to list TRA corrections; the listing must be included in the Descriptive Report for survey verification reference.

4.9.8. Scanning Analog Depth Records

4.9.8.1. CHECKING RECORDED DEPTHS. Hydrographers shall carefully inspect all graphic an. alog depth records (echograms, fathograms) to ensure that each important sounding has been scaled and recorded properly. (See 1.5.3.)

Digital soundings, when taken, shall be considered the primary sounding data because of their greater accuracy; graphic depth records comprise supplemental information and will be used for:

1. Scaling and recording peaks, deeps, and other important soundings that occur between the normal digital sounding interval (1.4.3).

2. Correcting digital soundings that differ significantly from analog soundings because of stray returns, side echoes, fish, and similar reasons.

3. Adjusting digital soundings for the effects of heave (wave action).

4. Determining the presence of shoals

and hazards that are undetectable in the digital records.

Graphic records are used to verify plotted soundings that appear doubtful when compared with other soundings on adjacent lines or that show abrupt changes in slope contrary to the general characteristics of the area. Inspecting or scanning the bottom profiles should be conducted as soon as possible after the lines have been run so the hydrographer can determine whether additional development work in the area is necessary.

In addition to scanning depth records for required intermediate soundings, each sounding, whether determined by digital methods or scaled and entered manually into a sounding record, shall be checked for accuracy. If the scan for completeness and the check for accuracy are carried out in separate steps, only competent and experienced personnel should be assigned to check the individual soundings for accuracy. Recorded soundings shall be scanned and checked prior to inking the soundings on the final field sheet.

When the bottom is irregular or the trace partially obscured by kelp, grass, strays, or side echoes, a considerable amount of experience is required for proper interpretation of the graphic record. Regardless of the character of the bottom, graphic records often display spurious marks, attributable to echoes from fish, vegetation, debris floating at various depths, turbulence in the water, abrupt changes in temperature or density of the water, noises generated in the sounding vessel, and instrumental faults. (See 4.9.8.2.) Skill is required to ensure that each trace is correctly identified and that the greatest value and most accurate results are extracted from the records.

Graphic depth records should first be examined to determine whether the initial trace has varied by an amount sufficient to require correction. Necessary corrections should be entered in the sounding records at the appropriate places. When soundings have been recorded on more than one scale (phase), each scale change shall be correctly labeled on the graphic record and noted in the sounding records. If a template must be used when scaling soundings, the paper speed should be checked at each template setting. If a template is not used, several paper speed checks should be made at random during the day's work. If there is evidence of incorrect speed, a detailed examination is necessary to determine the location and magnitude of the required corrections.

Soundings are then scaled from the analog record at the selected interval and compared with the recorded soundings; the latter are corrected as necessary. Significant peaks and deeps between interval soundings shall be scaled and entered with the times of their occurrence.

For standardizing the scanning and checking of graphic depth records and for meeting the International Accuracy Standards for Hydrographic Surveys (International Hydrographic Bureau 1968), the time tolerances in table 4-14 are specified to scale peaks and deeps.

When the bottom is extremely irregular making it impractical to scan and plot soundings that reveal every irregularity, soundings are selected to show the general topographic character of the bottom.

There are no rigid specifications that define acceptable differences between digital depths and depths scaled from graphic records. Close agreement, however, is essential since depths must be scaled from the graphic record to supplement digital data. The hydrographer must continually exercise sound judgment because acceptable differences vary with the depth of the water, the relative importance of the area, and the degree of bottom irregularity. For guidance, if digital depths agree to within ± 0.5 ft or ± 0.2 fm of scaled depths, the differences generally need not be taken into account; but differences should not exceed ± 0.2 ft or ± 0.1 fm under the following circumstances:

1. On shoals and other hazards.
2. On navigable bars.
3. In dredged channels.
4. At critical places in natural channels.

TABLE 4-14.-*Time tolerances for scaling peaks and deeps* *

Sounding interval	Scale time to nearest	Tolerance
5 $	$	± 0.5 $
10 $	$	± 1 $
15 $	$	± 2 $
20 $	$	± 2 $
30 $	$	± 5 $
1 min	$	± 10 $
5 min	min	± 1 min
10 min	min	± 2 min

* From Pacific Marine center (1974) *OPORDER*

5. For soundings that delineate the low water line.

On steep slopes, digital and scaled depths may vary substantially because of the nature of the returning echo and the recording devices. In these areas, digital depths are generally accepted.

When scaling depths from bottom profiles for insertion in the digital record tapes, the difference between digital and analog values at the time of the sounding must be determined. This difference is applied to scaled analog soundings to obtain the proper digital depth. Values are easily determined by measuring the differences between analog and digital depths for soundings immediately before and immediately following the time in question, then calculating the average. Particular attention must be paid to variations in the initial setting and to other known instrumental errors present during the record period. If a data-acquisition system is not equipped to compensate for the effects of heave (wave action) on the vessel, the digital soundings must be so adjusted.

Poor scanning techniques, careless scanning, scanning by inadequately trained personnel, and improper interpretation are major sources of defective data discovered during the verification of hydrographic surveys.

4.9.8.2. INTERPRETING ANALOG DEPTH RECORDS. Although echo-sounding depth recorders have been used for many years, correct interpretation of bottom profiles remains a major problem on many surveys. When recorded traces on the graphic record cannot be attributed with reasonable certainty to reflections from the bottom or from obstructions, they should not be recorded as soundings. Herein lies a major problem-differences of opinion frequently arise even among the most experienced hydrographers when identifying ambiguous or unclear bottom traces.

"Stray" echoes are marks on the graphic depth records or spurious digital soundings resulting from sources other than the bottom below the vessel. Traces from fish, kelp, grass, or electrical noise are properly classified as strays by the hydrographer. Unfortunately, what appears to be a stray may be, in fact, only too real. There are no rules of thumb that hydrographers can rely on to distinguish strays from actual bottom echoes. To continually and successfully differentiate between the two, surveyors must rely upon experience, good judgment, and luck. A sounding must never be classified as a stray if there is any reasonable doubt that it may be an object dangerous to navigation.

Hydrographers, must often investigate a reasonable number of representative strays, using a lead line to verify or disprove the interpretation of the bottom trace. Although this procedure may not ensure infallible results, it does provide tangible evidence on which to base an interpretation. Under certain circumstances, it may even be advisable to wire drag or wire sweep the bottom with a modified trawl sweep (A.6.1.4) or pipe drag before rejecting apparent strays. In many areas, depth recorders are an imperfect means of obtaining soundings total reliance should not be placed on their measurements. Supplemental lead-line or pole soundings are required to clarify certain traces, substantiate doubtful least depths, and, in areas of dense grass, even to measure depths for the basic development.

Strays caused by excessive gain settings, erratic operation of a depth recorder, or other phenomena about which only the hydrographer has personal knowledge should be adequately annotated on the bottom profile or in the sounding records. When gain settings are too high, strays recorded on the graph from various sources are generally identifiable as such. Figure 4-50(A) shows a typical recording of a stray caused by an overly high gain setting. Strays of this nature can also be generated by faulty electrical circuitry aboard the vessel, by mechanical vibrations, and by heavy percussions on the hull.

A section of the same graphic record is shown in figure 4-50(B). Note the unbroken bottom trace. The depression below the unidentified echo indicates current scour around a probable submerged obstruction. In this case subsequent wire-drag investigation revealed the presence of a wreck with kelp growing on top.

Kelp recordings probably cause the greatest difficulties when interpreting bottom profiles. Since kelp seldom grows in depths greater than 15 fm, difficulties from this source are encountered in relatively shoal water, usually in areas of irregular bottom. Kelp traces often resemble side echoes and are usually detached from the bottom trace as seen in figure 4-50(C), or the kelp echo may blend with the bottom trace as shown in figure 4-50(D). Actual bottom profiles can sometimes be traced through kelp echoes by viewing the graphic record at a slant to accentuate shading differences in the trace. Because clear lines of separation cannot always be seen, doubtful soundings must be investigated using

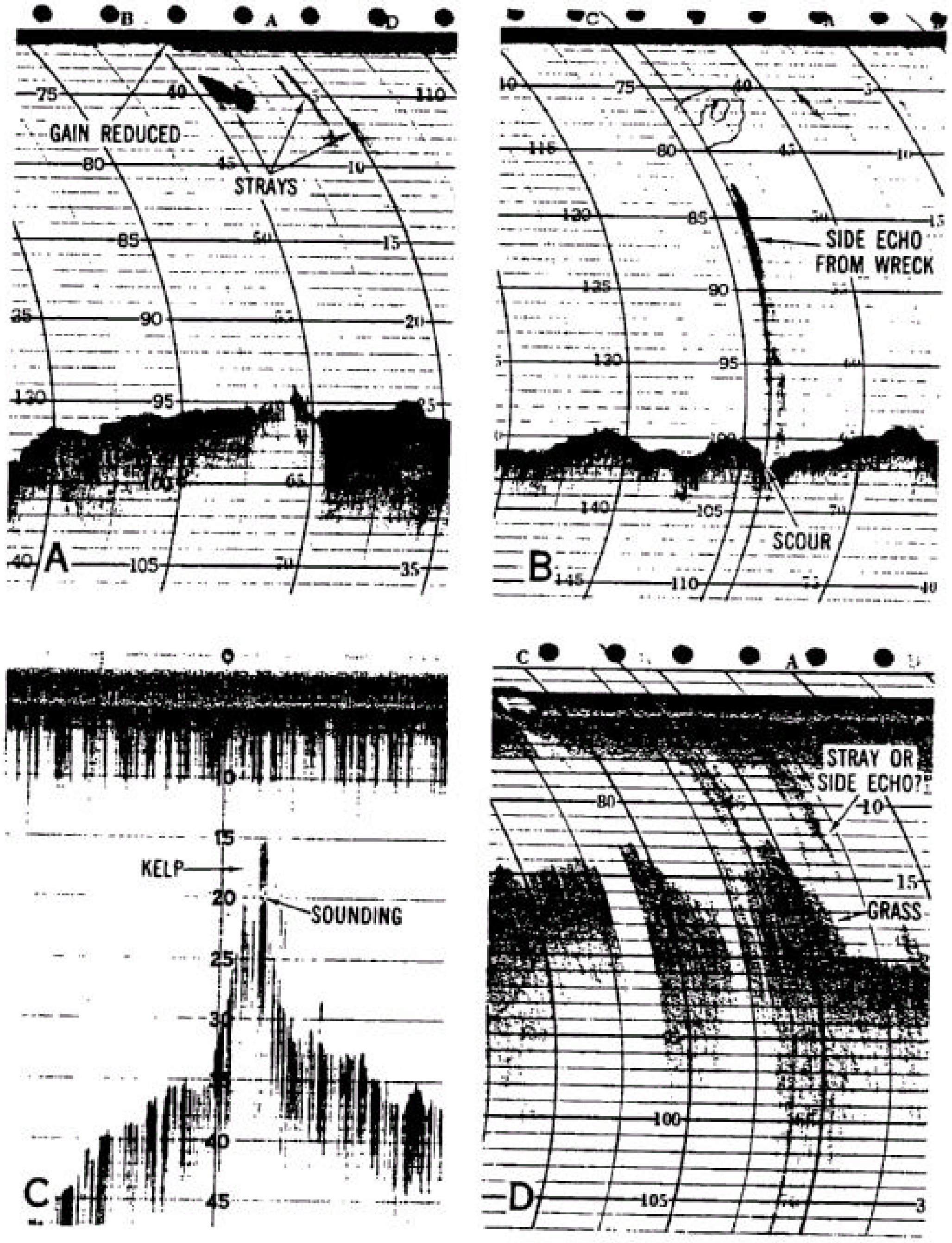


FIGURE 4-50-Typical bottom profiles (fathograms)

a lead line or sounding pole. Although not practical to investigate all such soundings in a foul area, the limiting features must be carefully sounded. Each indication of a pinnacle in or adjacent to a navigable water must be examined.

Interpretation in kelp or grass becomes

more difficult when higher transducer frequencies are used. Echoes from the bottom may be completely masked by kelp or vegetation when very high frequency transducers are used. In such cases, many lead-line, or pole soundings are required to substantiate the hydrographer's interpretation of the actual bottom profile.

In areas of heavy marine growth, the bottom trace may be completely obscured as in figure 4-50(D). The top of the profile usually has a ragged appearance compared with the smooth bottom; but in some instances, the top of the grass may appear to be no more irregular than the bottom profile. In figure 4-51(A), the bottom is easily identified in the gaps between traces from the grass permitting the bottom profile to be determined with assurance. Unless actual bottom soundings can be identified with sufficient frequency for a basic survey, supplemental lead-line or pole soundings must be obtained.

Areas where the growth of kelp is suspected should be investigated at low water or by a diver to resolve interpretation problem .

Echoes from fish are generally easy to distinguish in open seas over regular bottoms—unless the fish are lying very near the bottom. In such cases, fish echoes are usually distinct from the bottom; and the bottom echo trace is clearly visible. If in doubt as to whether fish are present, the depth recorder should be switched to slow speed and the gain setting increased to enhance the actual continuous bottom profile. Low frequency echo sounders generally amplify and enhance a profile if large dense schools of fish are below.

Echo traces caused by fish over shoals, rock pinnacles, and coral heads can be extremely difficult or even impossible to identify as such. Unless detailed and complete examinations of these features prove that echoes were caused by fish, the assumption must be made that the shoalest soundings resulted from small outcrops that form part of the bottom.

Side echoes produce traces that may be detached from the bottom trace, blend with the bottom trace, or mask it completely. Side echoes cannot always be distinguished from fish or turbulent water. Occasionally, side echoes are the only indications of boulders, pinnacles, or other submerged obstructions. Side echoes should neither be ignored nor initially accepted as vertical soundings. Such soundings should be noted in the remarks column; unless they come from previously identified shoaler features, additional lines should be run to obtain least depths. Typical side echo recordings are shown in figure 4-51(B), and another example of a kelp echo return is shown in figure 4-51(C).

The presence of side echoes and strays often creates a special problem when digital echo sounders are used. Digital depths are recorded when the returning echo reaches a certain intensity or signal response level. Echoes from fish, kelp, turbulence, and debris often reach this intensity and are recorded rather than the actual bottom return. Returns from a steep slope may or may not actuate the digital recorder. Weak side echoes frequently appear on the analog record but are not recorded-where the least depth over a feature is involved, the sounding from the analog trace must be scaled. Figure 4-51(D) shows such an example where both an analog record and a digital record were obtained. The weaker side echo over the ridge at the second sounding to the left of position 2192 was not strong enough to be recorded digitally. The least depth had to be scaled from the analog record and entered later in the data file.

Side echoes representing shoalest depths obtained on isolated features should be accepted and plotted as least depths thereon after reasonable efforts fail to obtain a shoaler sounding.

Side echoes recorded in deep water generate additional unresolvable dilemmas when interpreting the graphic record. The first echo return from a sloping bottom may not necessarily be from a point directly below the sounding vessel; it may be from that part of the bottom lying the shortest distance from the transducer. Under this condition, the recorded depth is less than the actual depth. In theory, when the slope of the bottom is more than half the angular beam width of the echo sounder, bottom echoes cannot reach the ship and produce a trace. In practice, however, echo traces are obtained over slopes steeper than half the beam width since the particles forming the sea bed are rough and do not reflect as would a flat surface. Experience has shown that the best traces from a steep slope are obtained when the survey vessel sails in a direction toward the shallower water and approximately normal to the depth contours.

If the bottom is undulating or slopes steeply, hyperbolically shaped side echoes often appear on the recorded bottom profile. In the following hypothetical case, a survey vessel with a 40°

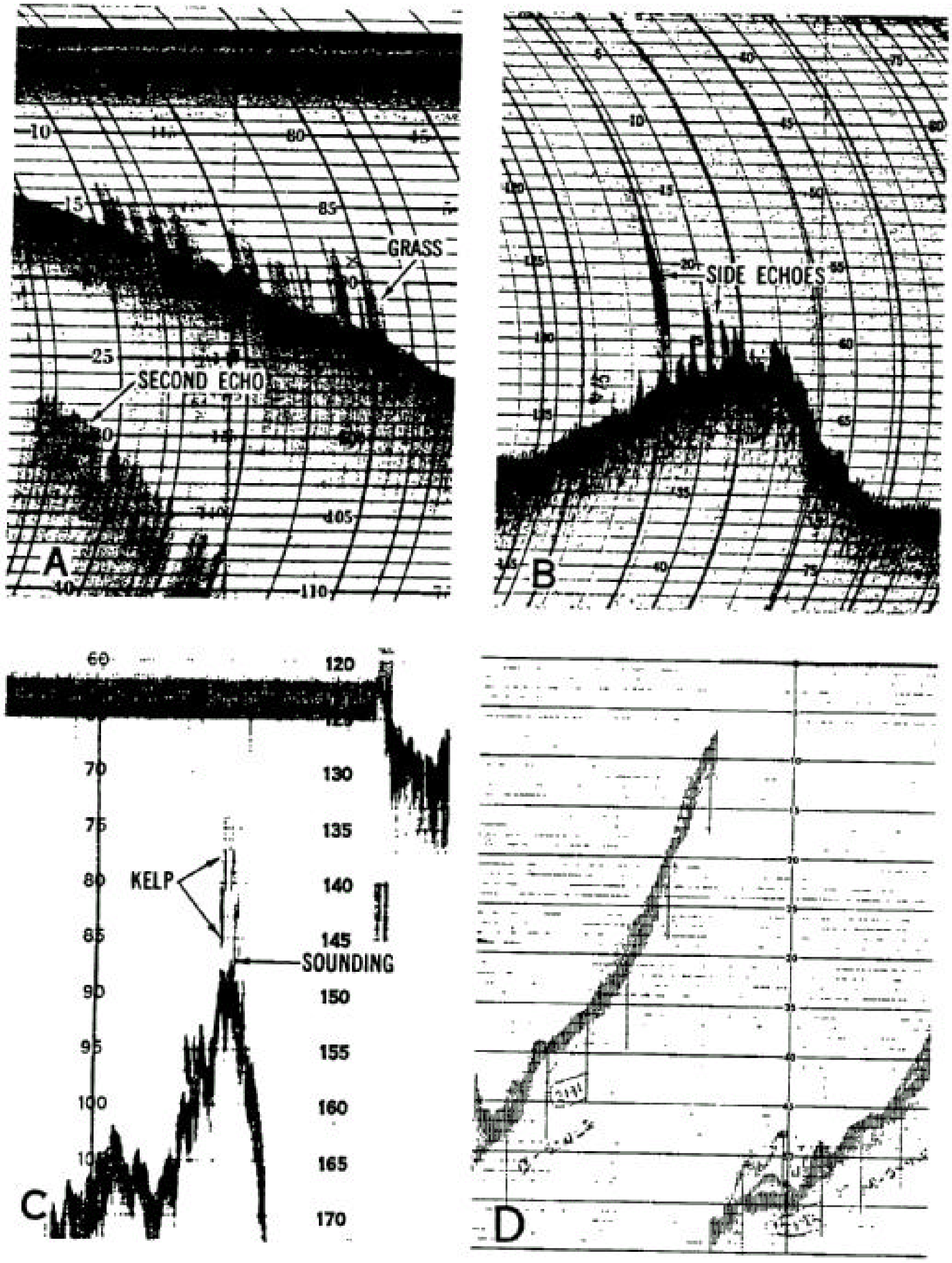


FIGURE 4-51.-Common problems of bottom profile interpretation

transducer beam width is sounding from left to right in depths of approximately 1400 fm. [See figure 4-52 (vertical scale not shown).] Prior to reaching position 1, the vessel was sounding over relatively smooth firm bottom. Nearing position 1, the forward edge of the acoustical beam strikes shoal A and records an echo both from the shoal and from the bottom directly below the ship. Because the slant distance to the shoal is greater than the vertical distance, a side echo, deeper than the sea bottom below, is recorded.

The slant distance to the shoal from position 1 is equal to the vertical distance to the bottom causing the two traces to intersect. Between positions 1 and 2 the bottom echo is masked by the side echo from the shoal because the slant distance is less. If shoal A were an isolated bottom feature, the side echo would crest at position 2, which is the only point on the side echo where the apparent depth and the actual depth are equal. Shoal B, however, is then detected by the leading edge of the acoustical beam just prior to reaching position 2. The new side echo begins to rise from a point below that caused by shoal A, then intersects with the other trace at position 2 where the two distances are equal. Again, the side echo masks the bottom profile. The depth recorded at position 3 is the actual depth because the vessel is directly over the crest of the shoal. Then, moving forward, the actual bottom is not recorded again until the distance becomes less than the slant distance to shoal B when the vessel is past position 4. Note that depression C has been totally masked out and remains undetected. This hypothetical case has been simplified by considering the problem in only two dimensions. Uncertainties become considerably more complex when additional features to the left and right of the vessel's path are introduced.

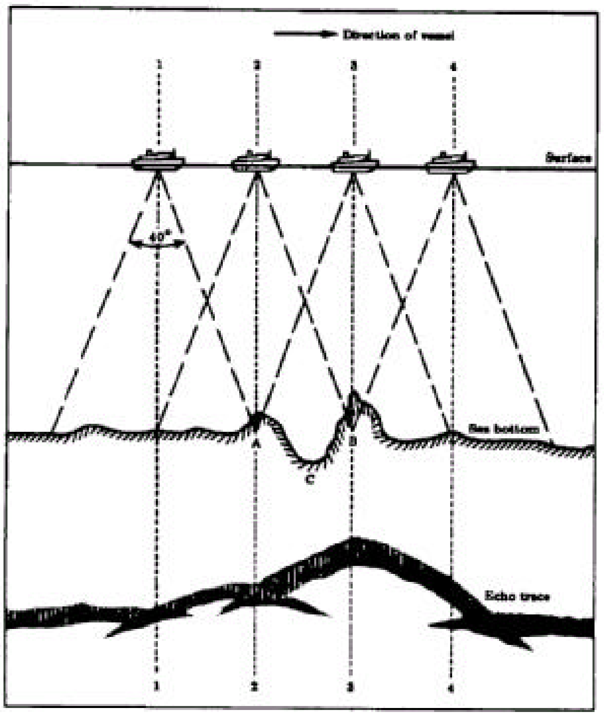


FIGURE 4-52.-Hypothetical example of deep water side echoes

Actual bottom profiles cannot always be determined with certainty because echo traces do not always represent actual physical conditions. Hydrographers must then follow a prudent conservative course when scaling soundings by joining crests with a smooth curve and making the assumption that the curve represents the bottom. When the bottom is extremely rough, the graphic depth record may literally be a maze of hyperbolically shaped side echoes, so complex that only indications of general depths can be extracted.

Irregular profiles resulting from swells or choppy seas are simils, to profiles of sand waves. When irregular profiles are caused by rough sea conditions, readings should be taken along a line representing the average depth, not from tops of peaks. Sounding records and analog depth records must contain sufficient notes that describe the cause of the irregular profile. If this information is unrecorded, an examination of the bottom trace may reveal the cause. Chop or swell is usually apparent over the entire line; the character of the graph changes when heading with or into the sea.

4.9.9. Final Field Soundings

Reduced field soundings are calculated by the hydrographic party for surveys on which the data are plotted manually on the field sheets. After all check scanning of the analog depth records has been completed and all corrections have been entered in the sounding record and checked, recorded soundings shall be reduced by the algebraic sum of the corrections; the corrected soundings are then entered in the column headed "field" (See figures 4-22 and 4-23.) These soundings must be entered in the same unit when recording, whether feet or fathoms. Because only one unit is used on a smooth sheet, recorded soundings must sometimes be converted. Conversions shall be made as shown in table 4-15, and the results entered in the double column headed "Office" (figures 4-22 and 4-23).

On automated surveys, listings or tabulations of final reduced soundings by the field party are not required. After the depth profiles and records have been scanned and checked for accuracy and corrections and additions made to the automated data listings, the original records, tapes, reports, and printouts are sent to the appropriate Marine Center for processing when the sheet has been completed.

TABLE 4-15. -*Conversion of reduced soundings*

Reduced soundings in Sounding Record		To be plotted on Smooth sheet in	Reduced soundings in Sounding Record		To be plotted on Smooth sheet in
(ft)	(fm)	(ft)	(ft)	(ft)	(fm)
-3.2 -2.3	-0.5 -3.4	-3		-1.3 -0.8	-0^{2}
-2.2 -1.3	-0.3	-2		-0.7 -0.2	-0^{1}
-1.2 -0.8	-0.2	-1		-0.1 0.4	0
-0.7 -0.3	-0.1	-0^{5}		0.5 1.0	0^{1}
-0.2 0.2	0.0	0		1.1 1.6	0^{2}
0.3 0.7	0.1	0^{5}	2	1.7 2.2	0^{3}
0.8 1.7	0.2	1		2.3 2.8	0^{4}
1.8 2.7	0.3 0.4	2	3	2.9 3.4	0^{5}
2.8 3.7	0.5 0.6	3	4	3.5 4.0	0^{6}
3.8 4.7	0.7	4		4.1 4.6	0^{7}
4.8 5.7	0.8 0.9	5	5	4.7 5.2	0^{8}
				5.3 5.8	0^{9}
			6	5.9 6.4	1

4.10. SPECIAL SURVEY TECHNIQUES

4.10.1 General

Operational requirements occasionally may suggest usage of survey techniques differing from those used for standard basic hydrographic surveys. Such techniques may greatly enhance the efficiency of surveying an area without causing an overall lowering of the survey quality or the failure of the survey to satisfy the requirements. Special techniques may be required in areas where recent photogrammetry is not available and/or development of the 0-foot curve or inshore waters is not required. Other techniques are used in performing a reconnaissance of an area of questionable adequacy. Still others are required to resolve the status of unconfirmed charted features and obstructions.

It is the purpose of these sections to provide guidance for such special surveys. This guidance will be referred to, as appropriate, by any project instructions requiring its implementation.

4.11. NAVIGABLE AREA SURVEYS

4.11.1.General

The Navigable Area Surveys (NAS) are designed to provide contemporary hydrographic surveys for updating existing nautical charts or constructing new charts. This type of basic survey is primarily designed toward meeting charting requirements in areas of increased commercial interest where scarce or obsolete data exist. By restricting the area of coverage of these surveys, yet retaining the basic hydrography concept within the surveyed waters, there will normally be a more rapid progression of field work and availability of data. The coverage is reduced by normally omitting requirements for: (1) development of the 0-foot curve and foul near shore areas not considered navigable and (2) complete field edit of the survey area.

4.11.2. Hydrogiraphy

Hydrography shall, in general, be basic except as outlined herein or by the project instructions.

4.11.2.1. INSHORE LIMITS. General inshore limits shall be designated by Headquarters; however, onsite deviations may be determined by the hydrographer and approved by the Chief of Party. Factors such as surf, the foul nature of an area, reefs, rocks awash, heavy kelp, and other unsafe conditions shall be used to determine the limits. As a general rule, the hydrography should be conducted to the 1-fathorn curve or within 100 meters of the shore, whichever is feasible. Where conditions do not permit extending the survey to these limits, it would be desirable to include in the Descriptive Report a simple statement briefly describing conditions that prevented nearshore operations. In some cases it will be obviously desirable and practicable to extend hydrography to the beach to develop a favorable landing area. Such cases should be obvious in the course of the survey and by examining the T-sheets.

4.11.2.2. SHOALS AND DANGERS TO NAVIGATION. Within the sounding area, the development of shoals and dangers to navigation shall be basic as instructed in sections 1.4.3, 4.5.9, and 4.5.10. This includes all shoals and other dangers to navigation that are covered or surrounded by navigable water. All detached shoals or indications thereof shall be investigated, developed, or areas delimited as required by basic hydrographic techniques. Those shoals or dangers which are the extension of nonnavigable waters shall be delimited. The technique of delimiting areas applies only to those features which cannot be safely developed by standard methods. Hydrography shall be run to within 50 meters of a delimited area. Foul areas shall be delimited by fairing a line through: (1) the positions of the outer off-lying rocks which rise above MLLW (2) the margins of dense kelp beds, or (3) the line at which breakers form.

4.11.2.3. CHART TOPOGRAPHY. A comparison of topography as depicted on the most recent chart edition with the actual topography will be accomplished to determine wherein the chart does not present a true picture of the area. When discrepancies are discovered and are within the field unit's capabilities, they should be resolved. Otherwise, recommendations should be made to secure updating photography. Such resolution of item discrepancies is imperative if the charts are to remain contemporary in their presentations.

4.11.2.4. LANDMARKS. Landmark verification or location shall be done in accordance with sections 4.5 and 5.5.

4.11.2.5. AIDS TO NAVIGATION. All floating and nonfloating aids to navigation in the project area shall be verified or located in accordance with sections 1.6.5 and 4.5.13. To prevent confusion, the latest edition of the chart, corrected via Notice to Mariners, should be used. Any discrepancies, once verified, should be reported to the local U.S. Coast Guard District and a copy submitted to National Ocean Survey Headquarters, through the appropriate Marine Center.

4.11.2.6. MISCELLANEOUS. All other data and activities pertinent to a basic survey shall be conducted.

4.11.3. Data Processing

All data processing shall be completed as for any basic survey and in the same format with no special priorities assigned to the Navigable Area Surveys.

4.12. CHART EVALUATION SURVEYS

4.12. 1. General

The Chart Evaluation Survey (CES) program is designed to:

1. Resolve all deficiencies reported or discovered. (A deficiency is defined as charted information that can be made more complete through field inspection, or information which should be but is not charted.)

2. Evaluate the adequacy/accuracy of hydrographic information on existing charts.

3. Verify or revise information published in the appropriate Coast Pilot.

4. Conduct user evaluation and public relations efforts to provide an awareness of NOS products and obtain user input.

Not all procedures will be required in each instance, but accomplishment of these program objectives will require one or more of the following operations: deficiency investigations, reconnaissance hydrography, waterfront planimetry verification, harbor reconnaissance, landmark verification, aids to navigation verification, Coast Pilot inspection, tide/water level observations, and user evaluation/public relations effort. This section will describe each technique, the effort required by the technique, and the desired results of each portion of the program.

A unit assigned to Chart Evaluation Surveys will progress through areas of NOS charting responsibility as rapidly as possible while fulfilling all prescribed objectives and requirements. To the extent possible, Chart Evaluation Surveys will be coordinated with the chart printing schedule and planned so as to provide the new revision data in a timely manner most beneficial to the users.

Control for these surveys shall be by the best available methods, including the use of charted landmarks and fixed aids, to navigation that have been verified or located to not less than third-order positional accuracies.

Normally accompanying the project instructions will be a series of charts with items identified (marked and numbered) for investigation along with a listing defining each item. Additional deficiencies may be found during the survey and these shall be investigated and resolved as well. Also included will be itemized tide/water level information- either where a staff or gage is required, bench mark information, and where and what predictions are to be used for reducing hydrographic data to chart datum or, perhaps, what maintenance shall be performed in support of another NOS program.

Where extensive hydrographic surveying is authorized and for any reconnaissance sounding lines, the Chief of Party shall ensure that adequate correctors are determined in accordance with provisions in section 1.5.4.

Bottom samples are not required unless specified.

4.12.2.Operations

The project instructions shall specify which of the following techniques shall be applied to the survey. Time frames, extent of effort, and area limits will be described in the instructions.

4.12.2. 1. DEFICIENCY INVESTIGATIONS. Copies of the latest chart editions will be furnished with discrepancy items annotated for resolution. All available background data describing these discrepancies will be provided by the Marine Chart Division, NOS. All indicated items shall be disposed of as well as any items brought out through local contacts; i.e., U.S. Power Squadrons, U.S. Coast Guard, U.S. Coast Guard Auxiliaries, port authorities, U.S. Army Corps of Engineers, and knowledgeable individuals. These contacts may also be of value in resolving assigned items. The Chief of Party is given the latitude to resolve deficiencies by the most expeditious and effective means available. Since many of the assigned items will be difficult to resolve using standard hydrographic methods, the use of an improvised wire drag or sweep is encouraged. The records must be clearly and accurately annotated to indicate the type of rig employed, the extent of the area investigated, and the time spent. Proper resolution of a submerged feature after it has been located includes the determination of a least depth. Techniques effective in accomplishing this objective include the use of divers as well as drift soundings employing a lead line. Where resources permit and the project area appears to warrant it, side scan sonar may be furnished. Instances occasionally arise which would indicate that resolution of an assigned item is impossible or impracticable. These items should be evaluated on a case-by-case basis by the Chief of Party. Factors which should be considered are proximity to vessel traffic areas, surrounding depths, existing control, and likelihood of resolution. If, in the opinion of the Chief of Party, resolution of an item does not merit the anticipated expense in time and manpower, that item may be omitted from the investigation list. When possible, the Hydrographic Surveys Division, OA/C35, should be notified of items not investigated prior to leaving an area. In all cases, a statement describing the factors affecting the decision should be included-in the Descriptive Report.

4.12.2.2. RECONNAISSANCE HYDROGRAPHY. Reconnaissance hydrography, as related to Chart Evaluation Surveys, is primarily for the purpose of evaluating the nonmaintained charted depth information although maintained areas should be checked also. This may range from just a few sounding lines to somewhat extensive operations in areas where dangers to navigation are known to exist or are found to exist. Since each situation is different, *general* guidance will be provided with each project with the final determination of survey effort left to the Chief of Party. If extensive hydrography is required, the Hydrographic Surveys Division, OA/ C35, should be notified through the appropriate Marine Center for a decision on what further action should be undertaken and the scope of this action. Reconnaissance hydrography should generally be conducted at the scale of the largest scale chart or manuscript available for the area.

4.12.2.3. WATERFRONT PLANIMETRY VERIFICATION. The waterfront planimetry depicted on the chart shall be compared with the existing conditions in sufficient detail to determine whether or not the chart presents a true picture of the area. Cartographic factors such as the scale of the chart must be given, due consideration; i.e., features that can and should be shown on a scale of 1-5,000 will not necessarily be depicted on a 1:20,000 or smaller scale chart.

When discrepancies are discovered and are within the field unit's capabilities, they should be resolved. U.S. Army Corps of Engineers' surveys, construction drawings, private surveys, and city or county maps shall be utilized wherever possible to eliminate duplication of effort. However, when prints from other Federal sources are used, verification of information shown thereon must be made to ensure that the resulting revision of the chart will be correct and adequate. When discrepancies are found which require corrections that are beyond the capability of the field party, recommendations should be made on ways to accomplish their resolution, such as securing chart updating photography.

4.12.2.4. HARBOR RECONNAISSANCE. Reconnaissance soundings shall be taken in active slips and along pier faces to verify the charted depths and contours. Adequate data shall be collected and recorded to permit evaluating charted hydrography. One sounding line should be run approximately where the keel of the pertinent vessel would travel in approaching and mooring to the pier. Lead line soundings are required close to pier and wharf faces to prevent false side echoes from being received and recorded on the echogram. To verify charted depths, reconnaissance soundings shall be taken in other portions of the inner harbor outside of regularly maintained project areas.

4.12.2.5. LANDMARK VERIFICATION. All charted landmarks shall be evaluated for their existence, accuracy of position, and usefulness for navigation. Recommendations should be made regarding the deletion and/or addition of landmarks. Any landmarks to be charted shall be located in accordance with provisions of the Hydrographic Manual. Landmarks can be verified by observing a multiobject sextant fix from a position along the shore. This initial fix will indicate charted landmarks misplotted in one direction. The fix should be plotted on the chart being verified and appropriate rays drawn through the landmarks observed. Subsequent fixes are then observed ensuring a minimum ray intersection angle of 30° at each charted landmark. Two intersecting rays should prove or disprove the adequacy of the charted landmark position. Should this method indicate an inaccurately charted feature, methods described in section 4.5.13.1 should be followed.

4.12.2.6. AIDS TO NAVIGATION VERIFICATION. All floating and nonfloating aids to navigation shall be checked for charted accuracy. To prevent unnecessary effort, the latest edition of the chart, corrected through the latest Notice to Mariners, should be used. Any discrepancies should be resolved and reported in accordance with section 4.5.13.

4.12.2.7. COAST PILOT INSPECTION. The appropriate Coast Pilot shall be examined for accuracy and completeness in the areas of operation, as well as en route. If modifications are required, reports shall be submitted in accordance with section 5.8.

4.12.2.8. TIDE/WATER LEVEL OBSERVATIONS. For any specified hydrography or item discrepancy investigations, tide/water level requirements will be issued with the project instructions.

Predicted tides are the only tidal data available to the mariner for reducing his observed depths to the chart datum; therefore, the accuracy of the predicted tides in the project area may require verification if so directed in the project instructions. This can be accomplished in several ways. A site having a flat bottom is selected near an offshore entrance to a harbor or other area of critical navigation within the working area. On a range, near a buoy, or using a marker installed by the survey party, depths are determined at the predicted times of low water, high water, and midway between during normal meteorological conditions. Depths should also be measured before and after the predicted tides to determine the actual times of high and low water and any differences noted. Depth observations should be made using a calibrated lead line or other calibrated direct means and the measurement location should vary as little as possible. At a number of station locations selected from table 2 of the tide tables, a bubbler tide gage should be installed and operated for a minimum of 3 days (installation of a staff is not required). Care should be taken to ensure the orifice will not be subject to movement while in operation. The analog record will be annotated for time, data, and weather (including unusual meteorological conditions). Any particular requirements such as location and priority will be furnished in the project instructions.

Water level requirements in nontidal areas are less complex and can generally be satisfied using temporary gage installations.

In most instances, a real-time reduction of hydrography can be accomplished in Chart Evaluation Surveys and still achieve the objectives of these surveys.

4.12.2.9. USER EVALUATION PUBLIC RELATIONS EFFORT. Every effort shall be made to contact users through the news media and local organizations. Names and addresses of suggested contacts will be furnished, when available, and will generally include: U.S. Army Corps of Engineers; U.S. Coast Guard; U.S. Coast Guard Auxiliaries; U.S. Power Squadrons; port authorities; commercial fishing organizations; Sea Grant Marine Advisers; pilots' associations; local newspapers, radio, and television; etc. Liaison will be maintained with the NOS Public Affairs Officer.

Contact with the user should be oriented with the objective of obtaining input as to the adequacy of the existing chart layout, scale, format, color, etc., and to inform the public of the mission of NOS and the many products and services provided by this Agency. Results of these contacts should be included in the Descriptive Report in detail sufficient to provide NOS (Marine Chart Division) support for future chart and survey planning.

4.12.3. Data Processing

Because of the special nature of these surveys and the need to reduce the time between field acquisition and office processing of the charting data, it is intended that the data will not be processed through the Marine Centers. Instead, the survey party will be responsible for field processing the data to a point where the responsible cartographer in the Marine Chart Division, OA/C32, can apply the data directly to the chart with a minimum of additional data reduction or verification required. Extreme care must be exercised by the field party to assure that the plotting of data on chart overlays or plotting sheets is done accurately and is in accordance with provisions of the Hydrographic Manual. A concise and yet comprehensive Descriptive Report must be included with *each* chart revised so that the office cartographer can readily determine and evaluate the merits of procedures employed by the field hydrographer in his data reduction. All appropriate correctors shall be applied to soundings. The use of correctors determined from real-time tide/water level observations is preferred over predicted tides if they are available. All revisions and notations to land and water features shall be made on the latest edition of the largest scale chart of each area. It is not mandatory that chart notations are color coded. It is, however, essential that each notation be legible and complete. If the hydrographer chooses to use a color code, he should ink all change and addition notes in red ink, all deletion notes in green ink, and all confirmation notes in blue ink. It is important that all inspection and revision notes be inked on the chart by the hydrographer as the field work progresses. If a color code is used, it must be briefly described in the Descriptive Report.

4.12.4. Data Distribution

Upon completion of a chart area, the report, records, field sheets, and other associated data shall be forwarded to the Hydrographic Surveys Division, OA/C35. All tidal records shall be forwarded to the Tides and Water Levels Division, OA/C23. All data transmitted should be clearly labeled and indexed (e.g., the folder containing graphic depth records should be indexed by date and position numbers). NOAA Form 61-29, Letter Transmitting Data shall be used for all data submissions.

4.12.5. Descriptive Report

A modified Descriptive Report as described herein is required for *each* chart investigated. For general guidance in preparing any Descriptive Report, refer to section 5.3.

4.12.5.1. COVER SHEET. NOAA Form 76-35A, "Descriptive Report," shall be used as the outside cover sheet; appropriate entries are made to identify the survey. (See figure 4-53).

The "Type of Survey" entry shall be Chart Evaluation. "Field No." should be struck out and the appropriate chart number indicated. "Office No." should be entered with N.A.

The "State" entry is the name of the state or territory nearest the center of the chart.

The "General Locality" in which the survey was performed must be defined by a well-known geographic name (e.g., Sumner Strait, Gulf of Mexico, or Lake Huron).

The "Locality" entry pinpoints the immediate area of the survey. Again, specific geographic names are used as reference (e.g., Approaches to Chincoteague Inlet, Northern Portion of Lake St. Clair, or NW of Cape Kumukahi).

4.12.5.2. TITLE SHEET. Information for the title of a survey shall be furnished on NOAA Form 77-28, "Hydrographic Title Sheet." Entries are made on all applicable spaces on the form. (See figure 4-54.) Since the Title Sheet is often referred to for information pertaining to the survey, be sure all entries are accurate.

The entries required on the Title sheet are self-explanatory. "State," "General Locality," and "Locality" entries shall be identical to those on the Cover Sheet. The "Date of Survey" entries are the inclusive dates of the field work. The name(s) listed in the "Surveyed by" entry are those who were actually in charge during the surveying operations.

If a field party has not completed all required work on a field sheet prior to transferring the data to another unit or to NOS Headquarters, enter a complete explanation in the "Remarks" section. Other Descriptive Reports or special reports containing information or data pertinent to the survey should be referenced under "Remarks."

4.12.5.3. DESCRIPTIVE REPORT TEXT. Descriptive Report texts are typed on letter-size (8½ X 11 in) paper with left-hand margins of 1.25 in to permit binding. The text must be clear and concise. All information required for a complete understanding of the records shall be included, but verbosity shall be avoided.

Each text shall be entitled "Descriptive Report to Accompany Chart Evaluation Survey of Chart ________"(insert chart number). The scale and year of the survey, the names of the survey vessel or party, and the Chief of Party are listed.

When reference is made to a hydrographic feature on the field sheet, the latitude, longitude, and position number of the feature shall be given. To provide uniformity of reports, the text is arranged under the following lettered headings in order appearing here.

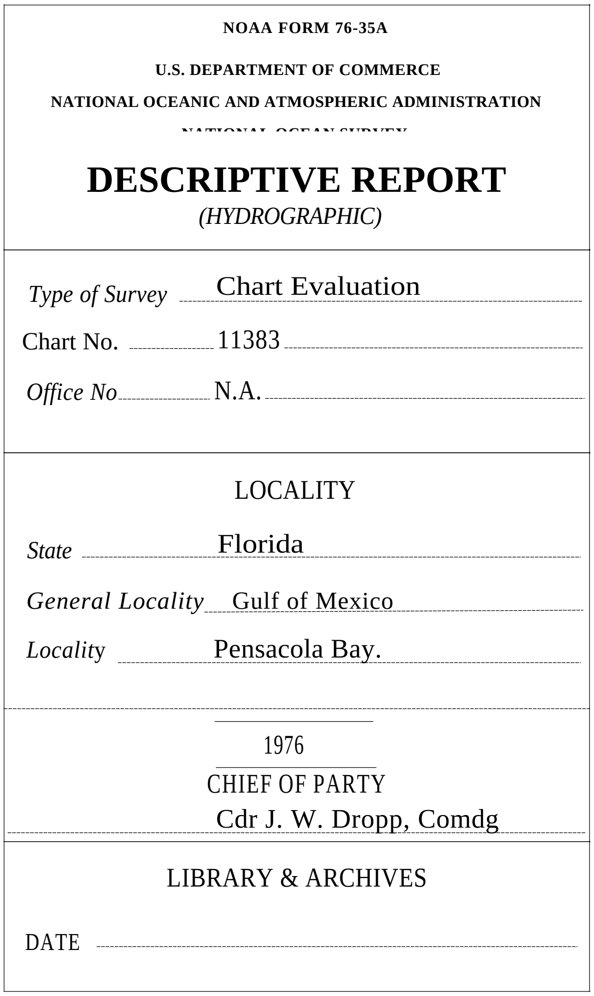
A. PROJECT. Include the project number, and date of original instructions, and the dates of all changes, supplemental instructions, amendments, and pertinent letters.

B. AREA SURVEYED. Briefly describe the area covered by the survey and the adjacent coast. State the general locality, approximate limits, and inclusive dates of the survey.

C. SOUNDING VESSEL. List all ships or launches by letter designations and electronic data processing (EDP) numbers that were used to obtain the soundings. Include in this section a narrative description of any unusual sounding vessel configurations and problems encountered.

D. SOUNDING EQUIPMENT AND CORRECTIONS TO ECHO SOUNDINGS. Identify by type and serial number all echo-sounding instruments used by each survey vessel. State the type of other sounding equipment used and the general areas and depths in which each was used. Discuss any faults in the equipment which affected the accuracy of sounding.

Summarize the methods used to determine,



NOAA FORM 76-35A

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY

DESCRIPTIVE REPORT
(HYDROGRAPHIC)

Type of Survey Chart Evaluation
Chart No. 11383
Office No N.A.

LOCALITY

State Florida
General Locality Gulf of Mexico
Locality Pensacola Bay.

1976

CHIEF OF PARTY
Cdr J. W. Dropp, Comdg

LIBRARY & ARCHIVES

DATE

FIGURE 4-53. - Descriptive Report cover sheet

evaluate, and apply the following listed corrections to the echo soundings:

1. Velocity of sound through water.
2. Variations in the instrument initial.
3. Other instrument corrections.
4. Corrections determined from direct comparisons (bar checks and vertical casts).
5. Settlement and squat.

If salinity, temperature, depth (STD) sensors; temperature, depth, conductivity (TDC) sensors; or similar instruments were used for velocity determinations, identify each instrument by serial number and provide the most recent dates of calibration or field check.

List the positions of the stations observed for velocity corrections with the date of observation; or prepare letter-size 8½ X 11 in) chartlets showing the locations and dates.

If unusual or unique methods or instruments were necessary for the determination of corrections to echo soundings, describe them in sufficient detail to provide subsequent users of the survey a full understanding of the data. It must be emphasized that sounding corrections be determined and reported in a standard manner (4.9) unless extenuating circumstances arise; extensive analysis of data acquired by nonstandard methods can be extremely time consuming.

When applicable, specify the vessels, areas, depths, and items for which any particular group of corrections are to be applied.

A copy of the Abstracts of Corrections to Echo Soundings should be inserted at the end of the Descriptive Report (4.12.5.4(B)); substantiating field observations, computations, and graphs are included with the field records (See 4.9.)

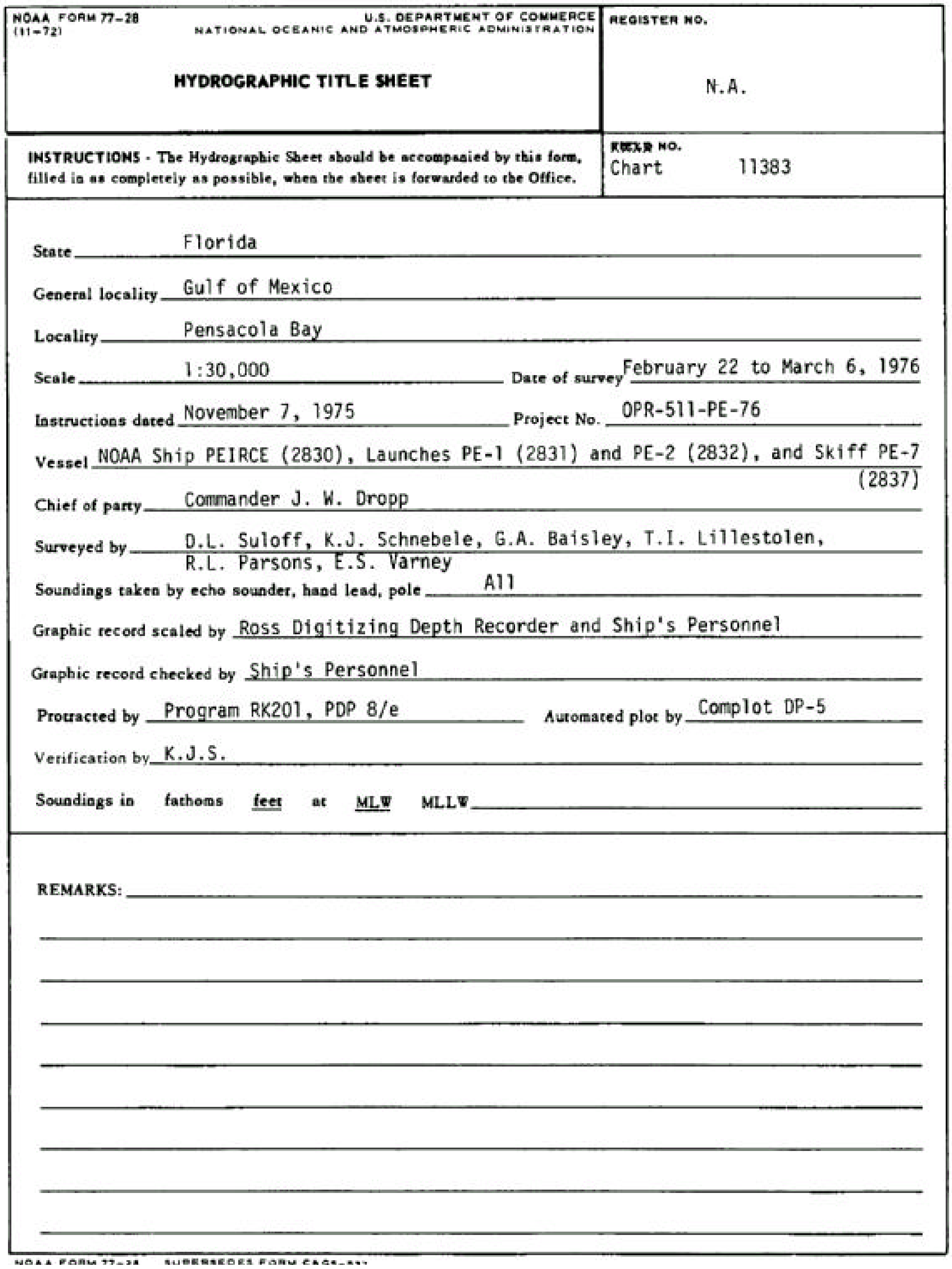
E. SURVEY SHEETS. List all charts, overlays, and blowups and state the scale and area of the sheets. Since no further processing of these sheets will be applied, they must be neatly, clearly, and accurately plotted.

F. CONTROL STATIONS. List the control stations on the sheet that have been monumented and described; state the surveying methods used to establish horizontal positions for hydrographic signals and stations. Define the general areas in which each method was used and indicate the datum used. If a geodetic control report is not available, copies of the appropriate geodetic abstracts; and computations shall be included with the survey records for verification of the positions. Explain in detail:

1. Unconventional survey methods, if used, for determining the positions of horizontal control stations.
2. Anomalies in the control adjustment or in closures and ties.
3. Any known photogrammetric problems that could contribute to position inaccuracies.

Refer to section 4.12.5.4(D) for control listings to be appended to the Descriptive Report.

G. HYDROGRAPHIC POSITION CONTROL. State the method or methods of sounding line position control used for the survey and explain in detail any known difficulties experienced with the control system that may have degraded the expected position accuracy. Electronic control equipment shall



NOAA FORM 77-28
(11-72)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HYDROGRAPHIC TITLE SHEET

REGISTER NO. N.A.

INSTRUCTIONS - The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

~~FIELD~~ NO. Chart 11383

State Florida

General locality Gulf of Mexico

Locality Pensacola Bay

Scale 1:30,000 Date of survey February 22 to March 6, 1976

Instructions dated November 7, 1975 Project No. OPR-511-PE-76

Vessel NOAA Ship PEIRCE (2830), Launches PE-1 (2831) and PE-2 (2832), and Skiff PE-7 (2837)

Chief of party Commander J. W. Dropp

Surveyed by D.L. Suloff, K.J. Schnebele, G.A. Baisley, T.I. Lillestolen, R.L. Parsons, E.S. Varney

Soundings taken by echo sounder, hand lead, pole All

Graphic record scaled by Ross Digitizing Depth Recorder and Ship's Personnel

Graphic record checked by Ship's Personnel

Protracted by Program RK201, PDP 8/e Automated plot by Complot DP-5

Verification by K.J.S.

Soundings in fathoms [✓ feet] at [✓ MLW] MLLW

REMARKS:

NOAA FORM 77-28 SUPERSEDES FORM C&GS-537

FIGURE 4-54.—Hydrographic Title Sheet

be identified by manufacturer, model, and component serial numbers for each vessel and shore station.

Briefly describe the methods for calibrating the electronic control systems. Evaluate, to the extent possible, the adequacy of the calibration data applied to raw position data throughout the survey area.

Items to be discussed in detail in this section include, but are not limited to:

1. Unusual or unique methods of operating or calibrating electronic positioning equipment.
2. Equipment malfunctions, substandard operation, and probable causes.
3. Unusual atmospheric conditions that may have affected data quality.
4. Weak signals or poor geometric configuration of the control stations.
5. Discovery and treatment of systematic errors in the position data.

A copy of the Abstract of Corrections to Electronic Position Control shall be inserted at the end of the Descriptive Report (4.12.5.4(C)), and the substantiating field observations, computations, and other pertinent data shall be included in the survey records. (See 4.8.)

H. WATERFRONT PLANIMETRY VERIFICATION. Specifically describe shoreline areas that have experienced *significant* modification and reference those survey sheets included which delineate the change. State the methods used in verifying the charted planimetry or acquiring revision data.

I. HARBOR RECONNAISSANCE. State the accomplishment of the investigation of harbor areas with a brief discussion of significant observations.

J. DEFICIENCY INVESTIGATIONS. Each numbered deficiency item that lies within the limits of the survey must be completely discussed. The standard format (see figures 4-55 and 4-56) shall be completed for each item and transmitted with the Descriptive Report. It is important that the form be completely and thoroughly filled out. Most top sections of the form are self-explanatory. The item description should reflect the abbreviated item designation and the source of that item. This information will be specified in the original instruction request or determined locally. For example:

Submerged Pile, PA
Chart Letter 1775 (73)

Visible Wreck, PA
1964 USPS Report

Dangerous Sunken Wrecks
NM 45/64

Dangerous Sunken Wreck, PA
Local Report, Delaware Bay,
Pilots Association

The geodetic position should be completed to show the position of the item as charted and the actual position as surveyed. A specific description of the positioning methods used shall be stated. The method of item investigation is the single most important portion of this form. Confidence in the hydrographer's recommendation is frequently dependent on the detailed description contained within the method of item investigation. For this reason, specific information describing the investigation shall be included. The least depths obtained over submerged features and the baring height of visible hazards shall be listed. Standard techniques employed shall be referenced to the source of that technique (Hydrographic Manual, NOAA Diving Manual, PMC OPORDER, AMC OPORDERS, etc.). Any unique survey method must be specifically described. Conditions of the investigation such as weather, water clarity, time spent, etc., can be important.

Limits of an investigation (area covered, width of a wire sweep, etc.) should be stated. Frequently a sketch can clarify details of an investigation which are otherwise difficult to explain. References to individuals in the area may be pertinent. Charting recommendations must be positive and explicit. Recommendations should include whether or not the item should be charted, and the symbolization to be used. If the hydrographer is unwilling to make a positive statement after an onsite investigation, it is most unlikely that the office cartographer will be able to rely on such a recommendation.

Copies of telegrams or letters that have been submitted recommending immediate changes to the charts and items for inclusion in the Local Notice to Mariners shall be included in the Descriptive Report.

K. CHANNEL AND SHOAL INVESTIGATIONS. Channels and shoals found and investigated during the survey shall be listed. Least depths or clearances for these features must be given. Reference to the appropriate position numbers and development overlays should be made.

CHART # 18661 ITEM # 34

ITEM DESCRIPTION: Submerged Pile, PA

SOURCE: Chart Letter 1775 (73)

INVESTIGATION DATE: 4/7/77 (JD97) TIME: 185OZ-1905Z VESSEL: DA 2

OIC: ENS Kenny

REFERENCES:

Position No.: 7028, 7029 Volume: 3, pg. 27

Velocity TRA Correctors Applied

Predicted Actual Tide Correctors Applied

GEODETIC POSITION	Latitude	Longitude
Charted:	38° 01 ' 05"	121° 30' 50"
Observed:	38° 01' 04.7"	121° 30' 51.7"

POSITION DETERMINED BY:

Sextant and visual observation.

METHOD OF ITEM INVESTIGATION:

The pilings were searched for and found visually. There is a row of pilings approximately 25 feet offshore and extending approximately 100 feet. Fixes were taken on the northernmost and southernmost piles, both of which were awash at the time of observation with the predicted tide 2.0 feet above MLLW. Most piles in between were uncovered approximately 2 feet. The pilings are visible at MLLW but most are covered at MHW.

CHARTING RECOMMENDATION:

Chart "Piles" from 38° 01' 04.7" N, 121° 30' 51.7" W to 38° 01' 06.3" N, 121° 30' 50.6" W.

Delete " Piling" presented charted in the same vicinity.

Compilation Use Only

<u>CHART</u> <u>APPLIED AS</u>

FIGURE 4—55.—Deficiency Item Report

CHART # 11388 ITEM # 7

ITEM DESCRIPTION: Shoal Rep. 1971

SOURCE: LNM 37/71

INVESTIGATION DATE: 3/15/76 (JD75) TIME: 1700Z-1735Z VESSEL: PE 1

OIC: LTJG Dreves

REFERENCES:

Position No.: NA Volume: 1, pg- 20-21

Velocity TRA Correctors Applied

Predicted Actual Tide Correctors Applied

GEODETIC POSITION	Latitude	Longitude
Charted:	30° 22. 5'	86° 30. 4'
Observed:	NA	NA

POSITION DETERMINED BY:

Sextant fixes and visual references to Buoy BW "CB"

METHOD OF ITEM INVESTIGATION:

The area surrounding the charted position of the reported 12-foot shoal was searched for a circle of a 100-meter radius with lines run in 30-meter intervals. General soundings in the area of the shoal were 30 feet and consistent with the gradual inshore shoaling. The fathometer was kept running the entire period of the search with no unusual features. The annotated fathogram is included with survey records. Water clarity allowed bottom visibility to 40 feet and no features or obstructions could be seen.

CHARTING RECOMMENDATION:

The charted "Shoal Rep. 1971" should be removed. Careful search by the hydrographer indicates that such a shoal is not existent. The report undoubtedly was errant in its position with the reporting vessel probably inshore from the reported position.

Compilation Use Only

CHART APPLIED

FIGURE 4-56.—Deficiency Item Report

L. RECONNAISSANCE HYDROGRAPHY. Compare the reconnaissance hydrography with the latest edition of the largest scale chart of the area, identifying the chart by number, edition, and date. State the quality of general agreement between the reconnaissance soundings and the charted depths, and give conclusions or opinions as to the reasons for significant differences.

M. LANDMARK AND NONFLOATING AIDS VERIFICATION. Copies of NOAA Form 76-40, "Report on Nonfloating Aids or Landmarks for Charts," that contain the required information on landmarks within the survey limits that are recommended for charting shall be attached to the Descriptive Report (4.12.5.4(F)). State the accomplishment of this task.

N. AIDS TO NAVIGATION. Reference shall be made to any correspondence with the U.S. Coast Guard regarding the location or establishment of floating aids in the surveyed area. The location and description of each floating aid shall be entered in the hydrographic records. A separate listing of floating aids by geographic position and characteristic need not be entered here. However, a comparison shall be made with data in the latest edition of the *Light List* and with the largest scale chart of the area. The hydrographer shall state the results of this comparison, and indicate whether the aids adequately serve the apparent purpose for which they were established.

List all aids to navigation located during the survey that are not shown in the *Light List*. State their apparent purpose, whether and by whom the aids are maintained, and whether or not such maintenance is seasonal, if known. Give the position and description of each such aid and the date of establishment, if known.

List all bridges and overhead cables not shown on the chart. State bridge and cable clearances measured by the survey party or as determined from other sources. Mention any submarine cables, pipelines, and ferry routes in the area. List the position of each terminal if not shown on contemporary shoreline manuscripts.

O. COAST PILOT INSPECTION. State the accomplishment of this task. Copies of the Coast Pilot report and/or NOAA forms 77-6 should be attached to the Descriptive Report (4.12.5.4(G)).

P. TIDE/WATER LEVEL OBSERVATIONS. Describe the methods used and the results of all comparisons to predicted tides. State the observed or user reported acceptability of predicted tides for this area.

Q. USER EVALUATION. State the results of the user evaluation effort. Carefully describe any recommendations for changes in chart layout, insets, scale, format, color, etc., and provide the justifications for such recommendations.

R. PUBLIC RELATIONS EFFORTS. Generally describe the unit's efforts in the area of public relations. Describe the more successful events and mention particularly cooperative individuals or groups.

S. STATISTICS. List the total number of items investigated, the total number of positions, and nautical miles of sounding lines run by each launch or ship during the survey. A tabulation of statistics for each day is not required. A summary of other survey statistics such as the number of tide comparisons, landmarks added, landmarks deleted, open houses, etc., should also be included.

T. MISCELLANEOUS. Provide information of significant scientific or practical value resulting from the survey which is not covered in previous sections. Where new silted areas are detected, the discussions should include the size of the areas, apparent thickness, and reference to typical depth profiles by date. Unusual submarine features such as abnormally large sand waves, mounds, valleys, and escarpments should be described. Discuss anomolous tidal conditions encountered such as the presence of bores and extremely fast currents not previously reported. If special reports have been submitted on such subjects, refer to them by title, author, and date of preparation or publication.

U. RECOMMENDATIONS. Specific charting recommendations should be included with the individual discrepancy items. Recommendations for new basic hydrography, tides or tidal current surveys, or shoreline updating photography should be stated and justified. Recommendations for future Chart Evaluation Surveys should be included.

V. AUTOMATED DATA PROCESSING. List by program name, number, and version date all routines used for automated data acquisition and processing. If any of the acquisition or processing methods used differ from those described in current NOS manuals or instructions, each difference must be listed and explained, and the data format defined.

W. REFERRAL TO REPORTS. List all reports, records, and forms not included with the survey records or Descriptive Report that have been submitted separately, but which are necessary for a complete evaluation and understanding of the survey record. Give the title and the date on which the report was forwarded.

4.12.5.4. SEPARATES FOLLOWING TEXT. Various tabulations and other information are required on separate sheets which are inserted in the Descriptive Report. Those applicable shall be furnished and inserted in the order listed below.

The first page of the text and the attached inserts shall be numbered consecutively. The approval sheet is always placed last.

A. FIELDTIDE/WATER LEVEL NOTE. A field tide or water level note shall be inserted in the Descriptive Report for each applicable survey. (See figure 5.5.) The note should state:

1. How the tide/water level corrections were derived and the zones or items to which these corrections were applied. (If automated computations for tides corrections to soundings were made based on multigage observations, the program number and gage sites must be given.)

2. The name, geographic locale, latitude, and longitude of each gage.

3. Dates of gage installations and removals, and any problems experienced with gage operations.

4. Staff value equivalent to the zero line on analog tide records. (In the Great Lakes, the elevation of the reference mark (zero electric tape gage or ZETG) on the electric tape gage shall be noted.)

5. Significant differences in comparative observations (AK.2.3), in tide or water level times, or in ranges or unusual fluctuations between adjacent gages.

6. The time meridian used for records annotation.

7. Observations of unusual tidal, water level, or current conditions.

8. A tabulation of missing hourly heights, if any, that may be required for reduction of soundings to the datum of reference.

9. Recommendations, if any, for zoning and time corrections.

B. ABSTRACT OF CORRECTIONS TO ECHO SOUNDINGS. Abstracts, in tabular form, for velocity and other corrections to be applied to the echo soundings shall be included as separate entries in the Descriptive Report. (See figure 5.7.) A similar abstract can be easily constructed for corrections determined solely by bar checks taken throughout the depth range.

The Sounding Correction Abstract shows the dates, times, vessels, and instrument serial numbers to which the corrections apply. If the same corrections apply to more than one survey, a copy of the abstract and applicable correction tables (4.9) are included in the Descriptive Report for each survey.

For substantiating these corrections to soundings, the following supporting material shall be assembled and separately bound or arranged in a cahier and included with the survey data that accompanies the hydrographic sheet and Descriptive Report:

1. Copy of the settlement and squat abstract.

2. Abstracts of bar checks, vertical cast comparisons, and echo sounder phase comparisons.

3. Copies of calibration data for STD, TDC, or other sensors used for velocity determinations.

4. Nansen cast observations.

5. All other basic data, computations, graphics, and material needed to verify the final corrections.

C. ABSTRACTS OF CORRECTIONS TO ELECTRONIC POSITION CONTROL. When all or any portion of the hydrographic survey is controlled by an electronic positioning system or by distance measuring equipment, an abstract of corrections to be applied to the observed data shall be compiled and inserted into the Descriptive Report. (See figure 5-8.) Supporting data shall be assembled and separately bound or arranged in a cahier and included with the survey data that accompanies the hydrographic field sheet and Descriptive Report. (See 4.8.)

D. LIST OF STATIONS. A numerical list of stations used for controlling the hydrographic survey shall be included as a separate sheet and inserted in the Descriptive Report. (See figure 5-9.) The following information shall be given for each station:

1. Station number (001-999).

2. Latitude (to nearest thousandth of a second).

3. Longitude (to nearest thousandth of a second).

4. Name and type of station (3.1), that is:

(a) Basic or supplemental (include year of establishment).

(b) Photogrammetric or hydrographic.

5. Source; that is, volume and page number for published geodetic control or, if new, a reference to abstracts of field observations.

E. ABSTRACT OF POSITIONS. The Abstract of Positions shall be assembled for each hydrographic survey vessel that worked on the field sheet. (See figure 5-10.) Each vessel is identified by its data-processing number, and the work accomplished is listed by Julian dates, inclusive position numbers, control codes, and electronic control station numbers.

F. REPORT ON LANDMARKS AND NONFLOATING AIDS TO NAVIGATION. NOAA Forms 76-40, "Report on Nonfloating Aids or Landmarks for Charts," shall be prepared as required herein and copies attached to the Descriptive Report. Separate forms 76-40 are submitted for:

1. Landmarks to be charted.
2. Landmarks to be deleted.
3. Nonfloating aids to navigation.

The hydrographer shall evaluate all charted landmarks from seaward to determine which are adequate and most suitable for the purpose intended and to determine which charted landmarks no longer exist and thus should be deleted from the charts. If there are more prominent objects in the area which would serve as better landmarks, their positions shall be determined and listed among the landmarks to be charted.

Reports on landmarks must be complete within themselves. Avoid additional references to geodetic, photogrammetric, or other data not readily available to other users. The report shall state positively whether or not a seaward inspection has been made to evaluate the landmarks. If the reports have been assembled without the benefit of a seaward inspection, the reason for omission shall be fully explained.

Objects of special importance or extraordinary prominence are indicated by an asterisk (*) preceding the name of the object. When selecting objects of special importance, the total area and chart coverage must be carefully considered. Flagstaffs, flagpoles, and other structures of a temporary nature are not listed as landmarks unless they are of a very permanent and prominent nature and there are no other suitable objects in the area. Recommended charting names should be short, general, and shown in capital letters (5.5.1.2). If the object was used as a hydrographic signal, a note is made to this effect and the station number indicated.

When a large number of landmarks are reported, or the hydrographer or field editor considers it necessary to clarify the tabulated data, a copy of the chart of the area should be cut into letter-size sections, appropriately annotated, and submitted with the copies of NOAA form 76-40. (See figures 5-11 and 5-12.) The area inspected is outlined on these chart sections and a recommendation made for each charted or plotted landmark within the outlined area.

If chart sections are submitted, separate forms for landmarks to be deleted need not be prepared. The following procedures are used:

1. New landmarks shall be plotted and identified by the landmark symbol (A) together with the name recommended for charting. The geographic datum of the chart must be known and considered in the plotting.

2. Charted landmarks recommended for continuance are checkmarked (A). If the position has been verified in the field, the word "verified" is entered beside the checkmark.

3. Charted landmarks recommended for deletion shall be indicated by an X in a circle (A), the word "delete" entered, and the reason for the recommendation given.

Names and notations on these chart sections shall be typed or lettered legibly in red ink. Care must be taken that such notations always appear on the same section of the chart section as the landmarks to which they refer.

A separate NOAA Form 76-40, "Nonfloating Aids or Landmarks for Charts," shall be used to report the positions of all nonfloating aids to navigation on a chart-by-chart basis. The geographic positions of all nonfloating aids, including privately maintained lights and beacons, shall be verified or determined in the field. Applicable parts of the requirements stated for form 76-40 shall be followed in compiling this report. If contemporary shoreline mapping of the area has been undertaken, copies of form 76-40 for new aids or aids to be deleted shall be sent to the Photogrammetry Division, OA/C34; otherwise, the forms are sent to the Marine Chart Division, OA/C32. For additional details concerning landmarks and aids to navigation see:

chart, corrected through the latest Notice to Mariners, should be used. Any discrepancies should be resolved and reported in accordance with section 4.5.13.

4.12.2.7. COAST PILOT INSPECTION. The appropriate Coast Pilot shall be examined for accuracy and completeness in the areas of operation, as well as en route. If modifications are required, reports shall be submitted in accordance with section 5.8.

4.12.2.8. TIDE/WATER LEVEL OBSERVATIONS. For any specified hydrography or item discrepancy investigations, tide/water level requirements will be issued with the project instructions.

Predicted tides are the only tidal data available to the mariner for reducing his observed depths to the chart datum; therefore, the accuracy of the predicted tides in the project area may require verification if so directed in the project instructions. This can be accomplished in several ways. A site having a flat bottom is selected near an offshore entrance to a harbor or other area of critical navigation within the working area. On a range, near a buoy, or using a marker installed by the survey party, depths are determined at the predicted times of low water, high water, and midway between during normal meteorological conditions. Depths should also be measured before and after the predicted tides to determine the actual times of high and low water and any differences noted. Depth observations should be made using a calibrated lead line or other calibrated direct means and the measurement location should vary as little as possible. At a number of station locations selected from table 2 of the tide tables, a bubbler tide gage should be installed and operated for a minimum of 3 days (installation of a staff is not required). Care should be taken to ensure the orifice will not be subject to movement while in operation. The analog record will be annotated for time, data, and weather (including unusual meteorological conditions). Any particular requirements such as location and priority will be furnished in the project instructions.

Water level requirements in nontidal areas are less complex and can generally be satisfied using temporary gage installations.

In most instances, a real-time reduction of hydrography can be accomplished in Chart Evaluation Surveys and still achieve the objectives of these surveys.

4.12.2.9. USER EVALUATION PUBLIC RELATIONS EFFORT. Every effort shall be made to contact users through the news media and local organizations. Names and addresses of suggested contacts will be furnished, when available, and will generally include: U.S. Army Corps of Engineers; U.S. Coast Guard; U.S. Coast Guard Auxiliaries; U.S. Power Squadrons; port authorities; commercial fishing organizations; Sea Grant Marine Advisers; pilots' associations; local newspapers, radio, and television; etc. Liaison will be maintained with the NOS Public Affairs Officer.

Contact with the user should be oriented with the objective of obtaining input as to the adequacy of the existing chart layout, scale, format, color, etc., and to inform the public of the mission of NOS and the many products and services provided by this Agency. Results of these contacts should be included in the Descriptive Report in detail sufficient to provide NOS (Marine Chart Division) support for future chart and survey planning.

4.12.3. Data Processing

Because of the special nature of these surveys and the need to reduce the time between field acquisition and office processing of the charting data, it is intended that the data will not be processed through the Marine Centers. Instead, the survey party will be responsible for field processing the data to a point where the responsible cartographer in the Marine Chart Division, OA/C32, can apply the data directly to the chart with a minimum of additional data reduction or verification required. Extreme care must be exercised by the field party to assure that the plotting of data on chart overlays or plotting sheets is done accurately and is in accordance with provisions of the Hydrographic Manual. A concise and yet comprehensive Descriptive Report must be included with *each* chart revised so that the office cartographer can readily determine and evaluate the merits of procedures employed by the field hydrographer in his data reduction. All appropriate correctors shall be applied to soundings. The use of correctors determined from real-time tide/water level observations is preferred over predicted tides if they are available. All revisions and notations to land and water features shall be made on the latest edition of the largest scale chart of each area. It is not mandatory that chart notations are color coded. It is, however, essential that each notation be legible and complete. If the hydrographer chooses to use a color code, he should ink all change and addition notes in red ink, all deletion notes in green ink, and all confirmation notes in blue ink. It is important that all inspection and revision notes be inked on the chart by the hydrographer as the field work progresses. If a color code is used, it must be briefly described in the Descriptive Report.

4.12.4. Data Distribution

Upon completion of a chart area, the report, records, field sheets, and other associated data shall be forwarded to the Hydrographic Surveys Division, OA/C35. All tidal records shall be forwarded to the Tides and Water Levels Division, OA/C23. All data transmitted should be clearly labeled and indexed (e.g., the folder containing graphic depth records should be indexed by date and position numbers). NOAA Form 61-29, Letter Transmitting Data shall be used for all data submissions.

4.12.5. Descriptive Report

A modified Descriptive Report as described herein is required for *each* chart investigated. For general guidance in preparing any Descriptive Report, refer to section 5.3.

4.12.5.1. COVER SHEET. NOAA Form 76-35A, "Descriptive Report," shall be used as the outside cover sheet; appropriate entries are made to identify the survey. (See figure 4-53).

The "Type of Survey" entry shall be Chart Evaluation. "Field No." should be struck out and the appropriate chart number indicated. "Office No." should be entered with N.A.

The "State" entry is the name of the state or territory nearest the center of the chart.

The "General Locality" in which the survey was performed must be defined by a well-known geographic name (e.g., Sumner Strait, Gulf of Mexico, or Lake Huron).

The "Locality" entry pinpoints the immediate area of the survey. Again, specific geographic names are used as reference (e.g., Approaches to Chincoteague Inlet, Northern Portion of Lake St. Clair, or NW of Cape Kumukahi).

4.12.5.2. TITLE SHEET. Information for the title of a survey shall be furnished on NOAA Form 77-28, "Hydrographic Title Sheet." Entries are made on all applicable spaces on the form. (See figure 4-54.) Since the Title Sheet is often referred to for information pertaining to the survey, be sure all entries are accurate.

The entries required on the Title sheet are self-explanatory. "State," "General Locality," and "Locality" entries shall be identical to those on the Cover Sheet. The "Date of Survey" entries are the inclusive dates of the field work. The name(s) listed in the "Surveyed by" entry are those who were actually in charge during the surveying operations.

If a field party has not completed all required work on a field sheet prior to transferring the data to another unit or to NOS Headquarters, enter a complete explanation in the "Remarks" section. Other Descriptive Reports or special reports containing information or data pertinent to the survey should be referenced under "Remarks."

4.12.5.3. DESCRIPTIVE REPORT TEXT. Descriptive Report texts are typed on letter-size (8½ X 11 in) paper with left-hand margins of 1.25 in to permit binding. The text must be clear and concise. All information required for a complete understanding of the records shall be included, but verbosity shall be avoided.

Each text shall be entitled "Descriptive Report to Accompany Chart Evaluation Survey of Chart ________"(insert chart number). The scale and year of the survey, the names of the survey vessel or party, and the Chief of Party are listed.

When reference is made to a hydrographic feature on the field sheet, the latitude, longitude, and position number of the feature shall be given. To provide uniformity of reports, the text is arranged under the following lettered headings in order appearing here.

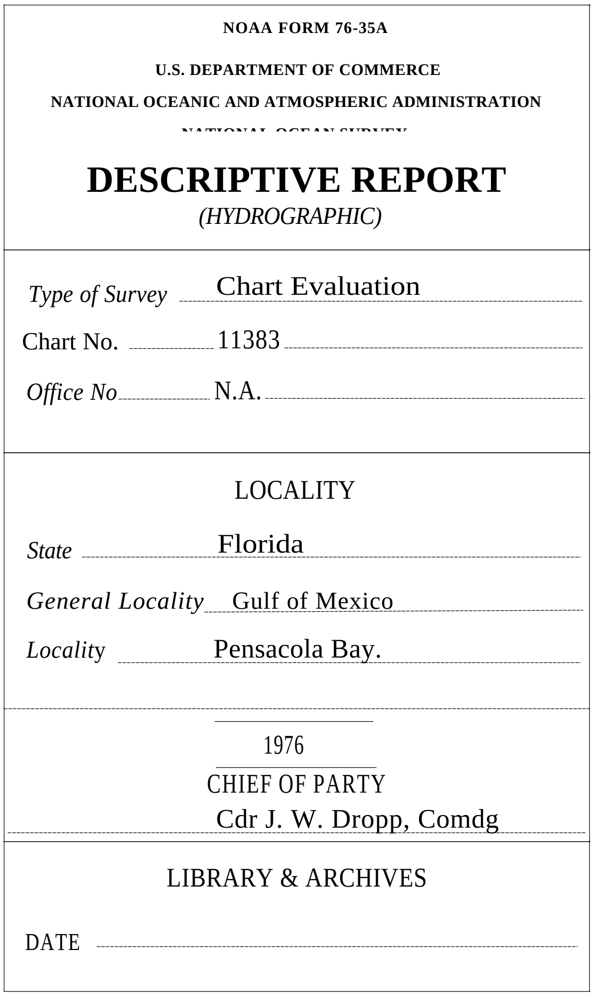
A. PROJECT. Include the project number, and date of original instructions, and the dates of all changes, supplemental instructions, amendments, and pertinent letters.

B. AREA SURVEYED. Briefly describe the area covered by the survey and the adjacent coast. State the general locality, approximate limits, and inclusive dates of the survey.

C. SOUNDING VESSEL. List all ships or launches by letter designations and electronic data processing (EDP) numbers that were used to obtain the soundings. Include in this section a narrative description of any unusual sounding vessel configurations and problems encountered.

D. SOUNDING EQUIPMENT AND CORRECTIONS TO ECHO SOUNDINGS. Identify by type and serial number all echo-sounding instruments used by each survey vessel. State the type of other sounding equipment used and the general areas and depths in which each was used. Discuss any faults in the equipment which affected the accuracy of sounding.

Summarize the methods used to determine,



NOAA FORM 76-35A

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY

DESCRIPTIVE REPORT
(HYDROGRAPHIC)

Type of Survey Chart Evaluation
Chart No. 11383
Office No N.A.

LOCALITY

State Florida
General Locality Gulf of Mexico
Locality Pensacola Bay.

1976

CHIEF OF PARTY
Cdr J. W. Dropp, Comdg

LIBRARY & ARCHIVES

DATE

FIGURE 4-53. - Descriptive Report cover sheet

evaluate, and apply the following listed corrections to the echo soundings:

1. Velocity of sound through water.
2. Variations in the instrument initial.
3. Other instrument corrections.
4. Corrections determined from direct comparisons (bar checks and vertical casts).
5. Settlement and squat.

If salinity, temperature, depth (STD) sensors; temperature, depth, conductivity (TDC) sensors; or similar instruments were used for velocity determinations, identify each instrument by serial number and provide the most recent dates of calibration or field check.

List the positions of the stations observed for velocity corrections with the date of observation; or prepare letter-size 8½ X 11 in) chartlets showing the locations and dates.

If unusual or unique methods or instruments were necessary for the determination of corrections to echo soundings, describe them in sufficient detail to provide subsequent users of the survey a full understanding of the data. It must be emphasized that sounding corrections be determined and reported in a standard manner (4.9) unless extenuating circumstances arise; extensive analysis of data acquired by nonstandard methods can be extremely time consuming.

When applicable, specify the vessels, areas, depths, and items for which any particular group of corrections are to be applied.

A copy of the Abstracts of Corrections to Echo Soundings should be inserted at the end of the Descriptive Report (4.12.5.4(B)); substantiating field observations, computations, and graphs are included with the field records (See 4.9.)

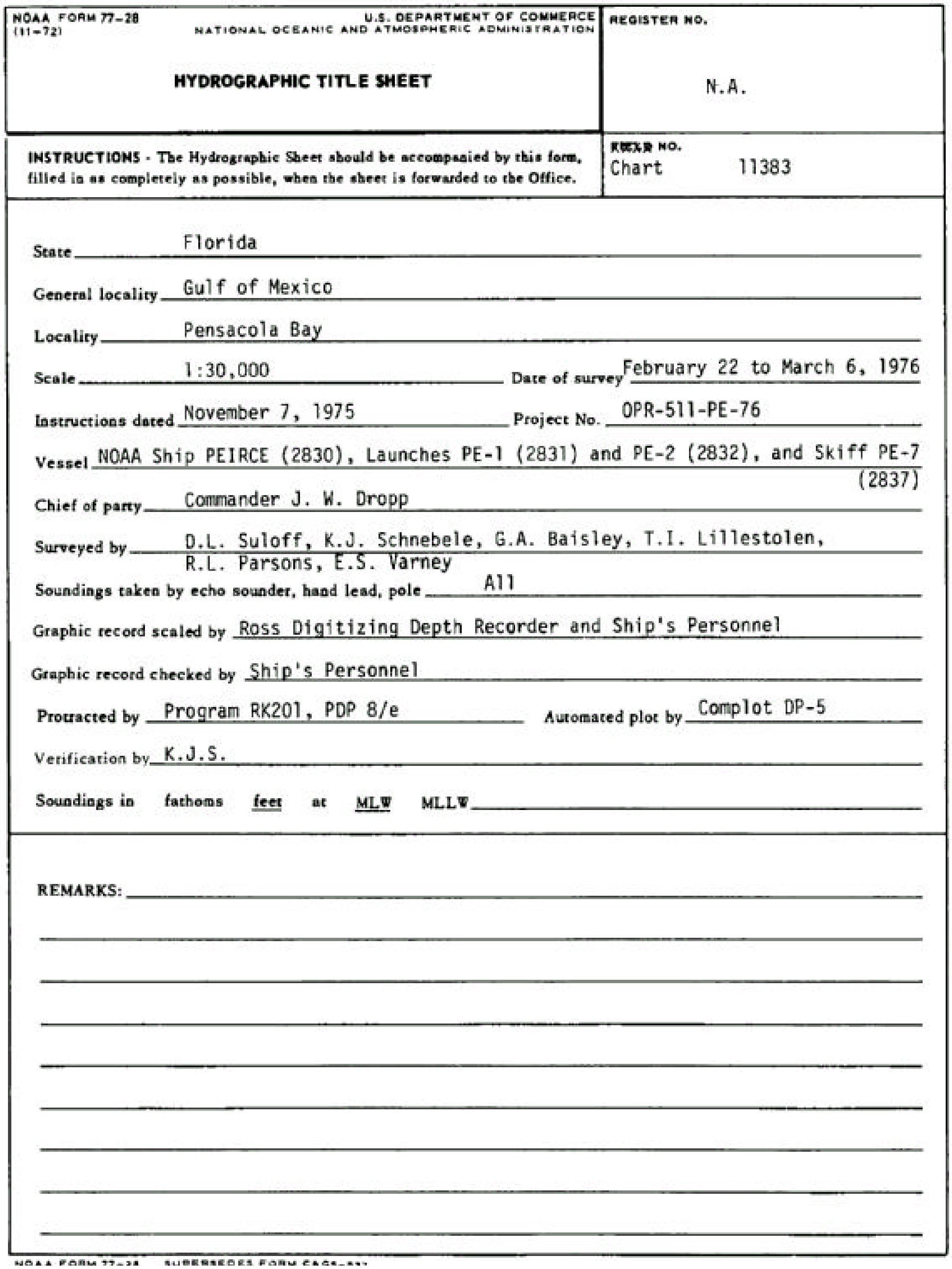
E. SURVEY SHEETS. List all charts, overlays, and blowups and state the scale and area of the sheets. Since no further processing of these sheets will be applied, they must be neatly, clearly, and accurately plotted.

F. CONTROL STATIONS. List the control stations on the sheet that have been monumented and described; state the surveying methods used to establish horizontal positions for hydrographic signals and stations. Define the general areas in which each method was used and indicate the datum used. If a geodetic control report is not available, copies of the appropriate geodetic abstracts; and computations shall be included with the survey records for verification of the positions. Explain in detail:

1. Unconventional survey methods, if used, for determining the positions of horizontal control stations.
2. Anomalies in the control adjustment or in closures and ties.
3. Any known photogrammetric problems that could contribute to position inaccuracies.

Refer to section 4.12.5.4(D) for control listings to be appended to the Descriptive Report.

G. HYDROGRAPHIC POSITION CONTROL. State the method or methods of sounding line position control used for the survey and explain in detail any known difficulties experienced with the control system that may have degraded the expected position accuracy. Electronic control equipment shall



NOAA FORM 77-28
(11-72)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTER NO.
N.A.

HYDROGRAPHIC TITLE SHEET

INSTRUCTIONS - The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

[illegible] NO.
Chart 11383

State Florida

General locality Gulf of Mexico

Locality Pensacola Bay

Scale 1:30,000 Date of survey February 22 to March 6, 1976

Instructions dated November 7, 1975 Project No. OPR-511-PE-76

Vessel NOAA Ship PEIRCE (2830), Launches PE-1 (2831) and PE-2 (2832), and Skiff PE-7 (2837)

Chief of party Commander J. W. Dropp

Surveyed by D.L. Suloff, K.J. Schnebele, G.A. Baisley, T.I. Lillestolen, R.L. Parsons, E.S. Varney

Soundings taken by echo sounder, hand lead, pole All

Graphic record scaled by Ross Digitizing Depth Recorder and Ship's Personnel

Graphic record checked by Ship's Personnel

Protracted by Program RK201, PDP 8/e Automated plot by Complot DP-5

Verification by K.J.S.

Soundings in fathoms [✓ feet] at [✓ MLW] MLLW

REMARKS:

NOAA FORM 77-28 SUPERSEDES FORM C&GS-537

FIGURE 4-54.—Hydrographic Title Sheet

be identified by manufacturer, model, and component serial numbers for each vessel and shore station.

Briefly describe the methods for calibrating the electronic control systems. Evaluate, to the extent possible, the adequacy of the calibration data applied to raw position data throughout the survey area.

Items to be discussed in detail in this section include, but are not limited to:

1. Unusual or unique methods of operating or calibrating electronic positioning equipment.
2. Equipment malfunctions, substandard operation, and probable causes.
3. Unusual atmospheric conditions that may have affected data quality.
4. Weak signals or poor geometric configuration of the control stations.
5. Discovery and treatment of systematic errors in the position data.

A copy of the Abstract of Corrections to Electronic Position Control shall be inserted at the end of the Descriptive Report (4.12.5.4(C)), and the substantiating field observations, computations, and other pertinent data shall be included in the survey records. (See 4.8.)

H. WATERFRONT PLANIMETRY VERIFICATION. Specifically describe shoreline areas that have experienced *significant* modification and reference those survey sheets included which delineate the change. State the methods used in verifying the charted planimetry or acquiring revision data.

I. HARBOR RECONNAISSANCE. State the accomplishment of the investigation of harbor areas with a brief discussion of significant observations.

J. DEFICIENCY INVESTIGATIONS. Each numbered deficiency item that lies within the limits of the survey must be completely discussed. The standard format (see figures 4-55 and 4-56) shall be completed for each item and transmitted with the Descriptive Report. It is important that the form be completely and thoroughly filled out. Most top sections of the form are self-explanatory. The item description should reflect the abbreviated item designation and the source of that item. This information will be specified in the original instruction request or determined locally. For example:

Submerged Pile, PA
Chart Letter 1775 (73)

Visible Wreck, PA
1964 USPS Report

Dangerous Sunken Wrecks
NM 45/64

Dangerous Sunken Wreck, PA
Local Report, Delaware Bay,
Pilots Association

The geodetic position should be completed to show the position of the item as charted and the actual position as surveyed. A specific description of the positioning methods used shall be stated. The method of item investigation is the single most important portion of this form. Confidence in the hydrographer's recommendation is frequently dependent on the detailed description contained within the method of item investigation. For this reason, specific information describing the investigation shall be included. The least depths obtained over submerged features and the baring height of visible hazards shall be listed. Standard techniques employed shall be referenced to the source of that technique (Hydrographic Manual, NOAA Diving Manual, PMC OPORDER, AMC OPORDERS, etc.). Any unique survey method must be specifically described. Conditions of the investigation such as weather, water clarity, time spent, etc., can be important.

Limits of an investigation (area covered, width of a wire sweep, etc.) should be stated. Frequently a sketch can clarify details of an investigation which are otherwise difficult to explain. References to individuals in the area may be pertinent. Charting recommendations must be positive and explicit. Recommendations should include whether or not the item should be charted, and the symbolization to be used. If the hydrographer is unwilling to make a positive statement after an onsite investigation, it is most unlikely that the office cartographer will be able to rely on such a recommendation.

Copies of telegrams or letters that have been submitted recommending immediate changes to the charts and items for inclusion in the Local Notice to Mariners shall be included in the Descriptive Report.

K. CHANNEL AND SHOAL INVESTIGATIONS. Channels and shoals found and investigated during the survey shall be listed. Least depths or clearances for these features must be given. Reference to the appropriate position numbers and development overlays should be made.

CHART # 18661 ITEM # 34

ITEM DESCRIPTION: Submerged Pile, PA

SOURCE: Chart Letter 1775 (73)

INVESTIGATION DATE: 4/7/77 (JD97) TIME: 185OZ-1905Z VESSEL: DA 2

OIC: ENS Kenny

REFERENCES:

Position No.: 7028, 7029 Volume: 3, pg. 27

Velocity TRA Correctors Applied

Predicted Actual Tide Correctors Applied

GEODETIC POSITION	Latitude	Longitude
Charted:	38° 01 ' 05"	121° 30' 50"
Observed:	38° 01' 04.7"	121° 30' 51.7"

POSITION DETERMINED BY:

Sextant and visual observation.

METHOD OF ITEM INVESTIGATION:

The pilings were searched for and found visually. There is a row of pilings approximately 25 feet offshore and extending approximately 100 feet. Fixes were taken on the northernmost and southernmost piles, both of which were awash at the time of observation with the predicted tide 2.0 feet above MLLW. Most piles in between were uncovered approximately 2 feet. The pilings are visible at MLLW but most are covered at MHW.

CHARTING RECOMMENDATION:

Chart "Piles" from 38° 01' 04.7" N, 121° 30' 51.7" W to 38° 01' 06.3" N, 121° 30' 50.6" W.

Delete " Piling" presented charted in the same vicinity.

Compilation Use Only

CHART APPLIED AS

FIGURE 4—55.—Deficiency Item Report

CHART # 11388 ITEM # 7

ITEM DESCRIPTION: Shoal Rep. 1971

SOURCE: LNM 37/71

INVESTIGATION DATE: 3/15/76 (JD75) TIME: 1700Z-1735Z VESSEL: PE 1

OIC: LTJG Dreves

REFERENCES:

Position No.: NA Volume: 1, pg- 20-21

Velocity TRA Correctors Applied

Predicted Actual Tide Correctors Applied

GEODETIC POSITION	Latitude	Longitude
Charted:	30° 22. 5'	86° 30. 4'
Observed:	NA	NA

POSITION DETERMINED BY:

Sextant fixes and visual references to Buoy BW "CB"

METHOD OF ITEM INVESTIGATION:

The area surrounding the charted position of the reported 12-foot shoal was searched for a circle of a 100-meter radius with lines run in 30-meter intervals. General soundings in the area of the shoal were 30 feet and consistent with the gradual inshore shoaling. The fathometer was kept running the entire period of the search with no unusual features. The annotated fathogram is included with survey records. Water clarity allowed bottom visibility to 40 feet and no features or obstructions could be seen.

CHARTING RECOMMENDATION:

The charted "Shoal Rep. 1971" should be removed. Careful search by the hydrographer indicates that such a shoal is not existent. The report undoubtedly was errant in its position with the reporting vessel probably inshore from the reported position.

Compilation Use Only

CHART APPLIED

FIGURE 4-56.—Deficiency Item Report

L. RECONNAISSANCE HYDROGRAPHY. Compare the reconnaissance hydrography with the latest edition of the largest scale chart of the area, identifying the chart by number, edition, and date. State the quality of general agreement between the reconnaissance soundings and the charted depths, and give conclusions or opinions as to the reasons for significant differences.

M. LANDMARK AND NONFLOATING AIDS VERIFICATION. Copies of NOAA Form 76-40, "Report on Nonfloating Aids or Landmarks for Charts," that contain the required information on landmarks within the survey limits that are recommended for charting shall be attached to the Descriptive Report (4.12.5.4(F)). State the accomplishment of this task.

N. AIDS TO NAVIGATION. Reference shall be made to any correspondence with the U.S. Coast Guard regarding the location or establishment of floating aids in the surveyed area. The location and description of each floating aid shall be entered in the hydrographic records. A separate listing of floating aids by geographic position and characteristic need not be entered here. However, a comparison shall be made with data in the latest edition of the *Light List* and with the largest scale chart of the area. The hydrographer shall state the results of this comparison, and indicate whether the aids adequately serve the apparent purpose for which they were established.

List all aids to navigation located during the survey that are not shown in the *Light List*. State their apparent purpose, whether and by whom the aids are maintained, and whether or not such maintenance is seasonal, if known. Give the position and description of each such aid and the date of establishment, if known.

List all bridges and overhead cables not shown on the chart. State bridge and cable clearances measured by the survey party or as determined from other sources. Mention any submarine cables, pipelines, and ferry routes in the area. List the position of each terminal if not shown on contemporary shoreline manuscripts.

O. COAST PILOT INSPECTION. State the accomplishment of this task. Copies of the Coast Pilot report and/or NOAA forms 77-6 should be attached to the Descriptive Report (4.12.5.4(G)).

P. TIDE/WATER LEVEL OBSERVATIONS. Describe the methods used and the results of all comparisons to predicted tides. State the observed or user reported acceptability of predicted tides for this area.

Q. USER EVALUATION. State the results of the user evaluation effort. Carefully describe any recommendations for changes in chart layout, insets, scale, format, color, etc., and provide the justifications for such recommendations.

R. PUBLIC RELATIONS EFFORTS. Generally describe the unit's efforts in the area of public relations. Describe the more successful events and mention particularly cooperative individuals or groups.

S. STATISTICS. List the total number of items investigated, the total number of positions, and nautical miles of sounding lines run by each launch or ship during the survey. A tabulation of statistics for each day is not required. A summary of other survey statistics such as the number of tide comparisons, landmarks added, landmarks deleted, open houses, etc., should also be included.

T. MISCELLANEOUS. Provide information of significant scientific or practical value resulting from the survey which is not covered in previous sections. Where new silted areas are detected, the discussions should include the size of the areas, apparent thickness, and reference to typical depth profiles by date. Unusual submarine features such as abnormally large sand waves, mounds, valleys, and escarpments should be described. Discuss anomolous tidal conditions encountered such as the presence of bores and extremely fast currents not previously reported. If special reports have been submitted on such subjects, refer to them by title, author, and date of preparation or publication.

U. RECOMMENDATIONS. Specific charting recommendations should be included with the individual discrepancy items. Recommendations for new basic hydrography, tides or tidal current surveys, or shoreline updating photography should be stated and justified. Recommendations for future Chart Evaluation Surveys should be included.

V. AUTOMATED DATA PROCESSING. List by program name, number, and version date all routines used for automated data acquisition and processing. If any of the acquisition or processing methods used differ from those described in current NOS manuals or instructions, each difference must be listed and explained, and the data format defined.

W. REFERRAL TO REPORTS. List all reports, records, and forms not included with the survey records or Descriptive Report that have been submitted separately, but which are necessary for a complete evaluation and understanding of the survey record. Give the title and the date on which the report was forwarded.

4.12.5.4. SEPARATES FOLLOWING TEXT. Various tabulations and other information are required on separate sheets which are inserted in the Descriptive Report. Those applicable shall be furnished and inserted in the order listed below.

The first page of the text and the attached inserts shall be numbered consecutively. The approval sheet is always placed last.

A. FIELDTIDE/WATER LEVEL NOTE. A field tide or water level note shall be inserted in the Descriptive Report for each applicable survey. (See figure 5.5.) The note should state:

1. How the tide/water level corrections were derived and the zones or items to which these corrections were applied. (If automated computations for tides corrections to soundings were made based on multigage observations, the program number and gage sites must be given.)

2. The name, geographic locale, latitude, and longitude of each gage.

3. Dates of gage installations and removals, and any problems experienced with gage operations.

4. Staff value equivalent to the zero line on analog tide records. (In the Great Lakes, the elevation of the reference mark (zero electric tape gage or ZETG) on the electric tape gage shall be noted.)

5. Significant differences in comparative observations (AK.2.3), in tide or water level times, or in ranges or unusual fluctuations between adjacent gages.

6. The time meridian used for records annotation.

7. Observations of unusual tidal, water level, or current conditions.

8. A tabulation of missing hourly heights, if any, that may be required for reduction of soundings to the datum of reference.

9. Recommendations, if any, for zoning and time corrections.

B. ABSTRACT OF CORRECTIONS TO ECHO SOUNDINGS. Abstracts, in tabular form, for velocity and other corrections to be applied to the echo soundings shall be included as separate entries in the Descriptive Report. (See figure 5.7.) A similar abstract can be easily constructed for corrections determined solely by bar checks taken throughout the depth range.

The Sounding Correction Abstract shows the dates, times, vessels, and instrument serial numbers to which the corrections apply. If the same corrections apply to more than one survey, a copy of the abstract and applicable correction tables (4.9) are included in the Descriptive Report for each survey.

For substantiating these corrections to soundings, the following supporting material shall be assembled and separately bound or arranged in a cahier and included with the survey data that accompanies the hydrographic sheet and Descriptive Report:

1. Copy of the settlement and squat abstract.

2. Abstracts of bar checks, vertical cast comparisons, and echo sounder phase comparisons.

3. Copies of calibration data for STD, TDC, or other sensors used for velocity determinations.

4. Nansen cast observations.

5. All other basic data, computations, graphics, and material needed to verify the final corrections.

C. ABSTRACTS OF CORRECTIONS TO ELECTRONIC POSITION CONTROL. When all or any portion of the hydrographic survey is controlled by an electronic positioning system or by distance measuring equipment, an abstract of corrections to be applied to the observed data shall be compiled and inserted into the Descriptive Report. (See figure 5-8.) Supporting data shall be assembled and separately bound or arranged in a cahier and included with the survey data that accompanies the hydrographic field sheet and Descriptive Report. (See 4.8.)

D. LIST OF STATIONS. A numerical list of stations used for controlling the hydrographic survey shall be included as a separate sheet and inserted in the Descriptive Report. (See figure 5-9.) The following information shall be given for each station:

1. Station number (001-999).

2. Latitude (to nearest thousandth of a second).

3. Longitude (to nearest thousandth of a second).

4. Name and type of station (3.1), that is:

(a) Basic or supplemental (include year of establishment).

(b) Photogrammetric or hydrographic.

5. Source; that is, volume and page number for published geodetic control or, if new, a reference to abstracts of field observations.

E. ABSTRACT OF POSITIONS. The Abstract of Positions shall be assembled for each hydrographic survey vessel that worked on the field sheet. (See figure 5-10.) Each vessel is identified by its data-processing number, and the work accomplished is listed by Julian dates, inclusive position numbers, control codes, and electronic control station numbers.

F. REPORT ON LANDMARKS AND NONFLOATING AIDS TO NAVIGATION. NOAA Forms 76-40, "Report on Nonfloating Aids or Landmarks for Charts," shall be prepared as required herein and copies attached to the Descriptive Report. Separate forms 76-40 are submitted for:

1. Landmarks to be charted.
2. Landmarks to be deleted.
3. Nonfloating aids to navigation.

The hydrographer shall evaluate all charted landmarks from seaward to determine which are adequate and most suitable for the purpose intended and to determine which charted landmarks no longer exist and thus should be deleted from the charts. If there are more prominent objects in the area which would serve as better landmarks, their positions shall be determined and listed among the landmarks to be charted.

Reports on landmarks must be complete within themselves. Avoid additional references to geodetic, photogrammetric, or other data not readily available to other users. The report shall state positively whether or not a seaward inspection has been made to evaluate the landmarks. If the reports have been assembled without the benefit of a seaward inspection, the reason for omission shall be fully explained.

Objects of special importance or extraordinary prominence are indicated by an asterisk (*) preceding the name of the object. When selecting objects of special importance, the total area and chart coverage must be carefully considered. Flagstaffs, flagpoles, and other structures of a temporary nature are not listed as landmarks unless they are of a very permanent and prominent nature and there are no other suitable objects in the area. Recommended charting names should be short, general, and shown in capital letters (5.5.1.2). If the object was used as a hydrographic signal, a note is made to this effect and the station number indicated.

When a large number of landmarks are reported, or the hydrographer or field editor considers it necessary to clarify the tabulated data, a copy of the chart of the area should be cut into letter-size sections, appropriately annotated, and submitted with the copies of NOAA form 76-40. (See figures 5-11 and 5-12.) The area inspected is outlined on these chart sections and a recommendation made for each charted or plotted landmark within the outlined area.

If chart sections are submitted, separate forms for landmarks to be deleted need not be prepared. The following procedures are used:

1. New landmarks shall be plotted and identified by the landmark symbol (A) together with the name recommended for charting. The geographic datum of the chart must be known and considered in the plotting.

2. Charted landmarks recommended for continuance are checkmarked (A). If the position has been verified in the field, the word "verified" is entered beside the checkmark.

3. Charted landmarks recommended for deletion shall be indicated by an X in a circle (A), the word "delete" entered, and the reason for the recommendation given.

Names and notations on these chart sections shall be typed or lettered legibly in red ink. Care must be taken that such notations always appear on the same section of the chart section as the landmarks to which they refer.

A separate NOAA Form 76-40, "Nonfloating Aids or Landmarks for Charts," shall be used to report the positions of all nonfloating aids to navigation on a chart-by-chart basis. The geographic positions of all nonfloating aids, including privately maintained lights and beacons, shall be verified or determined in the field. Applicable parts of the requirements stated for form 76-40 shall be followed in compiling this report. If contemporary shoreline mapping of the area has been undertaken, copies of form 76-40 for new aids or aids to be deleted shall be sent to the Photogrammetry Division, OA/C34; otherwise, the forms are sent to the Marine Chart Division, OA/C32. For additional details concerning landmarks and aids to navigation see:

"Photogrammetry Instructions No. 64, Requirements and Procedures for Collecting, Processing, and Routing Landmarks and Aids to Navigation Data–Photogrammetric Operations" (National Ocean Survey 1971*b*).

It is important that the names of the aids entered on the form be identical with those given in the *Light List* and that the *Light List* number be given. The position of each aid should be plotted on the largest scale chart of the area and compared with the charted position. Significant differences shall be reported to the U.S. Coast Guard District Headquarters and to NOS Headquarters through the appropriate Marine Center.

G. COAST PILOT REPORTS. The Coast Pilot Report and/or copies of **NOAA** form 77-6 shall be completed and attached as a separate. Any supporting documentation should be attached to the appropriate item report.

H. DISCREPANCY ITEM REPORTS. The report forms for discrepancy items shall be completed and attached as a separate. Supportive documentation of page size should be attached to the appropriate item report. Larger documentation should be included with the other survey records and appropriate reference made in the item report.

I. ABSTRACT OF DOCUMENTATION. All sources of information pertinent to the survey should be considered part of the survey and transmitted with other supportive data.

J. APPROVAL SHEET. The Chief of Party shall furnish, on a separate sheet attached to the Descriptive Report, a signed statement of approval of the field sheet and all accompanying records. Include a statement concerning the amount and degree of personal supervision of the field work and frequency with which he examined the field sheet and other records. State whether the survey is complete and adequate or if additional field work is recommended. Cite additional information or references that may be of assistance for verifying and reviewing the survey.

4.13. SPECIAL SURVEYS

4.13.1 Track Line Surveys

National Ocean Survey vessels occasionally conduct track line surveys on extended voyages from port to project areas for bathymetric mapping or for other research projects. Track line surveys are merely continuous records of sounding data gathered while sailing along assigned lines (e.g., International Hydrographic Bureau 1974). Track lines are normally required only when there is a specific need for the data, and are controlled using the most accurate positioning system available to the vessel. LORAN-C ground wave positions provide the minimum accuracy desired. If accurate long range navigation equipment is not available, other standard methods, with some refinements, may be used to follow and control the line. Because the requirements for each track line survey are unique, the following discussion is limited to generalities.

Track line surveys are plotted either on Ocean Survey Sheets (OSS series) or on U.S. Navy Bathymetric Charts (to be specified in the project instructions). Limits of the OSS series were designed to conform closely to the U.S. Navy Bathymetric series. The OSS, however, are twice the scale of the U.S.N. Bathymetric Charts.

Thirty OSS are used to span the area from latitude 0°30'S to 72°30'N. The sheets are turned 180° for use in southern latitudes. The Mercator Projection is used for these sheets; the sheets between the Equator and the 65th parallel are at a scale of 8 in = 1° longitude, and the sheets to the north thereof are at a scale of 4 in = 1° longitude. The scale 8 in = 1° longitude causes the natural scale to vary from approximately 1:548,000 at the Equator to 1:232,000 at the 65th parallel. Projections are ruled at 30-min intervals with 1-min graduations on the central and outer latitude and longitude lines of the sheet. The larger scale sheets cover 5° longitude sectors with the smaller scale sheets covering 7.5° sectors. Each sheet overlaps each adjoining sheet by 30 min of latitude and 15 min of longitude. Natural scales and a sheet index are shown on the margins. OSS series projections on paper and Stable base polyester drafting film can be ordered from the Marine Centers.

Stamp 30 (figure 4-57) shall be impressed on the lower right-hand corner of each OSS and all applicable entries made as follows:

Opposite "Registry no.," enter the registry number if assigned. Otherwise, enter the survey project number.

Opposite "BC index no.," enter the U.S. Navy Bathymetric Chart series number from the series index and identify the quadrant in which the OSS lies (figure 4-58).

Opposite "Field number," enter the field

TABLE 4-16.– *Ocean Survey Sheets (OSS) series numbers and limits*

OSS-1	00°30'S to 03°30'N
OSS-2	03°00'N to 07°00'N
OSS-3	06°30'N to 10°30'N
OSS-4	10°00'N to 14°00'N
OSS-5	13°30'N to 17°30'N
OSS-6	17°00'N to 20°30'N
OSS-7	20°00'N to 23°30'N
OSS-8	23°00'N to 26°30'N
OSS-9	26°00'N to 29°30'N
OSS-10	29°00'N to 32°30'N
OSS-11	32°00'N to 35°30'N
OSS-12	35°00'N to 38°00'N
OSS-13	37°30'N to 40°30'N
OSS-14	40°00'N to 43°00'N
OSS-15	42°30'N to 45°30'N
OSS-16	45°00'N to 47°30'N
OSS-17	47°00'N to 49°30'N
OSS-18	49°00'N to 51°30'N
OSS-19	51°00'N to 53°30'N
OSS-20	53°00'N to 55°00'N
OSS-21	54°30'N to 56°30'N
OSS-22	56°00'N to 58°00'N
OSS-23	57°30'N to 59°30'N
OSS-24	59°00'N to 61°00'N
OSS-25	60°30'N to 62°30'N
OSS-26	62°00'N to 63°30'N
OSS-27	63°00'N to 64°30'N
OSS-28*	64°00'N to 67°30'N
OSS-29	67°00'N to 70°30'N
OSS-30	70°00'N to 72°30'N

* Sheets 28 through 30 are at a scale where 1° of longitude equals 4 in.

number as a two-letter vessel identifier, the scale at the central latitude of the sheet (1:519,000 as 519), the sequential sheet number for the project, and the last two digits of the calendar year.

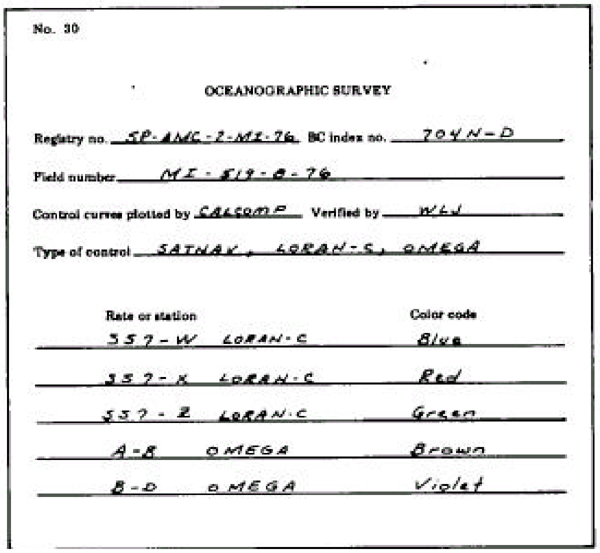
Opposite "Control curves plotted by," enter the method or type of automatic plotter used to draw line of position arcs on the sheet.

Opposite "Type of control," enter the primary control system in upper case letters and auxiliary or supplemental systems in lower case letters.

Opposite "Rate or station," enter all navigational rates and stations used for lines of position on the sheet with the colors used to draw the corresponding arcs.

When using U.S. Navy Bathymetric Charts for track line surveys, the recorded soundings are generally not plotted in the field. Processing requirements and data disposal for track line surveys will be included in the project instructions.

Positions are taken and recorded hourly and when significant changes in the course or speed of the vessel are made. Distance log or revolution counter readings and ship's courses shall be recorded with the fix data.



No. 30

OCEANOGRAPHIC SURVEY

Registry no. SP-AMC-2-MI-76 BC index no. 704N-D

Field number MI-519-8-76

Control curves plotted by CALCOMP Verified by WLJ

Type of control SATNAV, LORAN-C, OMEGA

Rate or station	Color code
557-W LORAN-C	Blue
557-X LORAN-C	Red
557-Z LORAN-C	Green
A-B OMEGA	Brown
B-D OMEGA	Violet

FIGURE 4-57. — Enlargement of rubber stamp 30, oceanographic survey sheet data stamp

Soundings are logged at intervals not to exceed 5 min in depths over 100 fm and at intervals not to exceed 2 min in depths under 100 fm. In addition, depths of all intermediate peaks and deeps

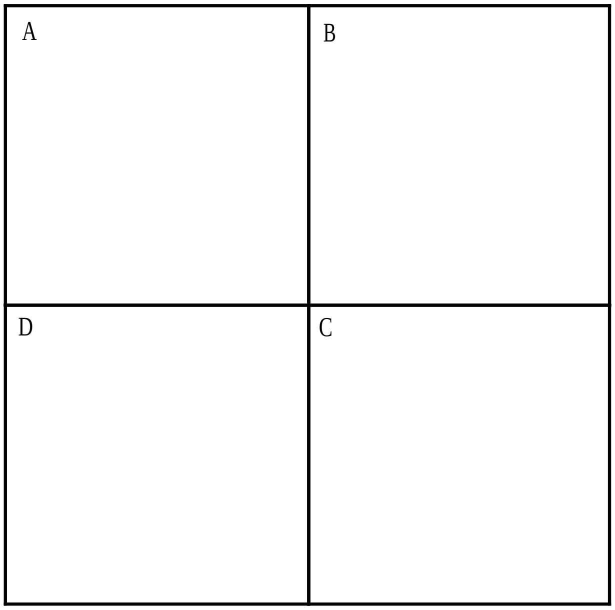


FIGURE 4-58. — Subdivision of a U.S. Navy Bathymetric Plotting Sheet into four Ocean Survey Sheets (OSS) and letter identifications

shall be recorded—times of occurrence are entered to the nearest minute. All soundings shall be logged to the closest 1 fm, even in areas of indistinct returns. Unless specified otherwise in the project instructions, velocity corrections are applied from applicable historical tables as the soundings are taken.

All position data for track line surveys shall be recorded on **NOAA** Form 77-15, "Dead Reckoning Abstract," and on magnetic or punched paper tape, depending on the vessel's capability. Positions are identified by sequential serial numbers followed by a cruise letter. Cruise letters begin with the letter "A" at the beginning of each calendar year and progress through the alphabet— letters "I" and "O" are not used. Serial numbers are reset to 1 at the beginning of each cruise. Bottom cores, bathythermograph profiles, and similar events shall also be assigned serial numbers and be recorded on **NOAA** Form 77-2, "Marine Operations Log."

Shore ties must be made at the beginning and ending of every track line by accurately fixing the vessel's position with reference to fixed objects of known position. Three-point fixes with check angles, cross bearings, or radar ranges are acceptable for shore ties, in that order of preference.

Frequent checks on the depth recorder shall be made to ensure that the recorded soundings are on the proper scale. For example, a sounding check should be made when recording on the 4000-fm range to ensure that the correct 400-fm scale is being used. Position numbers are assigned when simultaneous comparisons of soundings are made; all graphic records and tabulated data for these comparisons shall be included as part of the permanent survey data.

Analog depth records shall be removed from the depth recorder each time a plotter sheet has been completed or the sounding line continues on to a new sheet. The following notations shall be made in addition to the record stamps routinely required: beginning position number and its GMT, the last position number and its GMT, and the general direction of the sounding line (N S), (W E).

Commanding officers may be authorized by the appropriate Marine Center to develop one seamount per track line, if encountered, provided control is consistent and geometrically strong — two seamounts may be authorized when engaged on other ocean surveys. Developments should be complete to the extent necessary to determine that the feature is a seamount. The officially accepted definition of a seamount is "an elevation of the sea floor having a nearly equidimensional plane less than 60 nautical miles across the summit" (Bruder 1963). Significant uncharted features discovered during track line surveys shall be reported immediately to the director of the vessel's Marine Center who in turn shall inform NOS Headquarters. Significant features include uncharted seamounts, submarine valleys, and other similar physiographic phenomena. Reports should include the general characteristics, the approximate size, and the geographic location of the feature.

4.13.1.1. ASTRONOMIC OBSERVATIONS. When other control is not available, astronomic sights are used to position vessels on track or cruise lines. Observations are similar to those used for routine surface navigation, except that sights are taken with greater precision and care and are computed and plotted more accurately. Observation and computation procedures and the use of astronomic sights are described in "American Practical Navigator, an Epitome of Navigation" (Bowditch 1962); *Dutton's Navigation and Nautical Astronomy* (Beito 1957); and *Dutton's Navigation and Piloting* (Dunlap and Shufeldt 1969) and are not repeated here. The information contained herein is limited to the refinements for observations and the best methods of using the data. There is no **NOAA** form for computations with *H.O. Pub.* No. 229, "Sight Reduction Tables for Marine Navigation" (U.S. Naval Oceanographic Office 1970). For attaining required precision, computations are made to the nearest 0.1 s of time and to the nearest 0.1 min of arc. Each computation must be checked and the sheets bound in chronological order for shipment to **NOS** Headquarters with the survey records. Smooth copies of the computations are not required.

Astronomic observations should be made with navigation sextants read to the nearest 10 s—the time of each observation is recorded to the nearest 0.2 s using an accurate stopwatch. The stopwatch must be compared with an accurate chronometer or with another acceptable time standard such as **WWV**, National Bureau of Standards (Fort Collins, Colorado) radio station, before and after the observations. **WWV** and **WWVH** (Maui, Hawaii) broadcast continuous time signals on the frequencies 2.5, 5, 10, 15, 20, and 25 MHz. When sea and sky conditions permit, each observer makes a series of six measurements to each star or other body to be used for the position. A recorder should be assigned to each observer.

Log readings or revolution counter readings are recorded at 10-min intervals during morning and evening star sight observations. Star sights, when taken underway, must be advanced (run up) or retired (run back) to a selected dead-reckoning position.

Each star sight is used independently to determine the probable position of the ship. The results may be compared and weighted, if necessary, for the final position. Observations taken by different observers with different sextants or at different times of the day should never be combined to determine a probable position. Each observer's sights should be plotted on separate sheets of paper. The dead-reckoning position, the final position of the ship, and the lines of position (after being run up or run back) are inked. The name of each star observed and its direction are indicated alongside each line of position. Observed lines of position and the distance and direction each was run up or back are left in pencil. The final position is then transferred to the plotting sheet. If one observer obtained the astronomic position, the final plot may be made directly on the plotting sheet. (See 4.13.1.)

Several factors influence the accuracy of astronomic observations. A change of 1 min in altitude moves the line of position 1 nmi. At the Equator, the altitude of a celestial body on the prime vertical changes 1 min of arc in 4 s of time. For other latitudes and azimuths, the error in position caused by an error in time is less and varies with the cosine of the latitude and the sine of the azimuth. Greater errors in astronomic sights on celestial bodies are more likely in an east or west direction than in a north or south direction—an error in time affects the line of position proportionately more because the bodies change faster in altitude and make accurate observations more difficult. A distinct and clear horizon is essential for accurate observations. Evening star sights are made as early as possible, and morning sights as late as possible to assure a well-illuminated horizon. At the time of observation, each observer should rate each set of sights as "excellent," "good," "fair," or "poor." Ratings should be based on these factors:

1. Relative distinctness of the horizon below each star observed.

2. Disturbing effects of the roll and pitch of the vessel.

3. Direction of the wind and whether it is blowing into the observer's eyes.

4. Rate of change in altitude of the star.

5. Relative distinctness of stars of different magnitudes.

When selected stars are arranged symmetrically and are at approximately the same altitude, some observational errors will be partly eliminated in the final plot. Accidental errors of observation are not eliminated by a systematic arrangement. Official observations should be made only by experienced personnel able to obtain consistently good results.

For best results, celestial bodies to be observed should be selected so that lines of position will plot in a symmetrical quadrilateral. When more than four stars are observed, it is preferable to combine lines of position to a resultant rectangular figure of error with sides roughly north-south and east-west. The stars should be of about the same magnitude and about the same altitude. Observations on bodies at altitudes between 15° and 20° usually give the best results, but altitudes between 10° and 35° may be considered satisfactory.

Because of observational errors, the lines of position (corrected for the run of the ship between sights) normally will not intersect at a point. Three lines of position generally form a triangle of error. The probable position of the vessel derived from a series of morning or evening star sights is based on the assumption that there is an error common to all sights—approximately equal in magnitude and in the same direction with respect to the stars observed. It is not especially necessary that the magnitude of this error be small, but for best results it must be symmetrical. When determining the most probable position of the ship, the directions of the observed bodies must always be considered. For unweighted observations, the probable position should be equidistant from the lines of position and lie either toward or away from each star of the series—never away from some and toward others.

Two methods are used to find the most probable position; when a series of more than three sights is observed, a combination of methods is used. The first method is to move each line of position either away from or toward the objects observed by an equal distance to bring them as close as possible to a common intersection. (See A and C in figure 4-59.) In practice, the lines of position need not actually be moved; the probable position is determined by using dividers and visualizing the transfer of the line of position. Be certain to adopt a position on the correct side of each line of position considered (i.e., the position must lie either toward or away from each star of the series).

The second method is to draw bisectrices between intersecting lines of position. Each bisectrix is drawn so that it is either toward or away from the two objects observed. In the triangle of error formed by three lines of position, the three bisectrices intersect at a point, as shown in figure 4—59(B). For four lines of position from stars in four directions, two bisectrices are drawn—each between two opposite lines of position as shown in figure 4—59(D). Where two opposite lines of position are from stars in the same direction, a mean line should first be drawn between them. This mean line and the other two lines are treated as three lines and the bisectrices drawn as in figure 4—59(B).

When more than four stars are observed in one series, the lines of position in the same general direction should be combined to reduce the data to not more than four lines of position. Assuming all observations to be of equal weight, the lines of position from two stars in the same general direction should be combined by drawing the bisectrix between them. From the figure of error thus formed, the most probable position is determined as described. (See figure 4-59(E).)

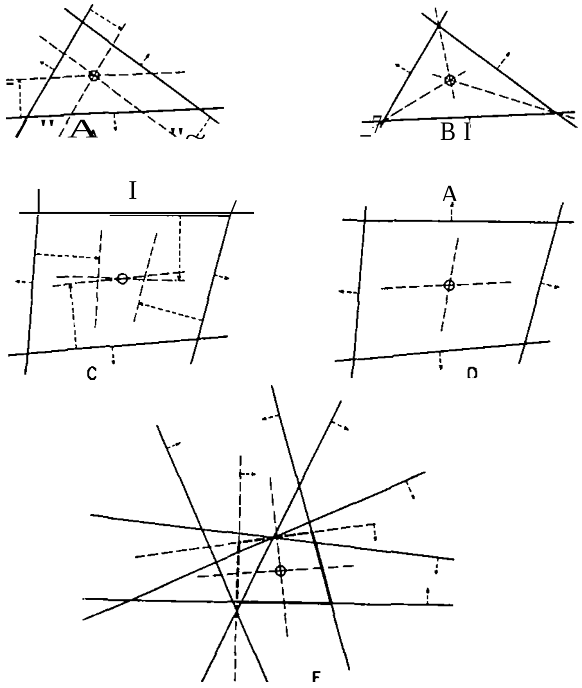


FIGURE 4–59. — Probable position of a ship from astronomic observations

When possible, observations should be made on the Sun at least five times a day. The first and last observations are made when the altitude of the Sun is between 12° and 25° the noon sight should be taken at local apparent noon, and the other two approximately halfway between the noon sight and the early morning and late afternoon sights. A meridian altitude sight should be taken independently by two or more observers. Individual Sun sights are not run up in the final plot, but are used as separate lines of position at the times of observation to which the track line, as a whole, is adjusted.

4.13.1.2. DEAD RECKONING. This is navigation by account, or reckoning, from the last known position (i.e., the position of a vessel at any instant is determined by applying the course steered and distance traveled from the last known well-determined position). Dead-reckoning is used to plot track or cruise lines between observed positions and to substantiate other position data. When electronic positioning systems fail and weather conditions do not permit celestial fixes, dead reckoning must be used.

Dead reckoning positions are not precise—positional uncertainty increases proportionally with the distance run from the last fixed position. Errors may be introduced in a number of ways. Those factors affecting the course include steering errors, incorrect allowance for compass error, leeway, and the effects of currents; those affecting distance traveled are inaccurate distance logs, unknown log factors, and incorrect allowance for current.

To attain greater accuracy, one applies several refinements when determining hydrographic positions by dead reckoning. Engine speeds should be maintained at a constant rate. Although the value of constant speed is reduced when the vessel must be stopped for other observations, maintaining constant speed is helpful when reconciling track line plots between fixed positions. Vessels should be equipped with accurate submerged electric logs. Revolution counters are read and the values recorded at each fixed position; these readings may be useful if a distance log fails to function properly. Courses must be steered very closely—within 1° if possible. Only the most competent helmsmen should steer the vessel when automatic steering is not used. Officers on watch must check the course being steered at frequent intervals. All compass errors must be determined accurately.

A complete record of events must be recorded on **NOAA** Form 77-15, "Dead Reckoning Abstract," as the line is run. All control data to be used in plotting and adjusting the dead reckoning line should be entered in this abstract. Each event must be recorded promptly and correctly and referenced to time. Data shown on the abstracts, the line-of-position computations, and the astronomic sights may all be used to make final adjustments of the plot.

Dead-reckoning positions are most accurate when operating in dead calm seas; however, this condition seldom exists. Trials should be made to determine the effects of leeway caused by winds of different velocities from various angles to the ship's heading. Graphs can be prepared from these data to be used when estimating course changes to compensate for leeway.

Allowances must also be made for the set and drift of the current. In addition to oceanic currents, persistent winds generate surface currents. Estimates of wind-driven currents may be based on the following:

1. Observations have shown that persistent winds set up wind-driven surface currents with velocities equal to approximately 2% of that of the wind in both coastal areas and the open ocean.

2. The direction of wind-driven currents in the Northern Hemisphere is about 20° to the right of the wind in coastal areas; theoretically, this deflection is probably closer to 40° to the right of the wind in the open ocean. Coastal wind-driven currents do not always follow this rule— specially when near the shore where the current direction depends primarily on the angle between the wind direction and the coastline.

Dead-reckoning positions should be corrected for all known factors affecting course and distance before they are plotted. Differences between dead-reckoning positions and positions determined by other methods are termed dead-reckoning closures. These differences are adjusted by distributing the errors proportionally with times between fixed positions. Adjustments are not always linear because Sun sights, electronic lines of position, or other recorded data must be considered and evaluated. Supplemental data obviously in error should be rejected. Soundings along the track often have to be compared with charted soundings for additional guidance when making the final adjustment.

4.13.2. Tag Line Surveys

When detailed surveys of important docks, anchorages, or restricted areas are needed, "tag line" surveys often prove to be the most efficient and accurate method. Depending upon the required line spacing and sounding interval, a special scale is selected that allows each sounding to be shown. For guidance, a scale of 1 in = 100 ft is generally adequate for sounding lines spaced 25 ft apart with soundings taken at intervals of 25 ft along the lines.

The following example is but one of many different methods that can be used to execute a satisfactory tag line survey:

1. A diagram of the area to be surveyed is prepared at the selected scale (figure 4–60); proposed sounding lines P, Q,..., U are plotted on the diagram.

2. Base line *A*, *B*,.... is plotted on the diagram. *A* and *B* may be existing control stations or new stations located by sextant fixes or other methods of equivalent accuracy.

3. Intersections of proposed sounding line extensions with the base line are laid out on the ground, temporarily marked, and for identification purposes assigned a letter or number. The diagram may be used later as a base for the final sounding plot.

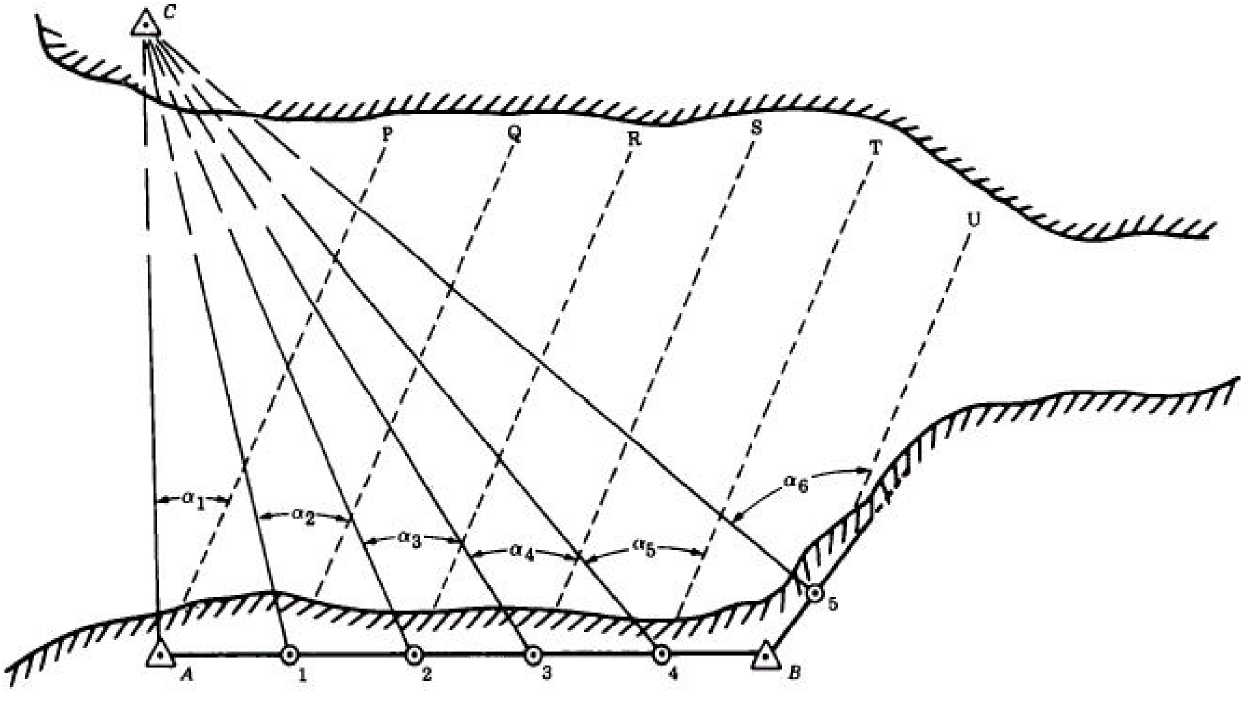
4. Point *C* is a distant control station used for azimuth control if the base line is too short for an accurate initial azimuth.

5. A sextant and lead line or echo sounder are used aboard a light skiff powered by a low horsepower outboard motor. The only special equipment needed is a sturdy metal reel large enough to hold the necessary length of small wire that will be used to measure the distances from the base line. The reel should be equipped with a strong brake and a geared crank for winding in the wire at the end of each sounding line. The tag line should be made of 3/32-in pliable stranded wire. Readily identifiable marks are attached to the wire at 100-ft intervals using crimp-type electrical splicers. Colored cloth is inserted between the wire strands to mark intervals of 25 ft.

6. An observer stands on each point along the base line (*A*, 1, 2,..., 5) as the survey progresses, and using a sextant sets the angles a_1, a_2,...., a_5 from azimuth station *C* to the azimuth of the sounding line. The observer then indicates to the skiff by prearranged signal its position relative to the proposed sounding line; he may also select a range object in the background to keep the skiff on line.

7. The zero end of the tag line is secured at the proper point on the base line and the reel manned by an operator aboard the skiff. The skiff is run slowly in reverse and the tag line played out over the bow. By braking the reel as each sounding interval mark appears, the skiff is stopped at the proper distance.

8. The coxswain maintains the proper tension on the tag line and maneuvers the skiff onto the sounding line as directed by the observer ashore. The leadsman takes a sounding when signaled by the observer—the recorder enters the appropriate sounding time, sounding, tag line distance, and line number in the records.



• FIGURE 4–60.—Layout of a tag line survey •

5. FIELD REPORTS

5.1. PERIODIC ADMINISTRATIVE REPORTS

Periodic reports are required from the field to keep **NOAA** and **NOS** management informed of the general activities, status, progress, and accomplishments of all hydrographic survey units. The following periodic reports shall be submitted in accordance with the indicated citations and related references:

1. Season's Report from the National Ocean Survey (1971*a*) "Operations Manual" *(NOS Manual* No. 1, chapter 77, section 61).
2. Cruise Report from the National Oceanic and Atmospheric Administration (1972) "NOAA Circular 72-134" *(NOAA Directives Manual*, chapter 17, section 17).
3. Special Report from the National Ocean Survey (1971*a*) "Operations Manual" *(NOS Manual* No. 1, chapter 77, section 63).
4. Monthly Ship Accomplishment Report from the National Ocean Survey (1971*a*) "Operations Manual" (*NOS Manual* No. 1, chapter 77, section 64). See also sections 5.1.1 and 5.1.2 for progress sketch requirements.

In addition to these reports, each Chief of Party shall compile and submit a Monthly Activities Report and a Monthly Survey Status Report in accordance with the appropriate Marine Center directives, that is:

The Atlantic Marine Center *OPORDERS* (1975-1980); and

The Pacific Marine Center (1974) *OPORDER.*

5.1.1. Monthly Progress Sketch

Vessels conducting hydrographic, tidal current, wire drag, or ocean investigation surveys shall submit a Monthly Progress Sketch for each project worked on during the month. The sketch shall be sent with a transmittal letter to the appropriate Marine Center as soon as possible after the end of the month. Vessels engaged only in oceanographic research and development projects or other projects of a special nature need submit only one progress sketch upon completion of each project or segment of a continuing project that has been completed during any one calendar year unless specified otherwise in the project instructions.

Progress sketches shall be drawn on a durable transparent drafting material that permits easy reproduction. Only black ink should be used. The sketch and title must be neat and legible.

The scale to be used is generally stated in the project instructions; if not, the scale should be that of the published chart which covers the entire work area of the season. Dimensions of the sketch should not be larger than needed to show the work accomplished during the reporting season.

Each progress sketch shall contain a title and legend giving the following information:

Type of survey;
General locale;
Scale of sketch;
Project number;
Inclusive dates of survey;
Name of vessel or party; and
Name of Chief of Party.

Scales may be given as ratios or by referring to a chart from which the projection has been traced. A labeled projection with sufficient shoreline and geographic names shall be shown on the sketch for easy identification of the general locale. Progress for all types of work accomplished should be added at the end of each month. The information should be generalized, using standard symbols as shown in figure 5-1. The principal objective is to report areas surveyed in such a way that information can be transferred quickly and easily to the progress charts maintained at the Marine Centers and at Headquarters. (See figure 5-2.)

Sheet limits are shown and identified on progress sketches as survey sheets are started and registry numbers assigned (2.4.3.2); if this information would create congestion and confusion, the sheet layout should be submitted on an accompanying transparent overlay.

Symbols shown in the upper portion of fig-

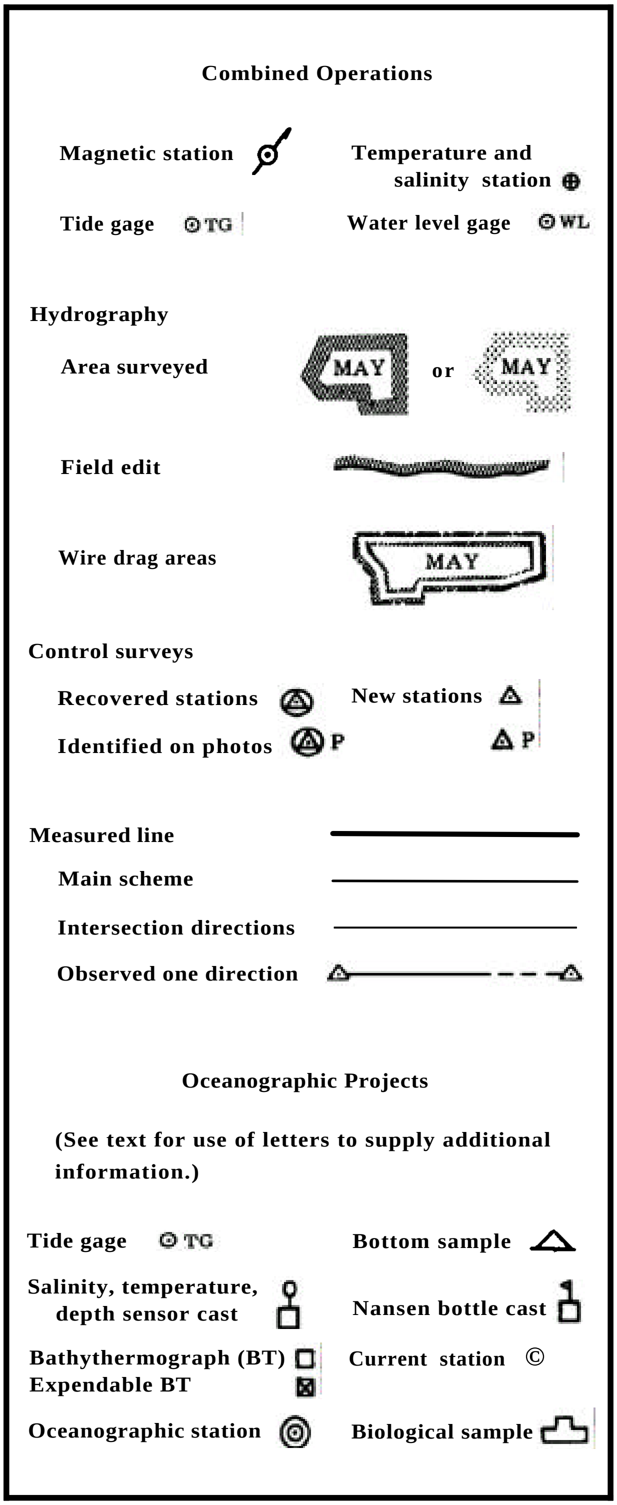


FIGURE 5-1-Symbols to be used for drawing progress sketches

ure 5-1 are used to report progress on hydrographic and combined operations projects. Different symbols shall be used to distinguish between hydrography accomplished in consecutive months. Additional symbols may be used as necessary to report other accomplishments, but such symbols must be explained in a legend. Oceanographic observations made as part of a combined operations survey are shown on the same sketch. Unless specified in the project instructions, horizontal control accomplishments are not shown on a monthly basis. (See 5.1.2.)

Vessels assigned to oceanographic projects shall use the symbols shown in the lower part of figure 5-1 to report progress. The symbol for Nansen casts or the equivalent is supplemented by letters and numbers to identify the water samples retained. An oceanographic station occupied for the determination of salinity shall be identified by the letter S, for oxygen by the letter O, for phosphate by the letter P, and for nitrates by the letter N. Sample bottle serial numbers are shown also (e.g., S 105-121 indicates that salinity samples numbered inclusively from 105 to 121 were obtained at that station).

Each bottom sample retained for analysis shall be numbered consecutively and the method used to obtain the sample indicated on the sketch as C for core; S, snapper cup; SF, scoopfish; and D, dredge. Dashed lines are used to show dredging routes.

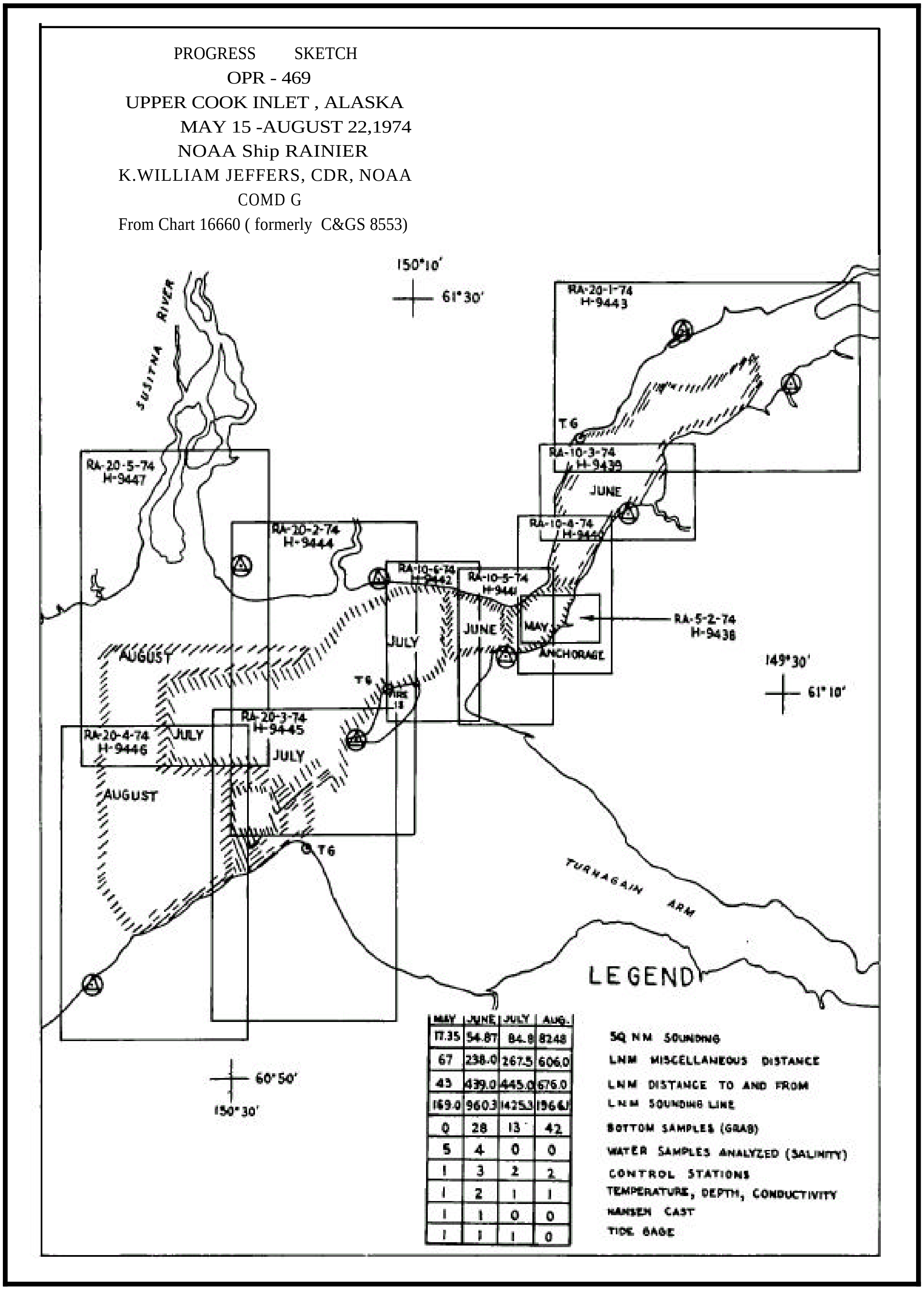
Station numbers are shown beside current station symbols and the methods of current measurements indicated by letters such as A for Aanderaa System, G for Grundy System and D for droque tracking.

In addition to the graphic data, a table of statistics showing a numerical listing of the monthly accomplishments shall be included on the sketch. A new Monthly Progress Sketch is prepared at the beginning of each calendar year for each project assigned to the hydrographic party.

5.1.2. Season's Progress Sketch

For each project, a Season's Progress Sketch shall be prepared on a transparent durable material, using the same guidelines stated for the Monthly Progress Sketch, and be submitted with the Season's Report. The information shown on the Season's Progress Sketch is a summation of all progress shown on the monthly sketches. A page-size reproduction of the final Monthly Progress Sketch may be used.

The title shall state "Progress Sketch To Accompany Season's Report" and include the date on



PROGRESS SKETCH
OPR - 469
UPPER COOK INLET , ALASKA
MAY 15 -AUGUST 22,1974
NOAA Ship RAINIER
K.WILLIAM JEFFERS, CDR, NOAA
COMD G
From Chart 16660 (formerly C&GS 8553)

LEGEND

MAY	JUNE	JULY	AUG.	
17.35	54.87	84.8	8248	SQ NM SOUNDING
67	238.0	267.5	606.0	LNM MISCELLANEOUS DISTANCE
43	439.0	445.0	676.0	LNM DISTANCE TO AND FROM
169.0	960.3	1425.3	1966.1	LNM SOUNDING LINE
0	28	13	42	BOTTOM SAMPLES (GRAB)
5	4	0	0	WATER SAMPLES ANALYZED (SALINITY)
1	3	2	2	CONTROL STATIONS
1	2	1	1	TEMPERATURE, DEPTH, CONDUCTIVITY
1	1	0	0	HANSEN CAST
1	1	1	0	TIDE GAGE

FIGURE 5-2. —Monthly Progress Sketch

which field work was closed in addition to the information shown in the title of the Monthly Progress Sketch.

Recoverable control stations established by the hydrographic party (3.1.1) are shown on a separate sketch that is then attached to the Season's Report. This sketch shall be prepared in accordance with instructions on pages 191 and 192 of *Coast and Geodetic Survey Special Publication* No. 247, "Manual of Geodetic Triangulation" (Gossett 1959), using the symbols shown in figure 5- 1.

5.2. PHOTOGRAMMETRIC PRECOMPILATION FIELD REPORTS

These shall be prepared to describe photogrammetric field operations conducted prior to the compilation of coastal maps and shoreline manuscripts. Supporting operations of this nature include recovering or establishing horizontal control stations and placing targets on the stations prior to aerial photography. Observing and reporting tidal stages in support of tide-coordinated photography may also be required.

Reports on these field activities shall be prepared in accordance with individual photogrammetric job instructions and "Photogrammetry Instructions No. 22, Field Recovery and Identification of Horizontal and Vertical Control" (U.S. Coast and Geodetic Survey 1965*b*).

5.3. DESCRIPTIVE REPORT

A separate Descriptive Report shall be written for each hydrographic survey sheet completed. This report furnishes all data necessary to complete office processing of the survey and plotting of the smooth sheet. The original and two copies shall be forwarded to the Marine Center with the field sheet and other survey records as soon as field work has been completed.

The Descriptive Report serves as a narrative document that describes the conditions under which the work was performed and discusses various factors affecting the adequacy and accuracy of the results. The primary purposes are to direct attention to important results and to supplement the hydrographic sheets and sounding records with information that cannot be shown clearly, concisely, and graphically on the sheets or in tabular form. The report should assist the cartographers compiling and verifying a survey, then charting the results. It serves to reference and index all records and reports applicable to the survey and to give, in concise form, required information on certain standard subjects. General statements and detailed tabulation of self-evident data (such as inshore rocks and shoals or rocks or coral heads already shown on the field sheet) serve no purpose and should not be included.

A daily journal or log sheet shall be maintained by the hydrographer. Without a carefully prepared journal, satisfactory Descriptive Reports cannot be written from memory or compiled by an individual lacking personal knowledge of the field work. To complete the tabulations or abstracts described in section 5.3.5, the hydrographer must evaluate and tabulate data daily while the data are being acquired, rather than waiting until the sheet is completed or the field season has ended. The inclusion of these tabulations permits standardization of data-collection methods and forms and results in more comprehensive and understandable field data. Notes made on the field sheet to supplement the daily journal shall, when applicable, be included in the Descriptive Report.

In surveys of large extent or of a complicated nature, it may be advisable to prepare special reports on certain phases of the work covering the entire project. Cross-references to each of these and to all other pertinent reports shall be included. [See 5.3.4(S).]

The Descriptive Report for a special project should include all data, computations, and forms that would ordinarily be assembled as separate reports, with the exception of those submitted individually such as Coast Pilot notes and forms for nonfloating aids and landmarks for charts (National Ocean Survey 1976*a*). (See 5.5.)

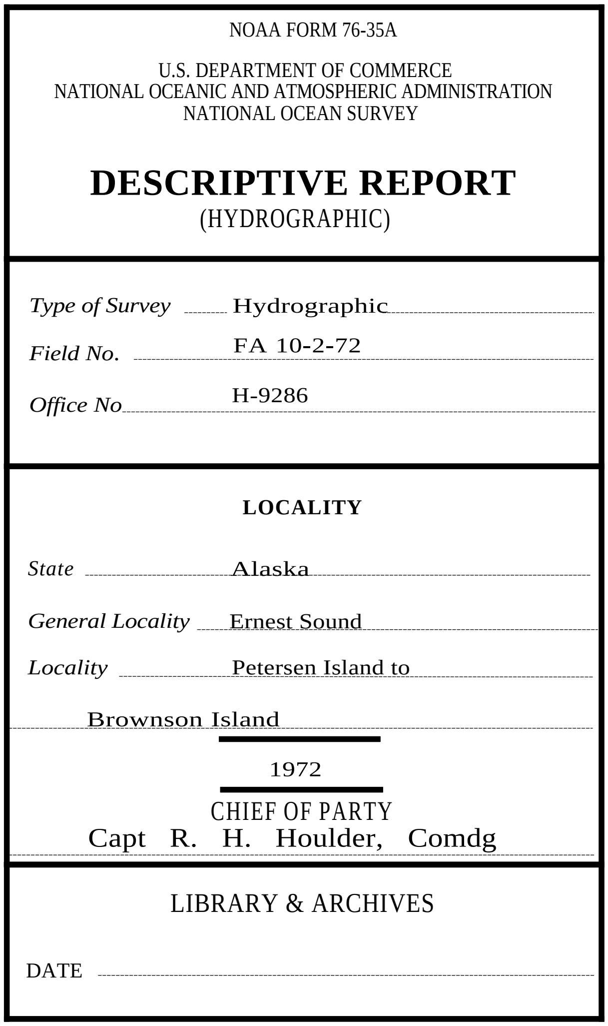
The various data required on separate sheets shall be arranged in the sequence described herein.

5.3.1. Cover Sheet

NOAA Form 76-35A, "Descriptive Report" shall be used as the outside cover sheet; appropriate entries are made to identify the survey. (See figure 5-3.)

The "State" entry is the name of the State or territory nearest the center of the hydrographic sheet.

The "General Locality" in which the survey was performed must be defined by a well-known geographic name (e.g., Sumner Strait, Gulf of Mexico, or Lake Huron).



NOAA FORM 76-35A

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY

DESCRIPTIVE REPORT
(HYDROGRAPHIC)

Type of Survey Hydrographic
Field No. FA 10-2-72
Office No H-9286

LOCALITY

State Alaska
General Locality Ernest Sound
Locality Petersen Island to
Brownson Island

1972

CHIEF OF PARTY
Capt R. H. Houlder, Comdg

LIBRARY & ARCHIVES

DATE

FIGURE 5-3.— Descripitive Report cover sheet

The "Locality" entry pinpoints the immediate area of the survey. Again, specific geographic names are used as reference (e.g., Approaches to Chincoteague Inlet, Northern portion of Lake St. Clair, or NW of Cape Kumukahi).

5.3.2. Title Sheet

Information for the title of a survey shall be furnished on **NOAA** Form 77-28, "Hydrographic Title Sheet." Entries are made on all applicable spaces on the form. (See figure 5-4.) Since the Title Sheet is often referred to for information pertaining to the survey, be sure all entries are accurate.

The entries required on the Title Sheet are self explanatory. "State," "General Locality," and "Locality" entries shall be identical to those on the Cover Sheet. The "Date of Survey" entries are the inclusive dates of the field work. In addition to the name or hull number of the surveying vessel or field party in the "Vessel" entry, the identification number assigned to the vessel for electronic data processing purposes shall be shown. The name(s) listed in the "Surveyed by" entry are those who were actually in charge during sounding operations.

If a field party has not completed all required work on a field sheet prior to transferring the data to another unit or to a Marine Center, enter a complete explanation in the "Remarks" section. Other Descriptive Reports or Special Reports containing information or data pertinent to the survey should be referenced under "Remarks."

5.3.3. Index of Sheets

If two or more smooth sheets are needed for the project area, a copy of the approved smooth sheet layout (2.4.1) shall be included in the Descriptive Report. The subject survey should be indicated on the sheet layout sketch and the adjoining sheets identified by both field and registry numbers.

Tide or water level stations must be clearly shown and identified by name. Separate sheet layouts showing the division between visually and electronically controlled hydrography and the amount of hydrography accomplished each month should be included. If necessary for clarity, a full layout of all insets, overlays, and partial field sheets shall be included to portray the coverage of the hydrographic sheet.

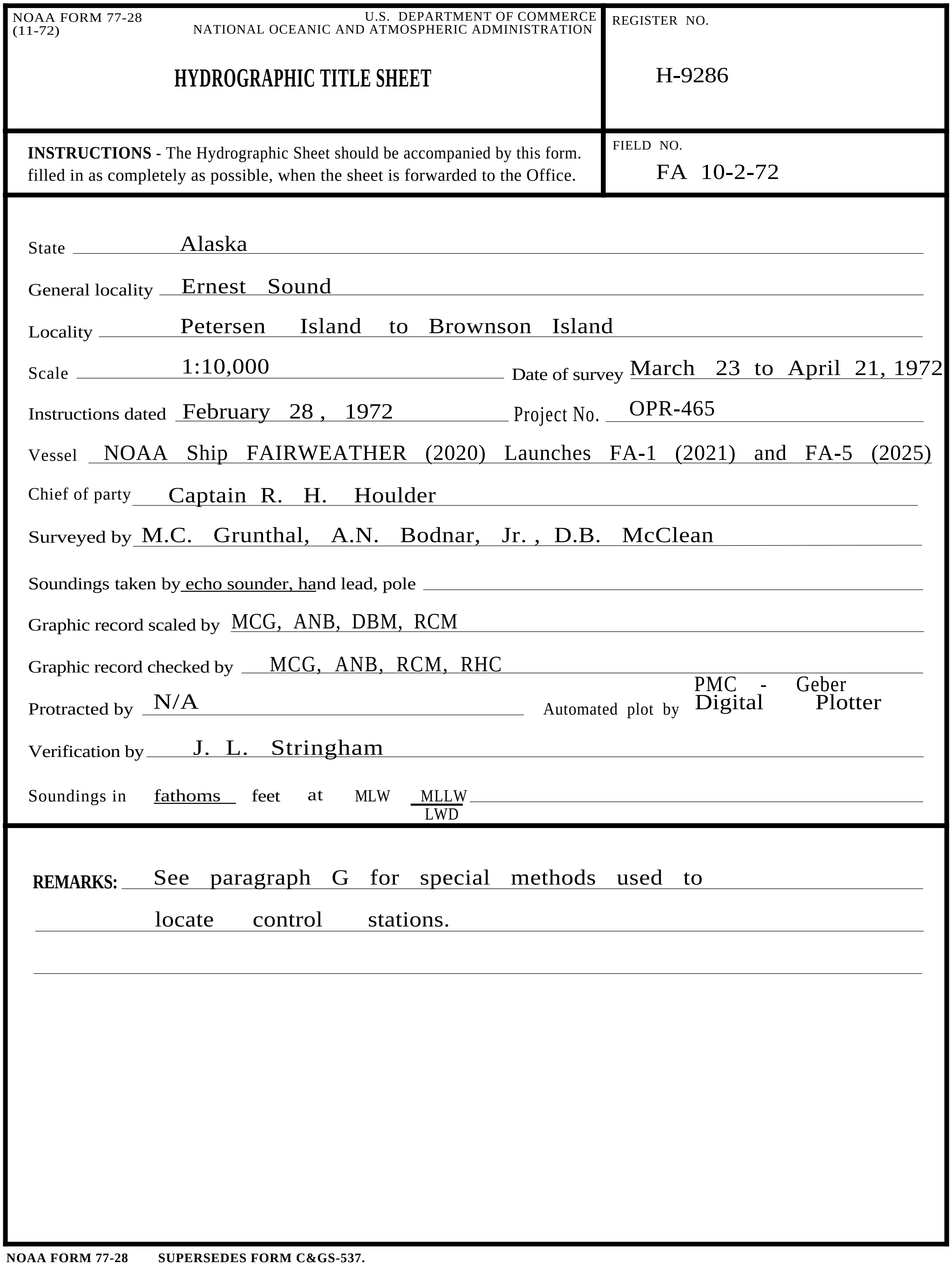
The scale of the index should be such that the sketches or drawings can be shown readily on letter-size paper (8½ x 11 in). A reduced copy of the smooth sheet layout will be furnished by the Marine Center on request.

5.3.4. Descriptive Report Text

This is typed on letter-size (8½ X 11 in) paper with left-hand margins of 1.25 in to permit binding. The text must be clear and concise. All information required for complete understanding of the records shall be included, but verbosity shall be avoided.

Each text shall be entitled "Descriptive Report To Accompany Hydrographic Survey H ——(Field No.——)." (Insert registry and field numbers.) The scale and year of the survey, the names of the survey vessel or party, and the Chief of Party are listed.

When referring to a hydrographic feature on



NOAA FORM 77-28 (11-72)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HYDROGRAPHIC TITLE SHEET

REGISTER NO. H-9286

INSTRUCTIONS - The Hydrographic Sheet should be accompanied by this form. filled in as completely as possible, when the sheet is forwarded to the Office.

FIELD NO. FA 10-2-72

State Alaska

General locality Ernest Sound

Locality Petersen Island to Brownson Island

Scale 1:10,000

Date of survey March 23 to April 21, 1972

Instructions dated February 28 , 1972

Project No. OPR-465

Vessel NOAA Ship FAIRWEATHER (2020) Launches FA-1 (2021) and FA-5 (2025)

Chief of party Captain R. H. Houlder

Surveyed by M.C. Grunthal, A.N. Bodnar, Jr. , D.B. McClean

Soundings taken by [✓ echo sounder], hand lead, pole

Graphic record scaled by MCG, ANB, DBM, RCM

Graphic record checked by MCG, ANB, RCM, RHC

Protracted by N/A

Automated plot by PMC - Geber Digital Plotter

Verification by J. L. Stringham

Soundings in [✓ fathoms] feet at MLW [✓ MLLW] LWD

REMARKS: See paragraph G for special methods used to locate control stations.

NOAA FORM 77-28 SUPERSEDES FORM C&GS-537.

FIGURE 5-4.—Hydrographic Title Sheet

the field sheet, the latitude and longitude and position number of the feature shall be given. To provide uniformity of reports, the text is arranged under the following lettered headings in the order appearing here.

A. *PROJECT.* Include the project number, the date of original instructions, the dates of all changes, supplemental instructions, amendments, pertinent letters, and purpose of the survey.

B. *AREA SURVEYED.* Briefly describe the area covered by the survey and the adjacent coast. State the general locality, approximate limits, and inclusive dates of the survey.

C. *SOUNDING VESSEL.* List all ships or launches by letter designations and electronic data processing (EDP) number that were used to obtain the soundings. Include in this section a narrative description of any unusual sounding vessel configurations and problems encountered.

D. *SOUNDING EQUIPMENT AND CORRECTIONS TO ECHO SOUNDINGS.* Identify by type and serial number all echo-sounding instruments used by each survey vessel. State the type of other sounding equipment used and the general areas and depths in which each was used. Discuss any faults in the equipment that affected the accuracy of sounding.

Summarize the methods used to determine, evaluate, and apply the following listed corrections to the echo soundings:

1. Velocity of sound through water.
2. Variations in the instrument initial.
3. Other instrument corrections.
4. Corrections determined from direct comparisons (bar checks and vertical casts).
5. Settlement and squat.

If salinity, temperature, depth (STD) sensors; temperature, depth, conductivity (TDC) sensors; or similar instruments were used for velocity determinations, identify each instrument by serial number and provide the most recent dates of calibration or field check.

List the positions of the stations observed for velocity corrections with the dates of observation or prepare letter-size (8½ x 11 in) chartlets showing the locations and dates.

If unusual or unique methods or instruments were necessary for the determination of corrections to echo soundings, describe them in sufficient detail to provide the survey verifiers a full understanding of the use and application of data. Sounding corrections must be determined and reported in a standard manner (4.9) unless extenuating circumstances arise; extensive analysis and validation during verification of data acquired by nonstandard methods can be extremely time consuming.

When applicable, specify the vessels, areas, and depths for which any particular group of corrections are to be applied.

A copy of each Abstract of Corrections to Echo Soundings is inserted at the end of the Descriptive Report (5.3.5(D)); substantiating field observations, computations, and graphs are included with the field records. (See 4.9.)

E. *HYDROGRAPHIC SHEETS.* State how and where the field sheets were prepared and where it is anticipated the field records will be sent for verification and smooth plotting. Information on the projection and electronic control parameters for all automated surveys is inserted at the end of the Descriptive Report. (See 5.3.5(A).)

Include any irregularity in projection, scale, or other salient properties of the field sheet that should be brought to the attention of the office cartographers; such information is helpful during verification.

F. *CONTROL STATIONS.* On the sheet, list the control stations that have been monumented and described; state the surveying methods used to establish horizontal positions for hydrographic signals and stations. Define the general areas in which each method was used and indicate the datum used. If a geodetic control report is not available when the survey is submitted for processing, copies of the appropriate geodetic abstracts and computations shall be included with the survey records for verification of the positions. Explain in detail:

1. Unconventional survey methods, if used, for determining the positions of horizontal control stations.
2. Anomalies in the control adjustment or in closures and ties.
3. Any known photogrammetric problems that could contribute to position inaccuracies.

Refer to section 5.3.5(F) for control listings to be appended to the Descriptive Report.

G. *HYDROGRAPHIC POSITION CONTROL*. State the method or methods of sounding line position control used for the survey and explain in detail any known difficulties experienced with the control system that may have degraded the expected position accuracy. Electronic control equipment shall be identified by manufacturer, model, and component serial numbers for each vessel and shore station.

Briefly describe the methods for calibrating the electronic control systems. Evaluate, to the extent possible, the adequacy of the calibration data applied to raw position data throughout the survey area.

Items to be discussed in detail in this section include but are not limited to:

1. Unusual or unique methods of operating or calibrating electronic positioning equipment.
2. Equipment malfunctions, substandard operation, and probable causes.
3. Unusual atmospheric conditions that may have affected data quality.
4. Weak signals or poor geometric configuration of the control stations.
5. Discovery and treatment of systematic errors in the position data.

A copy of the Abstract of Corrections to Electronic Position Control shall be inserted at the end of the Descriptive Report (5.3.5(E)) and the substantiating field observations, computations, and other pertinent data shall be included in the survey records. (See 4.8.)

H. *SHORELINE*. Give the source of shoreline details shown on the field sheet by listing all topographic sheets or shoreline manuscripts used. (See 1.6.1 and 3.2.) State whether the shoreline details have been field edited and whether the changes or corrections noted during field edit have been transferred to the field sheet. List and explain all areas on the field sheet where field edit was not accomplished.

If any of the shoreline or topographic details were plotted inaccurately or have changed since the date of photography on which the map was based and were revised by the hydrographer, identify the revisions on the field sheet in red and explain the changes. Discrepancies between photogrammetric and hydrographic locations of detail seaward of the shoreline must be mentioned and resolved. Control stations seaward of the shoreline will be noted here and described adequately on the field sheet.

I. *CROSSLINES*. State the percentage of crosslines run (1.4.2) and discuss any discrepancies at crossings. If the magnitude of discrepancy varies widely over the sheet, make a quantitative evaluation of the disagreements area by area.

A special note on the crossing agreements must be included if the vessel and sounding equipment used to run the regular system of lines were not used for the crosslines. In all cases, methods used to reconcile significant differences at crossings must be explained.

J. *JUNCTIONS*. If the survey junctions with prior surveys, list each prior survey by registry number, scale, and date. List each contemporary survey with which junctions were made or that have a common area by registry or field number. Discuss the agreement or disagreement in depths at junctions. If the hydrographer believes that an adjustment to soundings and depth contours should be made, the recommendation should be included here. Comprehensive statements must be made on the agreement or disagreement of soundings between the new survey and other contemporary surveys in the area.

K. *COMPARISON WITH PRIOR SURVEYS*. Each numbered presurvey review item that lies within the limits of the survey must be listed, referred to by its presurvey review item number, and discussed unless directed otherwise in the presurvey review. State positively whether or not the feature should be charted, its position replotted, or its symbolization revised. The least depths obtained over submerged features shall be listed together with the position number, latitude, longitude, and description of the feature. (See 2.3.3.)

Compare the results of the new survey with those shown on the most recent prior surveys of the area, identifying prior surveys by registry number, dates, and scales. State the quality of general agreement between the new and the old surveys and give conclusions or opinions as to the reasons for significant differences. List important features or depths on prior surveys—their existence having been disproved—and identify those that should be deleted from the charts.

Include bare rocks as well as subsurface features and depths.

Compare the new survey with recent surveys in the area made by the U.S. Army Corps of Engineers or with other surveys within the project area by authoritative public or private organizations. Surveys other than those by **NOS** must be identified by date, scale, and sheet number, and shall be forwarded with the survey records. A statement should be included as to whether these surveys meet **NOS** standards.

L. *COMPARISON WITH THE CHART.* Comparison of the survey with the chart by the field unit *and* processing office *and* quality control shall be with the edition of the chart as listed in the project instructions. If the comparison is not made with the edition of the chart named in the project instructions, a reason for this shall be included in the Descriptive Report. The field or office should recommend a change to the project instructions if they feel the named edition should be changed.

If the project instructions do not specify comparison with a specific edition of the chart, the latest edition of the chart available (for public distribution), at the time of commencing field work, shall be used.

In addition to (but not in lieu of) a comparison with the named edition of the chart, the field unit may take into account Notice to Mariners issued since the chart publication date. Any chart comparison item which is dependent upon a Notice to Mariners should be identified in the Descriptive Report with the source Notice to Mariners.

In addition to (but not in lieu of) a comparison with the named edition of the chart, the field unit may take into account later editions of the chart. This situation is most likely to arise when the field work is accomplished during more than one field season. When a later edition of the chart is also used, it needs to be clearly documented in the Descriptive Report. Identify the chart by number, edition, and date, and give similar information, without duplication, to that required for prior surveys. Charted features bearing the notation "reported," "PA," "ED," or "PD" must be mentioned specifically in this section and a positive recommendation made as to whether (and how) the feature should be charted in the future. When the charted feature is a numbered Presurvey Review item, it should be referred to by its Presurvey Review number. Mention how the depths were determined. Similar recommendations shall be made for features such as charted pilings, wrecks, and obstructions that may not be mentioned specifically.

Tabulate and describe newly found dangers to navigation, listing the latitude, longitude, and position number of each item. Mention specifically each danger reported to the U.S. Coast Guard. (See 5.9.)

Dangers and shoals investigated or found by wire drag, wire or pipe sweep, diver, or by other equivalent methods are listed separately. Least depths and clearances over these features must be listed. Include copies of telegrams or letters that have been submitted recommending immediate changes to the charts and also include items for incorporation into the *U.S. Coast Guard Local Notice to Mariners* (e.g., Commander, Third Coast Guard District 1976).

Recommend necessary changes to published charts (e.g., format and coverage) of the survey area. Mention special shoal investigations conducted and list the positions used. Hydrographic findings of special note should be included in this section.

M. *ADEQUACY OF SURVEY.* State whether the survey is sufficiently complete and adequate to warrant its use to supersede prior surveys for charting. Identify any part of the survey that is incomplete or substandard in any way.

N. *AIDS TO NAVIGATION.* Reference shall be made to any correspondence with the U.S. Coast Guard regarding the location or establishment of floating aids in the surveyed area. The location and description of each floating aid shall be entered in the hydrographic records. A separate listing of floating aids by geographic position and characteristic need not be entered here. A comparison, however, shall be made with data in the latest edition of the *Light List* (U.S. Coast Guard 1976) and with the largest scale chart of the area. The hydrographer shall state the results of this comparison and indicate whether the aids adequately serve the apparent purpose for which they were established.

List all aids to navigation located during the survey that are not shown in the *Light List.* State their apparent purpose, whether and by whom the aids are maintained, and whether or not such maintenance is seasonal, if known. Give the position and description of each such aid and the date of established, if known.

A copy of **NOAA** Form 76-40, "Report on Landmarks for Charts and Nonfloating Aids to Navigation" (5.5), should be included in the Descriptive Report for those located during the survey.

List all bridges and overhead cables not shown on the chart. State bridge and cable clearances measured by the survey party or as determined from other sources. Mention any submarine cables, pipelines, and ferry routes in the area. List the position of each terminal if not shown on contemporary shoreline manuscripts.

O. *STATISTICS*. List the total number of positions, nautical miles of sounding line, and square nautical miles of hydrography run by each ship or launch during the survey. A tabulation of statistics for each day is not required.

A summary of other survey statistics such as bottom samples and the number of tide, current, temperature and salinity, or magnetic stations should also be included. Copies of **NOAA** Form 75-44, "Oceanographic Log Sheet-M, Bottom Sediment Data," for the survey shall be appended to the Descriptive Report.

P. *MISCELLANEOUS*. Provide information of significant scientific or practical value resulting from the survey that is not covered in previous sections. Where new silted areas are detected, the discussion should include the size of the areas, apparent thickness, and reference to typical depth profiles by date. Unusual submarine features such as abnormally large sand waves, mounds, valleys, and escarpments should be described. Discuss anomalous tidal conditions encountered such as the presence of bores and extremely fast currents not previously reported. If special reports have been submitted on such subjects, refer to them by title, author, and date of preparation or publication.

Q. *RECOMMENDATIONS* . If any part of the survey is considered inadequate for charting, explain and submit recommendations as to additional field work required and methods necessary to make the survey adequate. Mention present or planned construction or dredging in the survey area that may affect the survey results. Include recommendations for further investigations of unusual features or sea conditions of interest in excess of routine charting requirements. For clarity, recommendations should be made for special insets to be shown on the smooth sheet or on the published chart of the area.

R. *AUTOMATED DATA PROCESSING*. List by program name, number, and version date all routines used for automated data acquisition and processing. If any of the acquisition or processing methods used differ from those described in current National Ocean Survey manuals or instructions, each difference must be listed and explained and the data format defined.

S. *REFERRAL TO REPORTS*. List all reports, records, and forms not included with the survey records or Descriptive Report that have been submitted separately but which are necessary for a complete evaluation and understanding of the survey record. Give the title and the date on which the report was sent to the Marine Center.

5.3.5. Separates Following Text

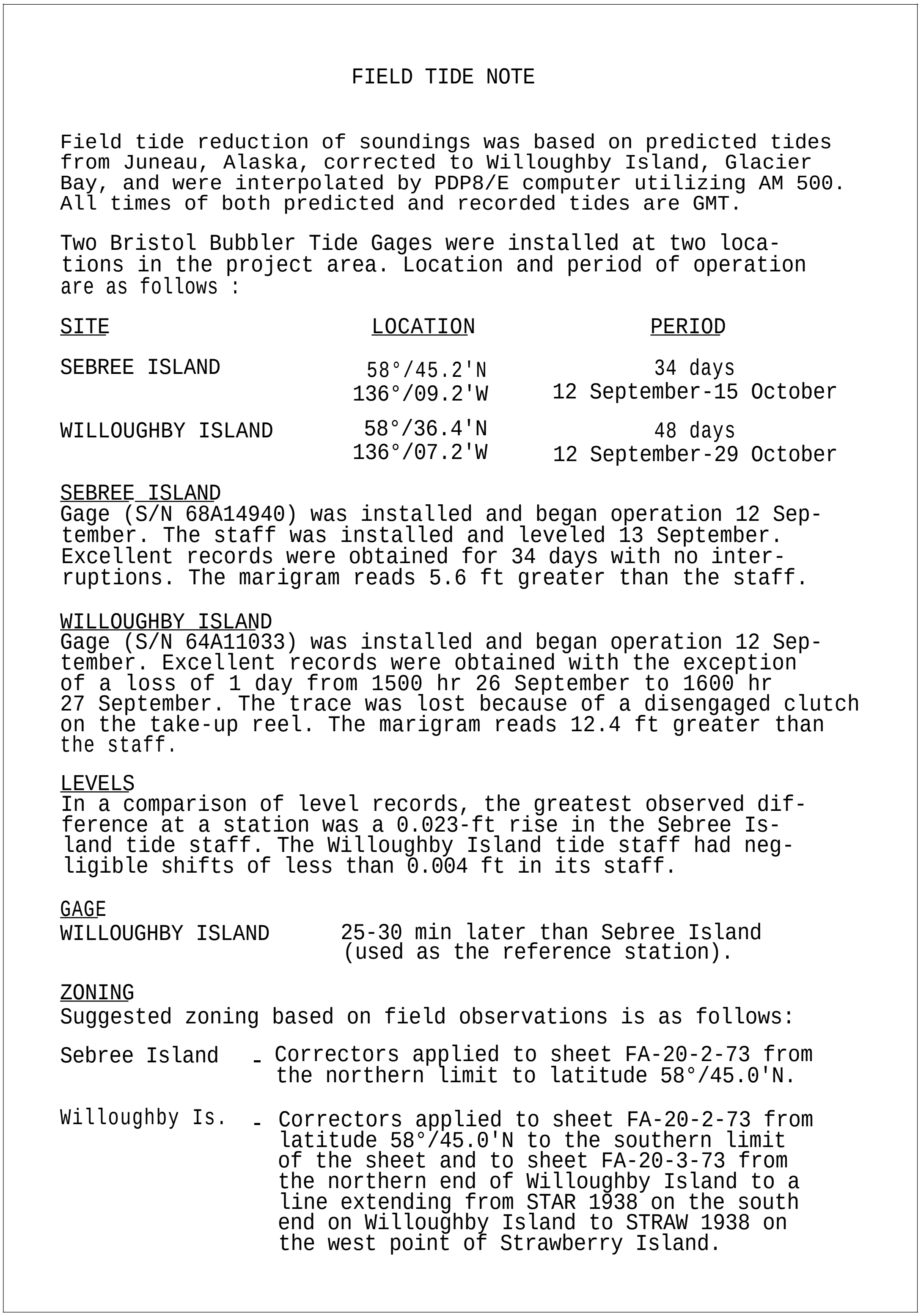
Various tabulations and other information are required on separate sheets that are inserted in the Descriptive Report. Those applicable shall be furnished and inserted in the subsequent order.

The first page of the text and the attached inserts shall be numbered consecutively. The approval sheet is always placed last.

A. *HYDROGRAPHIC SHEET PROJECTION AND ELECTRONIC CONTROL PARAMETERS*. A sheet listing the necessary projection and electronic control parameters is required for all surveys scheduled for automated smooth plotting. Each Marine Center, because of differences in automation equipment, prescribes the required formats.

B. *FIELD TIDE OR WATER LEVEL NOTE*. This note shall be inserted in the Descriptive Report for each hydrographic survey. (See figure 5-5.) The note should state:

1. How the tide or water level corrections were derived and the zones in which these corrections were applied. (If automated computations for tidal corrections to soundings were made based on multigage observations, the program number and gage sites must be given.)
2. The name, geographic locale, latitude, and longitude of each gage.
3. Dates of gage installations and removals and any problems experienced with gage operations.
4. Staff value equivalent to the zero line on analog tide records. (In the Great Lakes, the elevation of the reference mark (zero electric tape gage or **ZETG**) on the electric tape gage shall be noted.)
5. Significant differences in comparative observations (AK.2.3), in tide or water level times,



FIELD TIDE NOTE

Field tide reduction of soundings was based on predicted tides from Juneau, Alaska, corrected to Willoughby Island, Glacier Bay, and were interpolated by PDP8/E computer utilizing AM 500. All times of both predicted and recorded tides are GMT.

Two Bristol Bubbler Tide Gages were installed at two locations in the project area. Location and period of operation are as follows :

SITE	LOCATION	PERIOD
SEBREE ISLAND	58°/45.2'N 136°/09.2'W	34 days 12 September-15 October
WILLOUGHBY ISLAND	58°/36.4'N 136°/07.2'W	48 days 12 September-29 October

SEBREE ISLAND
Gage (S/N 68A14940) was installed and began operation 12 September. The staff was installed and leveled 13 September. Excellent records were obtained for 34 days with no interruptions. The marigram reads 5.6 ft greater than the staff.

WILLOUGHBY ISLAND
Gage (S/N 64A11033) was installed and began operation 12 September. Excellent records were obtained with the exception of a loss of 1 day from 1500 hr 26 September to 1600 hr 27 September. The trace was lost because of a disengaged clutch on the take-up reel. The marigram reads 12.4 ft greater than the staff.

LEVELS
In a comparison of level records, the greatest observed difference at a station was a 0.023-ft rise in the Sebree Island tide staff. The Willoughby Island tide staff had negligible shifts of less than 0.004 ft in its staff.

GAGE
WILLOUGHBY ISLAND 25-30 min later than Sebree Island (used as the reference station).

ZONING
Suggested zoning based on field observations is as follows:

Sebree Island - Correctors applied to sheet FA-20-2-73 from the northern limit to latitude 58°/45.0'N.

Willoughby Is. - Correctors applied to sheet FA-20-2-73 from latitude 58°/45.0'N to the southern limit of the sheet and to sheet FA-20-3-73 from the northern end of Willoughby Island to a line extending from STAR 1938 on the south end on Willoughby Island to STRAW 1938 on the west point of Strawberry Island.

FIGURE 5-5.—Field Tide Note

NOAA FORM 76-155
(11-72)

U.S DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

SURVEY NUMBER

H-9310

GEOGRAPHIC NAMES

Name on Survey	A On chart no. 234	B On previous survey No. H-6224	C On U.S. quadrangle maps	D From local information	E On local maps	F P.O. guide or map	G Rand McNally atlas	H U.S. light list	K	
Cape Island Creek										1
Cape May										2
Cape May Canal										3
Cape May Harbor										4
Cape May Inlet										5
Cedar Creek										6
Linger Point										7
Middle Thorofare										8
Mill Creek										9
Schellenger Creek										10
Schellenger Landing										11
Sewell Point										12
Spicer Creek Canal										13
Two Mile Beach										14
Upper Thorofare										15
										16
										17
										18
										19
										20
										21
										22
										23
										24
										25

NOAA FORM 76-155 5UPERSEDFS C&G5 197

FIGURE 5-6.— List of Geographic Names

or in ranges or unusual fluctuations between adjacent gages.

6. The time meridian used for records annotation.

7. Observations of unusual tidal, water level, or current conditions.

8. A tabulation of missing hourly heights, if any, that may be required for reduction of soundings to the datum of reference.

9. Recommendations, if any, for zoning and time corrections.

C. *GEOGRAPHIC NAMES LIST.* A list of Geographic Names that occur on the field sheet shall be prepared and inserted (figure 5-6). Names should be listed alphabetically. The list may be prepared either on a plain sheet of paper or on **NOAA** Form 76-155, "Geographic Names." If **NOAA** Form 76-155 is used, add the word "field" in parentheses to the title and do not enter any information in columns A through K. (See section 5.7 for additional requirements on geographic names.)

D. *ABSTRACT OF CORRECTIONS TO ECHO SOUNDINGS.* Abstracts, in tabular form, velocity and other corrections to be applied to the echo soundings shall be included as separate entries in the Descriptive Report. (See figure 5-7.) A similar abstract can be easily constructed for corrections determined solely by bar checks taken throughout the depth range.

The Sounding Correction Abstract shows the dates, times, vessels, and instrument serial numbers to which the corrections apply. If the same corrections apply to more than one survey, a copy of the abstract and applicable correction tables (4.9) are included in the Descriptive Report for each survey.

For substantiating these corrections to soundings and facilitating timely office processing of the field data and plotting of the smooth sheet, the following supporting material shall be assembled and separately bound or arranged in a cahier and included with the survey data that accompanies the hydrographic sheet and Descriptive Report:

1. Copy of the settlement and squat abstract.

2. Abstracts of bar checks, vertical cast comparisons, and echo sounder phase comparisons.

3. Copies of calibration data for **STD**, **TDC**, or other sensors used for velocity determinations.

4. Nansen cast observations.

5. All other basic data, computations. graphics, and material needed to verify the final corrections.

E. *ABSTRACTS OF CORRECTIONS TO ELECTRONIC POSITION CONTROL.* When all or any portion of the hydrographic survey is controlled by an electronic positioning system or by distance-measuring equipment, an abstract of corrections to be applied to the observed data shall be compiled and inserted into the Descriptive Report. (See figure 5-8.) Supporting data shall be assembled and separately bound or arranged in a cahier and included with the survey data that accompanies the hydrographic field sheet and Descriptive Report. (See 4.8.)

F. *LIST OF STATIONS.* A numerical list of stations used for controlling the hydrographic survey shall be included as a separate sheet and inserted in the Descriptive Report. (See figure 5-9.) The following information shall be given for each station:

1. Station number (001-999).

2. Octant plotting position of the station number.

3. Latitude (to nearest thousandth of a second).

4. Longitude (to nearest thousandth of a second).

5. Cartographic code (appendix B).

6. Control station antenna elevation.

7. Transmitting frequency (to nearest hundredth of a kilohertz); use 000000 for other stations. Electronic distance-measuring stations may be identified as such in the type/name or source columns.

8. Name and type of station (3.1), that is:

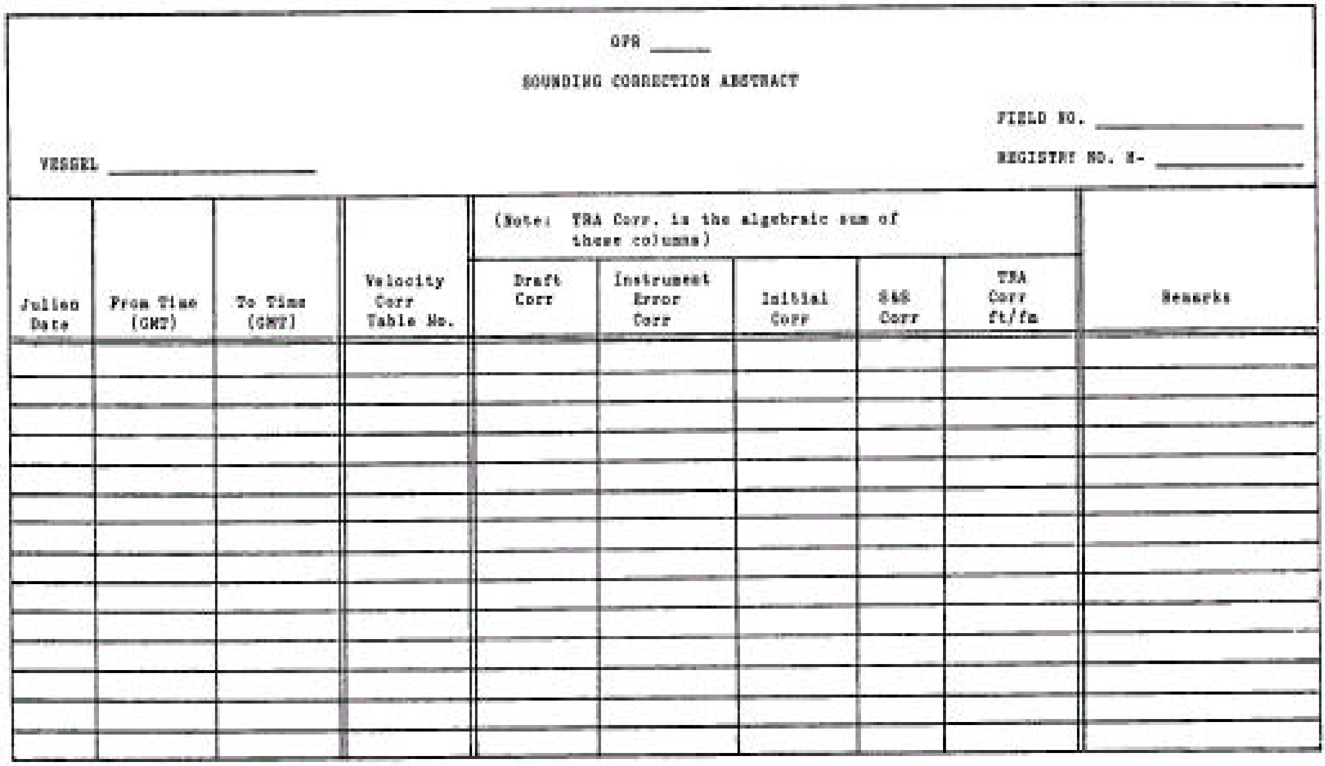
a. Basic or supplemental (include year of establishment).

b. Photogrammetric or hydrographic.

9. Source, that is, volume and page number for published geodetic control or, if new, a reference to abstracts or field observations.

G. *ABSTRACT OF POSITIONS.* This shall be assembled for each hydrographic survey vessel that worked on the field sheet. (See figure 5–10.) Each vessel is identified by its data-processing number, and the work accomplished is listed by Julian dates, inclusive position numbers, control codes, and electronic control station numbers.

H. *BOTTOM SAMPLES.* All copies of **NOAA** Form 75–44, "Oceanographic Log Sheet-M, Bottom Sediment Data," that tabulate the bottom characteristics in the survey area shall be inserted.



OPR ____

SOUNDING CORRECTION ABSTRACT

FIELD NO. ____________

VESSEL ____________

REGISTRY NO. H- ____________

Julian Date	From Time (GMT)	To Time (GMT)	Velocity Corr Table No.	(Note: TRA Corr. is the algebraic sum of these columns)					Remarks
				Draft Corr	Instrument Error Corr	Initial Corr	S&S Corr	TRA Corr ft/fm	

FIGURE 5-7.—Sounding Correction Abstract

ELECTRONIC CORRECTOR ABSTRACT

VESSEL : 2126 SHEET : RA-20-3-73

TIME	DAY	PATTERN 1	PATTERN 2
135415	150	-00015	-00009
140816		-00015	-00006
154006		-00015	-00002
160000		-00015	-00007
101746	151	+00003	+00012
130300		+00004	+00009
131000		+00001	+00007
145600		-00006	-00002
155500		-00006	-00002
112816	154	-00008	-00005
140730		-00005	+00005
154700		-00008	+00005
090545	158	+00011	-00002
103836		+00007	+00002
143000		+00007	+00002

FIGURE 5-8 — Electronic (position) Corrector Abstract

I. *LANDMARKS FOR CHARTS.* Include all copies of **NOAA** Form 76-40, "Report on Nonfloating Aids or Landmarks for Charts," that contain the required information on landmarks within the hydrographic sheet limits which are recommended for charting. Copies of **NOAA** Form 76-40 prepared by the field editor may be used for this purpose. (See 5.5.)

J. *APPROVAL SHEET.* The chief of party shall furnish, on a separate sheet attached to the Descriptive Report, a signed statement of approval of the field sheet and all accompanying records. Include a statement concerning the amount and degree of personal supervision of the field work and frequency with which he examined the field sheet and other records. State whether the survey is complete and adequate or if additional field work is recommended. Cite additional information or references that may be of assistance for verifying and reviewing the survey.

5.4 FIELD EDIT REPORT

A separate Field Edit Report shall be prepared and submitted for each shoreline manuscript within the project area (3.2.4) no later than 10 workdays after field work has been completed on that manuscript. Refer to "Provisional Photogrammetry Instructions for Field Edit Surveys" (National Ocean Survey 1974) for detailed directions on assembly and content of the report. The report accompanies other pertinent manuscript data and information including the Discrepancy Print, Field Edit Sheet, supporting annotated aerial photography and accompanies other miscellaneous data in accordance with the photogrammetric instructions.

The contents of the report are essential during the final review of the shoreline manuscript and for the resolution of discrepancies that may appear during hydrographic verification and chart compilation; frequently, the report provides invaluable reference, explanatory, and corroborative material for

STATION LIST: H - 7953

STA	0	LATITUDE	LONGITUDE	CRT	ELEV	F. KHZ	TYPE/NAME	SOURCE
001	7	58 38 51070	136 12 29730	243	0002	000000	Photo T-13042	Class II
002	7	58 45 00800	136 10 26740	243	0005	000000	Photo T-13045	
003	5	58 45 07820	136 09 37490	139	0010	179960	SPIT 2 1973 Ecc	Vol. II p. 3
004	5	58 45 00180	136 09 22430	139	0003	179850	RANGE 1842	
005	7	58 45 00520	136 09 14150	139	0004	179960	SMITH 3 1956	
006	1	58 43 51080	136 00 45200	243	0013	000000	Sextant	Vol. III p. 2
007	3	58 45 12200	136 01 28890	139	0009	179850	POPPY 1973	Vol. I p. 3
008	7	58 43 23960	136 03 26650	243	0011	000000	Photo T-13042	
009	7	58 36 30950	136 06 34320	243	0008	000000	Sext T-13045	
010	7	58 38 36330	136 02 35350	243	0003	000000	Photo T-13043	
018	4	58 46 47550	136 08 32880	243	0006	000000	Photo T-13043	
020	4	58 38 58770	135 59 13320	243	0007	000000	Photo T-13043	
022	6	58 37 51160	135 55 18340	243	0005	000000	Photo T-13044	
200	7	58 41 30190	135 59 14900	243	0010	000000	Photo T-13042	
201	7	58 41 37810	135 59 18560	243	0002	000000	Photo T-13045	
202	7	58 41 46150	135 59 19240	243	0007	000000	Sextant	Vol. III p. 3
203	7	58 41 57070	135 59 17380	243	0006	000000	Sext	Vol. III p. 4
204	5	58 42 07500	135 59 04350	243	0009	000000	Photo T-13042	
205	5	58 42 25760	135 58 38060	243	0011	000000	Photo T-13044	
206	7	58 42 28730	135 58 29310	243	0008	000000	Photo T-13044	
207	7	58 42 34420	135 57 59830	243	0012	000000	Photo T-13044	
208	7	58 42 40140	135 58 17260	243	0003	000000	Photo T-13044	

FIGURE 5-9. _ Station List

ABSTRACT OF POSITIONS: H-1314

VESSEL: 3030

DAY	POSITIONS	CTRL	Sl	M	S2	REMARKS:
116	2001-2316	04	098	---	126	Hydro
117	2317-2502	04	098	---	126	Hydro
118	2503-2717	01	---	VIS	---	Bottom Samples

VESSEL: 3031

DAY	POSITIONS	CTRL	Sl	M	S2	REMARKS:
106	0001-0182	05	098	213	126	Hydro
108	0183-0362	08	098	213	H-V	Hydro
108	0363-0511	08	H-V	213	126	Hydro
109	0512-0610	01	---	VIS	---	Detached Positions

VESSEL: 3032

DAY	POSITIONS	CTRL	Sl	M	S2	REMARKS:
112	4001-4204	09	098	---	R-V	Hydro
113	4250-4370	04	098	---	126	DP MLLW line
114	4371-4593	04	098	---	126	Hydro
117	4701-4657	01	098	VIS	---	Bottom Samples

<u>Control Codes</u> (CTRL)

01 - Visual
03 - Theodolite
04 - Range - range
05 - Hyperbolic
08 - Hypervisual
09 - Range - visual

FIGURE 5-10. — Abstract of Positions

cases in litigation. The Field Edit Report shall be approved by the chief of party designated by the hydrographic survey project instructions.

5.5. REPORT ON LANDMARKS AND NONFLOATING AIDS TO NAVIGATION

Copies of **NOAA** Form 76-40, "Report on Nonfloating Aids or Landmarks for Charts," are usually prepared by the field editor, checked by the hydrographer, and submitted for processing with the photogrammetric data. Detailed instructions are contained in "Photogrammetry Instructions No. 64, Requirements and Procedures for Collecting, Processing, and Routing Landmarks and Aids to Navigation Data—Photogrammetric Operations" (National Ocean Survey 1971*b*). [See also 5.3.5(I).] Separate Forms 76-40 are submitted for:

1. Landmarks to be charted.
2. Landmarks to be deleted.
3. Nonfloating aids to navigation.

A copy of each form must be provided to the hydrographic survey verifier.

5.5.1. Preparation of Reports on Landmarks

The hydrographer shall evaluate all charted landmarks from seaward to determine which are adequate and most suitable for the purpose intended and to determine which charted landmarks no longer exist and thus should be deleted from the charts. If there are more prominent objects in the area that would serve as better landmarks, their positions shall be determined and listed among the landmarks to be charted.

Preliminary 76–40 forms are assembled routinely during the photogrammetric compilation of the shoreline manuscripts and are provided as an aid to the field editor and the hydrographer. (See 5.5.) Positions of charted landmarks are determined in the office as a check, and descriptions and positions of new objects that appear to have value as a new landmark to be charted are listed. (See figures 5-11 and 5-12.)

Reports on landmarks must be complete and stand alone. Avoid additional references to geodetic, photogrammetric, or other data not readily available to other users. The report shall state positively whether or not a seaward inspection has been made to evaluate the landmarks. If the reports have been assembled without the benefit of a seaward inspection, the reason for omission shall be fully explained.

Objects of special importance or extraordinary prominence are indicated by an asterisk (*) preceding the name of the object. When selecting objects of special importance, the total area and chart coverage must be carefully considered. Flagstaffs, flagpoles, and other structures of a temporary nature are not listed as landmarks unless they are of a very permanent and prominent nature and no other suitable objects are in the area. Recommended charting names should be general and short (5.5.1.2); they should be shown in capital letters. If the object was used as a hydrographic signal, a note is made to this effect and the station number indicated.

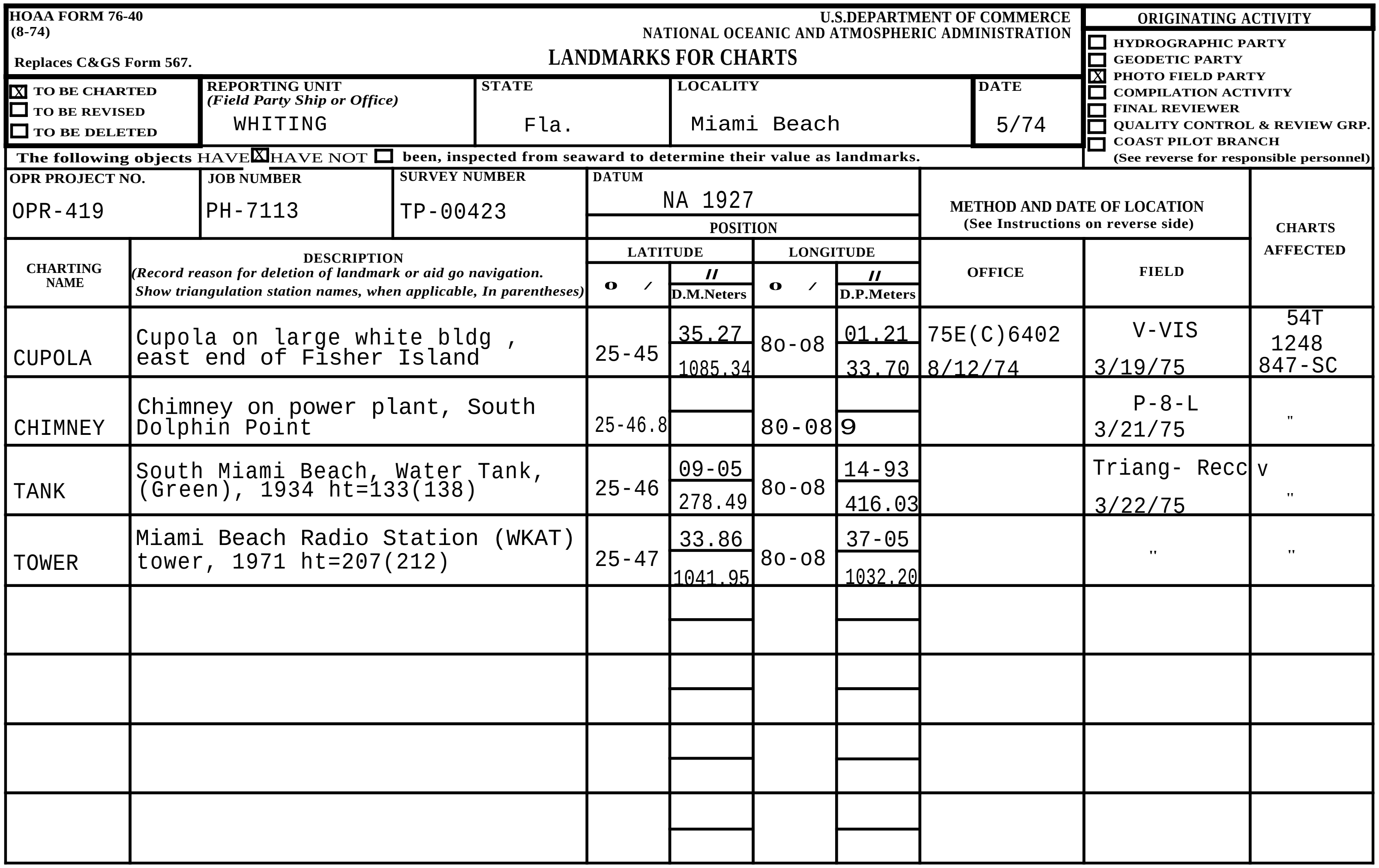
5.5.1.1. SUPPORTING CHART SECTIONS. When a large number of landmarks are reported or the hydrographer or field editor considers it necessary to clarify the tabulated data, a copy of the chart of the area should be cut into letter-size sections, appropriately annotated, and submitted with the copies of **NOAA** Form 76–40. (See figures 5–11 and 5–12.) The area inspected is outlined on these chart sections and a recommendation made for each charted or plotted landmark within the outlined area.

If chart sections are submitted, separate forms for landmarks to be deleted need not be prepared. The following procedures are used:

1. New landmarks shall be plotted and identified by the landmark symbol (⊙) together with the name recommended for charting. The geographic datum of the chart must be known and considered in the plotting.
2. Charted landmarks recommended for continuance are checkmarked (√). If the position has been verified in the field, the word "verified" is entered beside the checkmark.
3. Charted landmarks recommended for deletion shall be indicated by a cross in a circle (⊗); the word "delete" is entered, and the reason for the recommendation is given.

Names and notations on these chart sections shall be typed or lettered legibly in red ink. Care must be taken that such notations always appear on the same section of the chart section as the landmarks to which they refer.

5.5.1.2. STANDARDIZATION OF NOMENCLATURE. It is essential for charting purposes that the nomenclature used and the method of reporting landmarks be standardized. Cartographers should not have to interpret these data because they cannot see the object in the field and do not know what is most prominent about the landmark. If a landmark is reported on Form 76–40 (figures 5–11 and 5–12) as a "Tall yellow tank," the cartographer cannot tell whether the landmark is prominent because it is a tank, because it is yellow, or because it is tall. The



HOAA FORM 76-40
(8-74)
Replaces C&GS Form 567.

U.S.DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

LANDMARKS FOR CHARTS

ORIGINATING ACTIVITY
☐ HYDROGRAPHIC PARTY
☐ GEODETIC PARTY
☒ PHOTO FIELD PARTY
☐ COMPILATION ACTIVITY
☐ FINAL REVIEWER
☐ QUALITY CONTROL & REVIEW GRP.
☐ COAST PILOT BRANCH
(See reverse for responsible personnel)

☒ TO BE CHARTED
☐ TO BE REVISED
☐ TO BE DELETED

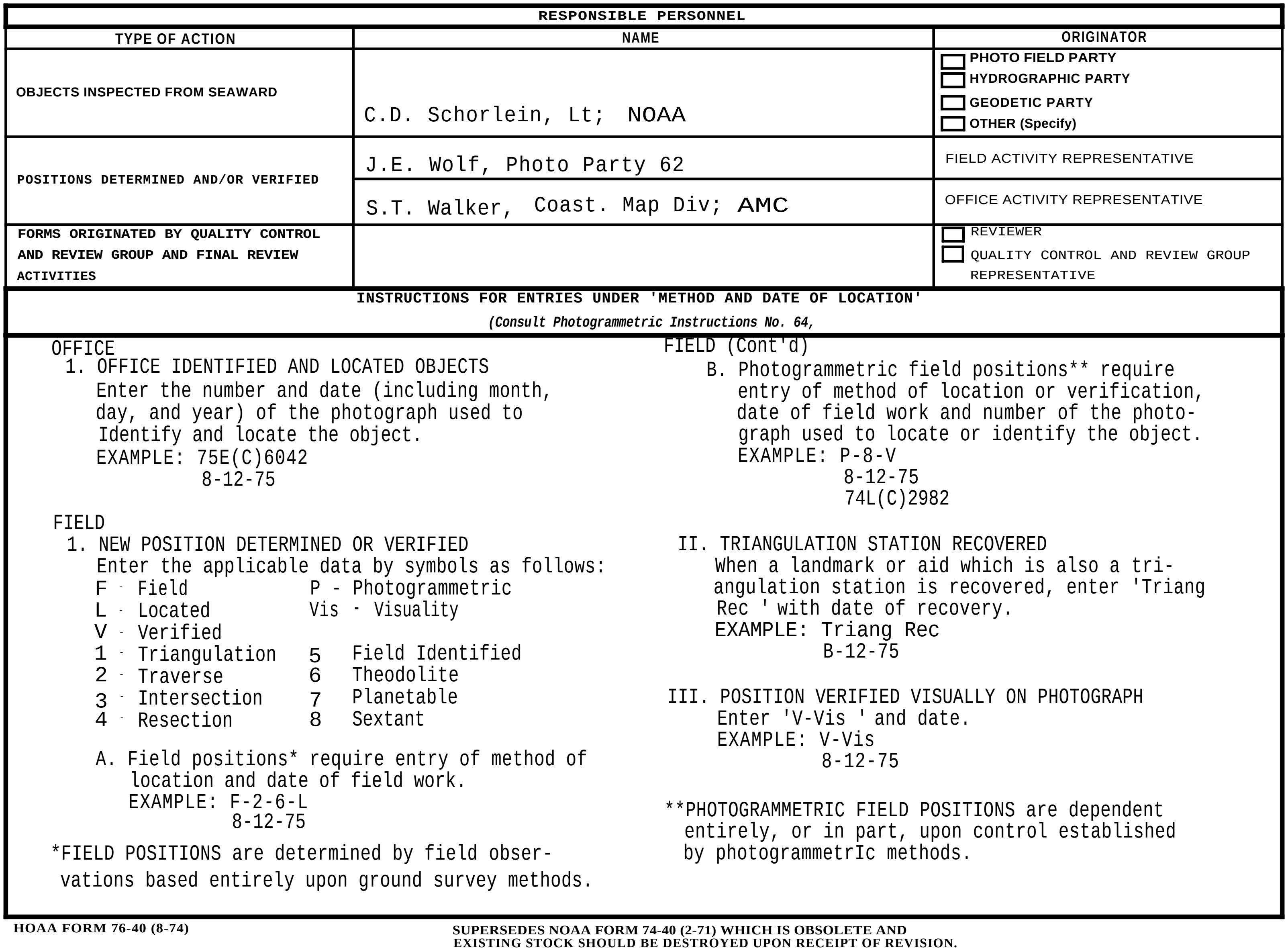
REPORTING UNIT (*Field Party Ship or Office*): WHITING
STATE: Fla.
LOCALITY: Miami Beach
DATE: 5/74

The following objects HAVE ☒ HAVE NOT ☐ been, inspected from seaward to determine their value as landmarks.

OPR PROJECT NO.: OPR-419
JOB NUMBER: PH-7113
SURVEY NUMBER: TP-00423
DATUM: NA 1927

CHARTING NAME	DESCRIPTION (*Record reason for deletion of landmark or aid go navigation. Show triangulation station names, when applicable, In parentheses*)	POSITION				METHOD AND DATE OF LOCATION (See Instructions on reverse side)		CHARTS AFFECTED
		LATITUDE		LONGITUDE				
		° ′	″ D.M.Neters	° ′	″ D.P.Meters	OFFICE	FIELD	
CUPOLA	Cupola on large white bldg , east end of Fisher Island	25-45	35.27 1085.34	8o-o8	01.21 33.70	75E(C)6402 8/12/74	V-VIS 3/19/75	54T 1248 847-SC
CHIMNEY	Chimney on power plant, South Dolphin Point	25-46.8		80-08	9		P-8-L 3/21/75	"
TANK	South Miami Beach, Water Tank, (Green), 1934 ht=133(138)	25-46	09-05 278.49	8o-o8	14-93 416.03		Triang- Recc 3/22/75	v "
TOWER	Miami Beach Radio Station (WKAT) tower, 1971 ht=207(212)	25-47	33.86 1041.95	8o-o8	37-05 1032.20		"	"

FIGURE 5–11.—Side 1 of **NOAA** Form 76–40, "Nonfloating Aids or Landmarks for Charts." See also figure 5-12.



RESPONSIBLE PERSONNEL

TYPE OF ACTION	NAME	ORIGINATOR
OBJECTS INSPECTED FROM SEAWARD	C.D. Schorlein, Lt; NOAA	☐ PHOTO FIELD PARTY ☐ HYDROGRAPHIC PARTY ☐ GEODETIC PARTY ☐ OTHER (Specify)
POSITIONS DETERMINED AND/OR VERIFIED	J.E. Wolf, Photo Party 62	FIELD ACTIVITY REPRESENTATIVE
	S.T. Walker, Coast. Map Div; AMC	OFFICE ACTIVITY REPRESENTATIVE
FORMS ORIGINATED BY QUALITY CONTROL AND REVIEW GROUP AND FINAL REVIEW ACTIVITIES		☐ REVIEWER ☐ QUALITY CONTROL AND REVIEW GROUP REPRESENTATIVE

INSTRUCTIONS FOR ENTRIES UNDER 'METHOD AND DATE OF LOCATION'

(Consult Photogrammetric Instructions No. 64,

OFFICE

1. OFFICE IDENTIFIED AND LOCATED OBJECTS
   Enter the number and date (including month, day, and year) of the photograph used to Identify and locate the object.
   EXAMPLE: 75E(C)6042
   8-12-75

FIELD

1. NEW POSITION DETERMINED OR VERIFIED
   Enter the applicable data by symbols as follows:

F	- Field	P	- Photogrammetric
L	- Located	Vis	- Visuality
V	- Verified		
1	- Triangulation	5	Field Identified
2	- Traverse	6	Theodolite
3	- Intersection	7	Planetable
4	- Resection	8	Sextant

A. Field positions* require entry of method of location and date of field work.
EXAMPLE: F-2-6-L
8-12-75

*FIELD POSITIONS are determined by field observations based entirely upon ground survey methods.

FIELD (Cont'd)

B. Photogrammetric field positions** require entry of method of location or verification, date of field work and number of the photograph used to locate or identify the object.
EXAMPLE: P-8-V
8-12-75
74L(C)2982

II. TRIANGULATION STATION RECOVERED
When a landmark or aid which is also a triangulation station is recovered, enter 'Triang Rec ' with date of recovery.
EXAMPLE: Triang Rec
B-12-75

III. POSITION VERIFIED VISUALLY ON PHOTOGRAPH
Enter 'V-Vis ' and date.
EXAMPLE: V-Vis
8-12-75

**PHOTOGRAMMETRIC FIELD POSITIONS are dependent entirely, or in part, upon control established by photogrammetrIc methods.

HOAA FORM 76-40 (8-74)

SUPERSEDES NOAA FORM 74-40 (2-71) WHICH IS OBSOLETE AND EXISTING STOCK SHOULD BE DESTROYED UPON RECEIPT OF REVISION.

FIGURE 5–12.—Side 2 of **NOAA** Form 76–40, "Nonfloating Aids or Landmarks for Charts." See also figure 5-11.

hydrographer must interpret the data and report it in proper form. Although the following standardization of nomenclature is general, it shall be followed insofar as practical.

In general, descriptive terms are omitted from the name recommended for the chart. Colors describing an object are particularly objectionable because of their temporary nature. Information on the material from which an object is built is not valuable on the chart because from even a short distance away the mariner may not be able to identify an object by its material. The adjective "tall" is unnecessary; if the object were not tall it would not be a prominent landmark. If a descriptive term is necessary to distinguish a charted landmark from other uncharted objects in the vicinity, the descriptive term is entered in capital letters.

Generally, an object's utilization is nonessential charting information unless knowledge of the use contributes to the identification of the object. When reporting buildings as landmarks, avoid insofar as possible using a charting name that indicates the function of the building. It is preferable to use a term such as DOME, TOWER, or SPIRE that describes the shape of the top of the building. The name describing the function, such as schoolhouse or courthouse, may follow in lowercase letters.

Company names usually are omitted from the chart unless these names or abbreviations are visible on the landmark in letters large enough to serve as identifying features to the mariner.

Names of especially well-known buildings are shown in parentheses following the names of the landmarks [e.g., DOME (STATEHOUSE), TOWER (EMPIRE STATE BLDG)].

If two similar objects are close together, the word "twin" shall be omitted if the objects are charted as two separate landmarks. Where indicated by a single landmark symbol, "twin" is used.

If only one of a set of closely grouped objects is to be charted, the name of the object is followed by a descriptive legend in parentheses. Include the number of objects in the group [e.g., STACK (TALLEST OF FOUR) or STANDPIPE (NORTHEAST OF THREE)].

The geographic relationship of a landmark with respect to other topographic features is not essential and should not be included in the description because this is shown graphically on the chart.

In table 5-1 is the standardization of terms that shall be used when practical.

5.5.2. Report on Nonfloating Aids to Navigation

A separate NOAA Form 76-40, "Nonfloating Aids or Landmarks for Charts," shall be used to report the positions of all nonfloating aids to navigation on an areal basis when a hydrographic project has been completed or work has ended for the field season. (See 4.5.13 and figures 5-11 and 5-12.) The geographic positions of all nonfloating aids, including privately maintained lights and beacons, shall be verified or determined in the field. Applicable parts of the requirements stated in section 5.5.1 for Form 76-40 shall be followed in compiling this report. If contemporary shoreline mapping of the area has been undertaken, copies of Form 76-40 for new aids or aids to be deleted shall be sent to the Photogrammetry Division; otherwise, the forms are sent to the Marine Chart Division. For additional details concerning landmarks and aids to navigation, see the following:

"Photogrammetry Instructions No. 64, Requirements and Procedures for Collecting, Processing and Routing Landmarks and Aids to Navigation Data— Photogrammetric Operations" (National Ocean Survey 1971*b*).

"Provisional Photogrammetry Instructions for Field Edit Surveys" (National Ocean Survey 1974).

It is important that the names of the aids entered on the form be identical with those given in the *Light List* (U.S. Coast Guard 1976) and that the *Light List* number be given. The position of each aid should be plotted on the largest scale chart of the area and compared with the charted position. Significant differences, shall be reported to the U.S. Coast Guard District Headquarters and to National Ocean Survey Headquarters through the appropriate Marine Center.

5.6. TIDE AND WATER LEVEL STATION REPORTS AND RECORDS

The following reports and information shall be submitted promptly after the installation, removal, inspection, or servicing of a tide or water level station:

NOAA Form 77-12, "Report—Tide Station."

NOAA Form 77-75, "Great Lakes Water Levels Station Report."

NOAA Form 76-77, "Leveling Record—

TABLE 5-1. — *Landmark classifications, definitions, and rules*

BUILDING	(See house).
CHIMNEY	That projecting part of a building for discharging smoke or effluvium to the outer air. This term is to be used only where the building is the prominent feature and the charting of some specific part of it is desirable (e.g., the tallest chimney of a large factory).
CUPOLA	A small turret or dome-shaped tower rising from a building; used in cases where the building is the prominent object and the cupola is small as compared to the building.
DOME	A large cupola or rounded hemispherical form, or a roof of the same shape, whether rounded or many-sided.
FLAGPOLE	A single staff flagpole rising from the ground and not attached to a building or other structure.
FLAGSTAFF	A single flagpole rising from a building or other structure. Flagstaffs are not usually desirable for use as landmarks because they may not be permanent. Although desirable that the most prominent definitive part of a building (such as a flagstaff) be pointed at when making visual survey observations, it may not be the most important part of the building for charting purposes. Wherever possible, indicate for use on the chart that part of the building from which the flagstaff rises, such as TOWER, CUPOLA, and DOME.
FLAGTOWER	Any scaffold-like tower on which flags are hoisted, such as a U.S. Coast Guard skeleton steel flagpole. Do not use the term "SIGNAL TOWER."
GAS TANK or OIL TANK	Since this tank differ in shape and size from water tanks, the compound name shall be used.
HOUSE or BUILDING	Although it is desirable to locate a house or building by observations on a specific point, such as the west gable or the flagstaff, such terms are not desirable for charting purposes if the structure itself is the landmark. Use HOUSE or BUILDING followed by a description of the point either in capitals or in lowerease letters, according to whether or not the description should be shown on the chart. Where the outline of the building should be shown on the chart, the notation "chart outline" is made on Form 76-40. (See figures 5-11 and 5-12.)
LOOKOUT TOWER	Any tower surmounted by a small house from which a watch is habitually kept, such as a U.S. Coast Guard lookout tower or a fire lookout tower. Do not use this term to describe an observation tower or parts of buildings from which a watch is not kept.
MONUMENT	Do not use "obelisk" or other similar terms.
RADOME	Dome-shaped structure used to enclose radar apparatus (may also have a cylindrical base with a dome top).
RADAR TOWER	A tower or structure used to elevate parabolic or mattress-type radar reflectors.
RADIO MAST	A general term used to include any polelike structure for elevating radio antennae.
SPIRE	Generally, a slender pointed structure that surmounts a building. Do not use the term "steeple." SPIRE is not applicable to a short pyramid-shaped structure rising from a tower or belfry.
STACK	Any tall smokestack or chimney more prominent than surrounding buildings or structures.
STANDPIPE	A tall cylindrical structure, usually part of a waterworks system, with a height several times greater than its diameter.

TABLE 5-1.–*Concluded*

TANK	A container for water. Its base rests on the ground or other foundation, and its height is not much greater than its diameter.
TANK (elevated)	A container for water. The tank is elevated high above the ground or rests on a foundation or skeletal framework.
TELEVISION TOWER	A tall slender structure for elevating television antennae.
TOWER	1. A part of a structure higher than the other parts but having vertical sides for the greater part of its height. 2. An isolated structure with vertical sides (not otherwise classified); high in proportion to the size of its base; simple structural form. 3. The top of a skyscraper, high in proportion to its horizontal size; rising above its surroundings. 4. Any structure, whether or not its sides are vertical, with its base on the ground; high in proportion to the size of its base.
TREE	Do not use the terms "lone tree" or "conspicuous lone tree." These characteristics are assumed; otherwise, the tree would not serve as a landmark.
WATER TOWER	A decorative structure that encloses a tank or standpipe (infrequently used).
WINDMILL	(Self explanatory).

EXAMPLES

CHIMNEY, schoolhouse (Mt. Vernon H.S.)
CUPOLA, schoolhouse (Normal School, 98 ft high)
FLAGPOLE (Green Hill Country Club)
LOOKOUT TOWER, fire (110 ft high)
SPIRE, church (Nanticoke Church Spire)
STACK (Aiea Mill)
STACK (at Hot House)

STACK (TALLEST OF FOUR)
STACK
TANK (BAY STATE CO.) (275)
TANK (SOUTH) (southernmost of the three tanks)
TANK *(*125 ft high)
TANK (GRAMP, 294)
TOWER (CITY HALL)

Tide Station." A detailed sketch showing the location of all station bench marks, the gage, and the staff shall be provided on pages 4 and 5.

A page-size section of a large-scale nautical chart or map (e.g., 1:24,000 U.S. Geological Survey quadrangle) indicating the station site.

If possible, photographs of the general area of the station with closeup snapshots of the gage and staff installations.

Original tidal and water level records are submitted directly to **NOS** Headquarters **(OA/C23)** for analysis and datum determination, and a copy of the transmittal letter is sent to the appropriate Marine Center. Copies of the records will be furnished to the Marine Center after inspection for completeness and accuracy.

Detailed instructions for gage installation and operation, bench mark and leveling requirements, and the reports listed are found in *Publication* 30-1, "Manual of Tide Observations" (U.S. Coast and Geodetic Survey 1965*a*).

5.7. GEOGRAPHIC NAMES REPORT

Complete or extensive field investigations of geographic names shall be conducted only when specified in the project instructions. The different types of investigations, field procedures to follow, and instructions for the assembly and submission of the Geographic Names Report are described in "Photogrammetry Instructions No. 63, Instructions —Geographic Names and Object Names for Photogrammetric Maps—Field and Office." (U.S. Coast and Geodetic Survey 1969*b*).

Although the project instructions may not specifically require a complete geographic names investigation, the hydrographer should be continually alert for new names and discrepancies in charted names throughout the project area. It is particularly important that all geographic names not only be correct in name but also in spelling and application. The hydrographer should take every opportunity to check both charted names and those in the Coast Pilots against local usage. If a published name differs from local usage, the hydrographer should ascertain from independent sources how well the local name is established and, if possible, the origin.

If a separate or detached unit is ashore conducting field edit or other supporting survey operations, information on geographic names usually can be gathered with little or no extra effort during the course of the daily work. The correct geographic names of water features such as channels, sloughs, rivers, inlets, bays, reefs, rocks, shoals, and small off-lying islands and their special features are of equal importance with the correct names of interior landforms and bodies of water. Copies of **NOAA** Form 76-155, "Geographic Names" (figure 5-6), shall be submitted to the NOS Chief Geographer on a project or seasonal basis, whichever occurs first. The names are listed alphabetically and appropriate data in columns A through K are entered.

A Geographic Names Report, when required, shall be prepared and submitted for the portion of all projects surveyed during the field season as soon as practical after work on each project has ended. The report shall be prepared in accordance with Photogrammetric Instruction No. 63. Refer to section 5.3.5(C) for Descriptive Report geographic names requirements.

5.8. COAST PILOT REPORTS

The Coast Pilots, published annually by **NOS** contain narrative information of importance to the navigator. This information cannot be shown conveniently on the nautical charts and is not readily available elsewhere.

Revision data and reports collected and submitted by hydrographic field parties are among the most important sources of information for updating the Pilots. Special efforts shall be made by all field units to collect all data pertinent to Coast Pilot publications so the published information in the project area can be updated completely and accurately. The opportunity should be taken at all ports of call and during passages between ports to verify or revise the information contained in the latest editions of the Pilots. Mere revisions of the published text are not sufficient; new information that will increase the value of the Pilot publications should be obtained whenever possible.

Pilot Reports shall be compiled and submitted as soon as practical after the data have been collected. If the Pilot information for an area is adequate and no revisions are recommended, a brief report stating this fact shall be submitted.

Coast Pilot Reports shall be assembled in accordance with the *Coast Pilot Manual* and submitted in duplicate. (See 1.7.1.) Where appropriate, **NOAA** Form 77-6, "Coast Pilot Report," may be used in place of a more lengthy narrative report.

5.9. DANGERS TO NAVIGATION REPORT

Discoveries of uncharted shoals, obstructions, wrecks, or other submerged features considered dangers to navigation must be reported immediately by radio, telephone, or telegraph to the commander of the nearest U.S. Coast Guard District and to the appropriate Marine Center. The message shall be in this form:

"(Object) covered by (depth of water) at (tidal or water level datum) discovered; Chart No. ———; Latitude ———; Longitude ———;distance ——— nautical miles (or meters), bearing ——— degrees true from (charted object)."

A tracing of the field sheet or largest scale chart available showing the exact location of the newly discovered danger shall be prepared and sent to Chart Information Branch, OA/C322, through the appropriate Marine Center, at the earliest opportunity. A description of the hazard and the method of location shall accompany the tracing. (See 1.6.4.)

A statement of all such reported dangers shall also be included in the Descriptive Report. (See 5.3.4(L).) Negative reports are required.

Floating wreckage, logs, derelicts, or other similar objects that are menaces to navigation shall also be reported promptly to the commander of the nearest U.S. Coast Guard District.

When a floating aid to navigation is found to be off station to an extent that it does not serve its purpose adequately and creates a danger to navigation, the facts should be reported immediately to the nearest U.S. Coast Guard District.

The necessity for prompt action in these situations cannot be overemphasized. Verbal communications and radio messages must always be confirmed in writing. Copies of all correspondence with the U.S. Coast Guard shall be forwarded to the Chart Information Branch, OA/C322 through the appropriate Marine Center.

5.10. CHART INSPECTION REPORT

Each field party, while en route to and from the project area, shall obtain data for revision of charts. The fact that time and circumstances do not permit obtaining precise field locations and information on new features should not deter the hydrographer from furnishing all practical information on observed changes.

New landmarks, waterfront construction, and other shoreline changes are frequently added to charts by photogrammetric methods without a full hydrographic survey of an area. Advance information on erroneous or incomplete chart data is extremely useful when scheduling aerial photography and compiling the survey.

Each chief of party must contact local members; of the U.S. Power Squadrons and U.S. Coast Guard Auxiliaries at every possible opportunity. As local knowledgeable users, they can furnish first-hand information on chart conditions and deficiencies. Chart inspection data submitted should consist of the following classes of information:

1. Landmarks to be added or deleted.
2. Waterfront improvements and changes.
3. Bridges or tunnels to be added or deleted.
4. Removal of piling. When marking piers and other structures for deletion, state whether piles have been removed. The feature will be retained as ruins if definitive information is not provided.
5. Rocks, shoals, and other obstructions. Include discrepancies between charts and observed conditions and provide information gathered locally on reported obstructions. Where not feasible to obtain positions and soundings on such reported dangers, the report should include recommendations for future surveys.
6. Aids to navigation. Positions of floating aids should be verified. Description, numbering, and light characteristics should be checked.
7. Channel depths. Report indications of shoaling in dredged channels.
8. Cable areas. Report new submerged cable areas and overhead cables not currently shown on the chart.

Chart inspection notes should be accompanied by sections of charts showing corrections in red ink. The method of submitting such data is discussed in detail in sections 7 and 8 of the *Coast Pilot Manual* (U.S. Coast and Geodetic Survey 1969*a*).

5.11. REPORT ON VISIT TO AUTHORIZED CHART SALES AGENT

National Ocean Survey authorized chart sales agents provide valuable assistance to the mariner by stocking the most recent editions of charts of the area. Field units are occasionally required to visit and familiarize the agents with **NOAA** services and to provide assistance and advice to the agent on his stock of charts. Special instructions and reporting forms will be issued for required inspection visits.

5.12. SPECIAL REPORTS AND PHOTOGRAPHS

Miscellaneous reports of a special nature in addition to those listed in this chapter and in other **NOAA/NOS** manuals are desirable and necessary from all hydrographic field units. These reports shall be prepared and submitted for all items of unique interest or historical documentation. Although the need for special reports generally will be included in the project instructions or identified by separate memorandums, the chief of party should prepare such additional reports he considers necessary. Items that should be handled by special reports include but are not limited to:

Innovative operational procedures and results.

Geodetic, magnetic, gravity, and other similar field operations.

Equipment trial and evaluation.

Other observations and operations not usually associated with hydrographic surveying.

Photographs of field activities, personnel, and equipment (particularly snapshots that portray actual field operations) are of considerable value. Each chief of party should designate a responsible person with an interest in photography to take such photographs whenever practical. A good-quality camera should always be used to assure sharp reproductions and enlargements. The negatives of each pertinent photograph should be sent to the appropriate Marine Center, with a recommended caption. The Marine Center shall provide copies to **NOS** Headquarters.

PART TWO

Final Data Processing

6. VERIFICATION AND SMOOTH PLOTTING

6.1. DEFINITION AND PURPOSE

Each registered hydrographic survey shall be verified to ensure that the survey data to be smooth plotted and stored in the hydrographic data bank are as accurate as possible and provide a true representation of the surveyed area. Although modern verification procedures rely heavily on high-speed automated techniques for batch processing the voluminous survey data, human judgment and intercession are still required during the verification process. Verifiers must be continually alert for lost or erroneous data that could compromise the quality of a survey. They must make frequent value judgments when assessing various data, and must be prepared to make final comprehensive statements as to whether or not surveys meet basic hydrographic standards and specifications.

Field survey data are processed through a sequence of both computer and automatic plotter operations and manual verification checks; the types and applications of these checks depend on the control system, method of sounding, and other equipment used to acquire the data. The timing of each verification check is important. All errors and omissions in field survey data must be systematically found and corrected to avoid unproductive repetitious work by the verifier and to not waste time on automation equipment.

A verifier's primary duty is to carefully check every phase of a survey for accuracy and for conformance to established specifications, conventions, and guidelines. His task extends beyond correcting obvious errors and providing a complete record of a survey; he must also detect and correct errors of a less evident nature that may affect the accuracy of a smooth sheet and the corresponding final data listings. Specific areas of discrepancy are frequently not revealed until the final verification stages. Because the factors affecting the plotted data are so complex, verifiers often find it necessary to review analog depth records, velocity correction data, echo sounder calibration data, tidal information, calibration of electronic control systems, and computer input data—then make other adjustments as necessary to eliminate discrepancies and provide a true cartographic representation of the survey area.

Utilization of sophisticated data acquisition and processing systems does not lessen the inherent responsibilities of a verifier. The high standards described in chapter 7 for the completeness and clarity of the cartographic presentation of hydrographic data must be adhered to rigorously. A slight knowledge of equipment and survey methods now in general use and a casual awareness of the contents of this and other pertinent manuals are not sufficient. *A verifier must be thoroughly knowledgeable about all phases of hydrography and automated data processing and must be capable of applying correctly the principles involved.*

6.2 VERIFICATION WORK SCHEDULES

Because of the difficulties encountered when scheduling the large number of plotting and verification phases through which each survey must progress, it may not be possible for one verifier to complete all stages. Assignments of the various phases therefore must be made giving consideration to the degrees of difficulty of the work and to the relative capability, experience, and judgment of an individual verifier. As each step of the verification process is completed, each unresolved problem or unusual situation must be documented to provide information and guidance to those assigned to the later stages of the work. A summary of significant changes to the raw survey data shall be prepared to accompany the completed smooth sheet.

Close working relationships must be maintained between survey verifiers and those responsible for automated data processing (Electronic Data Processing Branches). Such relationships help to ensure an efficient application of the many corrections and changes to preliminary data found during each phase of verification. All corrections and changes made by the verifier must either be clearly indicated in the Sounding Volumes, on the data listings or printouts, or be tabulated in a neat orderly manner that is easy to follow. Such notes made by verifiers become the basis for detailed instructions that list remedial actions and reprocessing requirements. Such lists of instructions must be inspected and approved by the

M) are useful in shallow waters and where mechanical cable handling equipment is not available. Longer tow cables (200 m to 10,000 m) are steel armored, high-density cables designed to achieve maximum tow depth and minimum noise interference at given tow speeds.

Depth of the transducer towfish is controlled by the length of cable deployed, vessel towing speed, and vessel course. Tow depths can be increased by the use of a depressor or suitable weights.

The graphic recorder contains most of the electronics for the system as well as the graphic mechanism. Most recorders are designed to operate from 24 V d.c. or 110 to 220 V a.c. power supply. (See figure AI-1.)

Al.3. Side Scan Sonar

The following discussion is limited to a description of the side scan sonar system currently used by the National Ocean Survey for hydrographic and bathymetric surveying. The technical manual published by the manufacturer is a necessity for satisfactory operation and maintenance of the system.

AI.3.1. KLEIN ASSOCIATES, INC; SIDE SCAN SONAR SYSTEM. The Klein side scan sonar system consists of the following components:

1. Dual Channel Hydroscan Recorder
2. 50-kHz Dual Channel Towfish.
3. 100-kHz Dual Channel Towfish.
4. Lightweight Tow Cable - 300 feet.
5. Lightweight Tow Cable - 600 feet.
6. Armored Tow Cable - 2,000 feet.
7. Towfish Stablizer Depressor.
8. Operation and Maintenance Manual, Recording Paper, Breakaway Tail Assemblers, and Spare Parts.

The Klein side scan system can be operated from both small and large ships. The system is impervious to marine environments including temperatures of 0ºC to 50ºC. The equipment will operate from both 24 V d c. ±10% and 120 V a.c. 60 Hz ± 10%. The service manual (Klein Associates, Inc.-1977) includes all necessary instructions, schematics, parts lists, troubleshooting, and general maintenance instructions. This manual is available as Klein Part No. 521-01 from Klein Associates, Inc., Route 111, RFD 2, Salem, New Hampshire 03079.

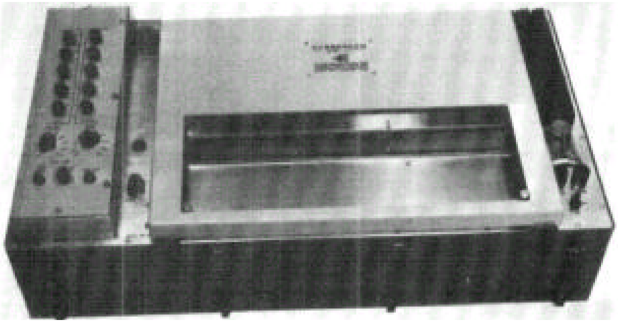


FIGURE AI-1.— Klein Hydroscan Dual Channel Side Scan Sonar Recorder (courtesy of Klein Associates, Inc., Salem, New Hampshire)

AI.3.1.1. *Side Scan Recorder.* The Klein recorder contains the patented Hands-Off-Tuning Ⓡ feature which provides automatic adjustment, making uniform results across the sonar chart. Switches are provided for each channel to additionally permit manual selective tuning. Three event mark features are included: an internally generated 2-minute mark, a pushbutton on the recorder control panel, and a remote event mark pushbutton.

Both recording channels print simultaneously, reading outward from the center of the record in true left/right perspective. The range of the system using the 100-kHz towfish is at least 1,500 feet port and starboard at speeds up to 6 knots. At a 5-knot tow speed the 50-kHz towfish range is at least 2,000 feet. The range of the side scan system is also dependent on the operational environment, target, and the tow speed.

AI.3.1.2. *Side Scan Transducers.* The towfish consists of individual modular port and starboard transducers whose vertical beam may be varied in 10º ± 2º increments from 0º to 20º by means of minor external mechanical adjustments to the transducer modules. (See figure AI-2.) The tail fin assembly consists of two individual breakaway tail fins, separating when they strike a submerged object. The towfish parts are capable of operation in water depths to 7,500 feet. Separate identical left and right channel plug-in circuit boards are housed in the nose of the towfish.

AI.3.1.3 *Tow Cable Assemblies.* Lightweight tow cable assemblies consisting of a polyurethane jacket and a Kevlar strength member are provided. The minimum breaking strength is 6,000 pounds. The core consists of four conductors, two of which are individually shielded and used for the right and left channel signal returns, while the other two are for power and trigger pulses. The entire core is additionally shielded. A 300-foot and a 600-foot lightweight cable are provided. The 2,000-foot cable has the same core as the lightweight cable and uses a dual-armored steel jacket providing a breaking strength in excess of 15,000 pounds.

AI.3.1.4. *Operations Considerations.* Although automatic tuning is available in the control circuitry manual tuning is superior when employed by a trained operator. Experience has shown that properly adjusted, manual controls strongly print a known target which might have been entirely overlooked among other returns on automatic tuning. Herein lies a problem, for if the manual tuning is not properly adjusted, it is worse than the automatic tuning for search. Manual tuning requires constant attention, and some skill to know, or feel, when proper tuning has been achieved. It is important to develop skill in hand tuning by working near a known target for a short period of time. This known target may be attached to an implanted buoy anchor line.

Environmental conditions limit the use of the sonar. The pulse repetition frequency is limited by the time required for the acoustic signal to reach the limit of the search band and return to the towfish. This physical limitation is in direct conflict with the desire to gain resolution on a target by getting as many separate pulses as possible to bounce off the target. There are two solutions to this problem: First, limit search path width; second, move at very slow speed. Both of these decrease the area which can be searched in a given period of time. It should be pointed out that speed over the ground is very important in side scan operations. Slow, constant speed can often be maintained by moving into the current.

Another environmental factor limiting use of side scan is sea state. This factor is most influential in water under 40 feet, but decreases with depth. Sea surface return is so strong with waves of only 2 and 3 feet in less than 40 feet, that it cannot be completely tuned out. As a result, targets on the bottom may be lost. One recourse is to lower the towfish below the interference. This would, of course, endanger the towfish in shallow water. Another means is by use of a recently developed towfish with a variable vertical beam (20° or 40°). The 20° setting is useful to minimize sea clutter.

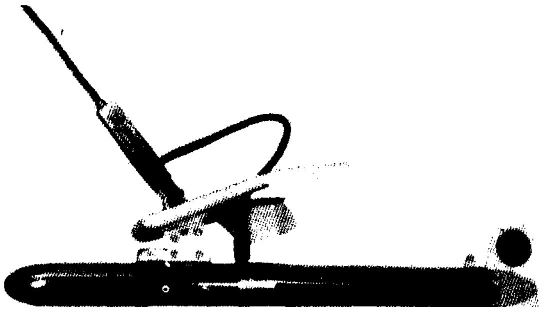


FIGURE AI-2.— Klein Side Scan Sonar Towfish (courtesy of Klein Associates, Inc., Salem, New Hampshire) speed—or when a position deviates from the dead-reckoned track without a recorded corresponding change of course. Other errors in positioning may be caused by incorrect visual angles, theodolite directions, or undetected electronic system lane jumps or other anomalies that may not become apparent until depth discrepancies are noted on sounding overlays. (See 6.3.4.)

"Weak" positions are likely to occur on electronically controlled surveys (4.4.3) if the control was inadvertently used beyond the limits of strong intersections or where the signal parallels, crosses, reflects, or otherwise attenuates from landmasses. Under these conditions, sextant or theodolite fixes may have been observed as a check on the electronic control. Where visual fixes are available or where junctions are made with visually controlled hydrography and conflicts in depths occur, positions located by visual methods are generally accepted and appropriate adjustments should be made to those controlled by electronic methods. In such cases, the survey Descriptive Report is consulted for the hydrographer's recommendations.

Estimated positions are frequently needed where it is not feasible to obtain geometric fixes (e.g., in narrow winding creeks or sloughs, arms, high-banked channels, and in other restricted areas where similar conditions prevail). Estimations based on dead reckoning are also used occasionally when positioning ends of sounding lines and when surveying in docking areas or along waterfront structures where it is impractical to control hydrographic lines conventionally. These positions are pricked on the field sheet and subsequently recorded as geographic positions by latitude and longitude. Except for positions in docks and around piers, which generally are smooth plotted as subplans (7.2.4) at enlarged scales, pseudo fixes (forced positions) must be scaled by the verifier for automated plotting, if not already done by the hydrographer.

Each detached position used to locate structures and objects (such as beacons, buoys, rocks) and to position other hydrographic data (such as submerged rocks, obstructions, least depths over shoals) must be checked by the verifier. When a hydrogapher has observed so many detached positions that congestion occurs delineating limits for shoals or reefs, the size and shape of piers, or other features, the verifier should retain only the most critical data—the remainder are rejected and excised from the data file.

Survey vessels equipped with fully automated **HYDROPLOT** systems usually record electronic positional data for each sounding. Vessels not equipped with a **HYDROPLOT** system or that are conducting visually controlled hydrography furnish position control data only for numbered positions; interval soundings between fixes are plotted by time and course. Positional data from either system may be adversely affected by electrical interference to electronic control. Such interference in phase-comparison measurements is manifested by sporadic "lane jumps" and "dial roll" when electronic receivers attempt to lock onto a spurious signal from outside the system. Super high frequency systems are subject to a number of distance-measuring errors. Signal reflection (multipath measurements), phase interference bands, line-of-sight interference, and improper voltage are among the causes that affect distance readout. Powerful radar transmissions in the vicinity of super high frequency operations frequently cause significant signal blockage.

Lane jumps and dial roll are usually detectable on the analog position record or sawtooth recording. (See 4.8.6.) Otherwise, the verifier must be alert for pronounced irregularities in dead-reckoned positions, poor agreement of depths at sounding line crossings, or depth contour anomalies. Positions in error usually are replotted to agree with time and course of the vessel; such replotting must be noted on the appropriate data lists so the correct data will be input for updated machine plots of the position overlays. Judgment is often required; however, corrections to positions must not be applied capriciously just to force agreement with dead reckonings. When spacings between soundings and positions are relatively constant and the course of a vessel is erratic, irregularity may be attributed to poor steering or to the effects of sea conditions. When such conditions exist, the soundings should generally be assumed to be positioned correctly.

Inshore preliminary position overlays are compared with the field sheets for changes made by the hydrographer and with photogrammetrically compiled shoreline manuscripts to detect and resolve discrepancies in the shoreline, datum line (1.6.1), electronic control correctors, and other hydrographic and topographic details. (See 6.3.5.)

Verifiers must exercise precaution and use every resource available to detect and list for correction every erroneous position prior to ordering sounding overlays. When this phase of verification is done thoroughly and efficiently, expensive electronic data processing time is not wasted; and potential problems that could surface at later stages of verification are often eliminated. All major positional errors, deficiencies, or unusual methods that have been discovered must be thoroughly documented for the information and guidance of those involved in the succeeding stages of verification and quality control.

Smooth position overlays are the final plots of positions that accompany each smooth sheet. Normally, a smooth overlay is not plotted until after completion of the sounding verification phase (6.3.4); previously undetected errors are often discovered during sounding verification making necessary further adjustment of positional data.

6.3.3.1. CHECKING MACHINE-PLOTTED POSITIONS. A sufficient number of machine-plotted positions on each smooth sheet shall be checked to ensure overall plotting accuracy. Each position need not be checked — the number of positions to be checked is a judgment matter. Checking methods depend on the positioning system used for the survey.

Visual sextant fixes are checked by plotting positions with three-arm protractors. (See A.9.1.1.) Plastic protractors cannot be adjusted and should be checked for error at least daily when in use. Index and other scale errors can be determined and applied to observed angles for accurate plotting or checking of positions. Plastic protractors have a tendency to warp, particularly near the ends of the arms; the usable portion must be determined and marked or the fiducial line rescribed. Plastic protractors may be used to the full limit of the arm length, but no protractor with an index error greater than 3 min either arm shall be used for verification or position plotting. To plot a three-point fix lying very near one of the three stations, one lays the three lines out on a piece of drafting film that can then be used as the protractor.

When electronic positioning systems are used in the range-range mode, positions are plotted or checked manually by using an Odessey protractor. (See A.9.1.2.) The concentric circles inscribed on the transparent plastic base permit placing the center over the position by measuring the proper increments from each of the nearest distance circles. Before using an Odessey protractor, the circular scales must be checked carefully with a beam compass and meter bar, taking into account the system operating frequency and resultant lane width.

Plotting and checking a position determined by a hyperbolic positioning system is best accomplished by scaling each line of position separately using a dependable variable scale device. Variable scales are available commercially. When only a few positions need to be plotted or checked, an engineer's scale can be used by skewing the scale between the plotted position arcs to match the scale values with the difference in arc values.

6.3.3.2. RESOLVING ERRONEOUS VISUAL POSITIONS. Erroneous sextant positions will normally be resolved by the hydrographer in the field and the data corrected accordingly. Resolution of undetected errors becomes the verifier's responsibility.

When a "split fix" (two angles without a common center object) is observed in the field, a psuedo three-point fix must be created to provide suitable input for a machine plot. An observed position is plotted by constructing the intersection of the loci of the angles. Then the values for a legitimate three-point fix are scaled from the sheet for use on the next plot.

When only one angle was recorded or accepted, the position of the vessel must be plotted on the locus of the angle at a point that coincides with the speed and course made good. The quality of a position of this nature depends on the vessel maintaining a steady speed and course and on the geometric strength and accuracy of the single line of position. It may be necessary to defer the determination of final positioning values until the sounding overlays have been constructed (6.3.4) so as to adjust the soundings to be in agreement with other surrounding hydrography. If a series of positions cannot be resolved, it may be necessary to reject that portion of the sounding line. "Swingers" and other geometrically weak fixes (4.4.2) that are detected and noted during the machine-plotting phase receive similar treatment as positions for which only one angle was observed.

Estimated positions are used when the hydrographer could not observe a strong three-point fix — such positions must be verified with a suspicious and critical eye. Estimated positions are often used close inshore where normal fixes are not available. The distance from a beach, structure, or station should have been estimated and entered in the records. Positions of line ends and beginnings can be plotted by dead reckoning on the extended line, provided that a speed change affecting the positioning interval did not occur during the period over which the last three reliable fixes were taken.

Structures and objects such as beacons, buoys, rocks, and piers are often referenced in the sounding records (by distance and direction) when the survey vessel passes the feature. These notes, to provide a check on the survey, must state positively on which side of the object the launch passed and the time of occurrence. See figure 4–24 (4.8.3.1) for an example of a proper entry where "can buoy 7" was 20 m abeam of the survey vessel at $20^h\ 31^m\ 50^s$ GMT. Skillful evaluation of the data is required to resolve the occasional discrepancies that can result from such estimates. Survey vessels often cannot safely get close to rocks and reefs when locating them. In such cases, the vessel stands off the feature, several positions of the vessel are taken, and a distance and direction to the feature are estimated from each position. When possible, sextant cuts or bearings to the feature should have been observed. When estimated positions disagree, a verifier must evaluate whether an incorrect estimate was entered or other "standoff" positions were determined and plotted, yet inadvertently not recorded.

Estimated positions are often used to plot soundings observed after a vessel makes a sharp turn then continues to record soundings. The forward momentum of a vessel varies with its size, hull shape, and speed; such variations should be reflected on field plots and by information provided by the hydrographer.

Occasionally, good fixes are not available, especially when sounding in narrow winding waterways. A hydrographer in such cases should have estimated the vessel position on the field sheet, using the adjacent features of the shoreline as a reference —in such cases, the note "See field sheet" (SFS) will have been entered in the sounding records. To machine plot an estimated position, a verifier must scale a pseudo fix if not already determined by the hydrographer.

Human blunders contribute heavily to the occurrence of sextant position errors. In most cases, erroneous positions can be salvaged if the contributory cause can be recognized. Original data shown in the field records must never be erased or otherwise obliterated; a single line is used to cross out erroneous data, and the revised or corrected data are entered above or alongside in a clear and concise manner. Typical errors that repeatedly occur in recorded positional data include:

1. Entry of an incorrect station number for an observed object because:

   a. A change in observed objects was not reported or recorded;

   b. A recorder misunderstood the station number; or

   c. A wrong object was observed or a signal misidentified.

2. Minutes and degrees of an observed angle were reversed (e.g., an observed angle of 30°50 ' was recorded as 50°30 ').

3. Transposition of numbers (e.g., an observed angle of 54°30 ' was recorded as 45°30 ').

4. A sextant angle was read incorrectly. Angular errors commonly result from misreading an adjacent vernier division by 20 or 30 min, depending on the type of sextant. Other misreading errors include: 10' on the drum of a Navy-type sextant; 1° on any sextant; 2°, 4°, or 6° when a 1°, 2°, or 3° increment is erroneously applied on the wrong side of the longer 5° or 10° division; 5° and 10° for the same reason as for 10 ', 20 ', 30 ', and 1°. Although errors of this nature occur repeatedly in field observations, recorded angles must not be corrected or adjusted unless the substituted value is confirmed by other factors.

5. A recorder may have misunderstood the reported value of an observed angle and recorded a 15 for a 50, a 7 for an 11, a 5 for a 9, or vice versa.

6. A station position may be in error. Occasionally, a more careful evaluation of a control station location by hydrographic methods may disclose previously undetected errors.

6.3.3.3. RESOLVING ERRONEOUS ELECTRONIC POSITIONS. These positions stem from a multiplicity of causes, many of which admittedly remain unknown. Weak positions occur on electronically controlled surveys when the hydrographer pushes the control system beyond the limits of geometrically strong intersections and acceptable lane widths. When discrepancies between visually controlled and electronically controlled hydrography occur in junctional areas, visual observations are usually more reliable and are generally accepted. See section 4.4.3 for a discussion of potential sources of errors in electronic positioning systems.

When discrepancies in electronic positions occur, one or more of the following actions usually will identify the source of error:

1. Check carefully both digital and analog (sawtooth) position records for indications of lane jump, dial roll, erroneous recording of values at positions, and evidence of external interference.

2. Check for line-of-sight obstructions that may have been present between shore stations and the vessel, for indications of landmass-induced signal attenuation, and for evidence of electronic signal reflection.

3. Review and check each calibration observation and computation.

4. Determine whether the position is geometrically strong based on the angle of intersection of the lines of position and the lane divergence factor.

5. Check shore station elevations to determine if significant slant range corrections to the observed electronic values are needed.

Every effort must be expended to resolve questionable electronic positioning data; however, changes to correction values applied by the field party should be made only with sound justification, and must be thoroughly documented and supported in the verifier's report.

6.3.4. Verification of Soundings

This verification to be plotted on smooth sheets is one of the most detailed and arduous phases of final data processing. As is the case in position verification, successive sounding overlays are machine plotted, each new needed overlay being a corrected and refined version of its predecessor. In areas where intensive investigations result in a density of soundings that would cause confusion and congestion if all were shown at the smooth sheet scale, excess sounding overlays are used as necessary. In addition, other plotted soundings that cause congestion and do not reveal important information for the delineation of bottom features should be considered excess and deleted from the plot. Although the information shown on sounding overlays must be displayed in a neat manner, the emphasis should be toward accuracy and completeness. Preliminary sounding overlays are work sheets and do not demand the more exacting drafting standards required for smooth sheets. These overlays provide verifiers with a graphic means of viewing the final results of his checks and his applications of depth corrections, junctional soundings, shoreline and datum line comparisons, depth contours, topographic detail, and for determination of the existence of previously undetected deficiencies or errors.

6.3.4.1. SOUNDING OVERLAYS.

6.3.4.1.1. *Preliminary sounding overlay*. In contrast to a field sheet, which is plotted during survey operations (using preliminary and possibly uncorrected data), a preliminary sounding overlay is plotted using corrected data. Before the initial preliminary sounding overlay is plotted, the verifier shall make every effort to eliminate errors and shall take the actions necessary to ensure that the plot will conform with hydrographic standards and specifications. Preliminary sounding overlays and their accompanying excess sounding overlays are used to detect and correct errors in the observed hydrographic data and any other errors that may have occurred. Original data must not be adjusted or altered unless the changes are justifiable and can be supported by other evidence. When completed, sounding overlays should have all discrepancies resolved insofar as practical. Except for the degree of neatness and totality of detail, sounding overlays should closely resemble a completed smooth sheet.

Specific actions to be taken prior to producing a sounding overlay include:

1. Tidal or water level reducers entered in the computer listings for application to soundings must be checked against verified tidal hourly heights or verified water levels. Whether time and range corrections are to be applied to hourly heights must be decided. Final determination and application of correct tidal or water level reductions to soundings is the responsibility of the Marine Center.

2. Velocity and transducer **(TRA)** corrections (4.9) and the Abstract of Corrections to Echo Soundings [5.3.5.(D)] compiled by the field unit and included in the survey Descriptive Report must be carefully checked. Some of the errors more frequently encountered include algebraic sign reversals, faulty interpretation and abstraction of correction data, and corrections entered in an improper format or applied to the wrong vessel.

3. Analog depth records and digital depth listings shall be reviewed for the accuracy and adequacy of the soundings selected to portray the bottom. Particular attention must be given to the

time, placement, and scaling of least depths, compensation for wave action, and the interpretation of questionable traces, side echoes, or strays. All corrections to soundings are entered in the data file and applied before the sounding overlay is plotted.

4. On inshore surveys, preliminary position overlays and accompanying field sheets are used as guidance for the placement of needed insets and subplans to the best advantage. Areas where intensive development of the bottom was conducted are examined to determine how many excess sounding overlays will be needed to show all soundings clearly. On offshore surveys where the depth unit is fathoms, the overlays are used as guidance when selecting the proper depth unit and to determine whether sounding numerals need be rotated to avoid deleting (as excess) too many soundings. At this stage, revisions are made to the projection parameters to center the hydrography within the edges of the final smooth plot.

5. Verifiers shall review each Descriptive Report and other related reports to become completely familiar with all field records connected with a survey. As the verification progresses, revisions and appropriate explanatory notes that affect the completed survey are penciled lightly in the Descriptive Report. Following approval of the survey by the appropriate Marine Center review board and prior to final administrative approval, the penciled notes and changes are inked.

6.3.4.1.2. *Excess sounding overlays.* These are assembled for the following basic purposes:

1. To avoid confusion and congestion of soundings in areas of intensive hydrographic development.

2. To show all soundings that are in the records but are not plotted on the regular sounding overlay or smooth sheet.

3. To show soundings that influence the delineation of depth contours.

Soundings are generally excessed by computer subroutines for preliminary plots, but the verifier should not hesitate to reinsert excessed soundings where he believes a better choice could have been made. The most critical soundings must be shown on the regular sounding overlay and on the smooth sheet; the less critical are shown on the excess sounding overlay to clarify certain bottom features, reveal discrepancies, and (if necessary) justify the placement of depth contours. Final listings or printouts of sounding data shall indicate which soundings have been excessed.

6.3.4.2. DATA LISTINGS AND PRINTOUTS. When checking and correcting hydrographic data listings and computer printouts, each verifier uses a code to identify his work; when more than one work phase is completed on a single listing or printout by one verifier, each phase is to be marked in a different color. Raw field data listings, final data listings, and new verification data-processing printouts must accompany each survey. Required listings include:

1. All raw data listings, including those with revisions to original entries—such listings or sounding volumes (if used) become original official survey records and are archived accordingly.

2. Final computer printouts corresponding with the final position overlay, smooth sheet, and excess sounding overlays.

3. A finalized listing of all horizontal control stations.

4. Velocity and TRA corrections and final verified data listings of tide or water level reductions.

5. Additional listings and printouts, as needed, to clarify the resolution of unusual conditions or problems encountered during verification.

Other preliminary intermediate listings and printouts may be destroyed with the approval of the appropriate Marine Center review board following final inspection. (See chapter 8.)

6.3.4.3. CROSSLINES. Regular systems of sounding lines are usually supplemented by a series of crosslines to check positional accuracy and validate soundings. (See 1.4.2 and 4.3.6.) Systematic crossing discrepancies usually indicate a fault with the sounding equipment, which requires study to determine the most probable cause and proper corrective actions. Sounding discrepancies caused by horizontal displacement may be attributed to questionable control. Otherwise, discrepancies may be caused by one or a combination of factors involving the observation or compilation of control, echo-sounding corrections, or faulty reductions to the datum of reference.

Allowable differences in depths at crossings are based on the amount of horizontal displacement corresponding to the difference in depth, rather than a set percentage of the depth. Generally, in area of flat or gently sloping bottom and in depths of less than 20 fm, discrepancies of one unit in feet or 0.2 units in fathoms can be expected occasionally; and, except where the natural delineation of depth curves is affected, such differences do not justify extensive investigation. Where considerable areas of hydrography are in disagreement, the verifier must carefully review each phase of the survey to resolve the problem satisfactorily; his report shall point out all unresolved discrepancies and include cross references as needed.

6.3.4.4. DEPTH CURVES. With the excess sounding overlays in proper registry with the preliminary sounding overlay and with their soundings taken into consideration, depth curves are first penciled lightly on the preliminary sounding overlay by the verifier. No single requirement for the spacing of these study curves can be prescribed for all areas and water depths, but they must be spaced closely enough to delineate the bottom configuration completely and accurately. Depth curves are indispensable for interpreting and examining a hydrographic survey; drafting closely spaced depth curves carefully and accurately requires inspection and consideration of each sounding. Merely delineating the standard curves specified in tables 4–5 and 4–6 is generally inadequate for study purposes. When drawing depth curves, incorrect soundings are easily detected; anomalous or improbable configurations are strong evidence that a further investigation of the plotted soundings is required.

The ability to represent submarine relief by means of depth curves is acquired only by training and experience. The shoalest depth curves should be drafted first, then continued in sequence to the maximum depths. To avoid confusion, a verifier should always bear in mind that he is separating shoal water from the deeper water; depth curves generally are drawn to include soundings of equal depth or less. When completed, depth curves should be continuous and extend to the limits of hydrography or approach the shoreline. Depth curves must never overlap, touch, or be drawn through a numeral or symbol. Lines are broken at soundings as necessary to avoid unnatural bottom configurations. Verifiers should not overlook a hydrographer's interpretation of depth curves, particularly those he drew using his local knowledge and direct observations.

Depth curves should eventually delineate natural bottom configurations. From a cartographic viewpoint, minor irregularities in soundings should not be overemphasized. Significant bottom features, however, should not be masked by injudicious smoothing of the curves. When more than one interpretation of depth curves can be deduced from the available sounding data, the depth curves shall be the most prudent representation from a safe navigational standpoint.

Preliminary study depth curves, which are drawn in pencil, must rigorously follow the soundings so as to graphically depict potential deficiencies. Because sounding overlays are used as guidance when constructing smooth sheets, the colors and conventions prescribed for standard depth curves are to be followed. (See 7.3.9.)

Plotting halves of sounding units on the sounding overlay is occasionally desirable in flat or gently sloping bottom areas to eliminate unnatural depth curves.

6.3.4.5. LEAST DEPTHS. Variations in newly determined least depths from previously surveyed values must be investigated in detail. Analog depth records and position data must be closely scanned and checked for errors or omissions. The Descriptive Report must be reviewed to see if the hydrographer made specific mention and recommendations concerning the feature. Occasionally, shoalest soundings are overlooked and not included in the digital data, or erroneous corrections were applied to the observed depths. A verifier must also evaluate whether or not an adequate search was made to determine a least depth. Significant differences with prior survey least depths not mentioned in the hydrographer's portion of a Descriptive Report shall be included in the verification report.

6.3.4.6. PHOTOBATHYMETRY. Water depths and bottom curves are often obtained by photogrammetric methods where the water is shallow and clear. (See 3.2.1.) Photobathymetric surveys are particularly advantageous in areas where coral pinnacles or other formations prevent running systematic patterns of sounding lines or prove dangerous to shallow-draft sounding launches. In most instances, photobathymetry will junction with or overlap conventional hydrography; but when two sounding methods are used, occasional conflicts are expected and must be resolved during the verification process. Merging these data together can best be done on the sounding overlay after the hydrographic data have been verified. When discrepancies between hydrographic and photobathymetric data arise and cannot be resolved by a combined review of the work by the verifier and the photogrammetrist, the hydrographic data are generally accepted.

Soundings and other details on the transparent photobathymetric overlay are transferred to the sounding overlay only when necessary for adequate verification. Photobathymetric data, however, are shown on the smooth sheet in accordance with section 7.3.8.3. Where junctional discrepancies cannot be resolved, the most reliable soundings shall be retained and a butt junction made. Photobathymetric information generally is compiled on the topographic or shoreline survey of the area. A copy of the report that describes the compilation shall be attached to the Descriptive Report of the hydrographic survey.

6.3.4.7. COMPARISON WITH ADJOINING SURVEYS. After a preliminary sounding overlay has been plotted, the verifier shall make a comparison with adjoining contemporary surveys to determine the completeness and relative agreement of the hydrographic findings. Descriptive Reports for adjoining surveys should be inspected to guard against gross errors in velocity of sound corrections. A hydrographer's interpretation of the comparisons stated in the Descriptive Report must be reviewed. It must be borne in mind that a hydrographer's evaluation may have been based on preliminary uncorrected data. Consistent differences in soundings, corresponding displacements of depth curves, and gaps in coverage must be described in the verifier's report. If a survey is incomplete, deficiencies shall be noted for investigation when field work on the project is resumed.

In a satisfactorily completed junction, depth curves must be in coincidence, soundings necessary to further define depth curves must be accurately transferred, and depths must be in good agreement. If depth curves and depths do not agree because of bottom changes or other causes, a butt junction is generally made. In this case, a dashed line is drawn in color to show the butt junction, and a note in the same color is entered to indicate the superseded soundings.

6.3.5. Verification of Shoreline, Hydrographic, and Topographic Features

On inshore surveys, preliminary position overlays and preliminary sounding overlays shall be compared in detail with the appropriate shoreline manuscripts to detect and resolve discrepancies in the shoreline, reference datum line (**MLW, MLLW, LWD**), and other hydrographic and topographic features shown thereon. Class I (final) shoreline manuscripts must be used for this purpose. Shoreline manuscript data need not be transferred to the overlays. Satisfactory comparisons can be made merely by placing one transparent sheet in registry over the other. Depending on the complexity of the survey, on the amount of shoreline and topographic details, and on the revisions recommended by the hydrographer as shown on the field sheet and in the Descriptive Report, one may find it desirable or necessary to transfer data from the shoreline manuscript to the sounding overlay for satisfactory comparison and evaluation. In this case, the cartographic standards and symbolization specified in chapter 7 for smooth sheets should be followed, although minor departures may be made for expediency.

Although all discrepancies between photogrammetric surveys and hydrographic surveys should have been resolved in the field, some occasionally escape detection or are not resolved clearly and concisely. Resolution of these discrepancies rests with the verifier if the hydrographic field unit has left the area. There are no set rules—only generalities can be stated as guidance toward a satisfactory solution.

Photogrammetric locations of shoreline, reference datum lines (**MLW** and **MLLW** when determined by tide-coordinated aerial photography), and objects awash or that uncover at the charting datum are usually more accurate and are accepted over hydrographic locations—unless there is unmistakable evidence of error in the shoreline manuscript. Errors in rock positions are among the most common. A verifier must examine carefully all available records to ascertain whether there are actually two rocks or whether the same rock is being shown at two locations. When a feature is clearly visible on aerial photographs and its position on the shoreline map has been verified, the photogrammetric location generally holds; however, if a hydrographer detected and investigated a discrepancy in the field and resolved it satisfactorily, the hydrographic determination takes precedence. In cases where a feature was located in different positions by two different methods (each appearing reliable), the feature must be shown at both positions in the interest of safe navigation. Additional field investigations shall be recommended by the verifier to resolve such discrepancies.

Positions of submerged features or breakers and the notes relating thereto generally should be accepted from the hydrographic data if it has been determined that the identical feature is involved. Exceptions to this policy may be exercised when a submerged feature was determined during the course of a photobathymetric survey. Elevations of bare rocks or rocks awash are accepted from the most credible source. Proximity to the feature, if known, and availability of accurate tidal or water level data at the time of observation will help determine credibility. Verifiers must be sure that the elevation shown for each rock has been accurately corrected for tidal or water level stage. Supervisors should check a sampling of rock elevations on applicable sheets to ensure accuracy.

6.3.6. Wire-Drag Comparisons

If wire-drag surveys have been made in the area, the results of the two surveys shall be compared and correlated. Except where a hydrographic survey has revealed shoaler soundings, items such as verified soundings, groundings, bottom characteristics, and wreck or obstruction notations are transferred from wire-drag surveys. Such data are entered in green ink; the grounding circle is omitted. Wire drag clearance depths are not transferred. Each discrepancy between hydrographic survey soundings and wire-drag effective depths must be resolved. Notation of features transferred to the smooth sheet shall be made as described in section 6.3.7.3. (See figure 7–7.)

6.3.7. Prior Survey Data

6.3.7.1. COMPARISON WITH PRIOR SURVEY DATA. The most recent prior hydrographic surveys of the area used for charting most of the soundings shall be carefully compared with the present survey. This comparison serves two important purposes. Primarily, it is necessary to determine whether the present survey is adequate to supersede prior surveys, and the comparison is used to transfer important data needed to supplement the new survey. Secondly, the comparison serves to reveal whether the character of the bottom is stable or transient; it provides a record of bottom changes that may be useful when scheduling future revision surveys.

6.3.7.2. EVALUATING PRIOR DATA. When comparing a prior survey with a new survey, differences in least depths, individual depths, general hydrography, and in other details are often revealed. Some differences are caused by natural changes, cultural changes, or by errors in plotted data. Since each significant difference must be evaluated, the survey verifier must carefully judge each case before accepting or rejecting data. Each verifier must be thoroughly familiar with procedures and techniques used in hydrographic surveying and expected accuracies since **NOS** began hydrographic surveying in 1834.

Unless there is sufficient evidence to show otherwise, the most recent basic survey findings will supersede prior survey data. When a discrepancy is discovered that cannot be resolved logically, extensive research into the prior survey records to prove or disprove data will not be undertaken. When doubts arise as to which information will be shown on a smooth sheet, the safest and most conservative course, from a marine navigational viewpoint, shall be taken.

6.3.7.3. RETENTION OF PRIOR DATA. Important soundings or features on prior surveys that were neither verified nor disproved by a new survey shall be brought forward and shown on the new smooth sheet. (See figure 7-7.) The notation "from H—— (year)" shall be placed near such items with a leader and arrow pointing to the sounding or feature. Where transferred items are scattered over large areas of the smooth sheet, a group notation "Detached Soundings in (color) from H—— (year)" shall be placed in a marginal area, preferably near the title block. Slanted lettering is to be used for all such notes. Red ink is preferred if not already used for photobathymetry, but most other colors may be used as necessary. The color selected should uniquely identify the intended source. The repetitive use of a particular color to identify data carried forward from several sources may cause confusion in determining the actual source of retained prior survey information. If all available colors have already been utilized, then the group notation should be appropriately formatted so as to eliminate confusion, One suggested format is: "Detached soundings in (color) (east/west of longitude X) from H-*xxxx* (19xx)."

It is emphasized that the note should clearly and uniquely state the source of the retained prior data. Green ink is reserved for wire drag survey data brought forward. Notations for wire-drag surveys are indicated by the initials "WD" entered after the year.

Locations of important shoals, rocks, and other obstructions and their least depths shall be compared. When differences in position are found for the same feature, the reliability of the present method of location must be evaluated with respect to earlier methods; the most probable position should be accepted. If the least depth on a permanent feature is neither verified nor disapproved by a survey, the prior least depth must be transferred. Wherever possible, shoalest depths from both surveys are shown; but if there is insufficient space on the smooth sheet, the deeper of the two should be treated as an excess sounding and not shown. If a retained sounding is from a prior survey, the note "Least depth—— (units) from present survey" is to be added to the present survey in black ink with a leader indicating the feature

Occasionally, a group of soundings must be transferred from a prior survey to complete hydrography in a gap or small unsurveyed area of a new survey. Similarly, a new survey may have to be supplemented by transferring ledge, reef, or rock delineations if both the new hydrographic and photogrammetric surveys are deficient.

When rocks shown on a prior hydrographic or topographic survey have not been verified by the new survey, have been located in a slightly different position, or are somewhat different in character, all available information should be consulted and the following rules applied for disposition of the feature:

1. If the position of what is presumably the same rock differs between a present and a prior survey, the newer position is generally accepted as correct provided the positioning method is considered to be more accurate and conclusive.

2. When an adequate examination made during the present hydrographic survey in the vicinity of a rock or rocks shown on the prior survey fails to disclose or verify existence of the rock, the disposition recommendation made by the hydrographer should be followed.

When general statements in a Descriptive Report indicate that certain rocks shown on old surveys could not be found, these rocks should not be deleted but should be transferred either as rocks awash or as submerged rocks, depending on the circumstances in each case. Without proof of an adequate examination, general statements of this nature can be accepted only as evidence that such rocks were not visible at the time of a cursory examination.

3. Bare rocks on a prior topographic or hydrographic survey that are not shown or are not disproved on the new hydrographic or topographic survey should be carried forward as rocks awash unless more specific information is available.

4. Rocks shown as being awash on a prior survey but shown as being submerged on a new survey, should be considered to be rocks awash (the safest course) unless the new survey shows clearly that the rock was not visible at the low water datum or unless it is known that submergence has occurred since the last survey. When revising a new survey, the rock awash symbol is shown in black ink and a note made in the sounding record.

5. Submerged rocks shown on prior surveys, when not disproved by the new survey, should be carried forward with caution. On some prior surveys, submerged rock symbols may have been used to indicate rocky bottom areas rather than individual submerged rocks that are dangerous to navigation.

6. Generally, the delineation inshore of the reference datum line on the new survey should be accepted as correct — except that significant rocks shown awash on prior topographic or hydrographic surveys which were neither located nor disproved on the new survey should be brought forward in an appropriate color.

6.3.8. Geographic Datums

Verifiers shall identify the geographic datum to which a prior survey was referenced and make adjustments as necessary to permit comparison at the datum used for the most recent survey.

During the early years of survey operations, many detached triangulation networks were established in the United States — each referenced to a datum based on independent astronomic observations within the network. Hydrographic and topographic surveys conducted within such areas consequently were based on these independent local datums. Upon completion of the first transcontinental arc of triangulation, the various detached networks were connected, then a coordinated network based on a single geographic datum was established for the whole country. Station **MEADES RANCH** in central Kansas was selected as the reference point for this single geodetic datum. In 1901, the adopted datum was officially named the "United States Standard Datum." When Canada and Mexico adopted this datum, it was renamed the "North American Datum."

In 1927, a unified adjustment of all first-order triangulation in the United States was initiated, and the "North American Datum of 1927" was adopted. Use of this datum has been extended into Alaska where several independent datums previously had been used. Modern hydrographic surveys in waters bordering the continental United States are now made on this geographic datum. Surveys in the Caribbean Sea areas, the Hawaiian Islands, and other South Pacific islands may be based on independent datums; these are specified in the project instructions.

Many older hydrographic surveys list the geographic position of a triangulation station that lies within the surveyed area. Positions of these stations were shown in the lower margin of the sheet; however, the reference datum was not always indicated. On later surveys, both the geographic position of the reference triangulation station and the geographic datum were listed.

6.3.9. Datum Ticks

Before comparing surveys made in various years, the geographic datums must be correlated. Never assume that an unlabeled projection on an older survey was referenced to any specific datum—differences in datums must always be determined before comparing surveys or transferring data. The U.S. Standard or North American Datum was shown by a complete projection (in color) on many of the older surveys. Others (figure 6-1) show only one or two marked projection intersections (ticks) on the U.S. Standard Datum or the **NA** Datum of 1927.

If a prior survey does not show the **NA** 1927 Datum, this datum shall be established before transferring data to the new survey. To establish the **NA** 1927 Datum, select at least three widely separated triangulation stations within the sheet limits for which geographic positions are available on the **NA** 1927 Datum. Two methods can then be used to determine the datum differences:

1. Geographic position data used for plotting an original survey are best determined from old registers, records, or publications. The mean of the differences between positions on the **NA** 1927 Datum and the datum used for an older survey is the correction to be applied. Position differences for each of the three stations should be nearly equal. If a significant variance is found, an investigation should be made for possible errors in computations or for failure to identify common stations on the two datums. The position of the **NA** 1927 Datum relative to the original projection can be determined by back plotting **NA** 1927 values for one of the triangulation stations or by following the rule that, if the latitude **(N)** and longitude **(W)** on the old datum are greater than the corresponding values on the new datum, the new projection will be north and west, respectively, of the old projection. If the old values are smaller, the datum shift is to the south and east.

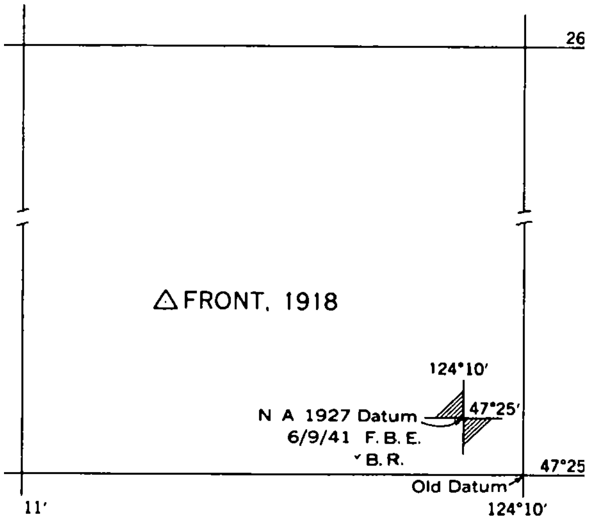


FIGURE 6-1.— Change of datum shown on a hydrographic sheet

2. This method is applicable where geographic position data used for plotting the selected triangulation stations on the prior survey are not available. A graphic method of determining the datum differences is used. Arcs based on the **NA** 1927 values of latitude and longitude are swung from the selected triangulation stations shown on the survey, and tangents to the arcs are drawn parallel to the projection. Datum differences between the tangents to the arcs and the original projection can then be scaled. An average of the differences is used to plot the datum tick.

Extreme care shall be exercised when determining the proper relation of the **NA** 1927 Datum to the original projection. Distortion in the original projection must be measured and applied carefully to all distances plotted. Plotting of the datum tick (in colored ink) is to be verified by another person. Each person enters initials and the date beside the tick. Each tick shall be identified by latitude and longitude and be labeled "**NA** 1927 Datum." If only approximate datum differences can be determined, the datum tick note includes the abbreviation "approx."

6.3.10. Chart Comparison

The verifier shall carefully check the hydrographer's comparison of the survey with the chart for errors or omissions. Comparison of the survey sheet with the chart by the verifiers shall be with the edition of the chart as listed in the project instructions. (See 5.3.4. (L.)). Charted items that were disposed of satisfactorily during the comparison with prior surveys need not be repeated here. Extensive research to resolve apparent discrepancies is not usually required of the verifier, particularly if an item was charted by approximate position or depth based on reported information. Marine chart compilers have more complete information on such items and are better equipped to make appropriate charting judgments. Such items, however, shall be individually identified and reported by the verifier.

Errors, omissions, and additional recommendations are to be tabulated and entered in the verification reports (6.6); references to these data must be entered in paragraph L of the Descriptive Report text. (See 5.3.4.) To avoid confusion, a chart section identifying the items may be submitted with the list. If the comparison reveals an uncharted danger or condition important to navigation not previously reported, the feature must be reported immediately by radio telephone or telegraph to the nearest Commander, U.S. Coast Guard District with a copy to the Chart Information Branch, OA/C322, for possible inclusion in the next Notice to Mariners. (See 5.9.)

6.4. QUALITY CONTROL

Procedures for quality control shall be developed by each Marine Center or other processing area to ensure that the procedures established for verifying surveys are sound and are so designed to assure that the final product meets the specifications prescribed for smooth sheets. (See chapter 7.) It must be emphasized that the quality of survey verification extends beyond specifications and depends primarily on the methods and thoroughness of the verification processes. Final approval of a verified survey by a Marine Center indicates that adequate verification and inspection have been performed. Hydrographic surveys that fail to meet the requirements of this manual and of the project instructions shall not be submitted to **NOS** Headquarters without specific recommendations for additional field work.

6.5. COMMON DEFICIENCIES OF VERIFIED SURVEYS

These can be grouped into three general categories: (1) inadequate or inaccurate field data with which a verifier has to work, (2) unrecognized or unresolved discrepancies in the field data, and (3) substandard verification practices and procedures.

Some faults lie in lack of training or careless supervision—others reflect the aptitude of the verifier and his attitude and approach toward the work. To produce a verified survey and smooth sheet that will conform to National Ocean Survey standards, a competent verifier should have had field experience and must be thoroughly familiar with all parts of this manual.

The following is a partial list of the most common deficiencies on both manual and automated surveys:

1. Positions were plotted incorrectly because of improper editing of logged positional data or because of failure to calibrate or register the automated plotter.

2. Errors in recorded observations of any kind were not detected and corrected.

3. Signal location errors or misidentifications were not detected.

4. Positions of signals were entered or plotted incorrectly.

5. Sounding line positions plotted from weak fixes were not properly adjusted to conform to supplemental information.

6. Soundings are spaced incorrectly (e.g., at the inshore end of a line or where a line began from a standing start, where a line began or ended on an uneven position or sounding interval, and where the spacing does not agree with recorded speed and course values).

7. Soundings were selected poorly or improperly to portray a complex feature.

8. Soundings have been spaced at excessively wide or unnecessarily close intervals.

9. The shoreline has been transferred inaccurately, and various symbols (particularly rock symbols) have been drafted carelessly.

10. Depths appearing erroneous or excessive differences at crossings were not checked.

11. Analog depth records were misinterpreted; erroneous digital depth values in kelp or grass were not corrected; soundings were not adjusted for the effects of strays or sea conditions.

12. The shoreline has been transferred to a smooth sheet from other than class-I shoreline manuscripts.

13. A feature is shown at two locations.

14. Sounding corrections were determined or applied incorrectly.

15. Erroneous elevations were determined for rocks or were incorrectly reduced to the chart datum.

16. Depth contours have not been shown in accordance with standard **NOS** conventions.

17. Bottom characteristics have been overly condensed and significant information omitted.

18. Inshore sounding lines parallel to the shoreline do not follow the actual path of the vessel.

19. Erroneous tidal or water level reducers were applied.

20. Soundings were not corrected for instrument errors.

6.6. VERIFICATION REPORTS

When a hydrographic survey verification has been completed, a verification report shall be prepared and appended to the Descriptive Report. The verification report is a summary of pertinent facts about a survey and an evaluation of the detailed comparisons made with prior surveys and the charts. The report shall include a description of unusual processing procedures, major changes or adjustments to data, and a list of complete work statistics. Specific statements must be included that evaluate the adequacy of the survey to supersede prior survey data and charted information. The verification report serves as a guide to the chart compiler and identifies areas where additional field work is needed to satisfactorily complete a survey. Subject matter pertinent to the report should consist of the following:

1. **NOAA** Form 77-27, "Hydrographic Survey Statistics." (See figure 6-2.)

2. A narrative account of the verification procedures and findings.

3. Documentation of all problems encountered and nonstandard procedures used during verification of the survey. Justify any procedure that may have compromised the quality of the data.

4. Statement(s) as to whether any of the following data entered in the Descriptive Report by the hydrographer were revised during verification: (a) projection parameters, (b) electronic position control parameters, (c) list of stations, (d) tide or water level reduction values, and (e) corrections to soundings. If the revisions were not entered on the Descriptive Report listings by the verifier, include them here.

5. Copy of the Headquarters-approved tide or water level note, as appropriate.

6. Reports or notes needed to understand the survey or to clarify procedures or results.

7. Control and shoreline. When the origin of the horizontal control is described adequately in the Descriptive Report, reference the pertinent section. If necessary, add supplementary information determined during verification.

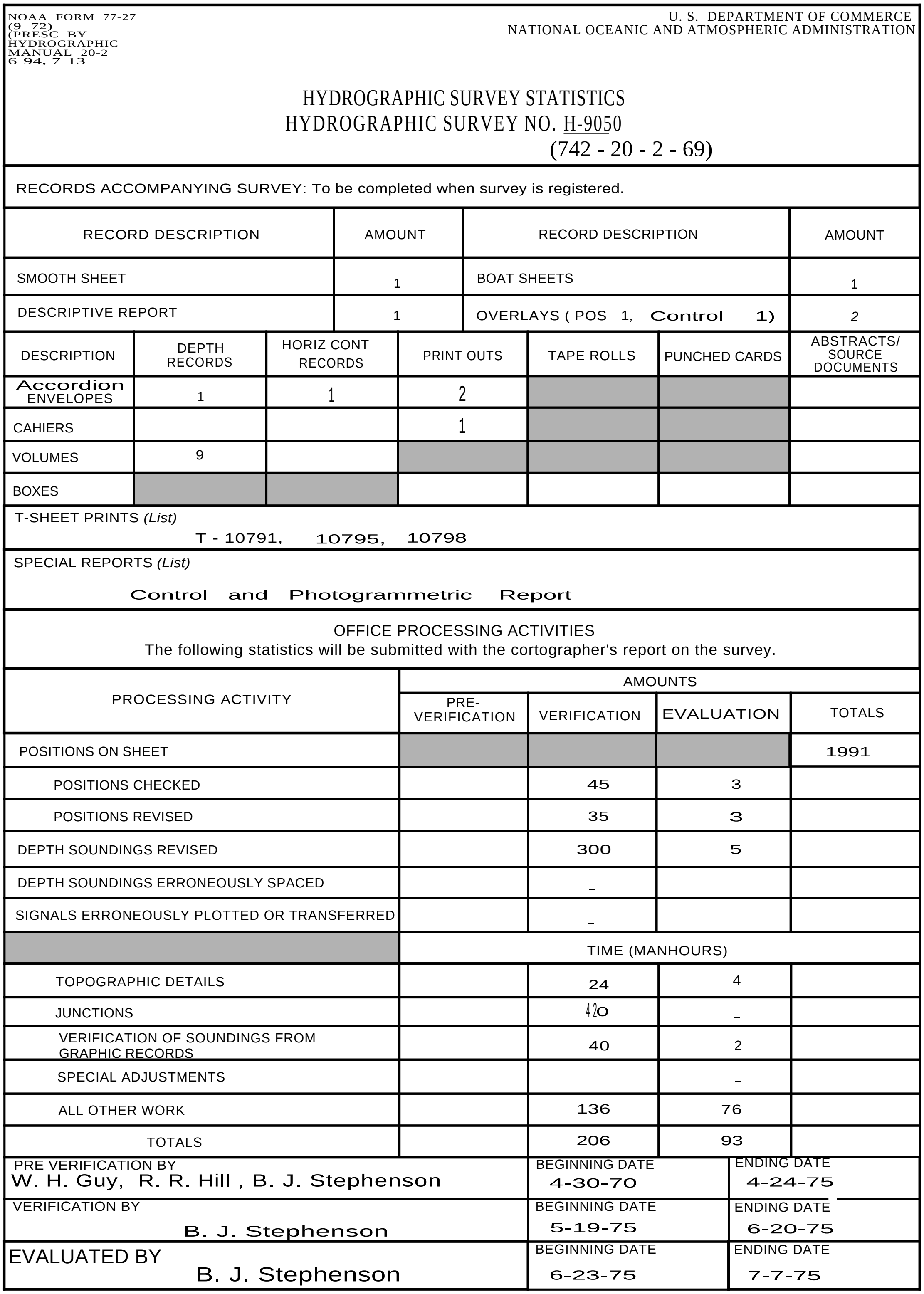
Statement(s) as to the source of shoreline data. Identify the numbers, the survey dates, and the classification of the shoreline manuscripts used for the final comparison.

8. Hydrography. Make a summary evaluation of the hydrography. Include specific statements regarding agreement of soundings at crossings and completeness and confidence with which depth contours could be drawn. List any discrepancies with respect to photogrammetric surveys. A statement is to be made evaluating the adequacy of development of the bottom configuration and the determination of least depths. Each significant deficiency shall be described.

9. Condition of survey. Comments in this submission are directed toward deficiencies in fieldwork procedures, in the survey records, and in the Descriptive Report. Mention specifically each case where a procedure was erroneously used or failed to comply with the requirements of this manual or other pertinent documents. Include constructive criticism that should be brought to the attention of the hydrographer. If the condition of the survey is found to be satisfactory, state only that the smooth sheet and accompanying overlays, hydrographic records, and reports are adequate and conform to the requirements stated in this manual.

10. Junctions. Adjoining surveys are referenced by registry number, year, and their position relative to the present survey. Junctions shall be evaluated and their adequacy discussed. Important irreconcilable discrepancies must be described and probable causes stated. Where butt junctions were necessary because of disagreements in depths, the condition shall be specifically described.

11. Comparison with prior surveys. In *hydrographic surveys,* the results of comparisons between the most recent prior survey and the present survey shall be summarized in a brief introductory



NOAA FORM 77-27
(9-72)
(PRESC BY
HYDROGRAPHIC
MANUAL 20-2
6-94, 7-13

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

HYDROGRAPHIC SURVEY STATISTICS
HYDROGRAPHIC SURVEY NO. H-9050
(742 - 20 - 2 - 69)

RECORDS ACCOMPANYING SURVEY: To be completed when survey is registered.

RECORD DESCRIPTION	AMOUNT	RECORD DESCRIPTION	AMOUNT
SMOOTH SHEET	1	BOAT SHEETS	1
DESCRIPTIVE REPORT	1	OVERLAYS (POS 1, Control 1)	2

DESCRIPTION	DEPTH RECORDS	HORIZ CONT RECORDS	PRINT OUTS	TAPE ROLLS	PUNCHED CARDS	ABSTRACTS/ SOURCE DOCUMENTS
Accordion ENVELOPES	1	1	2	▨	▨	
CAHIERS			1	▨	▨	
VOLUMES	9		▨	▨	▨	
BOXES	▨	▨				

T-SHEET PRINTS *(List)*
T - 10791, 10795, 10798

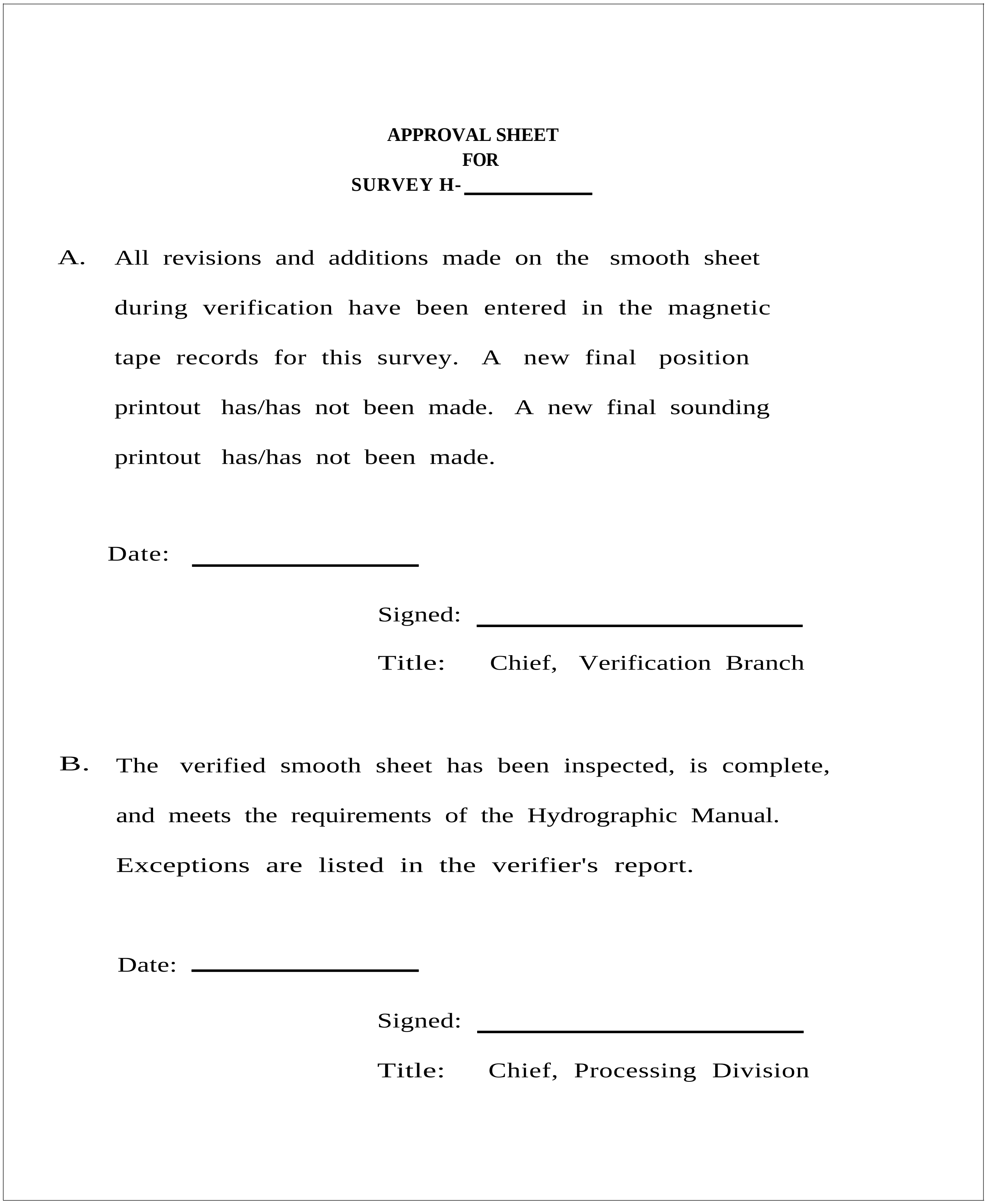
SPECIAL REPORTS *(List)*
Control and Photogrammetric Report

OFFICE PROCESSING ACTIVITIES
The following statistics will be submitted with the cortographer's report on the survey.

PROCESSING ACTIVITY	AMOUNTS			
	PRE-VERIFICATION	VERIFICATION	EVALUATION	TOTALS
POSITIONS ON SHEET	▨	▨	▨	1991
POSITIONS CHECKED		45	3	
POSITIONS REVISED		35	3	
DEPTH SOUNDINGS REVISED		300	5	
DEPTH SOUNDINGS ERRONEOUSLY SPACED		-		
SIGNALS ERRONEOUSLY PLOTTED OR TRANSFERRED		-		
▨	TIME (MANHOURS)			
TOPOGRAPHIC DETAILS		24	4	
JUNCTIONS		420	-	
VERIFICATION OF SOUNDINGS FROM GRAPHIC RECORDS		40	2	
SPECIAL ADJUSTMENTS			-	
ALL OTHER WORK		136	76	
TOTALS		206	93	

PRE VERIFICATION BY W. H. Guy, R. R. Hill , B. J. Stephenson	BEGINNING DATE 4-30-70	ENDING DATE 4-24-75
VERIFICATION BY B. J. Stephenson	BEGINNING DATE 5-19-75	ENDING DATE 6-20-75
EVALUATED BY B. J. Stephenson	BEGINNING DATE 6-23-75	ENDING DATE 7-7-75

FIGURE 6–2.— **NOAA** Form 77-27, "Hydrographic Survey Statistics"



APPROVAL SHEET
FOR
SURVEY H-__________

A. All revisions and additions made on the smooth sheet during verification have been entered in the magnetic tape records for this survey. A new final position printout has/has not been made. A new final sounding printout has/has not been made.

Date: ________________

Signed: ________________________

Title: Chief, Verification Branch

B. The verified smooth sheet has been inspected, is complete, and meets the requirements of the Hydrographic Manual. Exceptions are listed in the verifier's report.

Date: ________________

Signed: ________________________

Title: Chief, Processing Division

FIGURE 6–3.— Verification approval sheet paragraph. Changes in shoreline, bottom configuration, and general depths should be described. State whether such changes are attributable to natural, artificial, or less-detailed or less-accurate methods used during prior surveys. The magnitude of significant shoreline changes and bottom changes shall be indicated. Other items discussed individually that have been charted from the preceding survey or earlier surveys must be disposed satisfactorily.

In each discussion, there shall be a statement made that the prior survey is superseded — however, such a statement must be qualified when it is necessary to carry forward and retain specified details from a prior survey.

In *wire-drag surveys,* discuss separately the comparison made with wire-drag surveys. Comparisons shall be made with both contemporary wire-drag surveys that have been reviewed and prior wire-drag surveys in the area. Where there are no conflicts between present survey depths and effective depths of the wire-drag surveys, only a simple statement need be made to that effect. Discrepancies arising as a result of bottom changes should be identified as such. Wire-drag surveys, however, are not generally superseded by ordinary hydrographic surveys; thus statements to that effect need not be made.

12. Comparison with chart. The chart number and edition shall be entered beside this heading for ready reference. Discussion of the comparison is to be subdivided as follows:

a. Listing of the unresolved discrepancies between the new survey and the charted data. (See 6.3.10.) Do not include items discussed previously in the comparison with prior surveys or items that have been disposed satisfactorily by an adequate hydrographic investigation. Where charted data from sources other than **NOS** surveys have not been disproved by the present survey, a specific recommendation to retain the data on the chart should be made. The discussion should be concluded with a statement as to the adequacy of the present survey to supersede the charted hydrography. This statement may require qualification because of the verifier's recommendation to retain certain charted features.

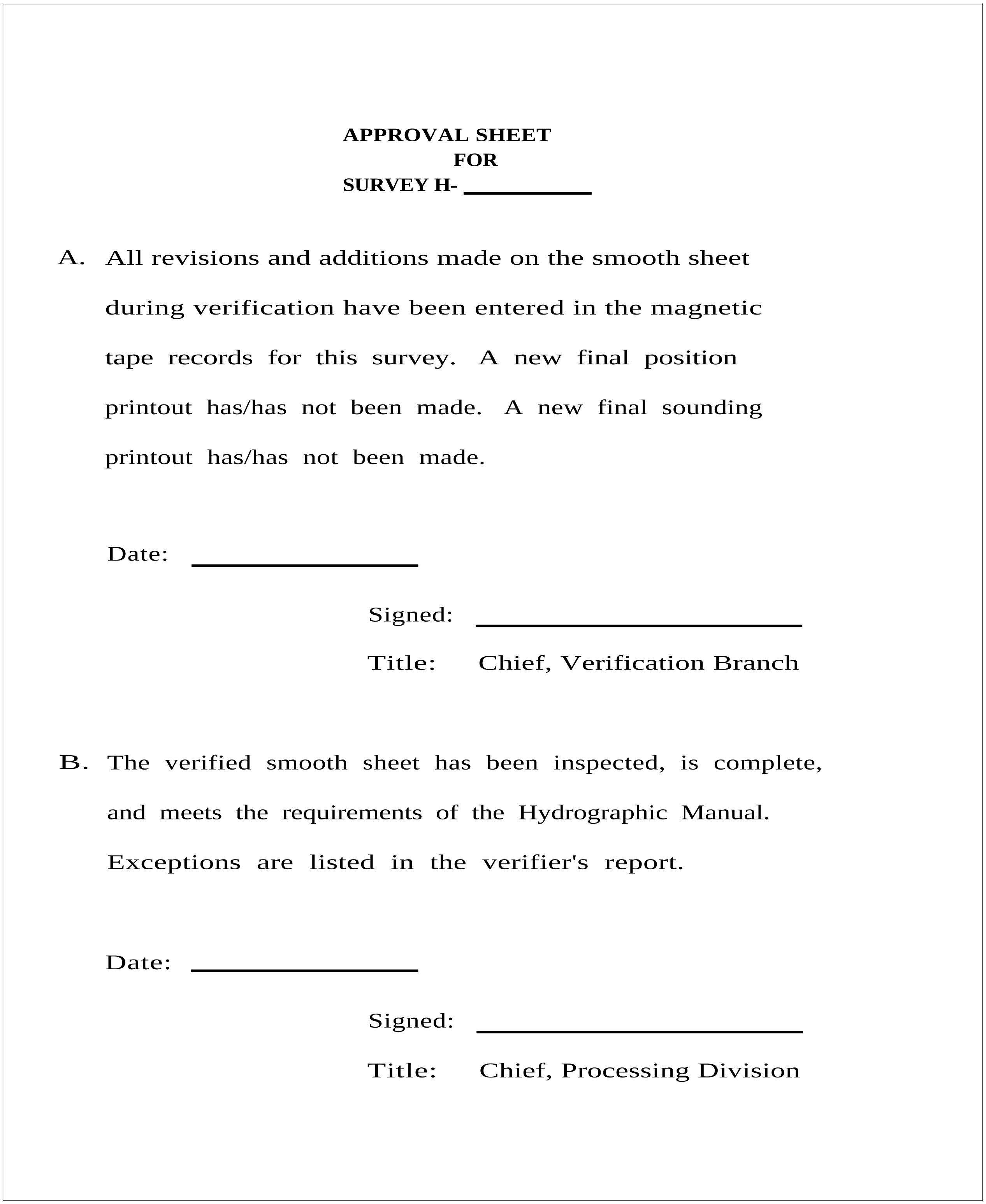
b. Controlling depths. Notes of controlling depths are usually based on data furnished by the U.S. Army Corps of Engineers. Discuss the comparison of the survey with these notes.

c. Aids to navigation. The adequacy with which the charted positions of aids to navigation mark the features or serve the purposes intended should be stated. Definite recommendations should be made when new unmarked dangers are noted or when shoals and channels have been shifted in position and are not properly marked by the charted buoys and fixed aids. Also, differences between the charted positions and present survey positions of nonfloating aids to navigation should be noted.

13. Compliance with instructions. Make a brief statement as to whether the survey adequately complies with the project instructions; note any significant exceptions.

14. Additional field work. Each survey is evaluated as an inadequate, an adequate, a good, or an excellent basic survey. Recommendations shall be made as to whether or not additional field work is needed. If additional field work is recommended, each item or area is to be clearly described or referenced to another specific discussion in the report. Further work, when needed, usually consists of examinations of shoal indications or of questionable charted information, disposal or clarification of discrepancies, and further development of outstanding features or inadequately developed areas.

15. An "Approval Sheet." This shall be included to attest that the verified and smooth-plotted survey, the Descriptive Report, and the verifier's report have been inspected by a designated verification supervisor, and meets the requirements and specifications stated in this manual, except as noted. (See figure 6-3.)



APPROVAL SHEET
FOR
SURVEY H- __________

A. All revisions and additions made on the smooth sheet during verification have been entered in the magnetic tape records for this survey. A new final position printout has/has not been made. A new final sounding printout has/has not been made.

Date: __________________

Signed: __________________________

Title: Chief, Verification Branch

B. The verified smooth sheet has been inspected, is complete, and meets the requirements of the Hydrographic Manual. Exceptions are listed in the verifier's report.

Date: __________________

Signed: __________________________

Title: Chief, Processing Division

FIGURE 6–5.— Verification approval sheet paragraph. Changes in shoreline, bottom configuration, and general depths should be described. State whether such changes are attributable to natural, artificial, or less-detailed or less-accurate methods used during prior surveys. The magnitude of significant shoreline changes and bottom changes shall be indicated. Other items discussed individually that have been charted from the preceding survey or earlier surveys must be disposed satisfactorily.

In each discussion, there shall be a statement made that the prior survey is superseded — however, such a statement must be qualified when it is necessary to carry forward and retain specified details from a prior survey.

In *wire-drag surveys*, discuss separately the comparison made with wire-drag surveys. Comparisons shall be made with both contemporary wire-drag surveys that have been reviewed and prior wire-drag surveys in the area. Where there are no conflicts between present survey depths and effective depths of the wire-drag surveys, only a simple statement need be made to that effect. Discrepancies arising as a result of bottom changes should be identified as such. Wire-drag surveys, however, are not generally superseded by ordinary hydrographic surveys; thus statements to that effect need not be made.

12. Comparison with chart. The chart number and edition shall be entered beside this heading for ready reference. Discussion of the comparison is to be subdivided as follows:

a. Listing of the unresolved discrepancies between the new survey and the charted data. (See 6.3.10.) Do not include items discussed previously in the comparison with prior surveys or items that have been disposed satisfactorily by an adequate hydrographic investigation. Where charted data from sources other than **NOS** surveys have not been disproved by the present survey, a specific recommendation to retain the data on the chart should be made. The discussion should be concluded with a statement as to the adequacy of the present survey to supersede the charted hydrography. This statement may require qualification because of the verifier's recommendation to retain certain charted features.

b. Controlling depths. Notes of controlling depths are usually based on data furnished by the U.S. Army Corps of Engineers. Discuss the comparison of the survey with these notes.

c. Aids to navigation. The adequacy with which the charted positions of aids to navigation mark the features or serve the purposes intended should be stated. Definite recommendations should be made when new unmarked dangers are noted or when shoals and channels have been shifted in position and are not properly marked by the charted buoys and fixed aids. Also, differences between the charted positions and present survey positions of nonfloating aids to navigation should be noted.

13. Compliance with instructions. Make a brief statement as to whether the survey adequately complies with the project instructions; note any significant exceptions.

14. Additional field work. Each survey is evaluated as an inadequate, an adequate, a good, or an excellent basic survey. Recommendations shall be made as to whether or not additional field work is needed. If additional field work is recommended, each item or area is to be clearly described or referenced to another specific discussion in the report. Further work, when needed, usually consists of examinations of shoal indications or of questionable charted information, disposal or clarification of discrepancies, and further development of outstanding features or inadequately developed areas.

15. An "Approval Sheet." This shall be included to attest that the verified and smooth-plotted survey, the Descriptive Report, and the verifier's report have been inspected by a designated verification supervisor, and meets the requirements and specifications stated in this manual, except as noted. (See figure 6-5.)

7. SMOOTH SHEET

7.1. DEFINITION AND PURPOSE

A smooth sheet is the final, neatly drafted, accurate plot of a hydrographic survey. In contrast to the field sheet plotted during field operations from preliminary field data, the smooth sheet is plotted from verified or corrected data**.** The smooth sheet and survey information shown thereon shall conform to the cartographic standards and conventions described in this chapter. Unless specified otherwise in the project instructions, verified hydrographic surveys are smooth plotted by the Marine Center Processing Divisions.

Each smooth sheet shall be accompanied by a smooth position overlay (6.3.3) drawn at the same scale. Smooth position overlays show each horizontal control station within the sheet limits that was used during the survey and all hydrographic positions that portray the sounding line system. Electronic position lattices are also shown provided the lines can be drawn without obscuring position dots and numbers. Otherwise, control stations and lattices must be drafted on separate horizontal control overlays. (See figures 7-6 and 7-7.)

Supplemental overlays are used for developments, insets, and excess soundings that cannot be shown on a basic smooth sheet in a clear and uncongested manner

Following inspection and administrative approval, a smooth sheet becomes the official permanent graphic record of a survey and is the principal authority for hydrographic data to be charted. Smooth sheets are referred to frequently during chart compilation; photographic copies are often furnished to surveyors, engineers, geologists, lawyers (for use in the courts), and others with interests in marine surveys. Field sheets are usually discarded after final administrative approval of smooth sheets and Descriptive Reports.

7.2. GENERAL SPECIFICATIONS

7.2.1. Sheet Material

Smooth sheets shall be plotted only on stable polyester drafting films specifically authorized by the Director, **NOS**, for this purpose. Arkwrite Drafting Film No. 2102W (manufactured by the Diazo Specialty Company, Fiskeville, R.I.) or equivalent is approved. The film is 0.0075 in thick, semitransparent, and matte finished on both sides.

Overlays are constructed on 0.003-in-thick stable polyester drafting film that is semitransparent and matte finished on one side. Ageproof Polyfilm (manufactured by the Dietzgen Corporation, Des Plaines, III.) or equivalent is authorized for overlays.

Sheets must be protected at all times from creasing, defacing, or smudging. A protective cover should be kept over the entire sheet exposing only the small area where work is actually being done. Avoid getting fingerprints on plotting surfaces because ink does not adhere well to oily areas.

7.2.2. Sheet Size and Layout

Smooth sheet sizes shall conform to the specifications contained in section 1.2.4. Overlays should generally be the same size as the smooth sheets they accompany. Smooth sheet limits should conform closely to those shown on the approved sheet layout (2.4) with respect to area coverage, orientation, and size. Field sheet limits usually are compatible with smooth sheet limits. Small limit shifts shall be made as necessary to ensure sufficient margins (7.2.3) and space for title blocks. Occasionally, original sheet layouts must be modified when unforeseen factors are introduced during field operations. Most of these factors and considerations thereof are discussed in 7.2.3 and 7.2.4. Skewed projections should be considered to avoid using "dog ears" to show control stations beyond the sheet limits, and at other times when necessary for marginal requirements.

Smooth sheet scales are generally identical to those of the corresponding field sheets. In some cases, however, it may be desirable to smooth plot at a smaller scale to avoid an oversize smooth sheet or to combine two adjacent surveys. Authorization to plot surveys at reduced scales must be obtained from the Director, **NOS.** Such reductions may be authorized where;

1. A smaller scale will not significantly reduce the value of a survey.

2. Publication of a chart at a scale larger than the survey scale is not anticipated.

3. Hydrography has not revealed shoals or submarine features that cannot be shown adequately at reduced scales, on subplans, or on overlays.

Smooth plotting at scales larger than those planned is generally confined to subplans as described in section 7.2.4.

7.2.3. Sheet Margins and Extensions

When determining final smooth sheet sizes and limits of hydrography to be shown on each sheet, remember that soundings and other hydrographic information are not to be plotted closer than 7.5 cm (3 in) to the final cut edge of the sheet. Data plotted near the edges may become obscured or destroyed because of repeated handling. Marginal areas may also be needed for labeling projection line or electronic control lattice values. Space for the sheet title, about 15 by 20 cm (6 by 8 in), must be reserved. The exact placement of a tide block on a sheet is not critical and is selected where most convenient and attractive.

Although automated computation and machine drafting has largely reduced the need to plot each horizontal control station used to position a vessel, extensions of smooth sheets to show control stations beyond sheet limits must occasionally be used for manual position plotting and verification. (See 2.4.4.) When possible, oversize sheets should be used to include such control stations, then trimmed to a standard size following final inspection.

If an oversize sheet is impractical, control station may be plotted on "dog ears" that should not extend more than about 15 cm (6 in) from the edge of the sheet. They are attached securely to a smooth sheet or a smooth position overlay by applying strips of masking tape to the underside of the sheet.

When control stations necessary to manually plot hydrographic positions lie beyond the sheet limits, three fine-inked lines to each station are drawn on the sheet. These lines should intersect at the stations at geometrically strong angles and lengths so each station can be replotted accurately after final trimming of a sheet or removing the dog ear. Such leader lines shall be hand drafted to avoid effacing soundings and other hydrographic details. (See figure 7-1.) Each line must be annotated with the station symbol, number, and name.

Dog-ear usage can usually be avoided by careful planning when laying out the sheets. (See 2.4.)

7.2.4. Insets and Subplans

These are used to extend survey coverage of smooth sheets as necessary and to combine contemporary small detached surveys of the same project. Small congested areas shall be shown at enlarged scales in subplans in otherwise blank spaces on the smooth sheet. (See 6.3.4.1 and figure 7-2.) Scales and extents of subplans must be large enough to show the hydrography clearly and to include control stations used.

Enlarged subplans, such as those made to include the water area of a small bay, cove, inlet, or anchorage area, shall be surrounded by a heavy margin in black ink. Each subplan includes the scale, name of the water area, if any, and at least one labeled meridian and parallel. Subplans are further defined by enclosing the area with a fine dashed ink line, then drawing an arrow leading to the subplan. Details shown in enlarged subplans may be omitted from the original scale.

If a smooth sheet is plotted by hand, inset or subplan scales can be conveniently enlarged by using the original smooth sheet projection lines and changing their values in the subplan area. On smooth sheets to be plotted by automated methods, projection lines must be omitted in the subplan area. A unique set of projection parameters for the subplan must be derived for a proper automated plot.

Where soundings are taken in small docks and along the sides and ends of small piers and where they are located by reference distances to or along pier faces, enlarged plans (figure 7-7) shall be shown nearby with arrows pointing to the area on the original scale plot. Such plans need not contain a scale or be surrounded by a margin. Each plan

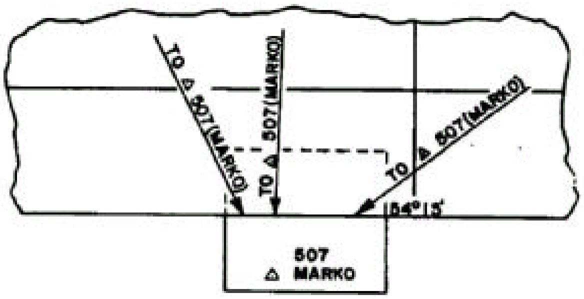


FIGURE 7–1.— Smooth sheet, dog ear or temporary extension

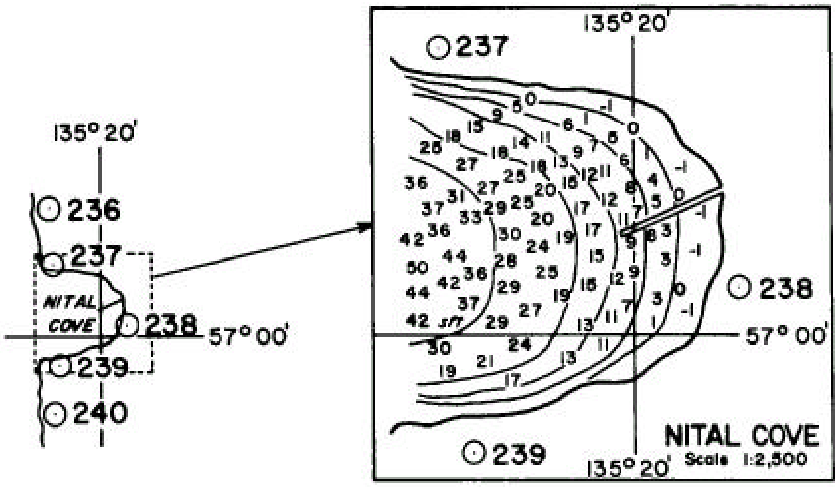


FIGURE 7–2.— Subplan of a small cove on a smooth sheet

shall show, in figures, the principal dimensions of the pier.

7.2.5. Drafting Standards

Approved smooth sheets are official government documents retained permanently in the National Ocean Survey archives. Standards of accuracy for smooth plotting and detailing, along with clarity and neatness of drafting, must reflect the high standards of accuracy of the collected data. Manual drafting should not be artistic, but shall be neat, clearly legible, and in accordance with the standards adopted for hydrographic smooth sheets as specified in this chapter. Characters drafted mechanically must be placed to avoid clutter and congestion insofar as possible.

7.2.5.1. CHARACTER OF LETTERING. When constructing smooth sheets and supporting overlays by automation methods, mechanical plotting capabilities shall be fully utilized to accomplish as much of the lettering and symbol drafting as possible. Otherwise, on manually processed or automated smooth sheets, mechanical lettering sets or guides shall be used for lettering all signal names and numerals, but not position numbers, soundings, bottom characteristics, buoy designations, and rock elevations. Generally, descriptive notes and penciled geographic names should be in freehand lettering. Geographic names are entered on smooth sheets in ink using lettering templates following approval of the list of names by the **NOS** Chief Geographer. (See 5.3.5(C) and 5.7.) See appendix B and the figures in this chapter for lettering character examples. Information originating from the present hydrographic and topographic surveys is generally shown in black ink—exceptions are discussed in the following sections.

7.2.5.2. LETTERING ORIENTATION. Symbols and lettering shall be aligned with parallels of latitude so they can be read from the south to the extent practical. Where geographic names cannot be lettered in an east-west direction, they shall be aligned at an angle or along a curve so they can be read from the south. (See 7.3.12.3.)

Regardless of the direction of the sounding line, sounding numerals are consistently oriented normal to an east-west projection line — except in deep-water areas where it may be necessary to plot three- or four-digit soundings at an angle. On east-west lines where soundings are spaced very closely, two-digit soundings may be shown at an angle to the line to avoid congestion. In such cases, orientation of these soundings shall be as consistent as possible and easily readable from the south. (See figure 7-3.)

Both vertical and slant-style lettering are used on smooth sheets. Vertical characters shall be used for:

1. Names and descriptions of topographic features that in general include all features above the high water line (or above low water datum in the Great Lakes).
2. Position numbers and soundings.
3. Control station and signal names and numbers.
4. Projection line labels.
5. Title block in formation.

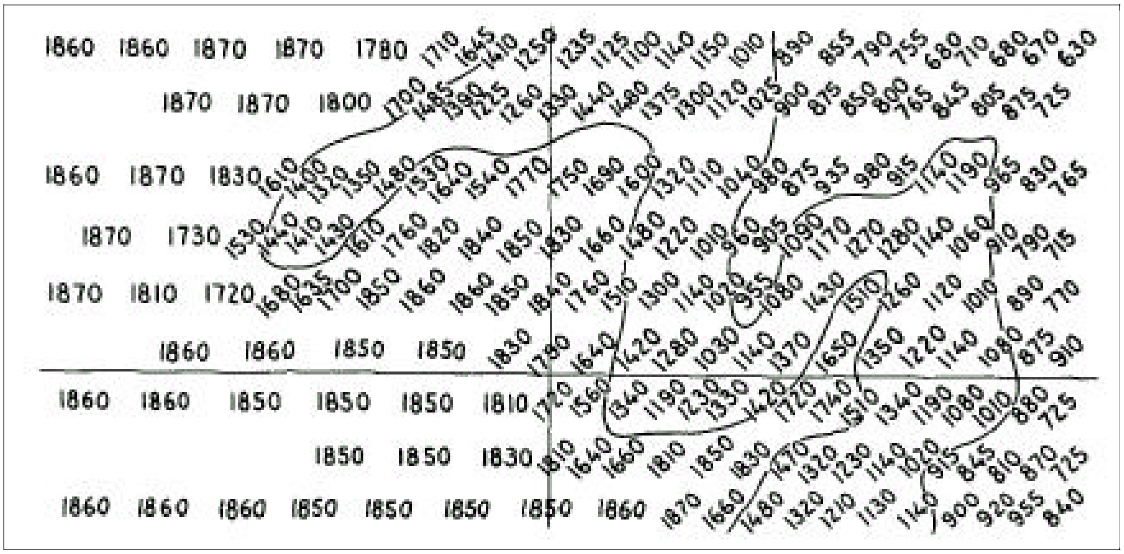


FIGURE 7–3.—Three- and four-digit soundings plotted at an angle

Slant-style characters shall be used for:

1. Names of hydrographic features; in general, all features below mean high water (or below low water datum in the Great Lakes); and related descriptive notes.
2. Elevations of bare rocks, rocks awash, piling, and other similar objects.
3. Official names and designations of all aids to navigation.
4. Bottom characteristics.

7.2.5.3 PLACEMENT OF LETTERING. For annotations, lettering shall be placed on smooth sheets in such a manner that there can be no doubt as to the item or feature it describes. Control station names, dates of establishment, identification numbers, and most other descriptive annotations are placed in the land areas if possible to ensure optimal clarity of hydrographic detail. (See also 4.2.5.) Where practical, annotations should be separated from feature symbols by the space of one letter, and be either on line with the symbol or placed as a subscript. Where an identification or annotation must be placed so that doubt could arise as to its reference, a fine inked arrow or leader, in the same color as the name, must be drawn to the symbol. Extensive usage of offset names, descriptions, and designations is undesirable and should be avoided.

As a rule, station designations should not be placed in water areas, particularly along rugged coast lines; but if such location cannot be avoided, relatively unimportant soundings in generally flat areas may be omitted to allow space. Where room exists for only a hydrographic signal number, the number may be placed there provided the complete station designation is shown on a nearby unused portion of the sheet.

Where hydrographic detail is too congested to permit normal station identification, a capital letter (A, B, C, . . .AA, BA, CA, . . .— omit I and O.) may be used to reference the full station name or number with a reference placed in an unused part of the sheet. Arrows can be used to offset numbers and descriptions provided they are not too long and do not cross congested hydrography. Arrows and leader lines should be broken when crossing a sounding.

7.2.6. Drafting Materials

7.2.6.1. SELECTION AND USE OF INK. Selecting and applying proper inks during smooth sheet drafting are important and require judgment and experience. Ink quality is critical because improper inks result in faint, nonphotographic, or watery detail that usually becomes illegible with age. Bottles of coagulated or otherwise aged inks should be discarded. Waterproof drawing inks are most often used on paper drafting surfaces; pigmented inks, when used, must be stirred or shaken to homogeneous consistency. When color intensity becomes weak, use new ink. Green ink is especially perishable and deteriorates rapidly.

Special inks are needed for modern plastic drafting films; ordinary waterproof drawing inks will not bond. Most commercial inks are unsatisfactory because of their tendency to "bleed" after an ink fixative has been applied; but Pelikan Drawing Ink, "Special Shades, 50 Series" (manufactured by Gunther Wagner, Germany, and distributed by Koh-i-noor Rapidograph, Inc., Bloomsbury, N.J.) has proven satisfactory and should be used.

Special pressurized ball-point pens are approved for machine-drafted detail on overlays provided the information is sufficiently dense and dark for easy sheet reproduction.

Standard characters for inked lettering are specified in appendix B. Freehand and mechanical pens shall be carefully selected and used to conform with these standards insofar as possible. Experienced draftsmen are familiar with the various types of pens available and acquire proficiency with a selected few. Less-experienced draftsmen should experiment with different types of pens and practice lettering until able to produce acceptable work. Quality of ink work may be improved by testing a variety of pens, selecting the best, then gently smoothing, rounding, or sharpening the nibs with fine crocus cloth or oilstone as necessary. A set of pens for each of the various colors should be used to avoid blending of colors.

Erasures on drafting film may be accomplished by careful use of plain water or a liquid detergent into which a cotton swab, soft rubber eraser (small areas), or an abrasive tissue (large areas) has been immersed. Hard abrasive erasers must never be used on any drafting surface.

When a sheet has been completed, a fixative must be applied to the inked surface to assure a permanent bond of the ink to the drafting film and prevent loss of hydrographic data. Krylon Workable Fixative Spray Coating, No. 1306 (manufactured by the Borden Company, Columbus, Ohio) or equivalent is approved for this purpose. The room must be well ventilated while spraying the fixative and a protective mask worn over both mouth and nose. Filter mask number 3500 (manufactured by the 3M Company, St Paul, Minn.) or equivalent is recommended.

If an erasure must be made after spraying, a small amount of water or additional fixative applied lightly with an eraser, then wiped off before drying, usually removes the original coat of fixative to permit corrections. Ink applied to a fixative-coated surface must be protected by additional spraying.

7.2.6.2. SELECTION AND USE OF PENCILS. Proper drawing pencils are essential for good drafting. Pencils that are too hard can mar the drafting surface, and lines from such pencils are often too dim to allow sharp clear reproduction. Soft pencil points become blunt quickly and often result in smearing the plotting surface with a layer of graphite that inhibits proper penetration of ink. Inked soundings deteriorate rapidly on graphite-coated sheets.

Types of pencils used on mylar smooth sheets for geographic names, junction notations, unverified high water lines, and similar details vary with the individual. Those with a heavy hand should use a 3H or 4H pencil as lightly as possible — those with a light hand can use up to a 6H. Care should be taken to keep pencil points sharp to maintain fine narrow lines applying as little graphite as possible. Pencil lines should never be drawn so firmly that permanent indentations are made on the paper or drafting film; such indentations may result in damage to the grained drafting surface and in tears or ruptures of the sheet.

7.2.7. Drafting Instruments and Plotters

All instruments used to plot, verify, and review positions of hydrographic data shall be checked periodically for accuracy; such instruments must be kept clean and in excellent repair and calibration. Poorly maintained or unadjusted instruments can result in serious inaccuracies of the smooth plot. Particular care must be given when using and checking plastic protractors since they have a tendency to warp. (See A.9.1.)

7.3. CARTOGRAPHIC SPECIFICATIONS AND CONVENTIONS

The following sections contain specifications and conventions for the cartographic representation of data on smooth sheets. See also appendix B, "Hydrographic Sheet Cartographic Codes and Symbols," for additional details.

7.3.1. Projection

The polyconic projection shall be used for all smooth sheets unless a different projection is authorized by the project instructions for special surveys. Projections are machine drafted at the Marine Centers as an integral part of the verification and smooth plotting process. Projections shall be shown by (1) black tick marks connected by fine blue lines or (2) continuous lines fine enough so that soundings will not be obscured. See sections 1.2.2 and 4.2.6 for additional details and projection line spacing requirements. Labels for meridians and parallels are placed in the sheet margins beyond the limits of hydrography.

Procedures for constructing projections by manual methods are described in the U.S. Coast and Geodetic Survey (1935) *Special Publication* No. 5, "Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridians and Parallels, Based Upon Clarke's Reference Spheroid of 1866."

7.3.2. Electronic Positioning Lattices

When specifically required by **NOS** Headquarters, electronic control lattices shall be drafted for appropriate areas of coverage on the smooth position overlay that accompanies the smooth sheet. (See 4.2.6 and 6.3.3.) Multiple horizontal control overlays (6.3.2) should be used (1) to show lattices for complex control schemes or (2) when the lattice lines cause undue congestion on the smooth position overlay. Distinctive contrasting colors should be used. Orange and yellow are to be avoided. Lattice lines are spaced at intervals between 7.5 and 10 cm and are shown by unbroken lines in ink not more than 0.2 mm wide.

Lattice labels must reference their source control station(s) by station number. (See 4.2.6.) Lattice points of origin that lie within sheet limits shall be symbolized by the appropriate station symbol and a 5 mm diameter circle. (See appendix B.) Distance, lane, or time intervals represented by each arc are shown in ink in their corresponding arc color using numerals about 2.5 to 3.0 mm high. When possible, these intervals are positioned in otherwise blank areas of the sheet.

7.3.3. Control Stations

All horizontal control stations within the sheet limits that were used for the survey shall be plotted and shown by the appropriate symbol using a line width less than 0.5 mm. Station annotation letters and numerals shall be approximately 3 mm high and in the same color as the station symbol. Actual positions of stations are shown as fine inked dots (penciled dots on manual plots) or small tick marks centered in the corresponding symbol. See chapter 3 for control station designations.

7.3.3.1. BASIC CONTROL STATIONS. Each geodetic control station of second-order or better accuracy is symbolized by a red equilateral triangle, 4.5 mm on a side, with the base leg parallel to the lines of latitude. Station names, years of establishment, and identification numbers are also shown in red ink.

7.3.3.2. SUPPLEMENTAL CONTROL STATIONS. Recoverable supplemental control stations (3.1.2) of third-order accuracy, for which descriptions have been prepared, are symbolized by a red triangle and annotated according to section 7.3.3.1.

Nonrecoverable supplemental stations, located for temporary use during the survey, are symbolized by red circles 3.0 mm in diameter; station numbers and names or designations are shown in red ink.

7.3.3.3. HYDROGRAPHIC CONTROL STATIONS. These have been located using less than third-order accuracy methods (3.1.3) (e.g., stadia traverse, identification on aerial photographs, plane table, or unconventional methods). Such stations are generally temporary and unmarked; they are used only for expedience during the hydrographic survey. Photo-hydro stations and other stations located by less than third-order conventional survey methods are shown by the same red circle symbol and annotation used for unrecoverable supplemental stations as specified in section 7.3.3.2.

Stations may be established during the progress of hydrography by transferring directly to the field sheet a point identified on an aerial photograph. Unless subsequently located by more accurate methods, such points are symbolized by a green circle 3.0 mm in diameter with the station identification number in green ink.

Hydrographic control stations located by sextant three-point fixes or intersecting sextant cuts are symbolized by blue circles 3.0 mm in diameter with the station number in blue.

7.3.4. Shoreline and Topographic Details

These details in the nearshore and water areas shall be carefully traced or transferred to the smooth sheet from the shoreline manuscript for all inshore hydrographic surveys. Generally, topography is not shown on offshore sheets, particularly where scale differences are involved. As a general rule, only contemporary photogrammetric or registered planetable surveys are used for delineation of shoreline. Only class-I manuscripts shall be used when transferring shoreline and topographic details from photogrammetric compilations. (See 3.2.) Copies of smooth sheets are frequently furnished to individuals unaware that the hydrographic survey is not the source document for shoreline location; therefore, the transfer of shoreline from a photogrammetric manuscript to a smooth sheet must be done accurately.

The shoreline, as defined for the project area (1.6.1) shall be shown with a solid black inked line about 0.4 mm wide. Apparent shoreline in marsh, swamp, or mangrove areas is shown by black inked lines 0.2 mm wide. Sections of shoreline shown as dashed or broken lines on class-I shoreline maps shall be left in pencil until the survey has been verified in its entirety. When verification has been completed, such shorelines are shown in ink by the appropriate symbol.

The shoreline is never generalized or smoothed on hydrographic sheets. Topographic detail shall never obscure a control station point. (See figure 7–4.) Minor details usually can be omitted within the station symbol; when necessary, use an extremely fine line to delineate important features within symbols. Shapes of islets must be shown accurately except in areas where slight distortions are permitted to prevent misinterpretation as zero soundings.

When a section of the shoreline is revised during hydrographic operations and supersedes a prior survey for reasons of natural change or error, that section is shown in red ink. (See 3.2.5 and 4.5.8.) Revised shoreline is shown by a continuous line 0.4 mm wide if located by acceptable field methods. [See National Ocean Survey (1974) "Provisional photogrammetry Instructions for Field Edit Surveys."] Otherwise, shoreline is shown by a dashed line.

Generally, shoreline is not shown beyond the limits of a survey. Although extended or flanking shorelines are sometimes shown for reference, excessive work on a large amount of unrelated shoreline is unwarranted; under no circumstances shall features be drafted that are offshore from the shoreline beyond the limits of the survey.

7.3.5. Low Water Lines

The low water line is the intersection of the land with the water surface when the water is at the elevation of the datum of reference prescribed for the area. (See 1.6.1.) Low water lines may also be considered as contours of zero depth. In ocean areas, these lines are often determined photogrammetrically from tide-coordinated infrared aerial photography. Low water lines located by this method are inked in black as dotted lines on smooth sheets.

A low water line delineated hydrographi-

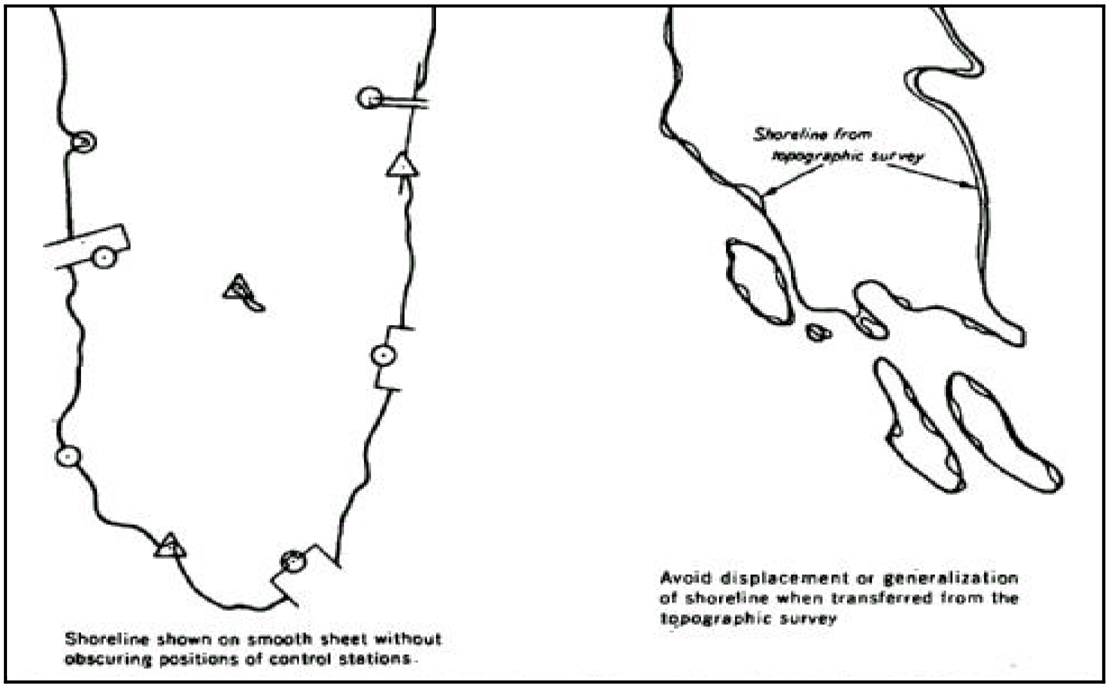


FIGURE 7–4. — Correct and incorrect shoreline delineation on a smooth sheet

cally from sounding values is shown by a continuous orange inked line. When located by estimated distances from a launch or by other approximate methods, it is shown by a dashed orange line. Low water lines around steep rocky features such as around ledge outcrops are usually represented by the ledge or reef symbol. In some areas, however, an outer ledge limit may be far enough inshore of the actual low water line that the low water line should also be shown. (See figure B-3 in appendix B.)

Low water datum lines are shown only when feasible on hydrographic surveys of the Great Lakes.

7.3.6. Limit Lines

Dashed lines on photogrammetric manuscripts that delineate approximate limits of features such as channels, shoals, kelp, or foul areas are intended to serve as guides to the hydrographer and usually are superseded by hydrographic information. (See 4.2.7.) After the survey has been smooth plotted, such limit lines not superseded by hydrographic information are added in black ink as accepted during office verification. These dashed lines shall be accompanied by an appropriate notation such as "shoal," "foul," "breakers," or "kelp."

Similarly, limits of other danger areas discovered during the hydrographic survey shall be defined by dashed lines and identifying notes; these are to be inked in black. Such areas usually cannot be sounded because of high-risk factors. (See 4.3.3.)

7.3.7. Hydrographic Features

Appendix B, "Cartographic Codes and Symbols," contains the conventional symbols to be used on smooth sheets to depict the hydrographic features discussed in the following sections.

7.3.7.1. LEDGES AND REEFS. Rock and coral formations that uncover during some stage of the water level or tidal range are classified as ledges and reefs. A ledge is a rock formation connecting and fringing the shore of an island or larger landmass; it is generally characterized by a steep shear in the submarine topography. A reef is a rocky or coral formation dangerous to surface navigation. Reefs may be above or below the datum of reference. Rocky reefs are always detached from the shore; coral reefs may or may not be connected with the shore.

Symbols for ledges and reefs transferred from shoreline manuscripts are not inked until the hydrographic survey has been smooth plotted and all delineation discrepancies resolved. When transferring very small isolated reef patches, substitute the rock awash symbol for the reef symbol; but where a cluster of closely grouped rock awash symbols extend over an appreciable area, use the reef symbol. Low water detail is not shown on smooth sheets in areas beyond the limits of hydrography.

Along continuous stretches of ledge or reef, the ledge symbol shall be substituted for the zero depth contour. Care should be taken not to extend such symbolization through intervening beaches where the symbol is not applicable and the zero depth contour should be shown.

Do not show zero soundings inside ledge or reef symbols where they may be mistaken for bare rocks or islets. Such soundings should be deleted and removed from the records.

7.3.7.2. CORAL. This feature is found as a reef fringing the shore, as an atoll, or as a detached coral "head" or a pinnacle (usually submerged). A coral reef awash or uncovering at the sounding datum is represented by the reef symbol with the legend "coral." Where all ledges and reefs are composed of coral, only a general note to that effect need be entered on the sheet. Pinnacles and small patches of coral are represented by rock symbols with the abbreviation "Co" or the legend "coral."

7.3.7.3. BARE ROCKS. These extend above the datum of mean high water in tidal areas and may extend above low water datum in the Great Lakes where the shoreline is determined by the water level at the time of the topographic survey. Rocks with elevations of 1.6 ft or more above mean high water on the Atlantic Ocean or Gulf of Mexico Coasts, 2.6 ft or more above mean high water on the Pacific Ocean Coast, or 4.3 ft or more above low water datum in the Great Lakes shall be shown as bare rocks. Actual sizes and shapes of rocks should be shown, if possible, at the scale of the survey. If not, small single rocks are exaggerated in size and shown on the smooth sheet with an open center. Where clusters of bare rocks are shown by dots on photogrammetric manuscripts, use one or more open center symbols as necessary. The bare rock symbol is never overlapped by rock awash or submerged rock symbols. Bare rock elevations in tidal areas are referenced to the datum of mean high water; in the Great Lakes, such elevations are referenced to low water datum. (See figures B-1 through B-3 in appendix B.)

7.3.7.4. ROCKS AWASH. In tidal areas, the rock awash symbol (*) is used to portray rocks that become exposed, or nearly so, between the datum of reference (1.6.1) and mean high water. In the Great Lakes, the rock awash symbol is used for rocks that are awash, or nearly so, at low water datum. The rock awash symbol shall be applied in accordance with appendix B and the following:

Atlantic Ocean Coast. When rock summits are in the zone from less than 1.6 ft below mean low water to less than 1.6 ft above mean high water.

Gulf of Mexico Coast. When rock summits are in the zone from less than 1.6 ft below Gulf Coast Low Water Datum to less than 1.6 ft above mean high water.

Pacific Ocean Coast. When rock summits are in the zone from less than 2.6 ft below mean lower low water to less than 2.6 ft above mean high water.

Great Lakes. When rock summits are in the zone from 2.7 ft below to less than 4.3 ft above low water datum.

Rock elevations are placed within parentheses beside the symbols as shown in figures B–1 through B–3 in appendix B.

Rock awash symbols are drawn with bold, neat pen strokes and must not be substantially reduced in size even where there is a congestion of other rocks or soundings. A symbol need not be shown for each rock in a closely grouped cluster of rocks. The number of symbols should be reduced to avoid overlapping. When appropriate, use the reef or ledge symbol.

7.3.7.5. ROCK ELEVATIONS. Heights of rocks, coral heads, reefs, and ledges are referenced to low water or high water datums as specified in sections 7.3.7.3 and 7.3.7.4. Elevations above any datum are shown to the nearest whole foot; 0.5-ft values are rounded down to the lower value (i.e., a 2.5-ft elevation is shown as 2 ft). Elevations are always shown close to the feature in slanting figures enclosed in parentheses. Elevations referenced to a low water datum are underlined as shown in appendix B. Elevations of bare rocks transferred from topographic surveys or shoreline manuscripts are shown by red inked numerals about 2 mm high; elevations of similarly transferred rocks awash are shown in black ink. All elevations determined by hydrographic methods shall be shown in black ink.

An elevation on a rock covered or exposed ≤ 0.5 ft at the sounding datum is shown as an underscored zero (0)—the notation "awash at (appropriate datum, **MLW, MLLW, GCLWD, or LWD)**" may be substituted to emphasize the existence of a dangerous isolated rock. The notation "covered 1 ft **MLW** (2 ft **MLLW** on the Pacific Ocean Coast)" should be used in inland waters where such covered rocks are seldom exposed by rough water or during low tide. On outer coasts or in areas where a rock is frequently exposed at low tide, the zero value or awash notation shall be used.

Where rocks are grouped closely, the elevations of lesser importance should be omitted. The important values are at the outermost edges of the group and on the highest rocks.

7.3.7.6. SUBMERGED ROCKS. These are covered at the sounding datum and considered to be potentially dangerous to navigation. Rocks with summits below the lower limit of the zone specified for rocks awash (7.3.7.4) are represented on the smooth sheet by symbol only (+) or by soundings accompanied by the legend "Rk," depending on the information available. (See 4.7.) Where several least depths were obtained over a submerged reef and the type of bottom was recorded, the proper notation is the abbreviation "rky" (indicating a rocky bottom). When a depth was not determined and the standard symbol used, the notation "breakers" is shown if so noted in the records.

7.3.7.7. SUBMERGED OBSTRUCTIONS. All submerged obstructions found during a hydrographic survey shall be shown on the smooth sheet using the appropriate symbol listed in appendix B. If least depths could not be determined over unnatural features such as stubs or piles, ruins of piers and other structures, and wreckage of various kinds, the feature is shown by a 1-mm circle or by a dashed outline with appropriate annotation. If the nature of an obstruction was not determined, the note "obstr" shall be used. Dashed lines are used to indicate an extension below the high water datum of marine railways, groins, breakwaters, sewer outfalls, or other unnatural features rising above the bottom. All annotations shall be in slanted lettering.

7.3.7.8. VISIBLE OBSTRUCTIONS. In water areas, visible obstructions such as wrecks, piles, breakwaters, groins, fences, duck blinds, and fish houses are generally located on photogrammetric manuscripts—then transferred to smooth sheets if field confirmation has been made. Such obstructions are depicted by the distinctive symbols shown in appendix B or, if necessary, by outlining the obstructing area with dashed lines. Annotations are to be in vertical lettering for features rising above the shoreline datum for the area (1.6.1); otherwise, use slanted lettering.

7.3.7.9. WRECKS. Stranded wrecks, where part of the hull uncovers at the sounding datum, are generally transferred to smooth sheets from shoreline manuscripts, particularly when a wreck is prominent and close to the shoreline. The small circle of the wreck symbol shown in appendix B is the actual position of the wreck. Wrecks occurring after aerial photography was obtained are normally located by detached positions or by reference to a sounding line; they may be spotted approximately on field sheets. Large hulks should be outlined and labeled accordingly if the scale of the survey permits.

Sunken wrecks are covered at low water, but the masts may uncover. In such cases, the notation "masts" accompanies the sunken wreck symbol. When a least depth over a sunken wreck has been accurately determined, the depth with the notation "wreck" is shown instead of using the wreck symbol. Offshore sunken wrecks are normally located by wire-drag surveys—least depths, groundings, and hangs are transferred to the smooth sheet in green ink with appropriate notation after verification of both surveys.

7.3.7.10. MARINE GROWTH. Limits of kelp beds and other forms of marine growth shown on shoreline manuscripts are frequently revised by hydrographic survey data prior to being smooth plotted. If discrepancies between the two sources arise, the hydrographic determination shall take precedence. Areas of marine growth are shown in pencil on the smooth sheet until the survey has been verified and the final limits accepted. Extensive areas of growth inshore of the sounding lines are finally delineated by dashed lines in black ink and annotated accordingly (e.g., "kelp"). When soundings are included in the growth area, the delineation line is not shown; the kelp legend alone is used. Small detached areas of kelp, whether inshore or offshore, are shown by symbol only. Grassy areas are identified by the abbreviation "Grs" or by the note "grass."

Masses of free unattached kelp or other floating marine growth noted during the survey are not shown. Marine growth recorded on the analog depth record is not shown by symbol or legend unless reported by the hydrographer to be visible at the sounding datum.

7.3.7.11. BREAKERS, TIDE RIPS, AND EDDIES. Breakers, whether offshore or alongshore, should be delineated by a dashed line in black ink with the notation "breakers." The intersection of directional cuts taken to breakers over submerged rocks should be indicated by the appropriate rock symbol.

Tide rips, which occur in conjunction with strong currents, are usually encountered near shoals or uneven bottom. Small areas of tide rips may be shown by legend. Approximate limits of extensive features should be outlined with dashed lines and an appropriate descriptive note added. Tide rips may be qualified as heavy, moderate, or light. Current eddies are shown by legend.

7.3.7.12. WIRE-DRAG HANGS, GROUNDINGS, AND CLEARANCES. Least depths over shoals or obstructions determined by wire-drag examinations conducted as a part of a hydrographic survey are shown on smooth sheets in green ink—provided that the least depth determined by wire drag was less than the depth determined hydrographically. Additional descriptive notes are entered on sheets in green ink as necessary with leaders and arrows used to indicate the proper area. Areas cleared, hangs, groundings, clearance depths, and other wire-drag data are shown on a separate overlay to accompany the smooth sheet, or are included in the Descriptive Report.

When contemporary wire-drag surveys have been conducted by another survey party, all drag hangs and groundings, but not clearances, are transferred to the smooth sheet in green ink following verification of both surveys. In such cases, a note must be entered on the sheet that identifies the wire-drag survey(s).

7.3.8. Soundings

These and related hydrographic detail needed to compile marine charts are the most important observations of a hydrographic survey. It is essential that the final corrected soundings plotted on the smooth sheet be accurately and graphically displayed in a uniform conventional manner. (See figures 7–6 and 7–7.)

Sounding numerals shall be between 2.0 and 2.5 mm high. At this size, legible photographic reproductions can be made at reduced scales. The center of the sounding numeral, excluding decimals, is the position of the sounding. Figures for the decimal part of a depth shall not be larger than three-fourths the size of the whole sounding integer. For depths of less than one whole sounding unit, decimal parts are always preceded by a zero (e.g.,0_4).

7.3.8.1. SOUNDING UNITS AND ROUNDING. Smooth sheet sounding units for various areas and depths are specified in section 1.5.5. Only one sounding unit may be used on a smooth sheet. Fractional parts of soundings are shown only in decimal form (e.g., 0_5).

Soundings are shown to the nearest 0.5 ft on smooth sheets for which the soundings are in whole feet in the following areas:

1. Over critical points on navigable bars.
2. For controlling depths in dredged or natural channels.
3. On both sides of the low water line.
4. As necessary or desirable for better definition of standard depth contours. (See figure 7–5.)

When rounding soundings to 0.5-ft increments, reduced decimal values from 0.3 to 0.7 ft are shown as 0_5-ft both positive and negative soundings. When rounding positive soundings to integral feet, decimals less than 0.8 ft are disregarded; decimals of 0.8 to 0.9 ft are increased to the next whole unit. When rounding minus soundings, decimals less than – 0.3 ft are disregarded and decimals from – 0.8 to – 0.9 ft are treated as – 1.0 ft. See table 4–15 for a method used to round-off soundings.

When the smooth sheet unit is the fathom, negative soundings and soundings in depths less than 20 fm are shown in fathoms and tenths. In depths greater than 20 fm, soundings are generally rounded to integral fathoms; but where depths are charted in feet over smooth bottom and gentle slopes, soundings shall be shown in fathoms and tenths to depths of 31 fm. In such areas, depths between 31 and 101 fm are shown to the nearest 0.5 fm.

The same ranges are applicable when plotting soundings in overlap areas between surveys plotted in fathoms that join surveys plotted in feet. In addition, fathoms and decimals are used in other areas as necessary to define depth contours more accurately. When soundings are shown in 0.5-fm intervals, decimals from 0.3 to 0.7 fm shall be plotted as 0_1–fm. When soundings are entered in integral fathoms, decimals less than 0.8 fm shall be disregarded; 0.8 and 0.9 decimal values increase the sounding to the next whole number.

When conversions between fathoms and feet are necessary, use table 4–15. (See 4.9.9.)

7.3.8.2. SPACING OF PLOTTED SOUNDINGS. The spacing and density of soundings on smooth sheets shall be such that each depth contour is delineated adequately and the configuration of the bottom is fully revealed. Soundings should have been observed and recorded at intervals appropriate to the scale of the survey, the configuration of the bottom, the speed of the sounding vessel, and the depth of water. (See 1.4.6 and 4.5.6.) Soundings in addition to those taken at regular intervals must often be scaled from the analog depth records to portray all hydrographic features adequately. Smooth sheet soundings are generally spaced uniformly, except as noted in section 7.3.8.3.

Over smooth bottom, soundings can be plotted without congestion at the following intervals.

East-west lines:

5 mm for single-digit soundings;
7 mm for two-digit soudings;
10 mm for three-digit soundings; and
15 mm for four-digit soundings.

North-south lines:

from 5 mm for single-digit numbers to 7 mm for up to four-digit numbers.

Soundings with decimals generally are spaced at slightly greater intervals on east-west lines.

Where the bottom is irregular, the spacing of soundings will also be irregular. Soundings must be shown at abrupt changes in the bottom slope and over peaks and deeps that characterize the bottom as irregular, undulating, ridged, or channeled.

Multiple-digit soundings should be shown at an angle to sounding lines when necessary to portray the bottom configuration adequately. In many cases, angled soundings provide an attractive alternative to plotting a smooth sheet at a scale larger than planned or to "excessing" an inordinate number of soundings because of overlapping numerals.

7.3.8.3. SELECTION OF SOUNDINGS AND EXCESSING. Soundings must be selected from the hydrographic records to plot on smooth sheets. It can-

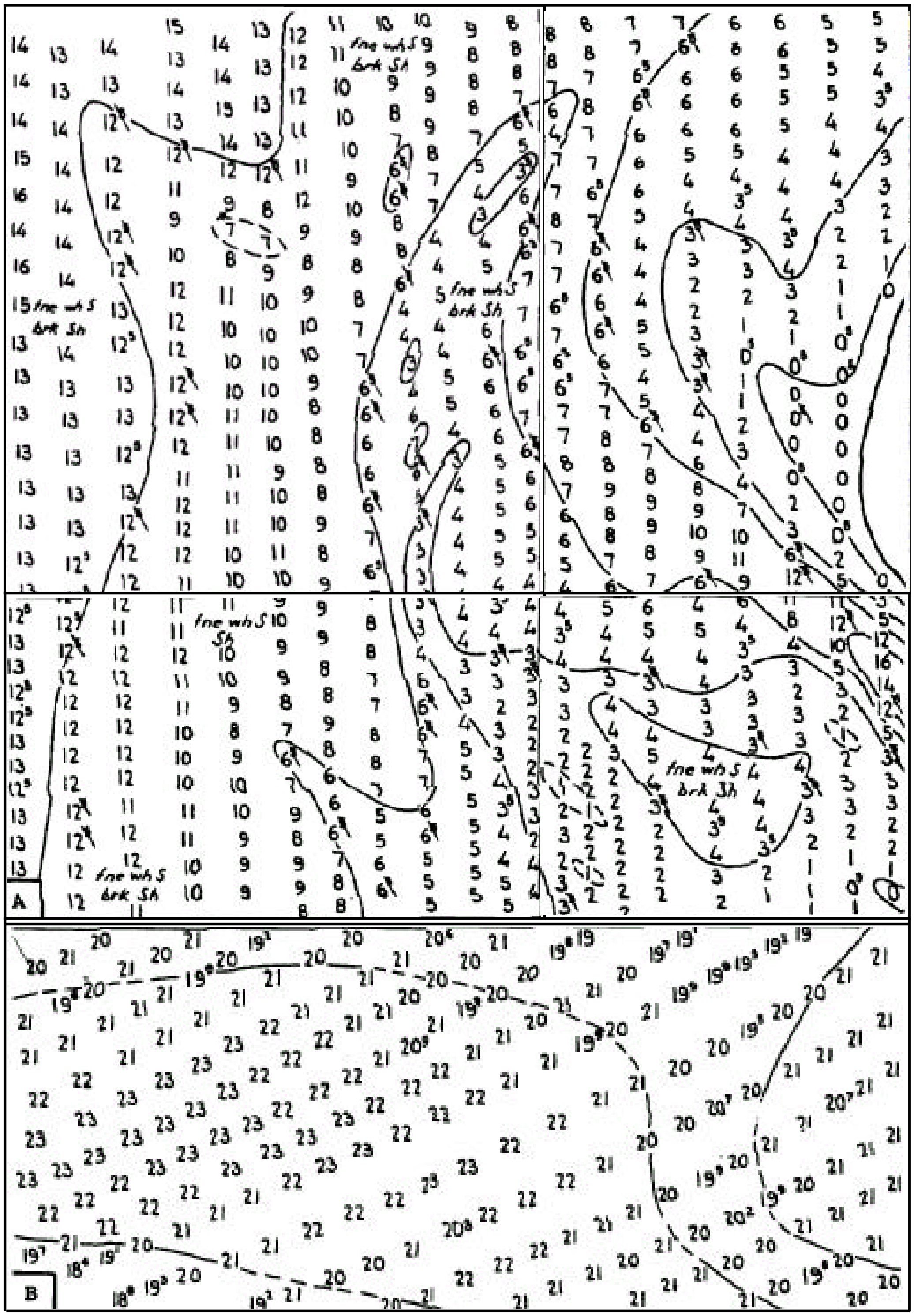


FIGURE 7–5.—(A) Use of 0.5ft soundings to smooth otherwise unnatural depth contours and to better delineate a natural continuous channel and (B) use of dashed contour lines (20 fm) over a flat bottom

not be overemphasized that the proper selection of soundings is essential for a complete and accurate portrayal of the bottom configuration. Analog depth records must be referred to frequently to provide the verifier with a proper conception of the bottom profile that must be reflected by the plotted soundings.

Realistically, every irregularity cannot be represented at the scale of the smooth sheet—minor relief and insignificant features in very irregular bottom generally must be disregarded. That significant peaks and deeps be shown is, however, essential. Soundings to be inserted at uneven intervals must not be shown in small distorted numerals or those that run together and fail to identify individual soundings. Under such conditions, slope soundings may be omitted if another sounding can be scaled from the analog depth records.

Because smooth sheets should reflect the relative density of hydrography, shoal and channel developments, investigations, and crossline soundings should be evident on an initial cursory inspection of the completed sheet.

Noncritical soundings from high-density developments and examinations and soundings that would obscure others (as in the case of line crossings) are nonessential and are shown on supplemental overlays for excess soundings. (See section 6.3.4.1.2 and figure 7–6.) Least depths and others needed to properly delineate depth curves and the bottom configuration must be shown on the smooth sheet.

When routine sounding lines overlap or cross, the shoaler soundings are plotted; however, consideration must be given to retaining the identity of a sounding line when selecting soundings. There should be no hesitation about erasing previously plotted soundings as necessary—such deletions should not mar the smooth sheet surface or impair the legibility of adjacent soundings.

When photobathymetry is used to support a hydrographic survey, soundings and other details shall be transferred from photobathymetric overlays to smooth sheets in red ink—except for depth curves that shall retain their prescribed colors. Identify the source of this data on the smooth sheet with the note "Soundings in red from photobathymetry of ——— (month and year) from T - ——— (sheet number). "In areas of overlap, useful and significant soundings shall be transferred; soundings that do not contribute to the development of the area shall be omitted.

7.3.9. Depth Curves

7.3.9.1. STANDARD DEPTH CURVES. Those listed in table 4–5 shall be drawn on each smooth sheet. Depth curves (isobaths or lines of equal depth) are comparable to topographic contours on land. Principles governing the delineation of topographic contours are equally applicable when drawing depth curves. They generally shall be drawn to include soundings equal to and less than the curve value, but should be broken at soundings as necessary to avoid an unnatural bottom configuration. Depth curves are usually transferred to smooth sheets from preliminary sounding overlays (6.3.4) compiled during the verification phase. See section 6.3.4.4 for a discussion of the conventions for drawing depth curves and see section 7.2.6.1 for the selection and use of inks for line work.

Depth curves are shown on smooth sheets by inked lines approximately 0.4 mm wide in the colors specified in table 4–5. Curves in congested areas and on steep slopes should be about half this width. Curve lines must not be drawn vertically above and below the numeral 1 or on a 45° alignment with the left part of the numeral 4. They should never overlap or cross a letter, numeral, or other symbol. Depth curves are broken into long dashes where not adequately defined by the soundings (e.g., extremely flat monotonous bottoms where the plotted soundings defy the drawing of a meaningful curve). See figure 7-5.

In some inshore areas, only short sections of depth curves can be drawn because of insufficient soundings. Where inshore curves can be extended with reasonable certainty of position, they should be completed to the extent determined by the hydrography. In comparatively shoal depths dangerous to navigation, the cartographer normally will bias the curves on the side of safety.

Drafting aids such as French curves shall not be used to "smooth" the drawn lines; the depth curves should delineate a natural bottom configuration. From a cartographic viewpoint, minor irregularities in soundings should not be overemphasized when drawing the depth curves. The two main reasons for overlooking minor irregularities are (1) when soundings are rounded to integral values, a tenth of a unit change from 0.7 to 0.8 causes a full unit change in the plotted sounding value and (2) continuous minor undulations and irregularities along depth curves detract from the desired emphasis on more significant irregularities. These criteria are difficult to describe and are best cited by illustration. (See figure 7–5.) On the other hand, generalization is desired to a point, but significant configurations of the bottom should not be masked by injudicious smoothing.

7.3.9.2. SELECTION OF DEPTH CURVES. Supplemental depth curves listed in table 4–6 should be added as necessary in shallow waters where (1) there is a considerable horizontal distance between standard depth curves or (2) where supplemental depth curves provide better definition of submarine features such as least depths, tops of shoals, and otherwise undefined channels and depressions. Deeper supplemental curves are added only when significant irregular configurations of the bottom warrant their use. Such applications are a matter of judgment. To emphasize an important shoal sounding or other feature that otherwise would not be delineated by the standard or supplemental depth curves listed in tables 4–5 and 4–6, draw additional depth curves as necessary using short dashes. Such additional depth curves are shown in the same color specified for the next shoaler curves provided that the additional line is only one unit deeper (e.g., (1) if a shoal rises abruptly to a least depth of 19 ft, a 19-ft curve is drawn with a dashed line in the color specified for the 18-ft depth curve or (2) a 10_1 fm depth curve may be drawn with a dashed line using the 10 fm curve color). Otherwise, additional necessary depth curves are inked as a solid brown line.

When depth curves become congested on steep slopes, only the shoalest and deepest curves need be shown; intermediate depth curves are omitted. The shoalest curves that emphasize hazards to navigation and the deepest curves that define limits of channels or passages are the most important. Where pinnacles, rocks, or steep shoals rise abruptly from much greater depths, one or more of the deeper curves should be omitted for clarity. Where islands, shoals, or reefs rise abruptly from much greater depths and several of the shoaler depth curves are very close to shorelines of the islands or edges of the reefs, the shoaler curves are omitted. To preclude redundancy, never draw depth curves around rock or reef symbols unless the curves can be justified by adjacent soundings that lie on both sides of the curves. The low water line or zero depth curve is an important foreshore feature; in many areas, this line is a legal seaward boundary. Particular care must be taken when delineating this line.

7.3.10. Bottom Characteristics

All recorded bottom characteristics shall be shown on smooth sheets except when an excessive number have been recorded on pole or lead line surveys. (See 4.7.) In the latter case, a selection should be made and all isolated rocky or hard bottom characteristics plotted. In important waters such as harbors and anchorages, the plotted characteristics should be adequate to define the approximate limits of various types of bottom in the area. On those surveys where bottom sampling density requirements have been reduced, bottom characteristics may be transferred (in color) from a prior survey following verification provided the general depths in those areas have not changed.

Standard abbreviations for bottom characteristics have been adopted and are used on smooth sheets. Such abbreviations are entered in black ink using slanted uppercase and lowercase letters as shown in appendix B. The capital letters should not exceed 2 mm in height. Bottom characteristics should be placed reasonably close to and slightly below and to the right of the pertinent soundings, provided there is space. Otherwise, characteristics can be placed in a convenient place nearby. When displacing a bottom characteristic, do not place the lettering where it does not represent the nature of the bottom unless the displacement is indicated by a leader and arrow. The descriptive note "Rk" should always adjoin least depths on submerged rocks when so identified in the sounding records.

7.3.11. Aids to Navigation

7.3.11.1. LANDMARKS AND NONFLOATING AIDS TO NAVIGATION. Most landmarks that have been recommended by hydrographers and are approved for charting (See 5.5) are plotted on smooth sheets using the symbols listed in appendix B. Source position data may be the shoreline manuscript, published geodetic position listings, or inclusions in the hydrographic records. Landmarks used to control hydrography or located by geodetic methods are shown on smooth sheets by the control station symbol, not the landmark symbol. To show that a control station is a landmark, enter the proper landmark name in black ink in parentheses after the station identifier. The word "landmark" is entered in parentheses below the station name—if

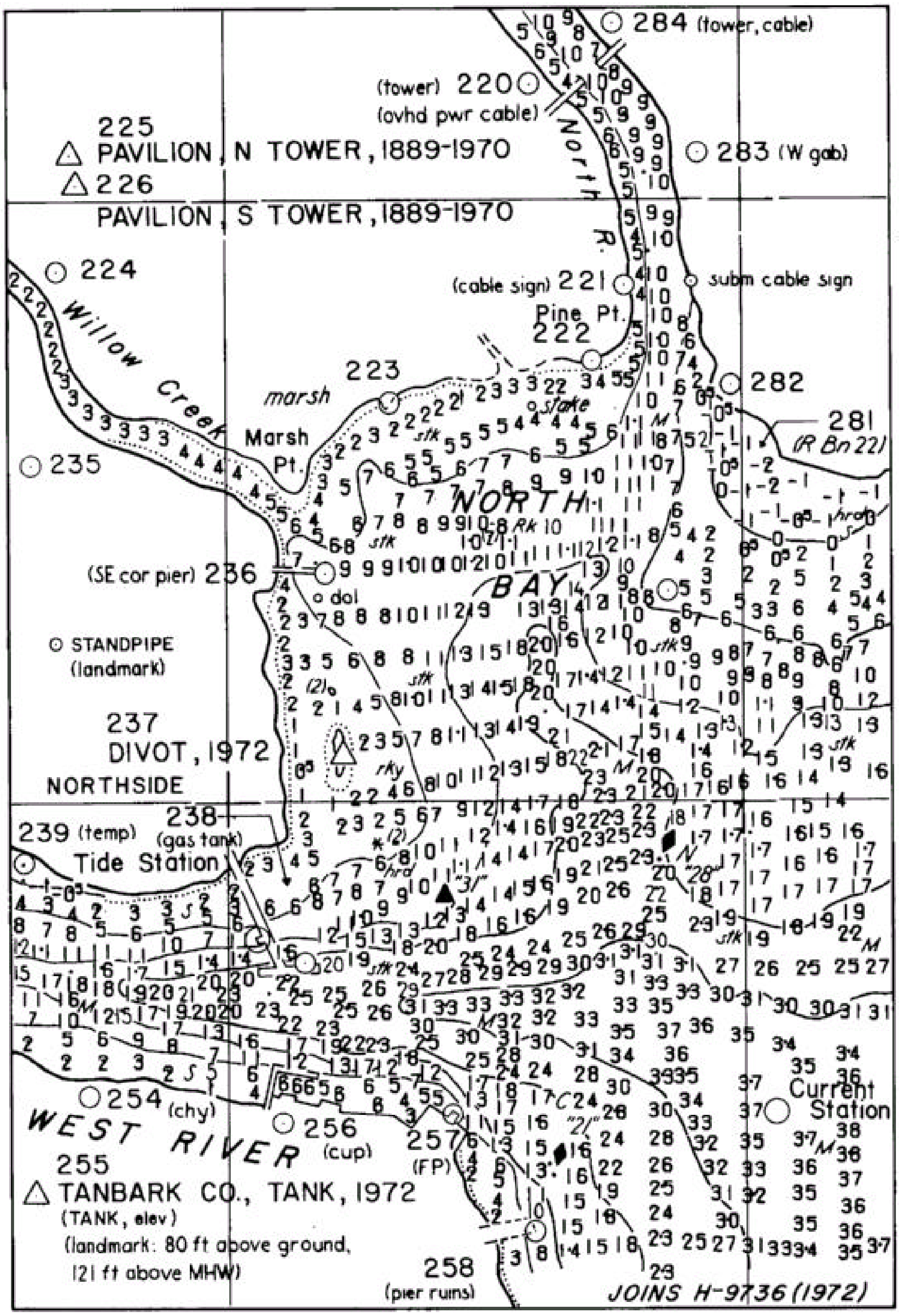


FIGURE 7–6. — Example one of a completed hydrographic smooth sheet. See also figure 7–7.

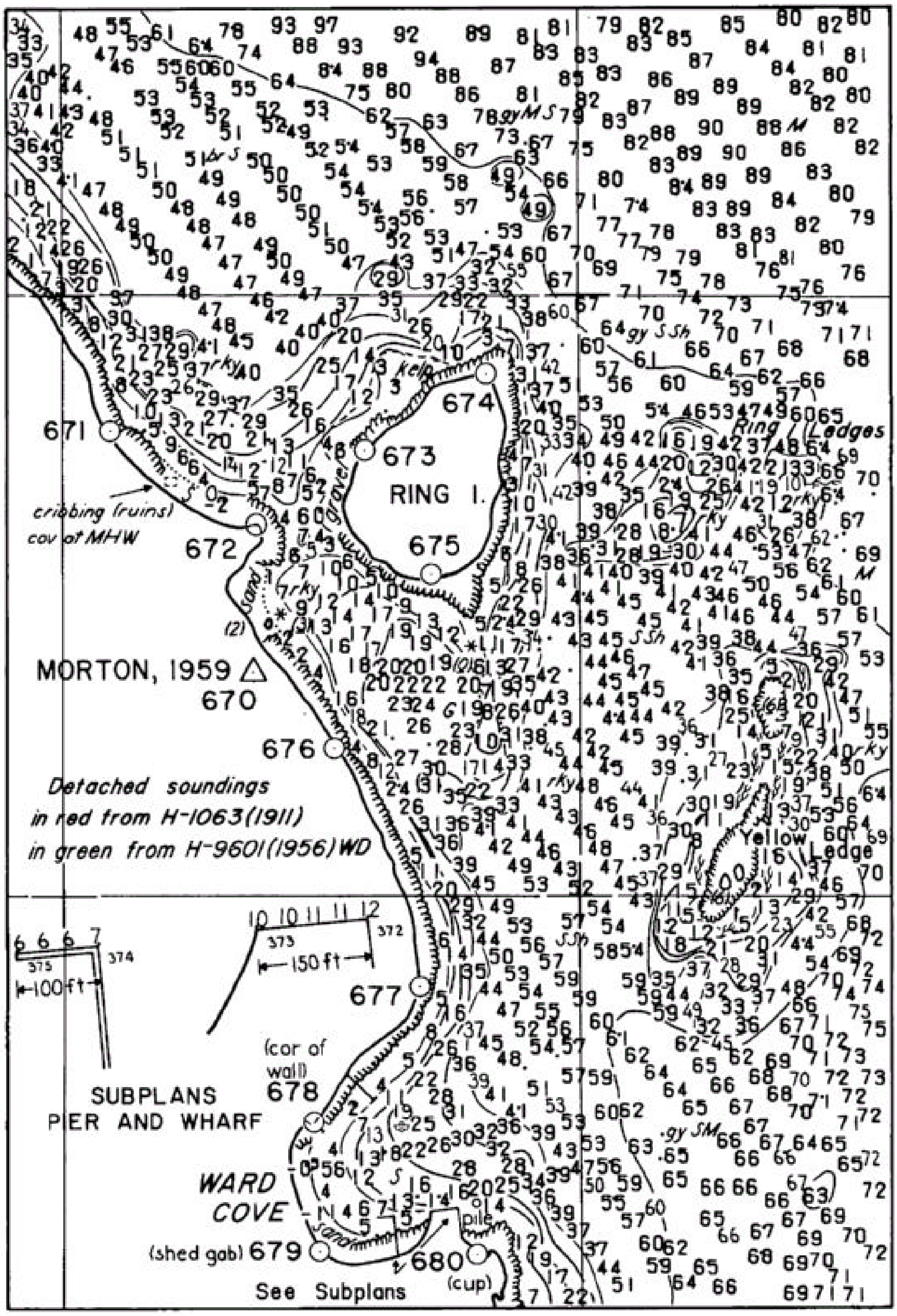


FIGURE 7–7. — Example two of a completed hydrographic smooth sheet. See also figure 7–6.

known, the height of the landmark above ground and above high water is also shown in black ink in these parentheses.

Objects recommended as landmarks but not used as signals, if not plotted on a shoreline manuscript, shall be plotted on the smooth sheet. Such landmarks are symbolized by a black circle 2 mm in diameter. Names of these landmarks and required annotations are entered in black ink.

All nonfloating aids to navigation found within the survey limits are shown on the smooth sheet. Most of these aids, which include both lights and daybeacons , will have been located previously by photogrammetric methods or by conventional ground surveys of third-order accuracy or better, and may have been used as control stations for the hydrographic survey. (See 1.6.5.) Because positions of new or relocated aids are often established during hydrographic operations, copies of Form 76-40 filed by the hydrographer or field editor must be consulted. (See 5.5.) Each fixed aid in the survey area at the time of the survey shall be shown by the appropriate control station symbol or by the approved cartographic symbol (appendix B) when not located by geodetic methods. If the name or designation of an aid as it appears in the U.S. Coast Guard *Light List* is not included in the control station name, enter the *Light List* name in slanting red characters.

Permanent aids established by individuals or nongovernment organizations that were not used to control hydrography are shown by a 1 mm diameter circle and described as " Priv marker," whether or not maintained. Private semipermanent aids such as stakes, with or without baskets or kegs, along shallow channels are plotted as a 1-mm circle and described as "stake."

7.3.11.2. FLOATING AIDS TO NAVIGATION. All of these located by the hydrographer shall be shown on the smooth sheet. Floating aids shall be indicated by the appropriate aid symbol in the proper color. (See appendix B.)

The buoy symbol circle is the position of the buoy. When plotting a mooring buoy, the lower circle indicates its position. Soundings taken at these aids, if important, are shown slightly lower and out of true position so not to overlap the symbol; such soundings may be excessed if they are unnecessary for bottom delineation. Each aid shall be identified by classification and number (e.g., N "7 " or Bell "4" as shown in the examples in appendix B). Any discrepancy between charted or U.S. Coast Guard *Light List* information, designation, description, or characteristic noted during the survey must be mentioned in the Descriptive Report.

7.3.12. Miscellaneous Detail

7.3.12.1. CABLES AND BRIDGES. Locations and paths of overhead and submerged cables are not transferred to smooth sheets from photogrammetric manuscripts; however, terminal points such as towers or signs that were used as signals must be plotted, identified, and described by suitable notes. (See figures 7–6 and 7–7.) Cable and bridge clearances are shown on the smooth sheet only when measured in accordance with section 4.5.14. When positions for towers or signs are unavailable, the approximate inshore ends of cables are shown by black dashed lines with appropriate notes entered in land areas.

7.3.12.2. TIDE AND CURRENT STATIONS. Locations of tide, water level, and current stations shall be shown on smooth sheets by blue circles 4 mm in diameter, without a center dot, and labeled accordingly. (See figure 7–6 and appendix B.) Locations of oceanographic stations or plots of current observations are not shown.

7.3.12.3. GEOGRAPHIC NAMES. These are entered on smooth sheets lightly in pencil after the soundings and other hydrographic data have been verified and plotted. Each name must be placed so as to indicate clearly the feature designated. Geographic names shall not obscure or otherwise confuse plotted soundings and related hydrographic data. Generally, all names are placed landward of the shoreline on inshore survey sheets. Where names must be lettered in water areas, particularly in congested areas, judicious placement and spacing of letters are necessary. Final selection, placement, and inking of geographic names are done after review and approval of the names list by the **NOS** Chief Geographer. (See 5.3.5(C) and 5.5.)

Since smooth sheets are the authority for the charted names of all features seaward from the shoreline, extreme care must be used when spelling and placing geographic names. Instructions for lettering names are contained in section 7.2.5. Published charts serve as excellent guides for placement of names and relative size of lettering for various features.

7.3.12.4. DESCRIPTIVE NOTES. A variety of descriptive notes is required on each smooth sheet to fully identify, reference, and complete the survey data. (See figure 7-6.) Notes are shown in parentheses when preceded by a station name or other similar designation. Notes shall be as brief as possible, sometimes preceded by a station name or other similar designation. Notes shall be as brief as possible, sometimes abbreviated, but always clear and specific. Lettering may be in neat freehand and not larger than 1.8 mm for most notes, except at landmarks where primary descriptions are entered in capital letters 2.2 mm high. Differentiation between elevated and submerged features and the corresponding placement of lettering are discussed in section 7.2.5. Control stations in water areas must be described. (See 4.2.5.) To avoid misinterpretation between bare rocks and positions, do not place dots over the letter " i " or use them as punctuation in water areas.

7.3.12.5. JUNCTIONS AND ADJOINING SURVEYS. A comparison shall be made with adjoining surveys to determine the completeness and relative agreement of hydrography. When necessary, statements are entered by the verifier in the appropriate Descriptive Report concerning consistent disagreements between soundings, significant displacements of depth contours, and inadequate survey coverage. Soundings and other hydrographic information generally should not be transferred from adjoining surveys to smooth sheets except when needed to reveal least depths, to delineate depth contours, or to better show significant bottom configurations. If an adjoining survey has not been completed or verified, pencil notes are used to indicate junctional surveys until such time as they can be inked.

Critical or significant soundings are transferred from adjoining surveys—even if less important soundings plotted on the smooth sheet must be deleted. Where there are unresolvable differences in general depths in the junctional areas, the less-reliable soundings are disregarded and a butt junction effected. The superseded area should be outlined with a dashed colored line and a label ***SUPERSEDED BY H-_____(19_________)*** should be added. The label on the superseding survey should be the normal junctional designation.

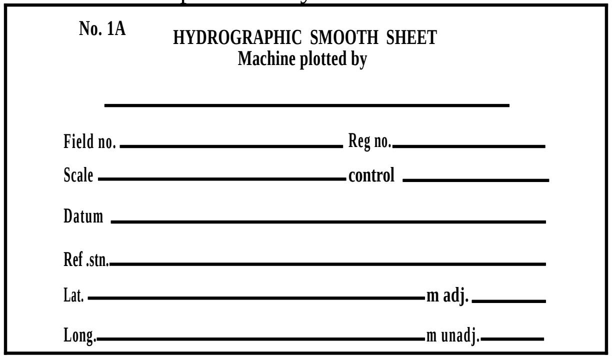
If verification of the survey shows good agreement, the notation "***JOINS H-______ (19_____)*** " is placed in the junctional areas beyond the limits of hydrography for that smooth sheet.

Lettering for junctional notes shall be mechanically drafted, approximately 2.5 mm high, slanted, and in colored ink. (See figure 7–6.) Different colors should be used to show junctional notes and critical soundings transferred from each consecutive adjoining survey. Preferred ink colors are carmine red, red violet, orange, and brown — in that order. Blue and green should be avoided because they photograph poorly. In wire-drag areas, the color green is reserved for transferring wire-drag soundings. Depth curves shall be drawn so there is a definite continuity and agreement in overlap areas. Supplemental depth curves shown on adjoining surveys, however, should not be transferred unless needed to delineate the bottom configuration adequately.

Junctions should be made with contemporary surveys which comprise surveys of the same year, the preceding year, or the following year. If no contemporary surveys are available in stable bottom areas or areas where no noticeable changes have occurred, adequate junctions usually can be completed with recent noncontemporary surveys. These comprise surveys more than 1 year older than the survey being processed.

Prior surveys are those listed in the Verifier's Report for comparison with the survey being processed. Usually overlapping surveys need be considered under only one section of the Verifier's Report, either under **JUNCTIONS or COMPARISON WITH PRIOR SURVEYS.**

7.3.12.6. SMOOTH SHEET IDENTIFICATION BLOCK. Stamp No. 1A (figure 7–8) shall be applied on the lower right-hand corner of each non-automated smooth sheet. Appropriate entries are made for the field number, registry number, scale, horizontal datum of the sheet, and reference station and its latitude and longitude. In the event geodetic control does not exist for the survey area and control is established by alternate methods, e.g., astronomically, the established control (reference control station and geographic position) will be so noted in the non-automated title block. It will also be indicated as to whether values are adjusted or unadjusted, and if unadjusted, to what geodetic datum. An identification block is not required on smooth sheets produced by automation.



No. 1A

HYDROGRAPHIC SMOOTH SHEET
Machine plotted by

____

Field no. ____________________ **Reg no.** ____________

Scale ____________________ **control** ____________

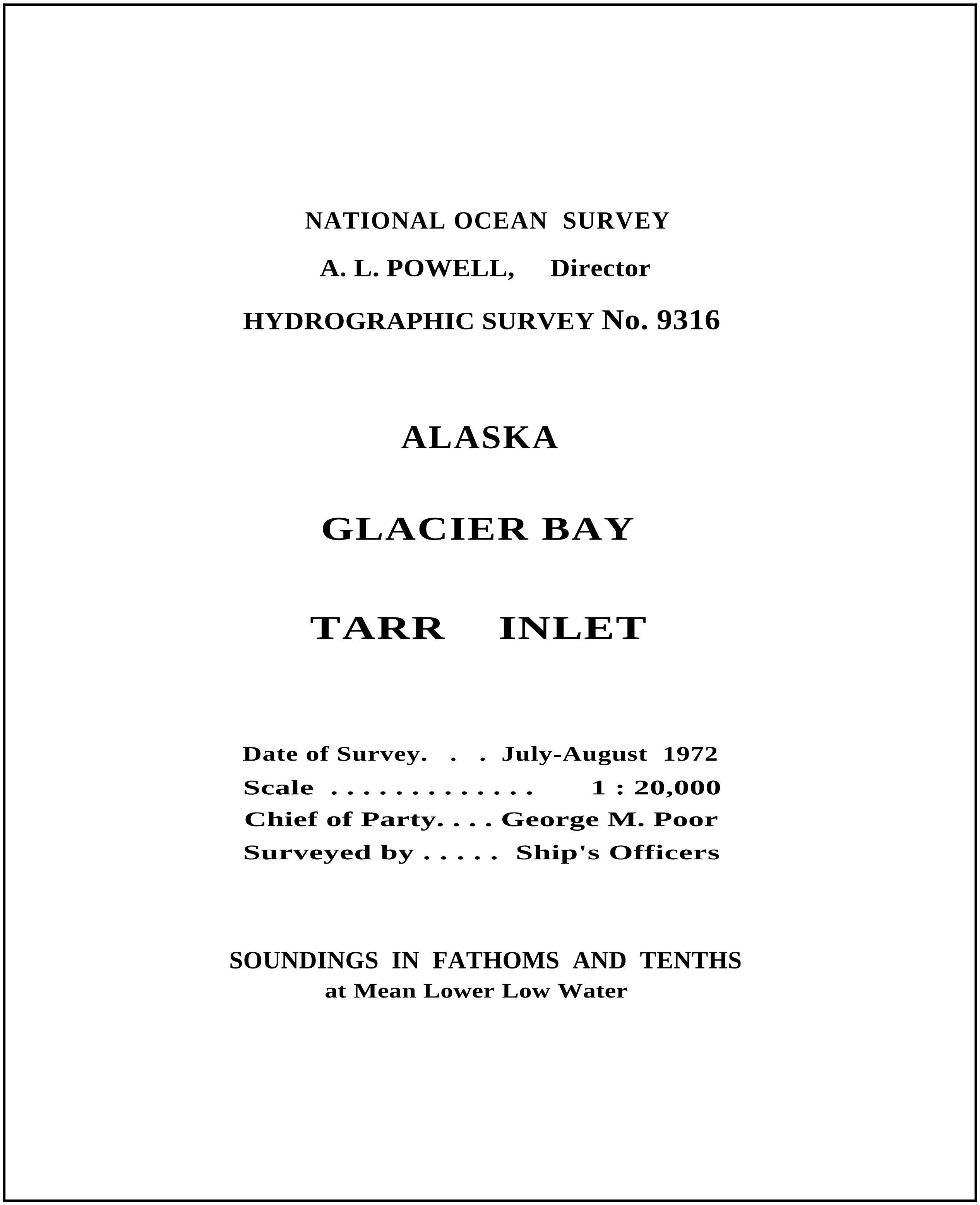
Datum ______________________________

Ref .stn. ______________________________

Lat. ____________________ **m adj.** ________

Long. ____________________ **m unadj.** ________

FIGURE 7 – 8. — Rubber stamp 1A, smooth sheet identification block



NATIONAL OCEAN SURVEY
A. L. POWELL, Director
HYDROGRAPHIC SURVEY No. 9316

ALASKA

GLACIER BAY

TARR INLET

Date of Survey. . . . July-August 1972
Scale . . . . 1 : 20,000
Chief of Party. . . . George M. Poor
Surveyed by . . . . . Ship's Officers

SOUNDINGS IN FATHOMS AND TENTHS
at Mean Lower Low Water

• FIGURE 7–9. — Title block of a non-automated hydrographic smooth sheet •

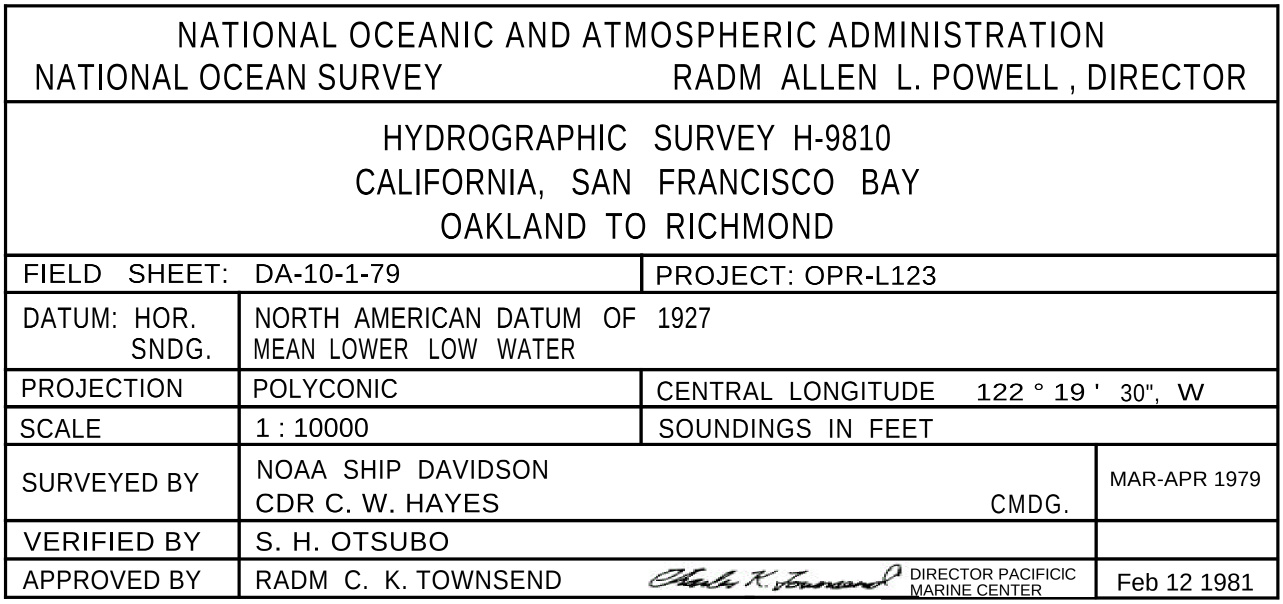
7.3.12.7. TITLE BLOCK. The information to be entered in the title of a hydrographic smooth sheet is extracted from the Title Sheet in the Descriptive Report. (See 5.3.2.) Approximate dimensions for the title block are a height of 6 in and a width of 8 in. Survey data or notes shall not, under any circumstances, be shown inside the block. On most inshore surveys, there is adequate title space in land areas or in unsounded water areas. Offshore sheets must be laid out so there is sufficient space for the title. No particular portion of a sheet is favored over another for the title block.

All titles manually drafted shall be in black ink— letter sizes and line widths are illustrated in figure 7–9. Title lettering for automated smooth sheets shall be as illustrated in figure 7–10. Titles shall be oriented with the bases parallel to the latitudinal projection lines. The proper entry for the Director is the name of the individual holding office at the time field work was completed. Each Chief of Party involved in the sounding operations shall be listed. Enter only months and years for the date of the survey. Use the general term "Ship's Officers" rather than names of the individual hydrographers.

Titles for wire-drag surveys are similar, except that the words "**WIRE DRAG**" replace the word "**HYDROGRAPHIC**" in the third line of the title. (See figure 7–9.)

7.4. SPECIAL PROJECTS AND FIELD EXAMINATIONS

The primary purpose of special projects and field examinations is to effect specific investigations of reported shoals, wrecks, or obstructions which constitute a potential danger to navigation. Special projects may also include equipment evaluation, or other special investigations unrelated to the charting program. Requirements for processing special project data will be spelled out in the project instructions. Field examinations are conducted using the same field procedures and office processing required for conventional hydrographic or wire drag surveys. A brief Descriptive Report or Descriptive Letter that provides the necessary details for the survey must be prepared to accompany the sheet. Survey sheets of field examinations shall be cut or folded to 8½ X 11 in. size and inserted into the Descriptive Report.



NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SURVEY RADM ALLEN L. POWELL , DIRECTOR

HYDROGRAPHIC SURVEY H-9810
CALIFORNIA, SAN FRANCISCO BAY
OAKLAND TO RICHMOND

FIELD SHEET:	DA-10-1-79	PROJECT: OPR-L123	
DATUM: HOR. SNDG.	NORTH AMERICAN DATUM OF 1927 MEAN LOWER LOW WATER		
PROJECTION	POLYCONIC	CENTRAL LONGITUDE 122 ° 19 ' 30", W	
SCALE	1 : 10000	SOUNDINGS IN FEET	
SURVEYED BY	NOAA SHIP DAVIDSON CDR C. W. HAYES	CMDG.	MAR-APR 1979
VERIFIED BY	S. H. OTSUBO		
APPROVED BY	RADM C. K. TOWNSEND	Charles K. Townsend DIRECTOR PACIFICIC MARINE CENTER	Feb 12 1981

• FIGURE 7-10 — Title Block of Automated Hydrographic Smooth Sheet •

8. FINAL INSPECTION AND APPROVAL

8.1. FINAL INSPECTION

Each Marine Center Director shall select and maintain a hydrographic survey inspection team (**HIT**) to conduct a critical inspection of each completed verified survey with regard to survey coverage, delineation of depth contours, development of critical depths, cartographic symbolization, and verification or disproval of charted data. The Verification Report is examined to ensure that all facts have been accurately and properly presented, that significant actions taken and procedures used during the survey verification were appropriate, and that recommendations made by the verifier are logical and justifiable. Survey records must be inspected for completeness and compliance with **NOS** requirements. An Inspection Report shall be prepared that expresses the team's concurrence or disagreement with the verifier's findings, actions, and recommendations. In addition, discrepancies and deficiencies in the survey or survey data that were previously undetected must be included in the report. Adverse findings of the inspection team concerning verification procedures are sufficient justification to require additional processing before submitting a survey for final administrative approval.

Although the members of a hydrographic survey inspection team may vary from time to time depending on local circumstances, each team could typically include the chief of the processing unit, a seasoned verifier, and a person experienced in the operational phases of hydrography. The team should neither be involved with the actual processing of a survey nor be expected to do any further processing. Each member of an inspection team must sign the final Inspection Report.

8.2 ADMINISTRATIVE APPROVAL

Following satisfactory final inspection, each smooth sheet and its accompanying overlays and reports shall be submitted to the appropriate Marine Center Director for final approval of the survey. The final approval statement and Marine Center Director's signature are placed on a separate sheet and inserted as the last page of the Descriptive Report. The Marine Center Director's signature is also required on the title block as shown in figure 7–10.

Copies of the approved Verification Report and Inspection Report will be furnished to the field survey unit, the Chief of Party, and other key personnel who participated in the survey.

Additional field work needed on a survey stated as deficient shall be scheduled by the Hydrographic Surveys Division in **NOS** Headquarters at the earliest opportunity — preferably before the project has been completed and the field unit leaves the area.

8.3. SHIPMENT OF RECORDS

Following final approval of a survey at the Marine Center, all survey records, the smooth sheet, and the accompanying overlays and reports shall be sent by registered mail to the Hydrographic Surveys Division, OA/C353. Certified mail should not be used when forwarding survey records. Original records must be packaged and mailed on a staggered schedule as a safeguard against losing an entire survey. Mailing procedures should be established that will provide a capacity for survey reconstruction if a shipment is lost in the mails. Computations and processed data listings should not be packaged with original field records.

The following records shall be transmitted with each approved survey:

1. The smooth sheet, smooth position overlay, and other overlays as necessary — these are to be sent only in the special containers provided for this purpose.
2. Preliminary overlays used during verification of the survey.
3. The original copy of the Descriptive Report and appended Verification Report, Inspection Report, and statement of final approval.
4. The field sheet(s) and accompanying overlays.
5. Smooth position and sounding listings.
6. Raw hydrographic field data listings.
7. Data listings corrected in the field.
8. Sounding Volumes or equivalent documents used to record field observations.
9. Analog position and depth records (to be filed and identified by day in accordion type folders).

10. A stable base copy of the shoreline manuscript used to locate hydrographic signals and delineate shoreline and the reference datum line.

11. Magnetic tapes containing the survey data in prescribed transmittal digital formats

12. Other information or documents needed for a thorough understanding of the survey, such as the contemporary nautical chart that was used for chart comparison.

PART THREE

Appendixes

A. EQUIPMENT AND INSTRUMENTS

A.1. INTRODUCTION

A complete description of the physical characteristics, theory, operation, and maintenance of each piece of modern equipment and instrumentation used by **NOS** for hydrographic surveying is considerably beyond the scope of this manual. Most of the information contained herein has been condensed and capsulized from various manufacturers' manuals, other publications, and in-house knowledge. References have been freely made to the source material used, and proper credit has been given where appropriate. This information is, hopefully, channeled toward the immediate needs of the hydrographer. It is the final responsibility of each chief of party to acquire and maintain a complete up-to-date set of the manufacturers' manuals needed for a given survey. The Marine Centers and the Office of Marine Operations are prepared to provide all necessary assistance in securing this information.

This appendix, however, contains a more complete description of hydrographic equipment and instrumentation not described adequately elsewhere. In addition, special **NOS** requirements on calibration, maintenance, and operation that may not be specified in the manufacturers' literature are included herein. Readers and users of the equipment described in the following sections are urgently requested to submit information on new procedures of interest to the field at large, updated information, and any corrections needed to keep this appendix current.

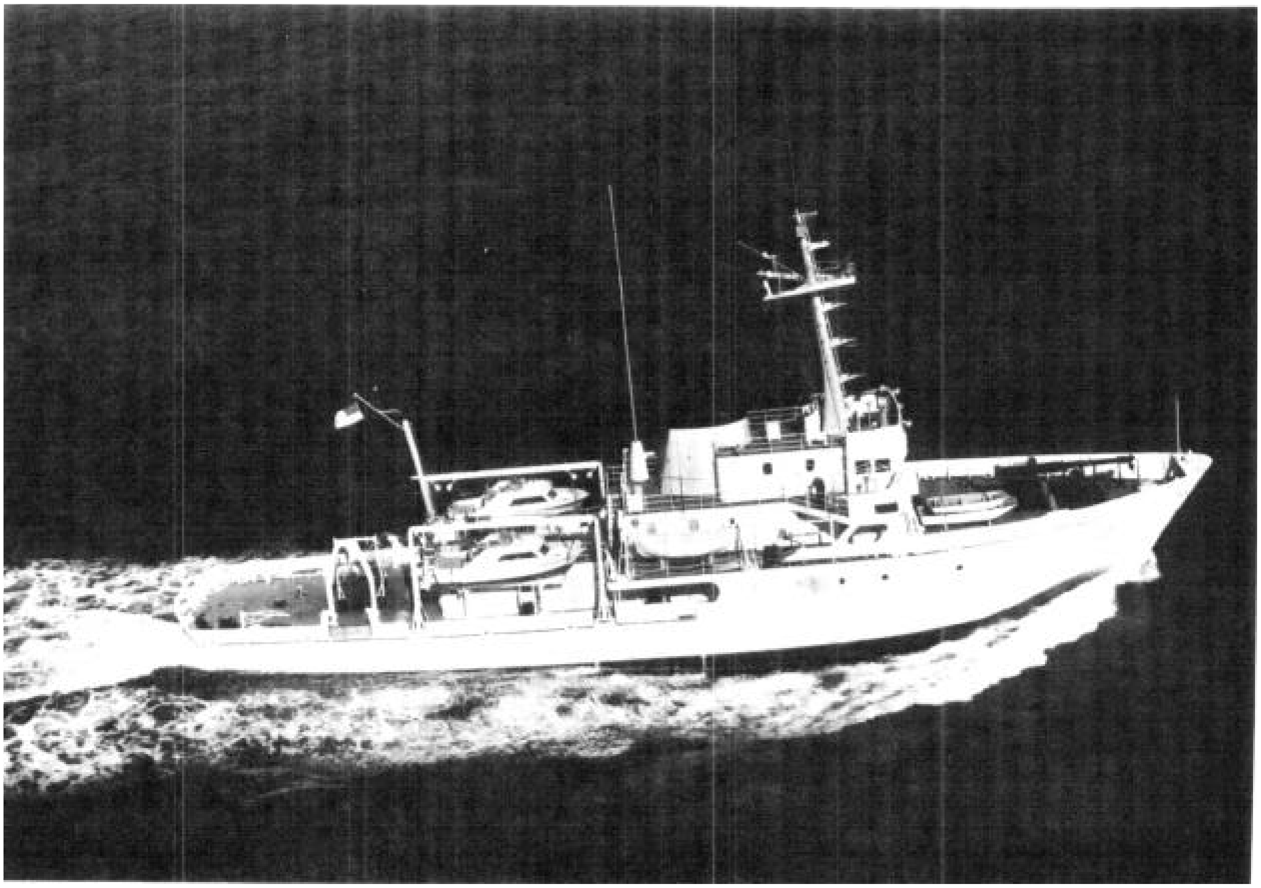


FIGURE AA–1.—NOAA Ship *Davidson,* a class-III hydrographic survey vessel

AA. HYDROGRAPHIC SURVEY VESSELS

AA.1. Major Survey Vessels

Major survey ships operated by NOS are capable of conducting detailed hydrographic surveys virtually anywhere in the world. For example, the NOAA Ship *Fairweather* (figure 1-1) generally operates in the North Pacific Ocean. The ship has a length of 231 ft, a cruising speed of 13 kn, a range of 7,000 nmi, and an endurance of 20 days. The *Fairweather* is also capable of performing a limited range of oceanographic and meteorological operations.

The complement of the ship is approximately 70 officers and crew. Each major survey vessel normally carries a variety of skiffs and small boats for inshore hydrography and three or four survey launches. The *Fairweather* and similar NOAA survey ships are fully equipped to carry out automated surveys.

AA.2. Coastal Survey Vessels

These ships are smaller than the major vessels and are generally used for conducting hydrographic surveys in the coastal waters of the United States and possessions. Coastal ships such as the NOAA ship *Davidson* (figure AA-1) are also capable of carrying out limited oceanographic and meteorological observations. The *Davidson* has a length of 175 ft, a cruising speed of 12 kn, a range of 6,000 nmi, and an endurance of 17 days.

The complement of the *Davidson* and other coastal survey ships is about 40 officers and crew. These vessels normally carry two survey launches and several smaller boats for inshore hydrography and other activities. All NOS operated coastal survey vessels used for hydrographic surveys are fully automated for data acquisition and processing.

AA.3. Auxiliary and Minor Survey Vessels

A wide variety of launches and small boats

FIGURE AA- 2.— NOAA launch 1257, a high-speed (20-kt) hydrographic survey vessel.

FIGURE AA- 3 - NOAA (Jensen) 29-ft hydrographic survey launch

FIGURE AA–4.— Skiff outfitted for shoal water surveying

are used to perform the field work necessary for nautical charting in inshore and shoal water regions. These vessels range from 59-ft high-speed launches (figure AA-2), 29-ft aluminum hull (Jensen) launch (figure AA-3), to 18-ft skiffs rigged for shoal water surveying (figure AA-4). Data acquisition and processing capabilities vary from full automation aboard 59-ft launches to fully manual recording methods aboard the skiffs.

AB. LONG RANGE NAVIGATION SYSTEMS

AB.1. Omega Navigation System

This system is an electronic position-fixing system developed by the U.S. Navy to meet the general requirements for continuous vessel and aircraft global navigation capability. Omega operates in the very low frequency (vlf) range (10.2 kHz) and is basically a phase difference measuring system; as such, it provides line-of-position information in terms of lanes. Although Omega is primarily used in the hyperbolic mode, range-range operation is possible provided the proper calibration adjustments are made. A cesium beam frequency standard is used for accurate timing in the range-range mode. At Omega operating frequencies, the lanes on the base line are approximately 8 nmi wide.

In addition to the basic 10.2 kHz frequency transmission, Omega stations transmit signals at 11.33 and 13.6 kHz. A third frequency, 3.4 kHz, can be derived by taking the difference between 13.6- and 10.2-kHz observations. This frequency difference generates an additional family of hyperbolic lanes that are about 24 nmi wide along the base line.

Although six Omega stations located throughout the world will provide complete global navigation coverage, eight stations have been established to generate check position lines and to maintain full coverage in the event of a base station failure or erratic operation.

Omega's very low frequency long-wave transmissions reflect off the ionosphere and, therefore, can be received by vessels at much greater distances from the base stations than signals of shorter wave lengths. This capability is Omega's principal advantage over most other electronic control systems; however, in Omega's strength also lies its weakness. Since skywaves (reflected from the ionosphere) rather than groundwaves provide line-of-position data, corrections must be applied to the observed electronic values. Published skywave corrections are predictions based on known properties of the ionosphere. Because meteorological conditions and solar activities cause significant disturbances in the normal behavior of the ionosphere, the predicted correction values can be inaccurate. Real-time methods of determining skywave correction values are being developed, as are similar systems such as Differential Omega and Micro Omega in an effort to enhance the navigational accuracy.

Although nominal accuracies of 1 nmi during daylight and 2 nmi at night have been claimed, recent **NOS** evaluations show that errors of 4 to 5 nmi are not uncommon if published skywave corrections are used without adding additional corrections based on in-port readings in the operating areas. Omega, therefore, is used only when and where more precise position fixing equipment is not available. Special Omega corrections are frequently included in the weekly U.S. *Coast Guard Local Notice to Mariners.*

For a more thorough technical discussion of the Omega navigation system, the reader is referred to *Dutton's Navigation and Piloting* (Dunlap and Shufeldt 1969) and *Navigation Systems, a Survey of Modern Electronic Aids (G. E.* Beck 1971).

AB.1.1. EQUIPMENT. Another advantage of Omega navigation is the comparatively low cost of the receiving and peripheral shipboard equipment. A typical Omega installation (figure AB-2) is composed of the following basic components: receiver and synthesizer, gating unit and comparator, lane counter, chart recorder (graphic record of lane changes), whip antenna, power supply with battery pack, and cesium beam frequency standard for range-range (rho-rho) operations.

A number of electronic firms currently manufacture Omega receiving systems. Depending upon the manufacturer, certain of these components may be integrated. The hydrographer must refer to the manufacturer's manual for specific details concerning his receiver— its use, calibration, and troubleshooting procedures.

AB.1.2. OPERATION. The Defense Mapping Agency/Hydrographic/Topographic Center, Washington, D.C. 20315, publishes charts showing Omega hyperbolic line-of-position lattices and skywave correction tables for most areas. Use and application of the published charts and skywave correction tables are straightforward. Ocean survey sheets (**OSS** series, section 4.13. 1.) showing Omega lattices are prepared at **NOS** Headquarters for surveys controlled by this system.

A minimum of two lines of position are required for a position fix. Wherever possible, one or more additional lines of position should be plotted as a check. When possible, the use of transmission paths along which sunrise is occurring should be avoided as these are the times for which the predicted propagation (skywave) corrections are least accurate.

FIGURE AB-1 — LORANC-C navigation coverage diagram (courtesy of the defence mapping Agency, U. S.Department Of Defence, Washington, D.C)

Line-of-position readout may also be noisy when electrical storms are occurring near the vessel. To observe a line of position, assuming the equipment is operating properly and the switches are properly set for the appropriate hyperbolic or range-range mode, the hydrographer simply reads the lanes and fractional lanes from the lane counter and applies the skywave correction values for the readings observed, the time of observation, and the dead-reckoned position of the vessel. The corrected line of position is then plotted directly on the hydrographic chart.

Time synchronization is essential for proper performance of an Omega shipboard receiver. If the gating unit is set and adjusted properly, it should maintain synchronization indefinitely. A battery pack should accompany each Omega power supply to avoid losing time synchronization during intermittent power fluctuations aboard ship. A system is in synchronization when the beginning of the transmitted aural tone from each station and keying of the gating unit light occur at the same time. Should synchronization be lost, it must be restored by following the procedures recommended in the manufacturer's manuals. After a loss in synchronization, lane counters may also require resetting.

Values on Omega lane counters must be verified at frequent intervals. Lane values are verified by monitoring the chart recorder and annotating the graphic record–a relatively simple task because the lanes are approximately 8 nmi wide. Hydrographers must be continually aware of the strength of the fix–a function of line-of-position intersection angle and lane expansion effects when receivers are operated in the hyperbolic mode. (See 4.4.3.) Switching base station arrays is easily done on the Omega comparator; however, the whole lane count values for new stations must be known to reset the lane counter properly.

Every opportunity should be taken to check Omega position fixes independently. Fixes by satellite navigation systems or by other similar methods are useful for determining systematic bias in Omega positions. Land ties shall always be made when possible. (See 4.13.1.) When offshore (weather permitting), take astronomic sights in the morning and in the evening. (See 4.13.1.1.) Accurate dead-reckoning records shall be maintained (4.13.1.2) for all surveys controlled by Omega.

AB.2. LORAN Navigation System

This long-range (LORAN) hyperbolic navigation system is usable during favorable conditions at ranges up to 3,000 nmi from transmitting base stations. LORAN-C has a far greater navigation range and higher positional accuracy than its predecessor LORAN-A. LORAN-C effective navigation coverage is not yet worldwide, but continues to expand. (See figure AB-1.) LORAN-C simultaneously employs the principles of both time difference measurements and phase comparison measurements to enhance the accuracy of an observed line of position.

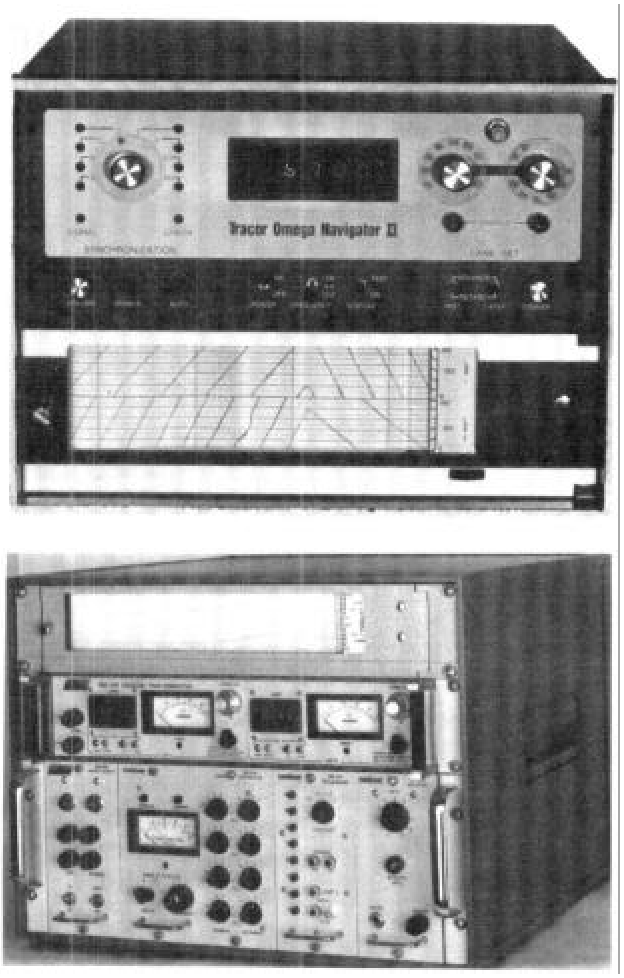


FIGURE AB–2. — Omega shipboard navigation unit (courtesy of Tracor, Inc., Austin, Texas)

LORAN-C uses 8 chains (31 transmitters) with base lines varying from 500 to 800 nmi in length. Although the system is usually operated in the hyperbolic mode, range-range positioning can be available provided that a frequency standard is used as the basic timing unit. (See U.S. Coast Guard (1974) "LORAN-C User Handbook," *Publication* CG-462.)

LORAN-C operates in the low frequency range (100 kHz), thus enabling a navigator or hydrographer to determine line-of-position information from the reception of either groundwaves traveling along the surface of Earth or skywaves reflected from the ionosphere. Nominal accuracy claims for **LORAN-C** are:

1. Groundwave, from 0.25 to 1 nmi over short distances and 0.1% of the distance the wave traveled for greater ranges.
2. Skywave, from 3 to 5 nmi.

See section AB.1. and the references in appendix D for more detailed technical discussions of the characteristics of **LORAN** and the uncertainty and inaccuracies of predicted skywave correction values. Lines of position based on skywaves shall not be used if the survey vessel is 350 nmi or less from transmitting stations. Groundwave coverage normally extends to approximately 2,000 nmi from the base stations under relatively stable atmospheric conditions, but can be expected to decrease sharply during periods of high electrical noise and external interference.

To simplify operating procedures, most manufacturers have mechanized receivers so that only the first part of each transmitted pulse or groundwave signal is used. Although such measures eliminate skywave contamination of fix data, skywave positioning at longer distances is curtailed.

AB.2.1. EQUIPMENT. A number of electronics manufacturing companies are currently producing a wide variety of **LORAN-C** navigation equipment. Available equipment varies from simple receivers and indicators to fully automated receivers with self-rate tracking capabilities that can be interfaced with shipboard computing systems. One of the more typical units is shown in figure **AB-3.**

AB.2.2. OPERATION. Operational usage and constraints for **LORAN-C** are generally similar to those of other low frequency long-range hyperbolic positioning systems (See 4.4 3 and AB.1) where the basic accuracy and strength of the fix is a function of the line-of-position intersection angle and divergence of equivalent rates with distance from the base line.

National Ocean Survey publishes nautical charts with **LORAN-C** line-of-position lattices superimposed. The U.S. Navy prints **LORAN-C** tables for computing latitudes and longitudes of **LORAN-C** observations if charts are not available. NOS Headquarters in Rockville, Maryland, has the capability to machine draft **LORAN-C** lattices on hydrographic sheets or on ocean survey sheets for use on offshore surveys. If tabular data are used, the hydrographer merely interpolates between listed rates and geographic values to determine the line of position corresponding to the readings observed aboard the vessel. Corrections and additions to charted and tabulated **LORAN-C** data are issued regularly in the U.S. *Coast Guard Local Notice to Mariners.* Skywave correction values are included with the tabulated data.

FIGURE AB-3. - LORAN-C shipboard navigation unit (courtesy of The International Navigation Co., Inc., Bedford, Massachusetts)

As with any navigation or position-fixing system, the hydrographer must select lines of position that will provide the strongest fix. (See 4.4.3.) Lines of position determined from groundwave observations are inherently more accurate than skywave determinations and shall be used whenever possible. A minimum of three lines of position is desirable for a hydrographic fix, although four are preferable. LORAN-C groundwave position determinations are preferable to Omega observations.

When **LORAN-C** positioning is used for hydrographic surveys, every opportunity shall be taken to check the system accuracy by making shore ties. (See 4.10.1.) If skywave observations must be used for positioning the vessel, morning and evening astronomic sights are taken in an effort to improve positional accuracy. (See 4.13.1.1.) Accurate dead-reckoning records must be maintained. (See 4.10.1.2.)

* FIGURE AC-1.-Decca Sea-Fix positioning system shipboard installation (courtesy of Decca Survey Systems, Inc; * Houston, Texas)

AC. MEDIUM RANGE POSITION-FIXING SYSTEMS

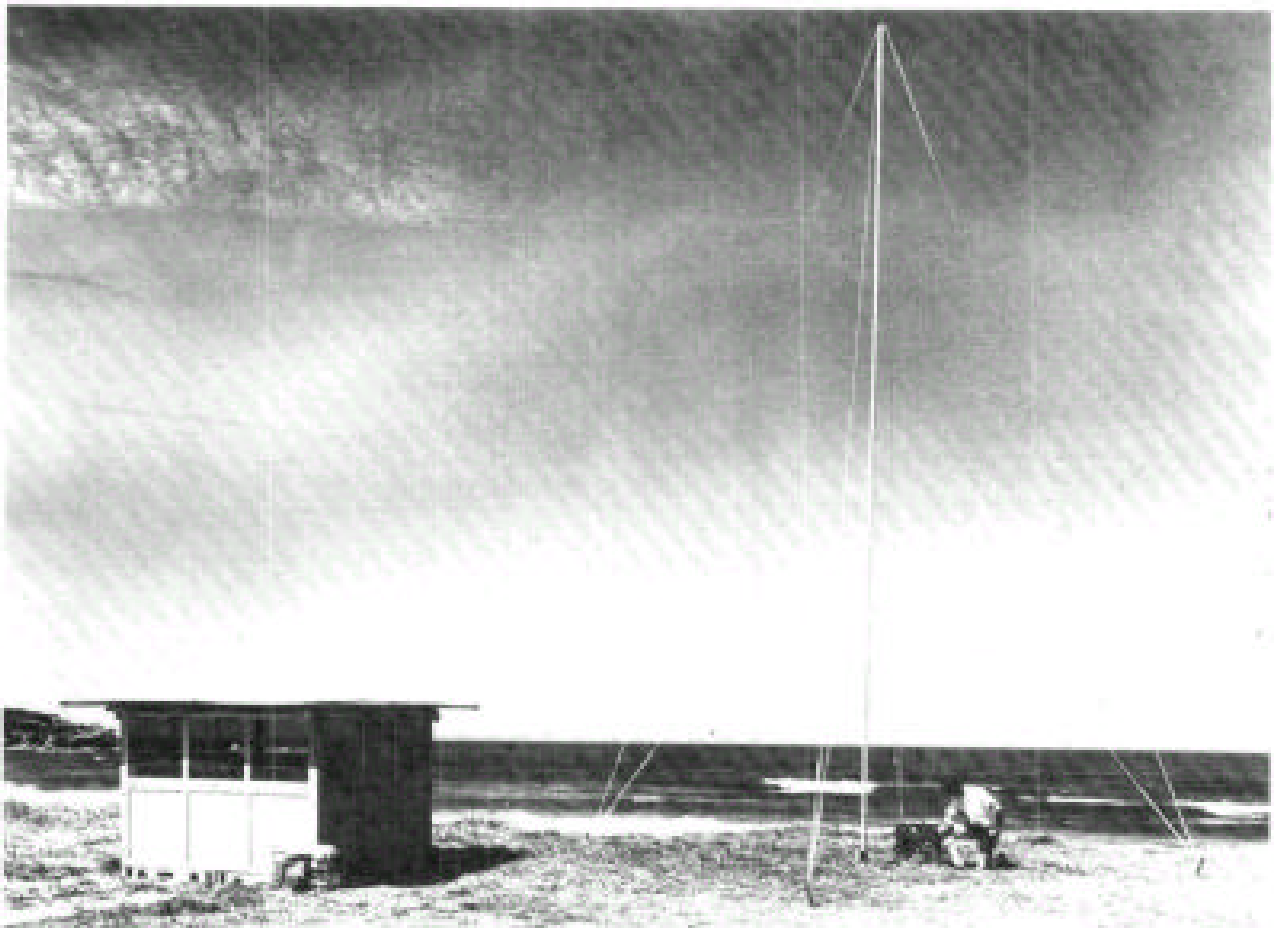
AC.1. Decca Hi-Fix and Sea-Fix Systems

These medium range electronic position-fixing systems are designed for hydrographic surveys. Much of the following discussion has been extracted from the Hi-Fix and Sea-Fix manuals published by Decca Survey Systems, 8204 Westglen, Houston, Texas 77042. These manuals and another publication entitled *Hydrographic Survey With Hi-Fix* should be referred to as necessary by each hydrographic field unit using either control system.

The systems are essentially the same; Sea-Fix is a newer modified version of Hi-Fix. Sea-Fix is generally considered more reliable under actual field conditions because of the use of solid-state components, and can be modified to operate at ranges equal or greater than Hi-Fix capability. Figure AC-1 shows a typical shipboard installation of Sea-Fix positioning equipment and data display; figure AC-2 shows a shore station installation. See the appropriate Decca manual for more comprehensive descriptions of the equipment required to operate a position-fixing chain.

The basic operating principle of the Hi-Fix and Sea-Fix systems is the generation and phase difference measurement of a pair of stationary wave patterns. An array of wave patterns is commonly called a "lattice." Receivers carried by hydrographic vessels give a continuous indication of positions with respect to the transmitting stations. If the positions of the shore stations are known, data given by the receiver can be transformed into geographic coordinates by computation or by reference to a map or chart on which Hi-Fix or Sea-Fix lattice patterns have been plotted.

Hyperbolic or circular patterns may be generated depending upon which mode was



• FIGURE AC–2. — Decca Hi-Fix shore station (courtesy of Decca Survey Systems, Inc., Houston, Texas) •

selected to control the hydrographic survey. The hyperbolic mode permits multivessel operations where many receivers can work on a time-sharing basis from one set of shore stations; the range-range mode allows only one receiver to be used.

With the systems operating in a hyperbolic mode, each set of hyperbolas consists of lines representing equal phase difference between the signals received from two transmitting stations. These hyperbolas form navigational position lines called "lanes." The intersection of a line of position from one pattern with a line from the other at the vessel's receiver fixes the position. A hyperbolic lattice, therefore, needs at least two pairs of transmitting stations to provide a fix. In practice, the one station common to both pairs is called the "master" station; the other two stations are called "slaves." An imaginary line between the master and each slave is the "base line"; the extension of which is the "base line extension." In hyperbolic lattices, the lines of position diverge with distance from the base line causing an increase in lane widths and a corresponding reduction in positional accuracy.

Where greater accuracies are required and line width expansion cannot be tolerated, Hi-Fix and similar position-fixing systems should be operated in the range-range mode. When in the range-range mode, two patterns are generated as before—but the master station is aboard the vessel rather than ashore. The resulting lattice patterns become concentric circles centered on each of the two slave stations rather than hyperbolic.

AC.1.1. HI-FIX AND SEA-FIX CHAINS. Both Hi-Fix and Sea-Fix chains require a minimum of three transmitting stations to provide a unique position fix — one master station and two slave stations.

Nominal transmission frequency ranges for Hi-Fix and Sea-Fix operations lie in the 1600- to 2100-kHz band.

When used in the hyperbolic mode, a master drive unit (**MDU**) signals a transmitter at the master station with trigger and master pulses. Each slave station and vessel also receive these pulses. The initial pulse activates the timing circuitry, and the second pulse locks each receiver to the phase and frequency of the master signal. When locked, a receiver stores the datum used for measurement of phase differences. Locking signals are transmitted about five times each second to maintain phase lock with the master station. The trigger pulse is relayed through each slave station to the vessel receivers where phase differences between the signals are resolved and displayed on lane counters for both base lines (pattern 1 and pattern 2). A series of constant phase differences results in a family of hyperbolas—a value displayed aboard a vessel identifies the hyperbola on which the vessel lies. At any given instant, a position fix can be determined by observing the readings on both lane counters. Values are displayed to the nearest hundredth of a lane on a five-digit counter.

In a two-range (range-range) system, the master station is installed aboard the vessel together with the receiver. The complement of equipment is identical to that required when operating in the hyperbolic mode. As a vessel maneuvers, the two

TABLE AC–1.— ***Characteristics of Hi-Fix and Sea-Fix Positioning Systems***

Characteristic	Hi-Fix	Sea-Fix
Mode of operation	Hyperbolic or range-range	Same
Pattern transmission frequency	1605-2000 kHz	1600-2000 kHz
Type of transmission	Interrupted continuous wave, time multiplex	Same
Radiated power	Approximately 40 W from 9.5-m vertical antenna	Approximately 100 W from 9.5-m vertical antenna
Maximum operating ranges over water paths	160-320 km in temperate latitudes	Same
	In tropical latitudes, this distance may be reduced by 50% by ambient noise levels.	Same
Maximum receiver speed	One lane per second	Same
Power supply	24 V d.c., positive ground; receiver requires 12-V center tap.	22-28 V d.c.
Readout accuracy	0.01 lane	Same
• Claimed positional accuracy	Hyperbolic: standard deviation of 0.015 lane (i.e., approx 1 m)	Better than 1 m on the base line under optimum conditions
	These figures represent long-term and short-term repeatability over water at the 65% probability level.	
	Over land, ground conductivity may be affected by factors such as weather —a reading taken at any given time may not be repeatable within the above limits if significant ground conductivity changes occur.	

• These accuracy figures do not rcflect the unknown, uncompensated systematic errors that maybe present in the observed line-of-position values

base lines vary in length—phase differences displayed aboard the vessel are now patterns of circular lines of position radiating from each slave station. Fixes are displayed on the lane counters as before. In range-range operation, however, lane count increases with vessel distance from a slave; in the hyperbolic mode, lane numbers increase along any azimuth with distance from the base line.

AC.1.2. SYSTEM CHARACTERISTICS. Table AC-1 contains a listing of various characteristics of Hi-Fix and Sea-Fix positioning systems as cited by Decca Survey Systems, Inc., Houston, Texas.

AC. 1.3. LANE INTEGRATION AND IDENTIFICATION. Hi-Fix and Sea-Fix receivers automatically provide the hydrographer with fractional lane readings as the result of the phase difference measurement. Determination of the whole lane number or count is not automatic. The geographic position of the receiver antenna must be determined independently, then transformed analytically or graphically to lane system coordinates. Calibration procedures and methods to resolve whole lane count are discussed in section 4.4.3.3. Once the whole lane value has been determined and set manually in the pattern lane counter, the equipment automatically counts whole lanes as they are crossed. If equipment malfunctions or other occurrences cause a lengthy loss of signal, the hydrographer may have to return to a known reference point or otherwise determine his position to reset the whole lane value. "Saw-tooth recorders" should always be used because they provide an analog record (See 4.8.6) of lane changes that can often be used to accurately reconstruct the whole lane count when brief signal losses occur. Signal stability is generally better with Sea-Fix than with Hi-Fix, provided that the receiver is properly phase locked into the chain.

AC.2. Raydist System

The Raydist **DR-S** Positioning System is a medium range all-weather radio location system capable of operating at distances greater than line of sight between transmitting and receiving antennas. Basic principles of the theory of operation, usage, and geometric considerations for Raydist positioning are similar to those of Decca Hi-Fix as described in the preceding sections. Much of the following discussion was extracted from Raydist system manuals published by Teledyne Hastings-Raydist, Hampton, Virginia 23361. Technical manuals that completely describe the system operation must be aboard any vessel using Raydist.

The Raydist **DR-S** system operates in the high frequency radio band and is comparable in range and accuracy with Hi-Fix and Sea-Fix. The equipment is transistorized and reasonably portable. Unlike Hi-Fix and Sea-Fix, Raydist can operate with up to four-party users in the range-range mode. Range-range operation is favored over hyperbolic because of increased accuracy over a broader area of coverage. The Raydist "T" net, which uses two master stations and two relay stations at crossed base lines to increase the area of strong geometric intersections, is not presently used by **NOS** survey vessels. Many of the variations of these operational modes described in the manufacturer's manuals are seldom used by **NOS**. Raydist integrates well with the **HYDROPLOT** system and provides continuous encoded data to the navigation interface.

As is the case with most other medium range positioning systems, the basic concept of the Raydist operating principle is measurement of phase differences between the antennas at the fixed shore stations and aboard the hydrographic vessel. Raydist operates on continuous wave rather than pulsed signals. Using the formulas cited in sections 4.4.3.1 and 4.4.3.2, one can construct a lattice of concentric circles or hyperbolic lines of position (depending on the mode of operation) for locating the vessel. The discussion on lane widths and station geometry included in section AC.1 is also applicable to the Raydist system.

Raydist is designed so that frequency errors (and resulting ranging errors) caused by oscillator drift are cancelled, provided that the frequency errors are small and the frequencies are centered on the narrow band-pass curve of the **NAVIGATOR** unit receiver filters. The filter band-pass is approximately 20 Hz wide.

Raydist lane integration and identification procedures are identical to those discussed for Decca Hi-Fix in section AC.1.3.

AC.2.1. SYSTEM CHARACTERISTICS. The general characteristics of the Raydist DR–S Electronic Positioning System are listed in table AC-2.

AC.2.2. SYSTEM COMPONENTS. See figure AC-3 for a typical Raydist shipboard installation. The **NAVIGATOR,** which is normally installed aboard the survey vessel, continually measures and displays the position of the receiving antenna in terms of system coordinates. When Raydist is operated in the range-range mode, these coordinates are the ranges, in lanes, from the antenna to each of the fixed slave or relay stations normally located ashore. Teledyne Hastings-Raydist literature designates the slave stations as "red" and "green" for convenient reference. When operating in the hyperbolic mode, the mobile transmitter is located at the master or reference station ashore, and the **NAVIGATOR** provides hyperbolic coordinates. Line-of-position data can be read from the phase meters to the nearest hundredth of a lane. In addition to direct readout capability, encoded signals can be made

TABLE AC–2.— *Ganeral characteristics of the Raydist DR–S Electronic Positioning System*

Characteristic	Description
Mode of operation	Range-range or hyperbolic
Operating frequencies	1600-4000 kHz. (NOS frequencies are approx 3300 kHz, resulting lane widths of 45 m.)
Range	200 nmi day, 150 nmi night
Wave transmission	Continuous wave
Radiated power	50 W from vertical antenna height of one-quarter wave length or less
Power supply	25.5 V d.c
Readout resolution	0.01 lane
Positional accuracy	* 10 ft (3m)

• The 10-ft positional accuracy is cited for range-range operation by Hastings and Comstock (1969). "Pinpoint Positioning of Surface Vessels Beyond Line-of-Sight" This value is a minimum theoretical limit probably not achievable on offshore surveys where it is impractical to calibrate with sufficient frequency to remove unknown systematic errors in line of-position data

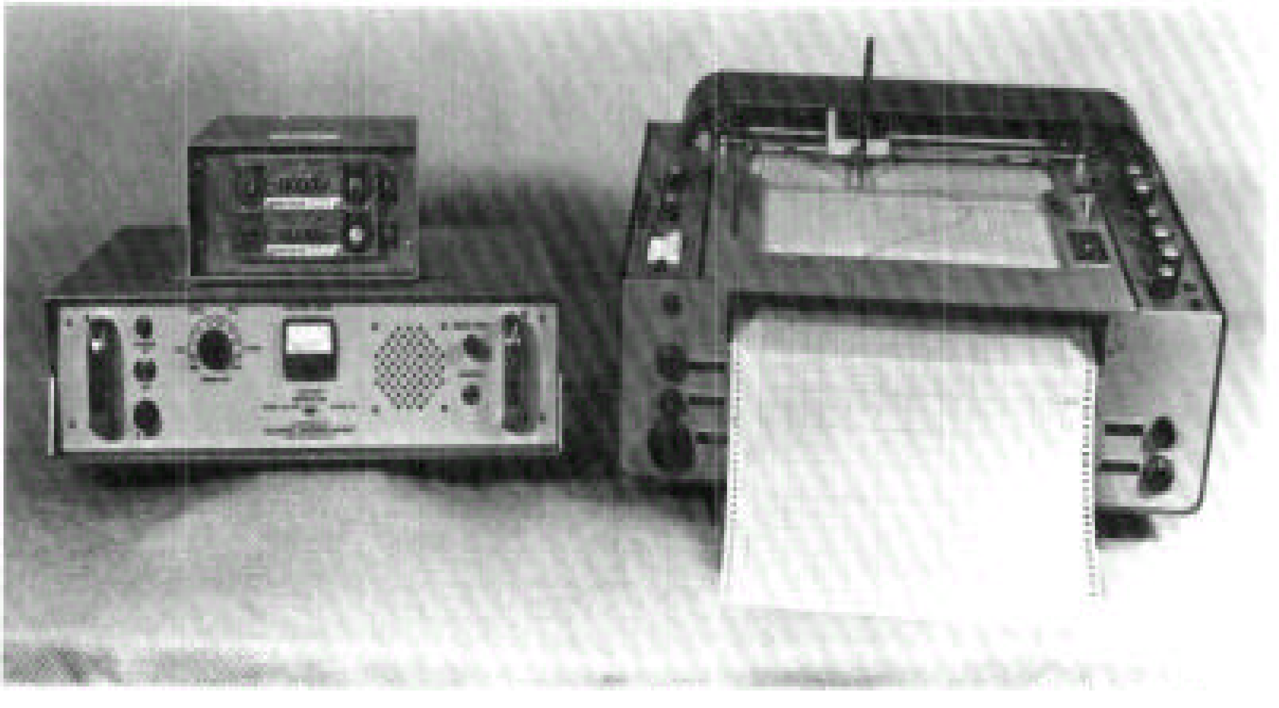


FIGURE AC–3.— Raydist positioning system vessel components, (left) navigator with position indicator and (right) track plotter (courtesy of Teledyne Hastings-Raydist, Hampton, Virginia) available to a navigation interface unit for **HYDROPLOT** automated operations. Outputs are also provided for driving a dual channel sawtooth recorder for analog position data.

The mobile transmitter contains the reference oscillator. The transmitter frequency is used to calculate lane widths. The mobile transmitter generates the reference that is relayed through the slave or relay stations back to the **NAVIGATOR**. At the **NAVIGATOR**, the phase of the returning signals is compared with the phase of the transmitted signal to determine the relative position of the vessel antenna with respect to the shore stations.

Ideally, the antennas at each of the relay stations and at the mobile transmitter must be one-quarter of a wavelength high (approximately 43 m) when operated in the range-range mode. As a practical matter during surveys at nominal ranges, antennas 20-25 m high can be used ashore and a 12-m fiberglass whip antenna used aboard the vessel. Antennas as low as 13 m have been used successfully at the shore stations for very short range operations. When Raydist is operated in the hyperbolic mode, a small "voltage probe" type of antenna about 55 cm high can be used aboard the vessel, although a 12-m fiberglass whip antenna, if already aboard, will suffice. Antenna heights at the master station and two slave stations vary from 13 to 43 m depending on the operational ranges. A ground plane of 24 radials, equal in length to the antenna height, must be constructed at each shore station.

Raydist slave or relay stations are compact portable units, each housed in a single weatherproof aluminum casing, (See figure AC-4.) Each relay station receives the signal from the mobile transmitter, then relays the phase information to the **NAVIGATOR** receiver aboard the vessel. Power requirements for the stations are approximately 2.6 A at 24 V d.c. for 50-W output. Operation at reduced output is possible for short ranges with a reduction in current requirements to 2 A or less. A fully charged pair of 12 V, 90 A-hr automobile batteries will operate a vessel or shore station satisfactorily for 24 hr should a power failure occur.

An antenna coupler (model QB-52B) permits the mobile transmitter to be installed in any convenient location aboard the hydrographic survey vessel. Without an antenna coupler, the transmitter would have to be mounted very close to the antenna when the system is operated in the range-range mode. Such connections are undesirable—a "hot" antenna wire would be needed inside the vessel that could cause radio frequency interference to echo-sounding equipment and computer systems. Antenna couplers should be mounted very close to the base of the antenna and be grounded securely. When used aboard fiberglass or wooden vessels, grounding can often be satisfactorily accomplished by installing large copper bottom plates and heavy ground cables. Elaborate shielding methods must be resorted to for protecting all electronic equipment from stray radio frequency fields. For these reasons, range-range operation should be limited to metal hulls if possible. Hyperbolic operations present no problems in this area because only a receiver is used aboard the vessel.

FIGURE AC-4. - Raydist shore station installation, (courtesy of Teledyne Hastings-Raydist, Hampton, Virginia)

Power supplies must be selected carefully for the satisfactory operation of Raydist. Voltage requirements for all system components is nominally 25.5 V d.c. Standard procedures, when commercial power is available, are to use a regulated power supply capable of recharging the batteries should an extended power failure occur. The power supply must be fully shielded from radio frequency interference that may be generated by the equipment. Such a shielding is especially important at the shore relay stations where harmonics of the transmitted signal are generated by the rectifiers in an unshielded power supply. These harmonics lie within the band pass of the station receiver and will override the desired signal from the mobile station. Only power supplies manufactured by Hastings-Raydist or custom-made units designed by **NOS** for this system meet the requirements for line load regulation, radio frequency interference shielding, and operational reliability. When these power supplies are used, batteries are not needed; however, when batteries are not used, there is no power backup if a power failure occurs.

Where shore power is not available, propane gas-powered thermal generators should be used. Although the energy conversion efficiency of these units is low (less than 5%), they are more economical to operate and maintain than gasoline or diesel generators because they can be run unattended for long periods of time. Gas-powered generators normally consume about 0.68 lb of propane per hour.

AC.2.3. CHECKOUT PROCEDURES. The following system checkout procedures are a combination of those recommended by Teledyne Hastings-Raydist and those learned from in-house experience.

Mobile station. As with any phase difference measuring system, one of the key elements to successful operation is a good antenna system. Intermittent connections cause phase shifts that are translated into positional errors. Extreme precautions must be taken to ensure that all electrical connections are clean and tight, including each joint in a sectional antenna, feed line attachments to the antenna and coupler, and each ground connection.

Each system component must be securely grounded through a common "bus" to the hull of the vessel. (A 0.75-in flat copper braid works well.) Cable connections and power supply voltage must be checked. Accurate operating frequencies of the chain are critical and should be checked before starting a new operation. Although the oscillators in the various components generally are stable, occasional spot checks should be made. The system should be allowed to stabilize, preferably overnight, before a final check is made following a frequency adjustment.

A quick operational check of each mobile station should be made before beginning daily operations:

1. Check the reflected and forward power levels on the front panel meter of the mobile transmitter. Reflected power should be near zero with a near full scale indication of forward power. If high reflected power readings are observed, adjust the antenna coupler according to instructions in the manufacturer's manual. Adjustments made to the equipment during survey operations at any station require that the system be recalibrated.

2. Each of the four audio tone levels should be clear and steady. Tones can be monitored using the speaker in the **NAVIGATOR** unit.

3. Phase meter amplifier levels should be steady and read approximately 0.4 on the meter (100 to 110 on the meter for the later model **ZA-67**).

4. Torque of the phase meters should be checked by slewing each meter plus or minus less than half a lane and observing how quickly the dial returns to its original reading.

5. Be sure that the navigation interface tracks with the phase meter dials.

Shore stations. Relay stations should be checked only during non-operational periods of the survey. To simplify the checks, activate only one mobile transmitter; switch all others to the standby mode.

The antenna system at each relay station should receive the same careful attention given to the mobile station. Clean tight connections are essential at all joints of the antenna tower, at the lead-in wire, and at each ground connection.

A recommendation is that each shore relay station be checked at 2-week intervals. Items to check include:

1. Proper tower guy tension and sand anchor exposure.

2. Water level in batteries.

3. General condition of antenna and ground plane wires with special attention given to all connections. Weeds must not be allowed to grow around a tower base insulator. Wet weeds tapping against the tower can generate electrical noise and instability at the phase meters.

4. Metal objects not allowed to touch any part of the grounding system.

5. Importance of good shelter ventilation. A small fan should be aimed at the station aluminum housing during warm weather.

6. Opening the relay station cover and using the high impedance head phones supplied with the system to monitor the tone quality. The tone should be clear and steady. While listening with the phones, jar the antenna tower using a dry insulated object. Loose or dirty connections will show up as static in the tone.

7. Turning the sideband "**SB**" switch to OFF. Move the meter selector switch to "Batt Test." The normal reading is about 125.

8. Using the meter selector switch to check the forward "**FWD**" and reflected "**REF**" power levels. Normal forward reading lies between 50 and 90. The reflected reading should be near zero. Refer to the manufacturer's manual if tuning is required.

9. Turning the meter switch to automatic gain control "**AGC**" position, then turning the sideband switch to the **ON** position. The **AGC** level should read between 50 and 150. The **AGC** level represents the strength of the received signal from the mobile transmitter and has approximately a double log reciprocal relationship to the signal strength. A value of 150 represents a lack of signal or a very weak signal; 50 represents a very strong signal. A good norm is between 70 and 90.

10. With the sideband switch ON and the meter switch on AGC, momentarily turning the FINAL switch to OFF, then back to ON. There should be no change in the AGC level. If the AGC level moves down the scale, internal adjustments to the equipment are required.

11. Turning the meter switch to OFF. Special caution, the station will not operate with the meter switch in the REF or FWD positions. Harmonics will be generated by the diodes in the SWR bridge that will totally block the receiver. As a final check before closing the cover, be sure all toggle switches are UP and the meter switch is OFF.

12. Potentially dangerous radio frequency voltages are present on Raydist antennas. Though not lethal, small painful burns could be inflicted. Radio frequency burns tend to heal slowly because of their depth. Shore stations, when located near public access areas, must be fenced off and warning signs displayed. Do not allow metal parts of the fence to touch the ground plane.

AC.3. Hydrotrac System

Hydrotrac is a medium-range positioning system operating in the 2-MHz frequency band and was designed and developed by Odom Offshore Surveys, Inc., Baton Rouge, Louisiana. It utilizes a single radio frequency by sequential transmissions from a master and two or three slaves, with synchronization between the stations achieved by use of a trigger signal 60 Hz below the pattern frequency. Within the receiver, three internal frequencies are generated which correspond in phase and frequency to the signals received from the master and two of the slaves; these internal signals are used for phase comparison so that position data are available continuously even though the transmissions are intermittent.

If the master station is installed in the ship, the system operates in range-range mode; but if the master is sited ashore, the mode will be hyperbolic. The range-range mode offers greater geometrical accuracy than hyperbolic but the effect of an error in the assumed velocity of propagation may be considerably greater—and in range-range, any variations in velocity cannot be detected. Since only one vessel may use the system in a range-range mode, this will often be the deciding factor between multivessel operations with hyperbolic or single vessel with range-range. Where a choice exists it is normally better to use hyperbolic on a concave coastline and range-range where the coastline is convex. Offlying islands can be used to overcome problems caused by coastline irregularities. Whichever mode is used, greater operational flexibility and a considerably greater area of cover may be achieved by establishing a third slave station.

The mathematical and cartographic treatment of Hydrotrac is similar to that of other systems in the 2-MHz band.

Hydrotrac is designed so that mistriggering during electrical storms—a frequent cause of lane loss in earlier single frequency systems—is eliminated. Each receiver and each control unit contains a precise time source that allows it to operate without update for several hours, and before it is updated, 256 consecutive good triggers, each 1,000 milliseconds apart, must be received. Another feature prevents the uncontrolled loss of lanes when skywave causes signal cancellation, by restricting the maximum rate of change of the display readings to that which would be caused by a vessel traveling at 25 knots along the baseline. Thus, if cancellation should occur, lane loss is minimized and the number of lanes lost may easily be counted on a sawtooth recorder.

The transmitted frequencies are generated by a synthesizer which allows any frequency within the range 1.6 to 2.0 MHz to be selected by thumbwheel switches, in steps of 10 Hz. Harmonics and sidebands are at least 65 dB down from the fundamental so that the system is acceptable in regions with stringent frequency licensing regulations.

Data outputs are available at a selectable rate, between 1 and 12 times per second, and in each case the output is of the current raw data, no filtering or smoothing being applied within the receiver. The standard outputs are serial **BCD,** serial **ASCII,** and 0-10 V d.c. analog for a sawtooth recorder. **NOS** uses a separate interface box which receives the serial **BCD** and converts it to both analog and parallel **BCD** for input to the **HYDROPLOT** navigation interface. The cable length between the **NOS** interface box and the **HYDROPLOT** navigation interface should not exceed 20 feet but the interface box may be as much as 500 feet from the Hydrotrac receiver. Much of the following discussion on outputs and other details has been extracted from the Odom Offshore Surveys, Inc. (Hydrocarta/Hydrotrac), system manuals, 1979.

AC.3.1. SYSTEM CHARACTERISTICS. The general characteristics of the Hydrotrac system are listed in table AC–3.

AC.3.2. SYSTEM COMPONENTS. The components of the transmitting stations are a Master Drive Unit (**MDU**) or Slave Drive Unit (**SDU**), as appropriate, a Power Amplifier (**PA**), and an Antenna Coupler. The **PA** serves also as a power distribution unit. In the hyperbolic mode, the shipboard installation consists only of a receiver and a receiving antenna, but in range-range mode the **MDU, PA,** and coupler will also be on board. In the latter case a solid state transmit/receiver switch within the **PA** allows use of a single antenna.

Ideally the transmitting antennas should be

TABLE AC–3. — *General Characteristics of theHvdrotrac System (courtesy of Odom Offshore Surveys, Inc., Baton Rouge, Louisiana)*

Characteristic		Description
Mode of operation		Range-range or Hyperbolic
Operating Frequency		1.6 to 2.0 MHz in steps of 10 Hz
Trigger Frequency		60 Hz below operating frequency
Transmission Cycle		Two Slave-1.0 seconds Three Slave-1.3 seconds
I. F. Band Width		120 Hz at 3 dB points
R. F. Sensitivity		1 µV from 50 Ω source
Range	Day -	250 nm in areas of high electrical noise, such as the Gulf of Mexico.
	Night -	Unpredictable. In the Gulf of Mexico 125 nm is attainable 80% of nights.
Wave Transmission		0.1 AO Time-shared continuous wave.
Radiated Power		0-150 watts Peak Envelope Power, continuously variable.
Power Supply		22-30 V d.c. (negative ground)
Readout Resolution		0.01 lane
Positional Accuracy		2–40 meters, depending on geometry, stability of the velocity of propagation, and the accuracy with which the system is calibrated.

¼ wavelength in height. This is often difficult to achieve in practice and may be reduced when less than maximum range is required; they should not be less than 30 ft.

All units except the Antenna Coupler are housed in watertight (when closed) transit/operating cases, measuring 22 in x 93 in x 16 in They may also be rackmounted, in which case each unit occupies 7 in of rack height.

AC.3.3. INSTALLATION. *Site Selection*: Transmitting station sites should be sought in areas which minimize the amount of landpath between the station and the ship and, for hyperbolic mode, between the master and each slave. In particular they should be located so that the length of landpath from each station will not vary as the ship moves through the survey area. The antennas themselves should be on ground of good electrical conductivity, have a clear view of seaward, and be sited so that tall objects are at least six times their own height distant. (Double this if they are metallic or liable to move.) Meeting these conditions will help to achieve a stable radiated pattern, but each must be weighed against the need for good geometry, as in any other positioning system.

Station Setup: The methods of interconnecting the units, tuning the transmitters, and initiating operation are covered in the Technical Manual. Particular care should be taken to ensure that all electrical connections are clean and tight. A ground plane of 36 (72 when conductivity is poor) radial wires, equal in length to the antenna height, should be laid out (and preferably buried) symmetrically round the antenna, a ground rod should be driven to refusal, and the electronic units connected to it. Precautions should be taken to keep vehicles, people, and animals off the ground plane.

Calibration: Although the Hydrotrac receiver is self-referencing, there is an **NOS** requirement for daily testing for instrumental accuracy. There is also a requirement to measure the systematic errors whenever a chain is established or a change is made in any of the shore station components.

The procedure is to measure the position of the ship's Hydrotrac antenna by an independent positioning system simultaneously with reading the Hydrotrac dials. The independent system values are converted to x-y and thence to Hydrotrac readings, described as the computed values. From these are subtracted the observed values to give a **C-O** correction.

With a hyperbolic chain it is desirable to carry these comparisons through the survey area, reducing random errors by meaning sets of three to five comparisons in each location. Advantage should be taken of the hyperbolic mode by recording readings at a monitor station throughout the calibration and whenever the chain is used subsequently, since these will indicate any further corrections necessary to eliminate diurnal changes in propagation conditions.

Calibration of a range-range chain is best performed in a different manner, taking each pattern separately. Since the pattern values represent ranges, the comparison is most easily effected by placing the remote station of a microwave system close to the slave antenna (but outside the ground plane) and comparing ranges directly. The ship's heading and the bearing of the slave should be recorded at each comparison so that the small distance corrections at each end may be applied to the microwave ranges. These ranges are then converted to Hydrotrac ranges directly and the **C-O** computed.

Every Hydrotrac range will contain a constant error and a variable error, where the variable error is caused by an incorrect assumption of the velocity of propagation and will vary directly with the range, while the "constant" error contains both a constant systematic element and an element caused by the different velocity of propagation along the land path from the antenna to the shoreline. This latter element may be assumed to be a constant on any one bearing but is likely to change with change of bearing, as the length and nature of the landpath will vary. It is therefore necessary to carry out the calibration by steaming the ship across the full range of bearings to the survey area at a distance of 2 to 4 miles from the slave station so that the effect of a velocity error is minimized.

Another source of error that should be removed by calibration is the reflection of the signal from the ship's structure. This error will vary with the relative bearing of the slave station from the ship and may be measured by taking a series of calibration comparisons while the ship turns through 360° at rest, so that the bearing from the slave remains constant. By plotting **C-O** against relative bearing, the position of the "electrical center", or apparent positioning from which the ranges may be assumed to be measured, may be determined. It should not be necessary to repeat this part of the calibration until there is a change in the ship's superstructure or the antenna location.

It should be noted that the range-range calibration procedure removes only the constant element of the systematic errors. Any error in the assumed velocity of propagation will cause an error in the range which is directly proportional to the measured distance. Furthermore, in the range-range mode it is not possible to use a monitor station to record the diurnal changes in velocity caused by changes in atmospheric conditions. In a hyperbolic mode, on the other hand, a change in the velocity of propagation will have no effect along the base line bisector, since the error will affect master and slave transmissions equally and one is subtracted from the other, while the maximum error, occurring on the two base line extensions, will be the same as that on a range-range chain at 30 miles range.

Where a survey is carried out at extreme range, the effects of changes in atmospheric conditions become significant and it is desirable that temperature, barometric pressure, and vapor pressure be measured during the calibration and subsequently whenever the optimum accuracy is desired.

AC.3.4. RECEIVER OPERATION.

1. Switch power on. Observe a.c. and d.c. lights and allow a 20-minute warmup before proceeding beyond step 5.
2. Select **SET** mode. Switch audio alarm off.
3. Check frequency thumbwheels.
4. Select required slave pair.
5. Set **C-O** correction appropriate to the area of operation.
6. After warmup, all alarms (decimal points in the displays) should be out. Select 7 on the Monitor Select; a reading of about 0.7 indicates reception of good trigger signals. Select 4, 5, and 6 successively on the Monitor Select; center scale indicates that master, slave 1 and slave 2, respectively, are locked.
7. At a point when lane count is down, set the whole lane value on each pattern. Select Operate mode.
8. Switch on audio alarm and adjust display intensity as necessary.

The receiver is then ready for use. In Operate mode the Frequency, Slave Select, and Display Slew controls are disabled. Operation of the Whole Lane toggle switches will change the respective whole lane count one lane at a time. For ease in recording, the Display Hold button may be depressed at each fix to freeze the display.

AC.4. ARGO System

The **ARGO DM-54** positioning system is a precision radiolocation system designed to provide accurate, long-range, positional information for a mobile station with respect to two, three, or four fixed location stations. The **ARGO** system operates in the medium-frequency **(MF)** band **(1600 to 2000 kHz),** utilizing the ground wave component of the radiated signal. The **DM-54** will provide some positional information at ranges up to 400 miles, depending on atmospheric conditions, antenna height, and power output. Tests conducted in April 1979 by the Office of Marine Technology revealed daytime observations were usable for at least 253 km (134 nmi) and much less than that for nighttime use. A small mobile antenna was in use during the tests.

AC.4.1. PRINCIPLES OF OPERATION. The **ARGO DM-54** operates on the principle that an **MF** radio signal traveling along the earth's surface in the "ground wave" mode experiences a time (and hence phase) delay proportional to the distance traveled. For short to moderate distances, the ground wave predominates at all hours over the "skywave" signal reflected by the ionosphere. Daytime absorption by the D-layer of the ionosphere attenuates skywave signals so that the ground wave predominates up to several hundred kilometers in distance. At night, due to changes in the ionosphere, the skywave may contaminate the ground wave. Since only the ground wave is useful for positioning, the range at night is reduced depending on the amount of skywave contamination.

The basic **ARGO DM-54** utilizes a multiplexing sequence and a shortened **RF** pulse to service up to seven mobile stations interrogating four fixed responders with 2-second update capability.

A typical multiplexing sequence is shown in figure AC-5. All **RF** pulses are 36 milliseconds, in overall length and are contained within a 44-millisecond time allotment except for the system timing pulse. The timing pulse occupies 70 milliseconds of a 120-millisecond allotment and is transmitted by a single network station designated the master. All other stations identify the timing pulse by its unique width and adjust their timing to coincide with the network before transmitting.

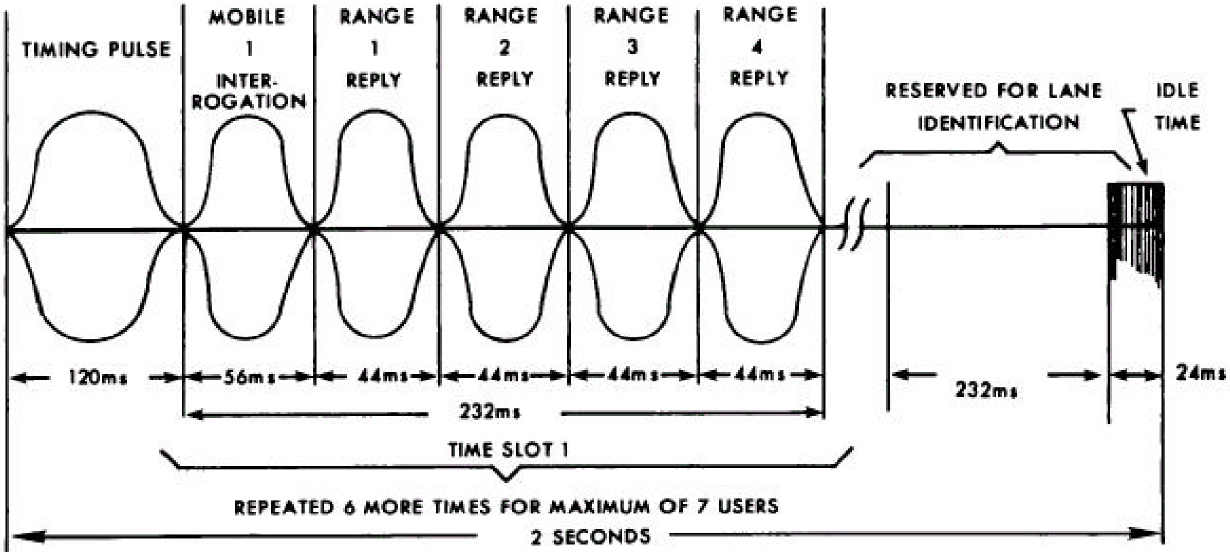


FIGURE AC–5. — Typical 4 Range Transmission Sequence (courtesy of Cubic Western Data, San Diego, Califomia).

Within each timeslot one **RF** pulse is generated by a designated mobile station as an interrogation. This signal is received by all the fixed responders which measure the carrier phase with respect to their locally synthesized references. Each fixed station replies with a comparable pulse having its phase adjusted to replicate the received phase. The mobile station receives the replies from each fixed responder and compares the received phases with the transmitted phase to determine the round trip phase delay to each fixed responder. The process is repeated with each timeslot having its own assigned mobile station.

In figure AC-5 the eighth timeslot is reserved for the sector Lane Identification feature. During the timeslot, all units of the system switch to an alternate frequency approximately 10% higher than the ranging frequency. One mobile station at a time may thus interrogate in its regular timeslot and frequency concurrently with an offset frequency. A comparison of the phase data on two frequencies is the basis of sector Lane Identification.

AC.4.2. DESCRIPTION OF EQUIPMENT. The standard **ARGO DM-54** as configured for **NOS,** consists of four land-based fixed stations and up to four mobile stations. Two- and three-range operations are also possible, with up to twelve and nine mobile stations, respectively. **ARGO** also allows unlimited user capacity in the hyperbolic mode of operation, while retaining three range-range users.

Each station, fixed or mobile, includes a Range Processing Unit **(RPU)** and an Antenna Loading Unit **(ALU)**. Each mobile station also has a Control and Display Unit **(CDU)**. Figures AC-6 and AC-7 show the equipment interconnection. (See also figure AC-8.)

1. Range Processing Unit **(RPU)**. The **RPU** contains the electronic components necessary to generate, transmit, receive, and process all signals for range measurement. The **RPU** also contains operator controls and associated circuits for remotely controlling the **ALU**.

2. Antenna Loading Unit **(ALU)**. The **ALU** contains the electronic circuits and components necessary to match the **RPU** transmitter output to the antenna.

3. Control and Display Unit **(CDU)**. The **CDU** contains the electronic components and operator interface necessary to perform all operational control, range displays, and interface functions between it and the **RPU**. In addition, the **CDU** provides output data for such peripherals as strip chart recorders, digital printers, and computer/calculators.

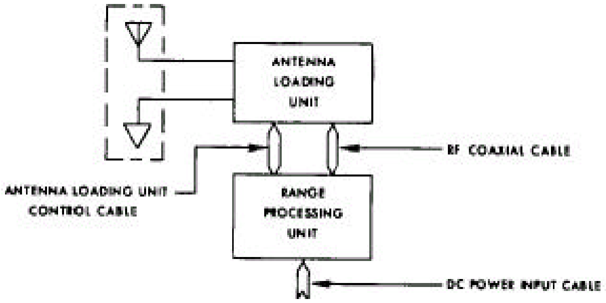


FIGURE AC–6. —Standard **ARGO** Fixed Station Interconnecting Cabling Diagram (courtesy of Cubic Western Data, San Diego, California)

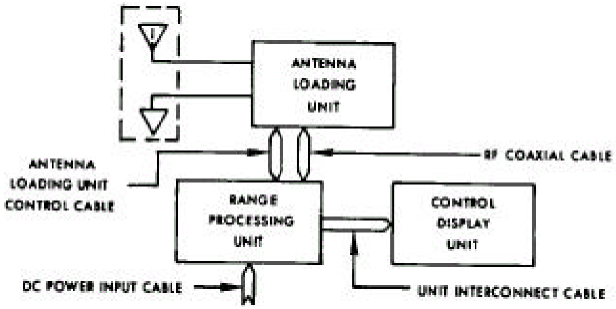


FIGURE AC–7. — Standard ARGO Mobile Station Interconnecting Cabling Diagram (courtesy of Cubic Western Data, San Diego, California)

AC.4.3. SYSTEM CHARACTERISTICS. See table A–4 for the physical and operational characteristic of the **ARGO DM-54** system.

AC.4.4. OPERATIONAL FEATURES. The **ARGO DM-54** has numerous features ranging from packaging to operating interface to network flexibility. The main features are discussed below.

AC.4.4.1. *Multiple Ranges.* The **ARGO DM-54** can be used in two-range, three-range, or four-range format. The capability of multiple ranges adds a new dimension to network flexibility with **ARGO**. In a conventional two-range system it is common to have two ranges deployed along the coastline, and a third station maintained on shore as backup. With **ARGO**, this third station would actually be installed at another location and on the air. If any one station of the three fails in this configuration, no downtime results to the mobile stations because two ranges are still available for positioning.

AC.4.4.2. *Range Quality Indications.* Each **ARGO** range is accompanied with two indications of signal quality. One is an indication of low amplitude. The second is an indication of poor data quality, occurring if the measured range has deviated more than a safe margin from the predicted range; i.e., the data were edited by the smoothing algorithms. These quality indicators are visually presented to the operator and available at the rear data output connectors. This provides a real time and permanent record of the quality of individual **ARGO** ranges at all times.

AC.4.4.3. *Data Smoothing.* Data smoothing consists of nonlinear (editing) and linear (filtering) processes . Smoothing is basically an exponentially weighted average with a selectable time constant. An **ARGO** operator may select 10 different smoothing codes from the front panel to the **ARGO** Control and Display Unit. Smoothing 0 is the lightest smoothing, being essentially raw data. Smoothing 1 through 9 are increasingly longer time constants with 9 being suitable only for slow moving operations such as a wire-drag survey. The operator may select or change smoothing during operation to compensate for varying signal conditions and ship dynamics. Note: **HYDROPLOT** should *not* be used with smoothing code 0, a smoothing code is recommended in Table AC-5.

Smoothing provides the potential for operation through impulse noise such as lightning storms, and during periods of moderate skywave activity, increases the number of hours per day or miles of range through which **ARGO** can operate.

TABLE AC–4. — ***General Characteristics of the ARGO Electronic Positioning System***

Characteristic	Description
Mode of operation	Range-range or hyperbolic
Frequency band	1600-2000 kHz. Lane identification (when used) requires a second frequency 9% to 10.5% higher than the range frequency. (Lane width 74 to 94 meters) Band width 80 Hz
Range	At least 253 km (134 nmi) by day Less than 253 km by night–quality of data obtained during either day or night operations depends on antenna height, atmospheric condilions, and power output.
Radiated power	100 watts peak
Range accuracy	0.02 lane instrumental, 0.05 lane achieveable field accuracy-4.7 m if lane width is 94 m

TABLE AC–5.— *ARGO Smoothing Codes*

SMOOTHING CODE	TIME CONSTANT (SECONDS)	APPLICATION
0	N/A	Raw Data Computer Processing
1	2.8	High speed-survey (launch)
2	3.0	High speed-survey
3	3.9	Moderate speed - survcy
4	5.6	Moderate speed-seismic
5	9.0	Low speed-seismic
6	13	Very low speed-seismic
7	19	Large ship. No maneuvers.
8	26	Large ship. No maneuvers.
9	39	Wire-drag survey. At anchor.

AC.4.4.4. *Lane Identification.* Another operational advantage is the incorporation of the lane identification feature. By intermittently making range measurements on an offset frequency, the **DM-54** can generate a lane count error over a sector of ±5 lanes. An operator may, if he suspects he has had a lane addition or subtraction due to the noise or interference, initiate lane identification which will then display the error in lanes.

AC.4.4.5. *Hyperbolic Operations.* The **DM-54** may be used in a range-range only operation, in a hyperbolic only operation, or simultaneously with both modes on the same net. The shipboard operator selects the mode of operation he desires for his particular vessel by front panel commands to the Control and Display Unit. Once selected by the operator, the rest of the net will automatically respond to the signals from that ship. This feature allows multiple range-range users on a net, unlimited hyperbolic users on a net, and individual users to switch back and forth between modes as their needs change.

In a net with hyperbolic operation, one timeslot is reserved for that function. A fixed station (the master) generates the interrogation for that timeslot, and the other fixed stations reply just as to a mobile interrogator. The master station may be one of the range-range responders, or it may be an added station. Therefore, a five-station net yielding four hyperbolic lines of position is possible.

AC.4.4.6. *Aircraft Operation.* Aircraft operation utilizes the hyperbolic mode at increased data rates. **ARGO** has been tested in aircraft traveling on the order of 100 knots, and the **ARGO** software can be modified for speeds in excess of 200 knots.

AC.4.4.7. *Built-In Test.* Both the **ARGO** Range Processing Unit and the Control and Display Unit contain built-in test software. The operator's built-in test always results in a go/no-go indication of the front panel and does not require the use of test equipment. The built-in test is designed to do three things: First, increase a user's confidence that the equipment will perform when deployed to the field; second, to reduce the downtime in case of failure; and third, to partially eliminate the need of expensive test equipment at maintenance facilities. With the use of standard test equipment, a technician can troubleshoot down to the component level.

AC.4.4.8. *Remote Antenna Tuning.* The **ARGO DM-54** is unique in that its Antenna Loading Unit is remotely controlled from the Range Processing Unit. Since an antenna may be tuned from the location of the Range Processing Unit, an operator need never go to the Antenna Loading Unit once installed. For this reason, **ARGO** antennas may be located for best performance, and not for ease of operator access for tuning.

AC.4.4.9. *Selectable Frequencies.* **ARGO DM-54** may be preprogramed at the factory for up to 16 fequency pairs, each pair having one frequency for ranging and one for lane identification features. Once programed, the operator may select any frequency pair desired by the use of a protected rotary switch on the Range Processing Unit front panel. Within a band of 200 kHz, no returning of any internal circuitry is required to select between the 16 preprogramed frequency pairs . Use of this feature allows **ARGO** stations to be programed for a wide choice of network frequencies. Stations may then be transferred between nets without the need for modifications, retuning, or being returned to a maintenance facility.

AC.4.4.10. *Transmitter Protection.* The **DM-54** transmitter design was improved to increase power output from 60 watts to 100 watts, and to allow **DM-54** stations to continue to transmit in spite of severely detuned antennas. The **DM-54** transmitter will continue to operate into a dead short or open load. The transmitter is protected from damage by a circuit that monitors the reflected power and reduces the transmitter output below destructive levels. This feature is a significant advantage for us on nonmetallic vessels such as small launches that have a very unstable antenna platform.

AC.4.4.11. *Data Outputs and Formats.* Model **DM-54** has a number of different data outputs making it possible to interface to a wide range of peripheral equipment. It provides analog output portional to each range suitable for use with strip chart recorders. On the GPIB output, these data include such information as 24-hour time formats, quality data for each range (including edits and low amplitude), and all operator commands to the front panel of the Control and Display Unit. In addition, the operator may command range data with time annotation and quality annotation to be output periodically at fixed intervals determined by the operator.

The **HYDROPLOT** system is interfaced to **ARGO** through the GPIB, which does not include the range quality data. Synchronization with the **ARGO** update is provided at the GPIB interface.

AC.4.5. INSTALLATION AND OPERATION. The details of **ARGO** station installations are described in the operator's manual. Both mobile and shore stations must have vertical antennas between 25 and 100 feet in height, and a stable efficient ground plane. On shore, this ground plane is normally accomplished by the installation of 32 radial wires, each 100 feet long. On board metallic ships, the ground plane consists of the ships' superstructure and hull; or on nonmetallic vessels, ground straps and grounding plates under the water line can often be sufficient. Quality in antenna installations is always essential for the best **ARGO** performance and accuracy.

Operation of individual units is described as follows:

1. Antenna Loading Unit. The Antenna Loading Unit requires no operation or adjustment. Once securely installed, the lead to the antenna and the lead to the ground plane and ground rods must be as short as possible and rigid so that they will not move in the wind.

2. Range Processing Unit. Operation of the Range Processing Unit begins at the left of the panel and proceeds to the right. Begin by turning the power switch on. Adjust the frequency selection knob to the desired frequency pair (which has been preprogramed at the factory). Verify that the Voltage Normal light is on and that the No Carrier light is not on. Move to the station configuration block and put the switch in the Antenna Tune position, press execute, and using the inductor and capacitor controls in the antenna tune block, tune for a peak reading for both the range and lane identification frequencies. Once tuned, put the station configuration switch in the desired station operation (mobile or fixed) and select the desired timing (master, slave, or relay). Press the execute button and the station will assume the desired operation.

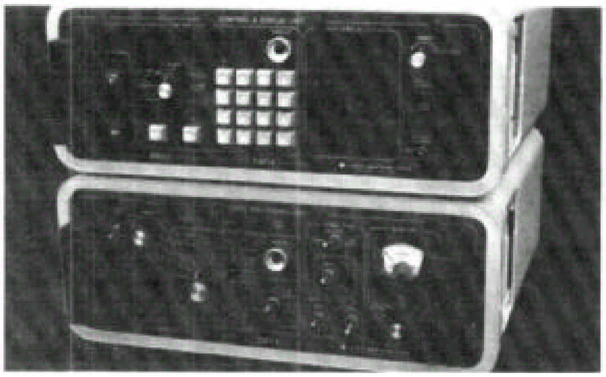


FIGURE AC–8. — ARGO Control and Display Unit, and Range Processing Unit (courtesy of Cubic Western Data, San Diego, California)

3. Control and Display Unit. When mobile station operation is desired, connect the Control and Display Unit to the Range Processing Unit with the Unit Interconnect Cable. Set the rear panel power switch to the remote position. Once on, go to the Control and Display Unit front panel. Beginning with the Clock position and proceeding in a clockwise direction, enter the desired information. First, set 24-hour time in hours, minutes, and seconds. Second, set Smoothing from 1 through 9 Third, select the desired timeslot. In the Range position, enter or store the desired lane count and fractional lane for each of the ranges in use. If at some future date it is desirable to add or subtract lanes or fractional lanes from any range, use the Delta Range position. The Lane Identification position may be used at the operator's discretion to enable the lane identification function. Any performance options available in **ARGO** software are accessed in the final Option Code position.

AD. SHORT RANGE POSITION-FIXING SYSTEMS

AD.1. Del Norte Trisponder System

The Del Norte Trisponder System, manufactured by Del Norte Technology, is a short-range, line of sight, electronic positioning system designed for use aboard vessels, aircraft, and land vehicles. Most of the material container herein was condensed from *Trisponder, Electronic Positioning System, Basic Operation Manual*, published by Del Norte Technology, Inc. (1974), 1100 Pamela Drive, P 0 Box 696, Euless, Texas 76039.

The basic Trisponder system is composed of a distance-measuring unit (DMU), a master station, and two remote stations. Each station is a combined transmitter and receiver. The master station has an omnidirectional antenna, and each remote station has a directional antenna. With the remote units placed over stations of known geographic positions, ranges are observed at the DMU. These values may be plotted manually on a hydrographic survey sheet or converted by trilateration methods to position values.

AD.1.1 DESCRIPTION OF EQUIPMENT. The Del Norte Trisponder system components are compact, portable, and weatherproof. Each master and each remote station consist of a transponder and an antenna. The DMU is installed aboard the vessel. See figures AD-1 through AD-3.

Coded bursts of microwave frequency (X-band) energy are transmitted from the master unit to each remote unit for a determination of range distances. These signals are received and decoded by each remote unit, but only the unit with the particular code is triggered to send back an identical burst of energy to the base unit. The time the signal takes to make the round trip minus electronic delays for decoding is converted to distance using the velocity of X-band energy in the atmosphere. Round trip distances are divided by 2 to obtain the displayed range distances. At microwave frequencies, the system is limited to line-of-sight distance measurements.

For obtaining accurate range values, the signal is transmitted and received 10 times or 100 times, at the operator's option, and the sum averaged. Each value is checked; spurious data are rejected internally. Final averaged values may be transmitted to the

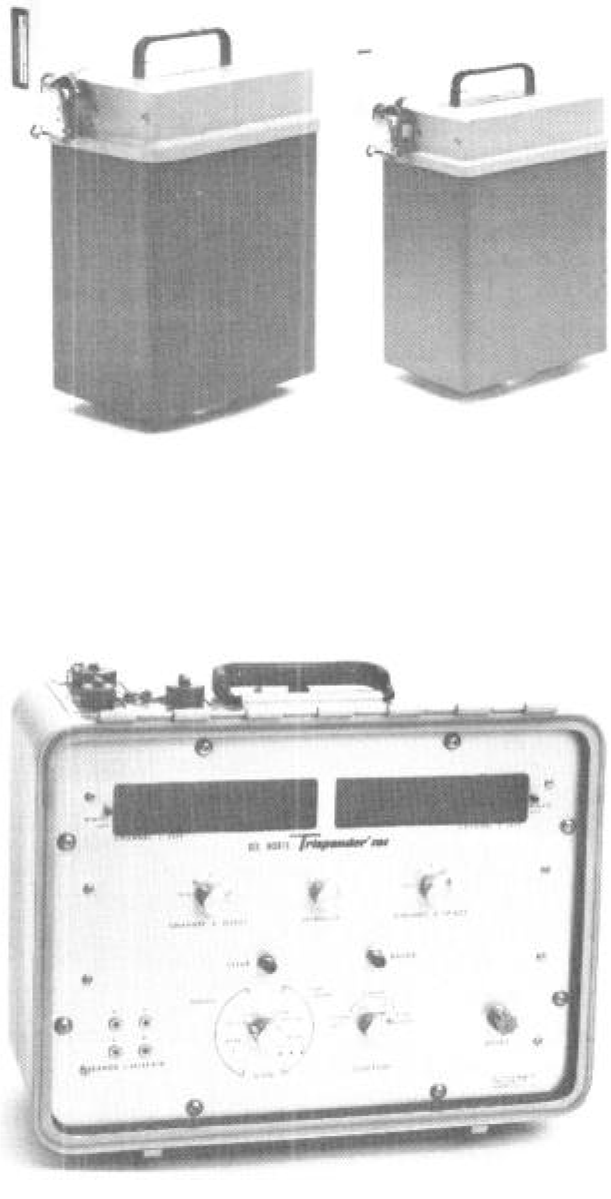


FIGURE AD–1.— Del Norte trisponder positioning system components, (top left) master trisponder with omni antenna, (top right) remote trisponder with sector antenna, and (bottom) distance-measuring unit (courtesy of Del Norte Technology, Inc., Euless, Texas)

HYDROPLOT controller (See AJ) through available interface units. If the required number of "good" observations cannot be obtained by the **DMU**, a red warning light, near the digital display for that range, goes on and the display is not updated. The averaging process improves substantially the measurement stability characteristics.

AD.1.2 SYSTEM CHARACTERISTICS. See table AD-1 for the physical and operational characteristics of the trisponder system as cited by Del Norte.

AD.1.3 INSTALLATION AND OPERATION. In addition to following the procedures recommended in the Del Norte Technical manuals, see section 3.1.2 for shore station control accuracy requirements and section 4.4.3.2.2 on the general characteristics of range-range distance-measuring systems. The Del Norte Trisponder system operates at microwave frequencies and, thus, is limited to line-of-sight distance measurements. Also in section 4.4.3.2.2. is a discussion of line-of-sight conditions and computations.

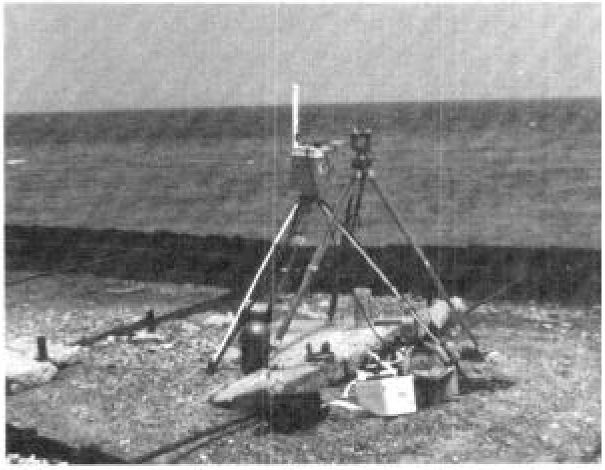


FIGURE AD–2. — Del Norte trisponder shore station installation (courtesy of Del Norte Technology, Inc., Euless, Texas)

Results from tests conducted by **NOS** indicate that electronic drift over a period of time may cause variations in the measurements. To maintain a ± 3 m range measurement accuracy, each unit must be calibrated over a measured base line at least once every 200 hr of operation. To maintain a ± 6 m range accuracy, a calibration at least once every 500 hr of operation will suffice.

TABLE AD–1.—*Del Norte Trisponder system characteristics*

Characteristic	Description
Mode of operation	Range-range
Remote transponder (shore unit)	
Input voltage	23 to 32 V d.c.
Power consumption	17 W
Receiver frequency	9480 MHz
Transmitter frequency	9325 MHz
Transmitter power	1000 W
Antenna beam width	87° horizontal, 5° vertical or 180° horizontal, 5° vertical
Weight	15 lb
Receiver-transmitter (vessel unit)	
Input voltage	23 to 32 V d.c.
Power consumption	17 W
Receiver frequency	9325 MHz
Transmitter frequency	9480 MHz
Transmitter power	1000 W
Antenna beam width	360° horizontal, 30° vertical
Weight	15 lb
Distance-measuring unit (DMU, vessel unit)	
Input voltage	23 to 32 V d.c.
Power consumption	40 W
Range	80 km
Channels (displays)	2
Code selection	4 codes available
Update interval	1 s, 2 s (jumpered internally)
Weight	25 lb
Other features	
Range readout resolution	0.5 in
Range error	± 3 in under good field conditions
Time-sharing option for multivessel, operation	Permits four vessels to time share position data from a common set of transponders
Transponder standby circuitry	Automatically switches magnetron filament circuit off to reduce current drain from batteries approx 40 min after interrogations cease
Voltage monitoring	Automatically shuts down remote stations when input voltage drops below 21 V d.c.
Packaging	Waterproof rugged housing; floating units
Transponder interchangeability	Master and remote transponders identical except for respective transmitting and receiving frequencies

Although calibrations over a measured base line are unnecessary each time a unit is moved, the system must be calibrated whenever the **DMU,** the master station, or the slave stations are replaced or have had parts replaced.

To conduct an acceptable base line calibration, lay out a short measured range (Third-order, Class II accuracy) with a known distance of about 2000 m (1800 to 2500 m). Set the master station and **DMU** at the zero reference point. Place each remote station over the other point. Adjust the **RANGE CALIBRATION** screws on the front panel of the **DMU** so the correct distance is displayed for each remote unit.

The initial equipment warmup and checkout procedures specified by the manufacturer must be adhered to rigorously. Del Norte transponders emit low-powered radar waves so there is no radiation hazard if nominal care is exercised whenever any unit is operating. However, high levels of radio frequency radiation can seriously affect the eyes of personnel standing near and in line with the antennas. *Do not look down the antenna while the transmitters are operating.* Distances greater than 1 m from the antennas are considered to be safe operating areas.

All radio communications equipment must be kept at least 3 m from the stations to avoid false range data. Each unit must be separated from any equipment that may emit radio frequency energy.

Position-fixing data may be recorded either manually or automatically depending upon the operational needs. For manual recordings, ranging data is simply observed from the numerical display for the appropriate channel. For automated recording, the position data are transmitted to the display indicators and transferred to an interface to the computer through an interconnecting cable. Any two of four ranges are available and can be furnished to the computer and be displayed on the **DMU**.

Trisponder systems using the time-sharing option allow four vessels to operate from the same remote units without signal interference. Such systems must designate one of the vessel units as the master (Base 1) and designate the remaining units as slaves (Base 2, 3, or 4). The master station first interrogates the remote units, then the slaves interrogate each remote station sequentially. If a slave detects loss of synchronization with Base 1, a front panel light indicates fail-safe operation, Internal circuitry prevents signal overlap and interference. Each vessel, therefore, must wait the maximum time that could be needed for the previous vessel to complete its interrogation and summing process (88 ms for a summation of 10 measurements and 354 ms for a summation of 100 measurements for codes 72 through 88).

Thus when planning a time-shared operation, a hydrographer is limited by the total number of vessels that can be used by the updating option of the system. Table AD-2 indicates these constraints.

TABLE AD–2. — *Trisponder time-sharing constraints*

Updating time	10 sum	100 sum
(s)	(Vessels)	(Vessels)
0.25	1	1
1	4	3
2	4	4

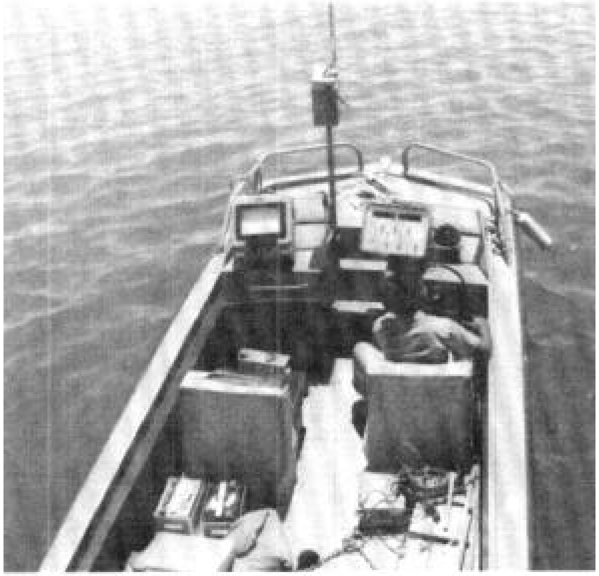


FIGURE AD–3.— Del Norte trisponder vessel installation (courtesy of Del Norte Technology, Inc., Euless, Texas)

When operating in the time-sharing mode, *n*–1 of the vessels must be equipped with the necessary time-sharing hardware – the nonequipped vessel acts as master (Base 1) and has the highest interrogation priority. Because fixes may not be obtained at precisely the right times when using any "summing" system, special care must be taken when working at high vessel speeds – particularly speeds in excess of 20 kn. Range values displayed on indicators and at the computer interface may not be correct at the instant observed.

There are two possibilities that can cause the distance measurements to be "old" at the moment the computer fetches the data. The first and most significant is the update timing. Data that have been waiting in the navigation buffer for as much as one update period may be used for a position. At a speed of 20 kn, a vessel moves 10 m/s. Thus at these higher speeds, special consideration must be given to the update rate to determine if the maximum update error can be tolerated at the scale of the survey. If the update error is significant, a faster update rate can be obtained by changing the update printed circuit boards. To obtain faster rates, however, one may find it necessary to reduce from a 100-sum mode to a 10-sum mode or to reduce the number of time-sharing vessels, or both.

The second possibility of position error is non-simultaneous range data. The position-fixing system first calculates a range (distance) for one channel, then calculates a range (distance) for the second channel. The computer, however, uses these two range values as if taken simultaneously. The time difference between the two measured ranges depends on how long it takes for the summing process for each channel. For a 10-summation system, time differences can range from 19 ms under ideal atmospheric conditions to 44 ms under poor conditions when a maximum of 50 attempts must be made for each channel to obtain 10 good readings to average.

In the 100–sum mode, time differences can range from 140 to 314 ms. This error can be converted from time to distance by multiplying by the speed of the survey vessel in meters per second. At high speeds on large-scale surveys, this sequential range error may be large enough to be of concern. In such cases, switch the **DMU MODE** switch to 10-sum operation, which will degrade the stability of the readouts slightly but will not reduce the ±3-m accuracy, and slow down the sounding vessel until the error magnitude becomes tolerable.

AD.2. Motorola Mini-Ranger III System

The **MRS III**, manufactured by Motorola, Inc., is a short range position-fixing system designed for vessels, aircraft, or land vehicles. Material in this section has been condensed from the "Operation and Installation Manual for Mini-Ranger III System **(MRS III)**," published by Motorola, Inc. (1974), Government Electronics Division, Scottsdale, Arizona 85252.

The **MRS III,** operating on the basic principle of pulse radar, uses a transmitter aboard the survey vessel to interrogate radar transponder reference stations located over geographically known points. (See 1.3.) Elapsed time between transmitted interrogations produced by the **MRS III** transmitter and the reply received from each transponder is used as the basis for determining the range to each transponder. This range information, displayed by the **MRS III** together with the known location of each transponder, can be trilaterated to provide a position of the vessel. The standard **MRS III** operates at line-of-sight ranges up to 37 km. With appropriate calibration, the probable range measurement accuracy, stated by Motorola, Inc., is 3 m. Ranges may be displayed in meters, yards, or feet. Time sharing of common transponders by more than one unit permits multivessel operation from a single control array.

A unique coding system is used in the **MRS III** system to minimize false range readings caused by radar interference and to provide selective transponder interrogation. **MRS III** is also capable of interrogating transponders with a single pulse if desired. Operating frequencies of the **MRS III** can be set, at the factory, above or below the operating frequencies of onboard radar systems to eliminate possible interference with normal radar operation. Because **MRS III** operates at C-band frequencies and most marine radars radiate at X-band, the possibility of mutual interference is minimal.

AD.2.1. DESCRIPTION OF EQUIPMENT. The **MRS III** is a compact, light, highly mobile distance-measuring system consisting of a receiver-transmitter assembly with antenna, a range console, and radar transponders with antennas. (See figure AD–4.)

The basic operating principles of these units are described in the following paragraphs.

The receiver-transmitter unit consists of a radar receiver and transmitter. Transponder interrogation signals from the transmitter are passed through a circulator to the antenna. Simultaneously, a signal that serves as the start pulse for the range counters is developed. Received transponder signals are routed from the antenna through the circulator to the receiver. The output of the receiver is decoded to provide a stop pulse to the range counters. Receiver-transmitter units operate on +28 V d.c. power supplied by the range console.

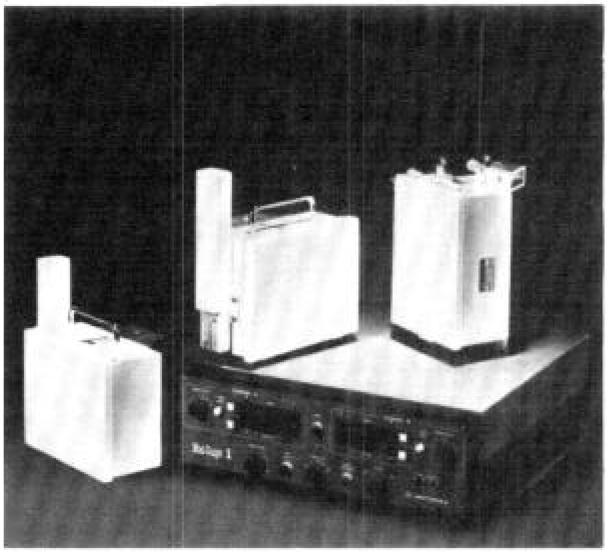


FIGURE AD–4.— Mini-Ranger III System. The range console is flanked by a radar transponder and is topped by another transponder and a receiver-transmitter assembly (courtesy of Motorola, Inc., Scottsdale, Arizona). See also figure AD-5.

The range console consists of a coder, a decoder, a range counter control, a numerical readout (range display), and a power supply that provides the necessary direct current (d.c.) operating voltages. The power supply also provides +28 V d.c. for the operation of the receiver-transmitter. (See figure AD-5.)

When a start signal transmitted by the receiver-transmitter is received, the range counter begins to count. After five sequential interrogations and reception of five replies from a transponder, the count is displayed on the range console front panel as range to the transponder. This range together with channel and code information are also transmitted in parallel binary coded decimal (BCD) format from a rear-panel connector to peripheral printers and computers. Channel A and channel B range data are gathered and displayed within 10 ms during each sample period of operation.

Solid-state radar transponders are installed at known locations and serve as reference points for the MRS III. The transponders receive pulse-coded interrogations from the receiver-transmitter. The interrogations are decoded by the applicable transponder (depending on the pulse spacings of the interrogation), and the transponder generates a reply.

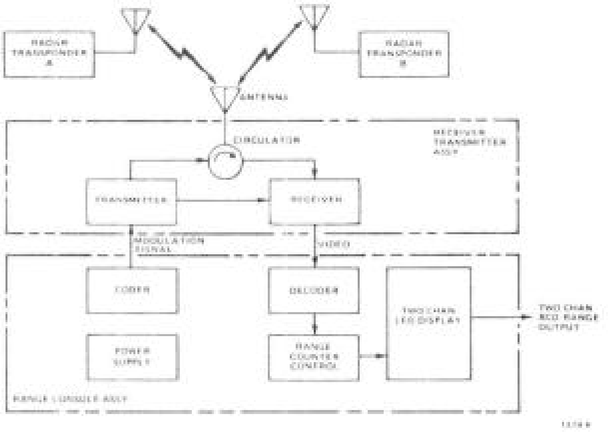


FIGURE AD–5. — MRS III schematic diagram (courtesy of Motorola, Inc., Scottsdale, Arizona). See also figure AD-4.

AD.2.2. SYSTEM CHARACTERISTICS. The physical and operating characteristics of the standard MRS III package, as cited by Motorola, Inc., in 1974, are shown in table AD-3.

AD.2.3. INSTALLATION AND OPERATION. In addition to observing the following procedures recommended by Motorola, see section 3.1.2 for shore station control accuracy requirements and section 4.4.3.2.2 on the general characteristics of range-range distance-measuring systems.

TABLE AD–3.— *MRS III package operating characteristics*

Characteristic	Description
Radar transponders	
Receiver	
Frequency	5570 MHz C-band 9410 MHz X-band (optional)
Band width	18 MHz maximum
Sensitivity	-70 dB
Maximum signal input	+20 dB
Transmitter	
Frequency	5480 MHz C-band 9310 MHz X-band (optional)
Peak power output	400 W
Reply pulse	Single or coded
Reply pulse width	0.5 µs maximum
Antenna	
Frequency range	5400 to 5600 MHz C-band 9200 to 9500 MHz X-band (optional)
Polarization	Horizontal
Gain	13 dB nominal
3-dB beam width	
Azimuth	80°
Elevation	15°
Operating temperature	-54°C to +71°C (-65°F to +160°F)
Receiver-transmitter	
Receiver	
Frequency	5480 MHz C-band 9310 MHz X-band (optional)
Sensitivity	-70 dB
Maximum signal input	+20 dB
Transmitter	
Frequency	5570 MHz C-band 9410 MHz X-band (optional)
Power	400 W peak
Pulse width	0.5 µs maximum
PRF	875 pulse groups per second
Omnidirectional antenna	
Frequency range	5400 to 5600 MHz C-band 9200 to 9500 MHz X-band (optional)
Gain	6 dB nominal
3-dB beam width	
Azimuth	Omnidirectional
Elevation	25°
Operating temperature	-40°C to +60°C (-40°F to 140°F)
Range console	
Range	100 m minimum 20 nmi maximum (approx 37 km)
Range channels	2
Code selection	Pulse coded (4 codes available), single pulse
Operating temperature	0°C to +50°C (32°F to +122°F)
Power consumption	a.c.-60, d.c.-40 W nominal (excluding receiver-transmitter power consumption)
Update interval	May be selected by switch on front panel at various intervals from 1/s to 10/s

Because the Mini-Ranger System III operates at microwave frequencies, the range of the system is limited to line-of-sight distances. To obtain the maximum usable range, install the radar transponders at the highest possible elevation. (See 4.4.3.2.2 for slant range considerations.) When locating each transponder at the selected site, maintain a minimum separation of 7 ft between the transponder and other magnetic sensing devices, such as compasses, and be sure that the transponder is positioned at least 2 in from all iron, steel, or other magnetic material. Adequate ventilation must be provided. During transponder operation, the case temperature of the unit must not exceed 71°C (158°F). Transponder units and antennas must be installed vertically.

The receiver-transmitter and omnidirectional antenna are installed as a unit using these same precautions. Each unit should be mounted at the highest possible point aboard the vessel where no part of the superstructure will shield the antenna.

Typical radiation patterns for shore based transponder fixed antennas and for rotating antennas aboard survey vessels are shown in figure AD-6.

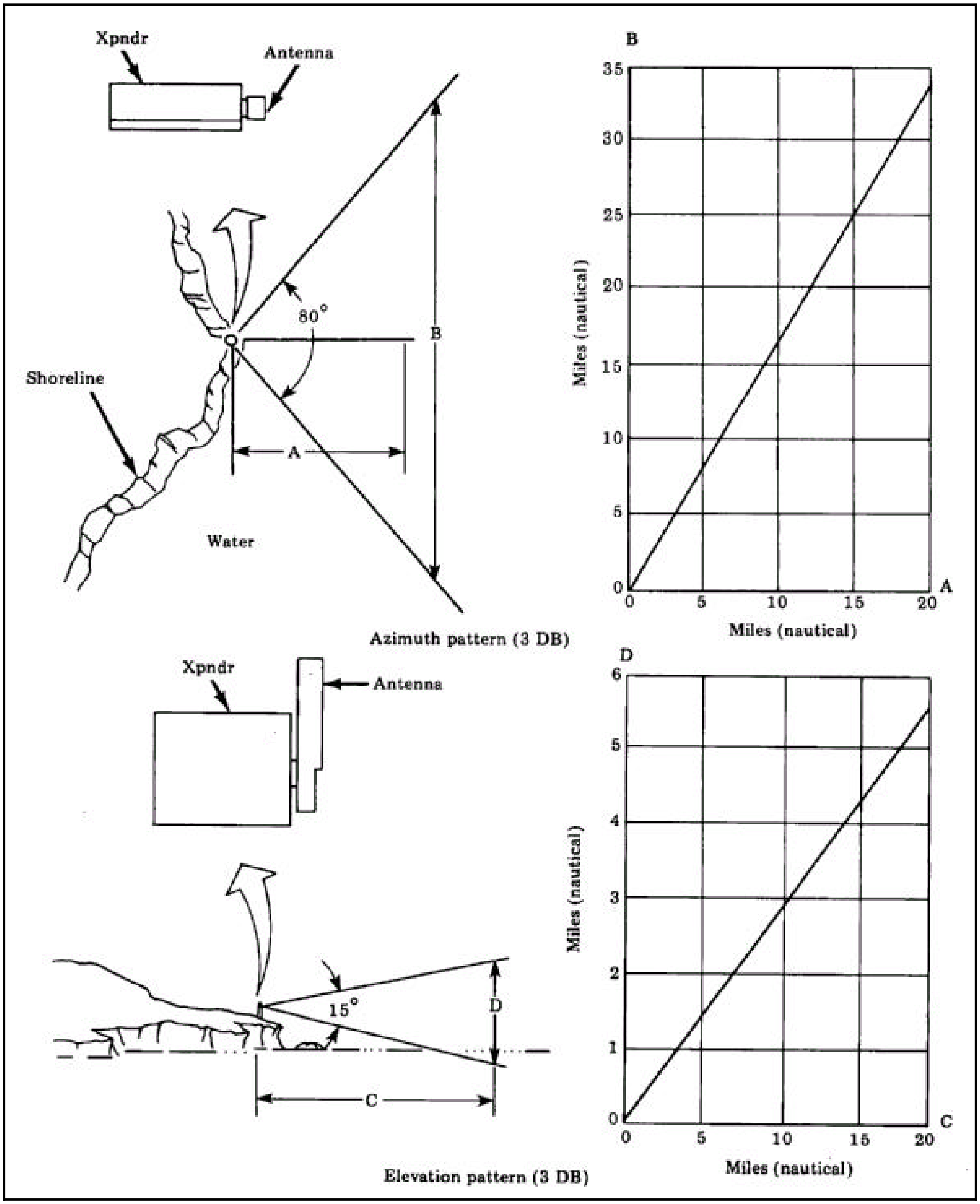


FIGURE AD–6.—Transponder antenna and typical radiation patterns (courtesy of Motorola.)

AE. SEXTANTS

AE. 1. Navigating Sextant

A sextant is a hand-held instrument used to measure angles between two points up to a maximum of about 140º. Navigating sextants, which can be read to 10 s or 0.1 min of arc, depending on the design, are classified as vernier or micrometer drum according to the method used to obtain final readings. See chapter 15 of the "American Practical Navigator, an Epitome of Navigation" (Bowditch 1962) for a complete discussion of various types of sextants in use.

To use a clamp screw sextant, wet the index arm at the approximate angle, then clamp the arm firmly to the frame. Bring the two objects into exact coincidence using the tangent screw. Modern vernier sextants have a worm gear attached to the arm that functions as an "endless" tangent screw.

Micrometer drum sextants (figure AE-1) also have an endless tangent screw, but the final reading is made on a graduated drum rather than on a vernier scale. Drums are graduated to 10 s, 0.1 min, or 1 min of arc. Drum-type sextants are preferred by most observers; however, it may be difficult to measure angles accurately when they are changing very rapidly.

AE.1.1. ADJUSTMENT OF SEXTANT. Each sextant used for hydrographic surveying must be adjusted as necessary before beginning a day's work. Sextant adjustments must be verified each night at the close of the day's work and amounts of index correction found entered in the sounding records. (See 4.8.3.) Proper adjustment should be checked periodically throughout the day and index errors, if present, noted.

Sextants are adjusted as follows: the index mirror (large mirror on the index arm) must first be made perpendicular to the plane of the instrument. To make this adjustment, set the index arm at about 10º and hold the sextant with the eye close to the index mirror and as nearly as possible in the plane of the sextant. Observe the graduated arc directly and its reflection in the index mirror, moving the arm back and forth slowly. The arc and its reflection should form an apparently continuous unbroken arc if the mirror is perpendicular to the plane of the arc. If the arc is discontinuous, correct the position of the mirror by adjusting the screw at the back of the frame.

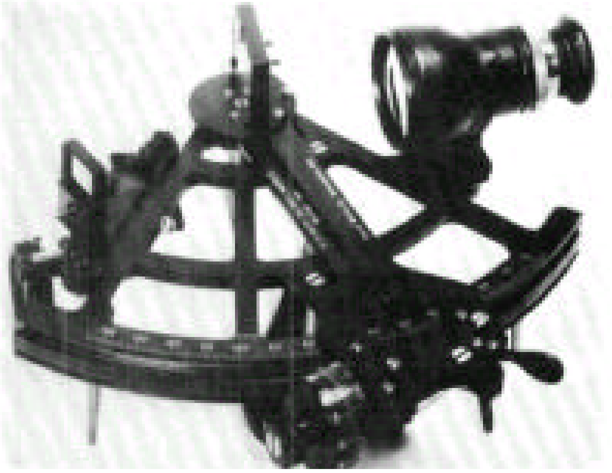


FIGURE AE–1. — Hydrographic sextant with telescope

Next, adjust the horizon mirror to be perpendicular to the plane of the arc. With the index mirror in adjustment, set the index arm near zero. Hold the sextant so that its plane is vertical; sight the sea horizon. Bring the horizon and its image into coincidence using the tangent screw. Rotate the sextant slowly and observe whether the horizon and its image remain in coincidence. If not, adjust the position of the mirror with the screws at the back of the frame until coincidence is obtained.

Finally, the two mirrors must be parallel to each other when the index arm is set at zero. After making the two adjustments described above, set the index arm exactly at zero; then hold the sextant in a vertical position and sight at the horizon. The observed and reflected horizons should coincide. If not, adjust the mirror with the screws at the side of the mirror until the observed and reflected horizons coincide. This adjustment may disturb the vertical adjustment. Repeat each until the horizon mirror is adjusted for all positions of the sextant.

AE.1.2. INDEX ERROR OF SEXTANT. These errors in sextants are caused by nonparallelism of the reflecting surfaces of the mirrors when the index arm is set at zero. Index error magnitude can be determined by one of these three methods:

1. Hold the sextant vertically and observe the sea horizon. Bring the direct and reflected images into coincidence and read the setting of the index arm. Repeat the process several times, alternately bringing the reflected horizon down to

coincidence and up to coincidence. Average the results. If the zero of the vernier is to the right of the zero of the are, or "off the arc," the correction is positive and is added to the measured angles. If to the left or "on the arc," the correction is negative and is subtracted from measured angles.

2. At night, substitute a star for the sea horizon. Point the sextant at the star and bring the direct and reflected images into coincidence and read the setting of the index arm. Repeat several times and use the average of the results as described.

3. Measure the apparent diameter of the Sun by holding the sextant vertically. Bring the upper limb of the reflected image to touch the lower limb of the direct image. Read the angle. Then bring the lower limb of the reflected image to touch the upper limb of the direct image and read the setting off the arc. Half the difference of the two readings is the index correction. The correction is positive if the larger of the two values is off the arc. For example, if the diameter measures 33'50" (on the arc) and 32' 40" (off the arc), the index correction would be ½ (33'50"-32'40") = 35" (minus). Several such observations should be taken and the average used. Observational accuracy may be verified by comparing the Sun's semidiameter for the date of observation from the Nautical Almanac with one-quarter of the sum of the two readings (regardless of the sign).

AE.1.3. USE OF SEXTANT. To measure a horizontal angle between two objects with a sextant, sight the left object over the top of the horizon mirror. Unclamp and move the index arm until the reflection of the right object can be seen (by double reflection) in the horizon mirror directly under the left-hand object. Bring both objects into exact coincidence using the index arm tangent screw.

When objects are definite and readily visible, many observers use the sextant without a telescope, especially when angles change rapidly or if the sounding vessel is unsteady. When objects are distant, indistinct, or indefinite and angles are changing slowly, a sighting telescope should always be used on the sextant—particularly when a small error in an angle will significantly affect the position.

Little experience is required to measure sextant angles between prominent objects when an angle is changing slowly and the observer's platform is steady. In hydrographic surveying, the circumstances are often reversed— angles change rapidly, objects are indistinct, and the survey vessel is far from steady. Under such conditions, a great deal of practice is required to enable an observer to measure sextant angles quickly and accurately.

As a general rule, after measuring and reading an angle, an observer should not move the index arm until the position has been plotted, so the reading can be verified if necessary. Sextant angles should always be verified before the arm is moved.

The two angles of a three-point fix must be measured simultaneously on signal. If one of the objects cannot actually be seen or if they are not in coincidence at that instant, the angle must be recorded as a "miss."

AE.1.4. ANGLES TO FAINT OBJECTS. When signals are faint, it may be difficult to reflect right-hand objects although they can be seen fairly well when looking directly at them. In such cases, the sextant should be set to the expected angle at the next position so the reflected image of the right-hand object will be in the field of view of the telescope. There are several methods of determining approximate angles:

1. Angles may be scaled from field sheets with a protractor at the approximate location of the next position.

2. If an angle is not changing too rapidly, the rate of change between the two preceding angles may be applied to determine the approximate angle at the next fix.

3. The relation between the faint signal and a conspicuous object near the signal may be noted and that object reflected initially. A slight movement of the sextant brings the correct signal within the field of view.

4. If the observer first determines the angle subtended between the ends of thumb and little finger with the arm outstretched, he can roughly approximate an angle by sighting over his hand and visually stepping off the angle along the horizon.

If the center object is difficult to reflect, observers can measure the right angle and the total angle between right and left objects, then subtract the former from the latter to obtain the left angle. If the right-hand object is difficult to reflect and the left object is very distinct, the sextant may be held upside down to look directly at the right-hand object and reflect the left-hand one.

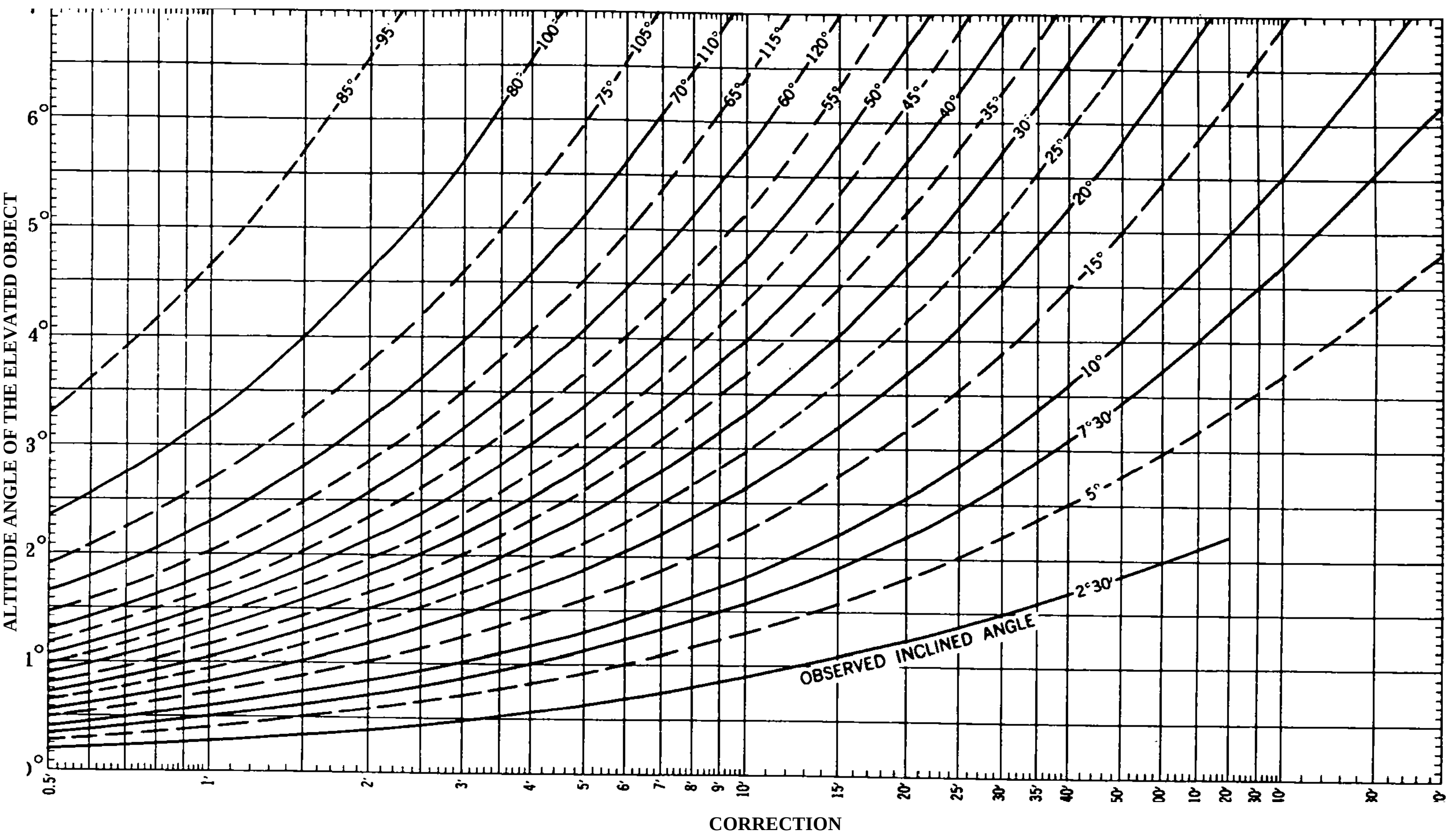


FIGURE AE–2.— Corrections to inclined sextant angles when one object is elevated appreciably above the second object

AE.1.5. INCLINED ANGLES. Sextant angles for hydrographic control must be measured between objects that lie approximately in the same horizontal plane as the observer. If an angle between two objects of considerable difference in elevation must be measured, the observed value is corrected according to the graph in figure AE-2; this graph is based on

$$\text{Cos } C = \frac{\cos O - \sin (h^1) \sin (h^2)}{\cos (h^1) \cos (h^2)}$$

where C is the horizontal or computed angle, O is the observed inclined angle, and h^1 and h^2 are the angular elevations of the elevated objects from the point of observation. This formula reduces to

$$\text{Cos } C = \frac{\text{Cos } O}{\cos h}$$

if only one signal is elevated (h^1 or $h^2 = 0$).

To find the correction to an observed angle, enter the graph at the left-hand margin with the altitude angle as the ordinate. From this point, extend a line horizontally until it intersects the curve representing the observed inclined angle–interpolate between the curves if necessary. The abscissa value at the point of intersection on the horizontal scale at the bottom of the graph is the correction to be applied. Corrections for observed angles from 0° to 90° are negative; corrections for observed angles from 90° to 180° will be positive.

AE.2. Electronic Digital Sextant

This sextant, manufactured by Teledyne-Gurley, Troy, New York, is designed to provide accurate angular data to the **HYDROPLOT** system for automatic recording and machine-plotted positions. The digital sextant is a modified U.S. Navy Mark III sextant–lightness (4 lb), durability, and corrosion resistant characteristics of the standard sextant have been retained. (See figure AE–3.) The instrument is used and operates in a manner similar to that of a conventional sextant, except that the observer does not read the arc drum and vernier values–all angular data are transmitted by cable directly to the processor.

In electronic sextant operation, a curved glass scale replaces the conventional graduated arc; an electro-optical reading head is used to extract standard arc values; and electronic interpolation is used to determine drum vernier readings. The curved scale is attached to the sextant base, and the electro-optical encoder head is mounted on the radial arm that pivots with the sextant mirror shaft.

The encoder scale is a vacuum deposited chrome ruling on an optical glass arc segment. The reading head uses phototransistors as sensing elements and light-emitting diodes as illumination elements. All components are extremely durable and are highly resistant to rough handling, vibration, salt water, and corrosion. A reticle of vacuum deposited chrome on glass with a minimum clearance of 0.003 in from the encoder scale is used to ensure zero wear, striction, or drag in the encoder readout assembly. The conventional sextant bearing is replaced by a high accuracy, preloaded ball bearing pair to increase the rigidity of the pivot arm and achieve error-free digitizing under all conditions. A large

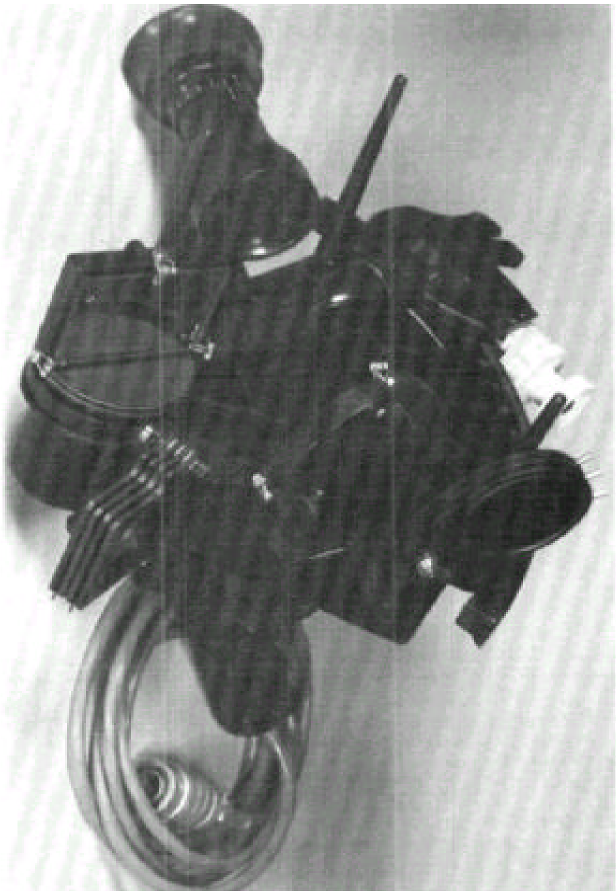


FIGURE AE-3.— Electronic digital sextant

0.25-in-diameter movable mirror shaft is used for the same reason. The entire assembly is sealed in a removable lightweight fiberglass enclosure to which a contoured balanced observer's handle is attached. The entire electronics assembly is on a single printed circuit board mounted on the inside of the fiberglass enclosure. Reading head outputs are electronically amplified by a factor of 4 to permit a less dense ruling and increase the quality of scale readouts.

Conventional sextant configuration was preserved in the design of the electronic digital version. Electronic sextants are easy to handle and operate and are safe to use under all environmental conditions. The rapid coarse angle setting and fine adjustment features are identical to those of a standard sextant—observer's "feel" is not affected. The electronic sextant is well balanced when held by the handle, which is located beneath the center of gravity and is canted slightly forward to reduce arm strain to a minimum. A push-button switch that causes an interrupt to the computer is located in the handle where it can be easily depressed by the index finger. The function of this push button is controlled by the computer software and may be used to reject fixes, record fixes, or take check fixes depending upon the particular program being used. In general use, a fix is taken automatically on a programmed schedule rather than at the push of a button. The observer's left hand is free to perform the same adjustments necessary for conventional sextant operation. The conductor cable leads from the bottom of the handle for minimum interference to the observer. The connecting cable is mechanically strain relieved at the instrument handle so the seals will not be damaged by stress or strain. Special materials such as titanium and fiberglass are used to keep the weight of the electronic digital sextant to an absolute minimum (4 lb without telescope, 4.5 lb with telescope attached). Approximate dimensions are 11.5 in x 11 in x 10.5 in.

Observer safety was a primary consideration in the design of the instrument. Probability of electric shock is nil. Power supply buses are completely isolated from all metallic parts. The cable connecting the sextant to the navigation interface provides a ground path between the two system subassemblies. The ground lead on the digital sextant frame terminates at the other end of the cable by a grounding pin on the connector. Digital sextants are designed to operate without accuracy degradation or loss of repeatability in temperatures from 35° to 120°F (approximately 2° to 49°C) and in a relative humidity range of 10 to 90%. Low to moderate vibrations normally encountered aboard ships or smaller survey vessels will not affect the instrument. Each electronic digital sextant must be stored and carried in the specially designed carrying case provided with the instrument—the case affords reasonable protection against vibration and impact damage and also provides storage space for the telescope, special adjusting instruments, and the connecting electrical cable. When in use, the sextant can be rested in the "optics down, handle up" position on the three legs mounted for this purpose.

AE.2.1. ADJUSTMENT AND CALIBRATION. The electronic digital sextant is a factory calibrated instrument. Electrical or electronic adjustments shall not be attempted in the field. Basic settings are locked by epoxy bonding or pinning of components.

A special wrench for making optical adjustments is included in the instrument carrying case. When adjusting or operating the instrument, use the digital values only. Direct readings from the arc, drum, and vernier are not accurate and are intended only for use when making approximate angle settings to the nearest degree. Optical adjustment procedures for electronic sextants are identical to those described in section AE.1.2 for conventional sextants. The need to make frequent optical adjustments is an indication that the instrument is defective or is being mishandled. The rear lens housing of the telescope must be adjusted by each individual observer for the sharpest and clearest image possible. Remember the reading on the diopter scale for use when making future settings.

When using the telescope attachment, difficulty in bringing two objects into coincidence indicates that the telescope line of sight is not parallel to the plane of the sextant frame. Unfortunately, there are no adjustments that can be made in the field to remedy the situation. Adjustments can be made only by the manufacturer. Telescope alignment can be checked by:

1. Holding the sextant horizontally in the left hand with the horizon glass nearest to the observer.

2. Setting the index arm at approximately 0°.

3. Aligning the centerline of the horizon mirror with its image in the index mirror.

4. Seeing in the index mirror the image of the entire telescope tube back to the eyepiece.

AE.2.2. OPERATION. Procedures for observing an angle with an electronic digital sextant are nearly the same as those when using a conventional sextant, but there are two important differences:

1. After the instrument has been adjusted to an angle of 0°, set the angular digital display values on the navigation interface to 0 and set the mode switch to the **ENCODER** position. (Remember that values read from the graduated marks are inaccurate.)

2. When the "mark" signal for the fix is sounded, the value of the angle is instantaneously transmitted from the sextant to the computer for recording and machine plotting of the fix. Observers do not have the luxury of being able to make another "crank" on the tangent drum to "touch up" the angle after the signal. The fix, however, can be rejected by pressing the button on the sextant angle.

AF. SOUNDING EQUIPMENT

AF.1. Manual Depth-Measuring Devices

AF.1.1. LEAD LINE. All field units engaged in hydrographic surveys where general depths are less than 20 fm shall have one or more lead lines marked and calibrated. Lead lines are required for the following purposes:

1. To search for or to confirm least depths over shoals and sunken rocks.
2. To confirm echo soundings in kelp or grass areas.
3. To obtain bottom samples (when sampling device is attached).
4. To obtain vertical cast comparisons with echo soundings.
5. Occasionally to suspend instruments for temperature and salinity observations from a small vessel.

Standard lead-line material is mahogany-colored tiller rope with a phosphor-bronze wire center. The center consists of six strands of seven 33-B (S-gage) wires each. The wire core is flexible and should not break after continual use and coiling. The rope is size 8 (about 0.24 in. in diameter), and is made of waterproofed, solid braided, long-staple cotton. The braid should be tight enough so that broken wire strands will not protrude through the covering and injure a leadsman's hands. Material for lead lines may either be requisitioned from the Marine Centers or be purchased from a well-equipped marine supply dealer.

AF.1.1.1. *Marking lead lines.* Depending on the depths in which they will be used and on the size of the vessel, lead lines should be 15 to 30 fm long. Each lead line is identified by a consecutive number stamped on a metal disk attached at the inboard end of the line. Identification is made when a line is initially graduated. This number is to be retained throughout the life of the lead line or until re-marking is necessary.

The braided covering of an unseasoned lead line tends to shrink when wet causing the wire core to buckle and the strands to break. Broken strands are likely to protrude through the covering and cause hand injuries. To prevent rupturing the core with repeated use, preseason each lead line as follows:

1. Prepare the lead line by soaking it in salt water for 24 hr. Then, while the line is still wet, work the cotton covering along the wire by hand until the wire protrudes from the covering. The wire should protrude about 1 ft for each 10 fm of line. This is a tedious procedure requiring the cooperative efforts of several people. The covering can be pushed back and slackened only a few inches at a time; this length of slack must be pushed nearly the full length of the line before the next few inches can be started. The excess protruding wire is cut off. The covering must not be worked back too far, or it will form bulges along the wire. Lead lines so prepared will maintain an almost constant length for future use.
2. Next, the line is dried under tension (about 50 lb) and then soaked again for 24 hr. Never boil a lead line as this destroys the waterproofing of the cover.
3. After attaching a lead to the line, the line should be wetted down again and placed under a tension equal to the weight of the lead; this tension is maintained while the line is being graduated. Temporary marks made at this time can be used for later permanent marking. Graduation marks on a new lead line may be laid off with a steel tape. The best method, however, is to mark the distances permanently on a suitable surface such as on the deck of a ship or on a wharf if the survey party is shore based. Permanent markings are convenient when verifying the graduations in the future.

Two units of measurement, the fathom and the foot, have traditionally been used to mark lead lines for hydrographic surveys in the United States. Only one unit is to be marked on a lead line. Hydrographic parties surveying in both depth units should be equipped with at least one lead line graduated in each unit.

Traditional markings for lead lines graduated in fathoms are shown in Table AF-1.

Intermediate marks are placed between the fathom marks to permit readings to the nearest tenth of a fathom. Each half of a fathom is marked by a seizing of black thread; each even tenth of a fathom (0.2, 0.4, 0.6, and 0.8) is marked by a seizing of white thread. Odd tenth readings are estimated.

Each fathom mark should extend 2 in from the lead line. Leather marks are made in one piece with strips (about ¼ in in width) that are slit in the free end of the mark. Bunting marks are made by folding a small piece of bunting to about 5/8 in wide by 5 in long; this length of folded bunting is then folded once again in the middle then secured to the lead line so the folded end is free.

TABLE AF–1. — *Markings for lead lines graduated in fathoms*

Fathoms	Marks
1, 11, 21	One strip of leather
2, 12, 22	Two strips of leather
3, 13, 23	Blue bunting
4, 14, 24	Two strips of leather secured in the middle so that two ends point upward and two downward
5, 15, 25	White bunting
6, 16	White cord with one knot
7, 17	Red bunting
8, 18	Three strips of leather
9,19	Yellow bunting
10	Leather with one hole
20	Leather with two holes

Waxed linen thread should be used to secure marks to the lead line in such a manner that there can be no possibility of slippage. Do not insert the thread through the braided covering of the line. All marks except 4-, 14-, and 24-fm marks should be secured so that their free ends are up when sounding. Marks so secured will tend to stand out more from the line when vertical.

Traditional markings for lead lines graduated in feet are shown in table AF-2.

Intermediate odd feet (1, 3, 5, 7,...) are marked by white seizings. Leather markings at the 10-ft multiples should be the same size as the fathom marks on lines graduated in fathoms. Bunting marks that identify intermediate even feet should be slightly smaller in size.

On occasional surveys for which the depth unit is the meter, soundings may be taken with lead lines graduated in feet, provided that the measurements are converted to meters prior to plotting. In such cases, the hydrographic records must clearly and unmistakably identify which soundings are in feet. When extensive soundings in meters are anticipated, a metric lead line should be prepared. Each meter and half meter is marked using an identification system convenient to the observers. A marking similar to that of a lead line graduated in feet is recommended (such as red, white, blue, yellow, and leather).

TABLE AF–2.— *Markings for lead lines graduated in feet*

Feet	Marks
2, 12, 22, ...	Red bunting
4, 14, 24, ...	White bunting
6, 16, 26, ...	Blue bunting
8, 18, 28, ...	Yellow bunting
10, 60,110	One strip of leather
20, 70, 120	Two strips of leather
30, 80, 130	Leather with two holes
40,90, 140	Leather with one hole
50	Star-shaped leather
100	Star-shaped leather with one hole

AF.1.1.2. *Verification of lead lines.* Lead lines used for sounding are compared with a standard at the beginning of a season and at frequent intervals thereafter, depending on usage. When the checks are made, lead lines must be wet and under a tension equal to the weight of the attached lead in water. The testing standard should be a good recently calibrated steel tape or premeasured graduation marks on deck or ashore.

Stamp 5 (figure 4-29, section 4.8.3.6), Lead-Line Comparison, is used to record comparison results in sounding records. A comparison should be made either at the beginning or at the end of each day a lead line is used. (See 4.8.3.6.) If a lead line is found to be correct, a statement to that effect is sufficient. When incorrect, comparison results are entered for each fathom or for each 5 ft to the extent of the depths measured. True lengths of the graduation marks as determined by comparison against the standard are entered on stamp 5 in the column headed "D"; corresponding graduation mark values are entered under the column headed "M." Corrections to lead-line soundings are obtained by subtracting column M from column D. Replace or re-mark lead lines if the errors exceed 0.5 ft or 0.2 fm.

AF.1.1.3. *Sounding leads.* These in standard weights of 5, 7, 9, 14, and 25 lb are requisitioned from the Marine Centers. Each survey unit should have one or more leads with a snapper-type bottom-sampling device attached. (See AK.2.7.) Various methods may be used to attach the lead to the lead line. The preferred method is to have a galvanized thimble at the lower end of the lead line to which the lead can be attached by a shackle. The sounding lead and the snapper sampling lead can then be interchanged on the same line.

AF.1.2. SOUNDING POLE. Shallow depths over extensive flat areas in protected waters can be measured more easily and more accurately with a sounding pole than with a lead line. Sounding poles shall be used in areas too shoal for echo soundings, but restricted to depths less than 12 ft. Sounding poles are generally not used in depths greater than 6 ft except to provide supplemental soundings needed to interpret analog depth records, Pole soundings are read and recorded to the nearest half foot.

A sounding pole is made from a 15-ft length of 1.5-in round lumber capped with a weighted metat shoe at each end to hasten sinking. Shorter poles may be used depending on the depth conditions. Any convenient system of marking that is symmetrical toward both ends and will minimize reading errors may be used. The following marking system is recommended:

Mark each foot and half-foot graduation permanently by cutting a small notch in the pole. Paint the entire pole white; then paint the spaces between the 2- and 3-ft, the 7- and 8-ft, and the 12- and 13-ft marks black. Other foot marks are indicated by 0.5-in colored bands—red at the 5- and 10-ft marks and black at the 1-, 4-, 6-, 9-, 11-, and 14-ft marks. Half-foot marks are 0.25-in bands, white where the pole is black and black where the pole is white.

AF.1.3. BAR CHECK APPARATUS. A bar check is one method used to verify the accuracy of an echo sounder and to determine corrections for instrument error and velocity error. When accurate bar checks can be obtained throughout the full range of depths in the project area, velocity corrections can be determined without making oceanographic observations. (See 4.9.)

The bar apparatus must be a sound-reflecting surface that can be lowered to a known depth below the transducer. Various types of bars can be used, such as a section of 2- to 3-in pipe that is sealed at both ends, a section of sheet steel about 9 in wide and 3 ft long, or a weighted board. One of the more effective bars is constructed of six to eight sections of thin walled tubing, such as condenser tubes. The ends of the tubes are plugged and made watertight. The tubes are placed about 0.25 in apart and clamped in position with three sections of strap iron. A hinged yoke secures each end of the bar. Additional weights are added as necessary to overcome the buoyancy of the trapped air and to keep the suspension lines taut where the bar is lowered. The overall length of the bar should be about the same as the beam of the sounding vessel. Bars used in depths greater than 30 ft should be at least 9 in wide.

Flexible wire or line with a wire core is used to suspend the bar below the sounding transducer. Bar check lines are marked and verified by the same methods prescribed for lead lines. (See AF.1.1.)

AF.1.4. MODIFIED TRAWL SWEEP. This can be used to search for and locate submerged snags and obstructions when only one vessel is available. The sweep is made of two small or miniature trawl boards or doors identical to those used by commercial shrimp or fish trawlers. Completely finished and outfitted trawl boards (also called trawl doors or otter boards) are available at most of the larger commercial fishing outlets. The trawl boards are connected by 150 to 200 ft of 3/16- or 1/4-in oval link chain as illustrated in figures AF-1 and AF-2. The sweep is bridled and towed so that the connecting chain is dragged along the bottom approximately 200 ft astern of the towing vessel. Chain is easier to handle than steel cable and does not kink and fray, although chain will "mud up' faster than cable. Towlines of 1/2-in nylon or 5/8-in manila line are adequate for most small modified trawl sweeps.

A small buoy should be anchored in the immediate search area to provide a visual reference during the sweep operaton. Radial or closely spaced sweep lines are run with about one-third overlap over the adjacent swept area. Fixes along and at the ends of the sweep lines are plotted to show the area covered by each run. When an object is snagged, the trawl board towlines converge gradually and allow sufficient time for the coxswain to stop the vessel. The towlines are then hauled aboard and the vessel maneuvered until the snagged object is close enough to fix its position and take a pole or lead-line sounding.

A similar trawl sweep suspended between two vessels can be used advantageously in areas where the bottom is foul with oyster clumps, rocks, or other debris too insignificant to locate individually.

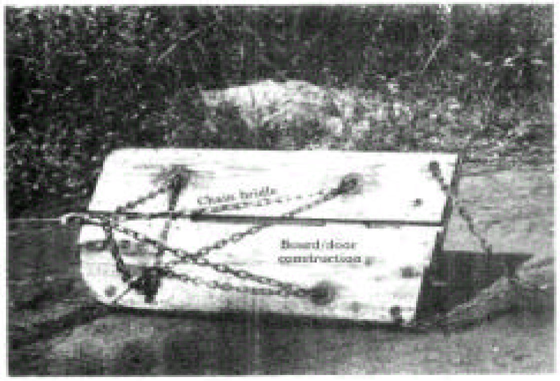
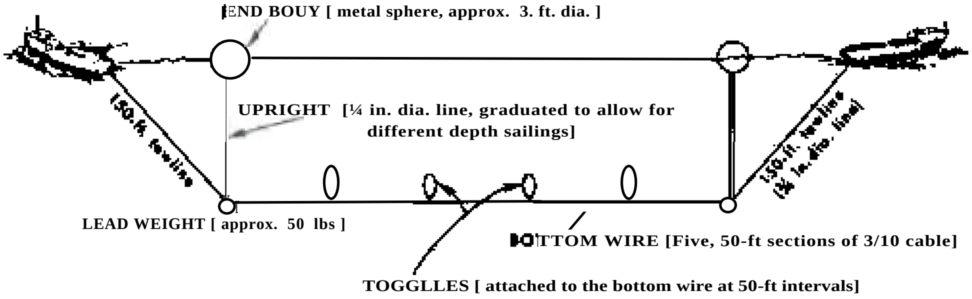


FIGURE AF– l.— Trawl board construction

FIGURE AF-2. — Modified trawl sweep

LAUNCH WIRE – DRAG GEAR



NOTE all connections between adjoining sections of bottom wire, bottom wire and towline, upright and bottom wire, load weights and bottom wire. and toggle to bottom wire should be made with shackles and swivels.

FIGURE AF–3. — A simple technique for launch wire-drag

Suspended sweeps are made up of 200 ft of 3/16-in stainless steel cable in 50-ft lengths. Half-gallon "Clorox" type plastic containers spaced at intervals of about 16 ft support the cable during a sweep. Weights of 50 lb are placed at each end of the bottom wire to resist the lift of the sweep as it is being towed. These weights are supported by larger floats with uprights set an appropriate distance off the bottom. Such systems must be towed slowly to minimize lift. Normally, there will be 1 ft of lift at 2 or 3 kn.

AF.1.5. PIPE DRAG. This is often more effective and easier to handle than a trawl sweep from very small boats. Construction is simple. The pipe is a standard length (21 ft) of approximately 1.5-in pipe. Each end of the pipe is packed with lead to provide more weight and reduce lift when underway. The pipe is suspended below the vessel by graduated lines over each gunwale. Pipe weight is the major factor in allowable vessel speed. Trial and error variations are usually necessary to determine the best combination. Dragging with the current permits greater speed over the ground.

AF.1.6. LAUNCH WIRE DRAG. This is a system of locating submerged items and in some instances is a variation of standard wire drag procedures. Launch wire drag has been used for several years especially in Alaska and to some extent along the U.S. east coast for item investigation and area clearance. For areas in Alaska, standard wire drag equipment— including bottom wire, buoys, weights and bridles—has been used with continued success. In recent years along the U.S. east coast a modified wire drag procedure has been used aboard launches for item investigation. The equipment and layout are shown in fig. AF-3. This modified wire drag is recommended for shallow water (less than 20 feet) and then only when other efficient techniques would not be more effective in locating items. Divers are highly recommended for obstruction identification and for accurate determination of least depth over the obstruction. See Special Report-Launch Wire Drag (Ethridge 1979).

AG. ECHO SOUNDING

AG.1. Introduction

Echo sounders measure the time required for a sound wave to travel from its point of origin to the bottom and return, then convert this time to distance or depth. Various instruments and methods have been devised to generate the sound, then receive and record its echo. The transmission of sound used in echo sounding is dependent on certain properties of the water and on the reflecting surface. If a sound wave is to travel at a constant velocity from surface to bottom, the water must have the same physical characteristics throughout the entire depth —there should be no attenuation of sound, and there should be total reflection from a bottom parallel to the surface. Such conditions are nonexistent.

AG.1.1. GENERAL PRINCIPLES. Nearly all soundings for hydrographic surveys are measured by echo sounders that record a nearly continuous profile of the bottom below the survey vessel. All echo sounders operate on the basic principle that a sound produced near the surface of the water travels to the bottom and reflects back to the surface as an echo.

Echo-sounding equipment is designed to generate the sound wave, receive and amplify the echo, measure the intervening time interval, then convert the time interval into units of depth and record the results graphically, digitally, or both. It is important to remember that an echo sounder does not and cannot measure depth directly. An echo sounder measures time (i.e., the time it takes for a sound pulse to travel from the transmitter to the bottom or other reflecting surface and back again). The time interval is converted mechanically or electronically to depth by multiplying by the velocity of sound in water:

$$\text{Depth} = \frac{1}{2} \mathbf{v}t$$

where v is the velocity of sound in water and t is the time for the pulse to travel to the bottom and back. Conversion to the proper sounding unit is a function of the recording equipment.

If depths indicated by echo sounders are to be correct, then (in theory) the measurement of t must be correct. The value of v used in the calculation must equal the average velocity of sound in the water through which the pulse has traveled.

Sound travels through water at a fairly constant velocity; however, velocity varies with density, which is a function of temperature, salinity, and depth. Echo-sounding instruments convert time to depth using a preset or an assumed velocity of sound—the "calibration velocity." Measured soundings will be in error by an amount directly proportional to the variation of the actual velocity from the assumed or calibrated value.

Velocity corrections usually are determined for all hydrographic surveys; however, corrections of less than 0.5% of the depth may be ignored.

Electrical energy pulses are converted to acoustical energy by a transducer mounted in the hull. Transducers with various frequencies are used for different ranges of depth and for specific purposes. Low-frequency pulses are used for sounding in deep water because high-frequency signals are subject to greater absorption and require greater initial power.

Pulses transmitted by an echo sounder are in the form of sound or compression waves, and may be varied in frequency, duration, and shape. The sound wave may be dispersed in all directions or may be contained and concentrated into a narrow beam by a reflector. The suitability of any echo sounder for a given requirement depends upon how these variables are combined. The repetition rate of the pulse may also be varied to suit a particular sounding requirement.

AG.1.2. ECHO-SOUNDING TRANSDUCERS. These convert electrical energy pulses to acoustical energy, then reconvert returning echoes back to electrical energy. Returned energy pulses are amplified and used to determine and record depths. Transducers are normally designed to operate at specific frequencies (AG.1.3) depending on the application and depth range. Transducer frequencies are divided into three groups: (1) low frequency—below 15 kHz, (2) medium frequency—from 15 to 50 kHz, and (3) high frequency—above 50 kHz.

AG.1.3. ECHO PULSE FREQUENCY. Variation of pulse frequency causes great changes in echo-sounder capabilities. Most instruments used for general navigation lie in the audible frequency range. Because audible frequency echoes have a low absorption rate, their high penetrating power makes them useful for deep soundings. Audible frequencies, however, have certain limitations. They cannot be used to measure extremely shoal depths with a high degree of accuracy. Because most of the noise in the water generated by the sounding vessel and other sources is in the audible frequency range, soundings are more susceptible to interference from stray sources; and because of their long wavelengths, low-frequency pulses cannot be beamed directionally without using transmitting and receiving units of a prohibitive size.

Ultrasonic frequencies overcome, to a large extent, most of the disadvantages of audible frequencies. Advantages of ultrasonic frequency pulses are:

1. High directivity and concentration of acoustical energy achieved with small transmitting and receiving units.
2. Less recorded interference from vessel and water noises.
3. Shoal depths measured more accurately.
4. A more detailed profile of an irregular bottom.
5. Reduced side echoes (AG.1.5).

With ultrasonic frequencies, however, the sound pulse suffers greater attenuation, and strays are often recorded when sounding in turbulent water or when in areas where rapid changes in water temperature or density occur throughout the water column. The higher frequencies are ineffective in deep water.

AG.1.4. PULSE DURATION AND SHAPE. Shapes of acoustical pulses through water vary considerably. General purpose echo sounders usually transmit a short pulse similar to that shown in figure AG–1. When a transducer is energized, it oscillates at its design frequency and transmits a sound pulse into the water. The damped oscillations diminish rapidly until they cease to be effective at a point approximately half the original amplitude. The effective pulse length for this type of transmission is approximately 0.2 ms. Although pulses of this type are relatively easy to produce, they generally do not contain very much power. Under good conditions, however, this type of pulse does provide good bottom definition in waters as deep as 1000 fm.

Figure AG–2 shows an undamped transmission pulse. With a long pulse of this type, a transducer is energized over a longer period of time, which prevents the transducer oscillations from diminishing, and results in a more powerful transmitted pulse. Deep water echo-sounder pulses vary from about 0.001 s to 0.04 s. Under good conditions, initial pulses with these durations assure bottom echo reception in waters over 5000 fm deep; howev-

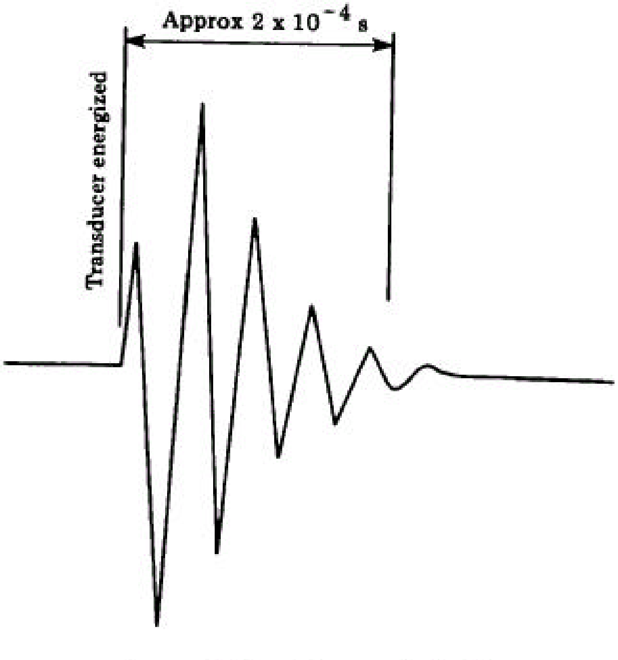


FIGURE AG–1.— Short acoustical pulse

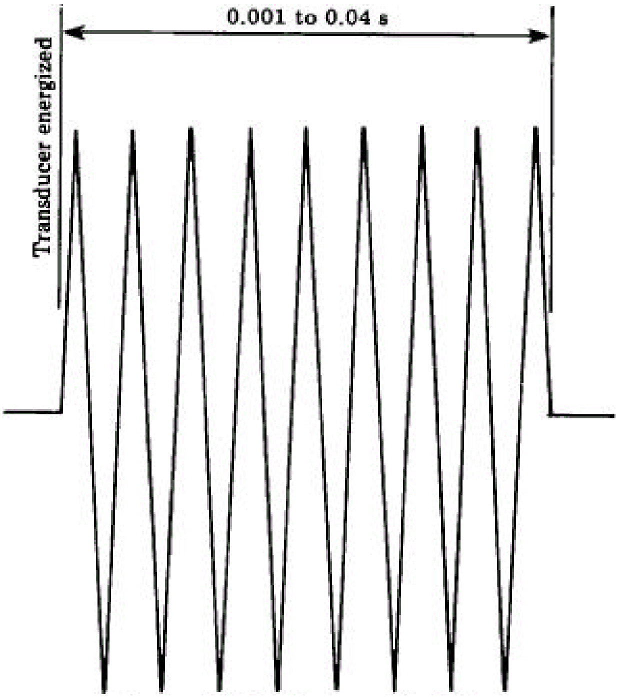


FIGURE AG–2.— Long acoustical pulse

er, as a result of pulse length, the return echoes provide a relatively poor definition of the bottom because in 0.04 s a sound wave travels about 33 fm.

AG.1.5. TRANSDUCER BEAM WIDTHS. A transducer is generally mounted in the hull of a vessel and has its radiating face directed toward the bottom. Transmitting units are equipped with reflectors that concentrate the acoustical energy into a beam. The shape of the beam depends upon the diameter of the reflector and the pulse frequency. The greater the diameter of the reflector and the higher the pulse frequency, the narrower and more concentrated the beam will be. Echo sounder beam widths generally vary from 2° to more than 50° depending on the purpose for which the instrument was designed. A transmitted beam may be symmetrical about its main axis or be wider in one direction than in another. The shape of a beam transmitted by a general purpose echo sounder is shown in figure AG-3. Most of the acoustical energy is concentrated in the main lobe, which for all practical purposes may be considered a cone.

Unfortunately, the energy of a beam cannot be confined entirely within the limits of the main lobe. Outside the main lobe, the strength of the pulse diminishes rapidly, except in the two side lobes where the power increases again and is centered about the axes approximately 30° to either side of the main axis. Side lobes serve no useful purpose and often cause false echoes that could mislead the hydrographer. Some transducers generate more than one pair of side lobes; but if the unit is well designed, most of the acoustical energy is confined to the main lobe. Reflectors cannot confine all of the transmitted energy within the main lobe.

Transducer beam width has an important effect on the accuracy and appearance of a recorded echo. Energy directed toward the bottom will increase as the width of beam is decreased and, at the same frequency, the energy in the echo will increase. Smaller beams also reduce the adverse effects of noise arriving from directions other than the bottom. For obtaining the greatest accuracy in echo sounding, a beam should be extremely narrow. Under this condition, the echo comes from a very small bottom area, and side echoes from slopes and other irregularities are reduced to a minimum. Certain other practical aspects, however, govern the selection of beam width.

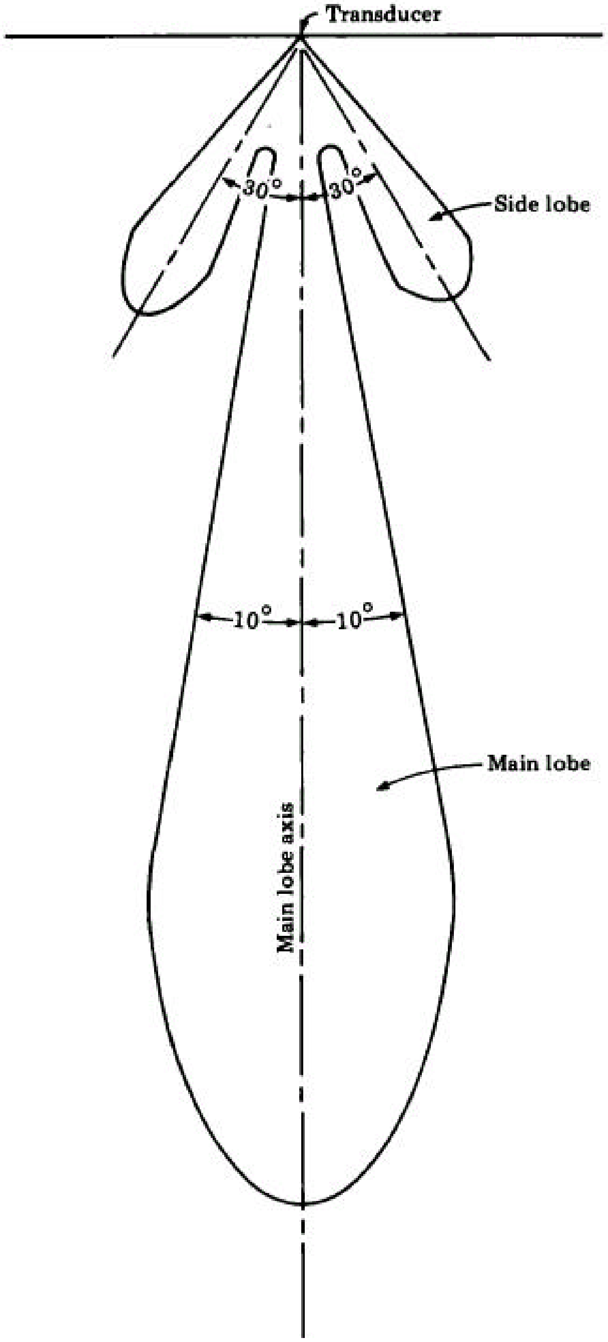


FIGURE AG–3.— Shape of a general-purpose echo sounder acoustical beam

For example, low-frequency sound waves must be used in deep water; however, it is impractical to install a transducer large enough to produce a narrow beam at low frequencies. (On **NOAA** vessels, frame spacing varies from about 20 in to 27 in.) More accurate delineation of bottom slopes will be attained by partial elimination of recorded side echoes when wide beam transducers are used.

Unless a stabilizing system is used, narrow beaming is ineffective when sounding in deep water and rough seas— as a vessel rolls, the beam is transmitted along a nonvertical path. Although an echo may not be lost, it will not represent a true depth.

AG.1.6. ATTENUATION OF ACOUSTICAL SIGNALS. After a sound wave is transmitted by the transducer, it is continuously subjected to losses in strength, and the echo returning to the transducer is often quite weak. Sound waves spread out or radiate as they make the round trip to the bottom and back, causing a gradual and continuous loss of energy. Some of the energy is absorbed in the water by conversion to heat. Absorption losses increase with signal frequency. Such losses are significant with high-frequency echo sounders, but have little effect at lower frequencies. Scattering losses occur when sound waves are diverted from their original direction of travel. Discontinuities in the water column caused by turbulence, aeration, changes in water density, or by solid matter in suspension contribute to scattering loss.

When a sound wave reaches the bottom, only part of the sound is reflected as an echo and returns to the transducer. If the bottom is rough and irregular or if the sound wave strikes at an angle, a portion of the wave is reflected away from a direct line to the transducer and becomes lost. Part of the sound energy penetrates the bottom and is absorbed by or reflected from deeper layers of the bottom material.

AG.1.7. FREQUENCY, PULSE LENGTH AND SHAPE AND BEAM WIDTH. Because damped pulses (figure AG–1) are considerably easier to produce than undamped pulses (figure AG–2), most echo sounders use damped pulses—unless sheer power for extremely deep soundings is a basic requirement. Undamped pulses are generally necessary for soundings deeper than 2500 fm. Long pulses transmit more energy than short pulses, making it more likely that some energy will be directed vertically to the bottom from a rolling and pitching ship. Long pulses, however, impair definition of the bottom profile and are used only when absolutely necessary.

Deep water echo sounders almost universally use low frequencies (less than 15 kHz). Absorption losses are least at these frequencies. Beams are wide —often as much as 25° on each side of the main axis of the lobe. Such wide beams decrease sounding accuracy over steep slopes and irregular bottom. Side echoes from slopes may overlap or mask echoes from the bottom of a valley or trench. Higher frequencies with narrower beams are desirable, but cannot be used in great depths because of the high rate of attenuation. Increased power to the transducer to overcome attenuation is not a solution because there is a limit to transducer driving power. If the limit is exceeded, cavitation occurs, and the power of the generated sound is decreased.

Medium frequencies (15 to 20 kHz) are used for most medium depth echo sounders designed to operate. in depths less than 300 fm. In this range, transducers are quite small— the maximum dimension does not exceed 8 in; however, the higher frequency generates a comparatively narrow beam that results in a more accurate definition of the bottom.

High-frequency echo sounders are characterized by small transducers and narrow beam widths. Short wavelengths and narrow beams result in excellent detailed bottom definition; however, high absorption losses restrict their application to maximum depths of about 300 ft. Most of the high-frequency sound will be reflected from the top of the sea bottom; there will be very little reflection from lower formations.

Because all of the desirable features cannot be combined for optimum performance, the design of most general purpose echo sounders is a compromise.

AH. ECHO SOUNDERS

AH.1. Introduction

The following discussions are limited to general descriptions of echo-sounding systems currently used by the National Ocean Survey for hydrographic and bathymetric surveying. Technical manuals published by the appropriate manufacturer are a necessity for satisfactory operation and maintenance of each system.

AH.1.1. RAYTHEON ANALOG AND DIGITAL DEPTH SOUNDERS. Raytheon portable precision recording fathometer produces a nearly continuous analog chart record of water depths. DE-723D systems provide, in addition, a remote digital display of depth values. These digital depth data are transmitted in standard binary coded decimal (BCD) format to external equipment such as the **HYDROPLOT** system or to peripheral data loggers.

Most of the following discussion has been extracted from the Raytheon Co. (1974*a*, 1974*b*) DE-723B and DE-723D systems manuals. The Raytheon Marine Co. (1975) *Bathymetric Systems Handbook* is an excellent detailed technical reference for the specification, installation, and operation of Raytheon systems. Their address is Raytheon Marine Company, Ocean Systems Center, P.O Box 360, Portsmouth, Rhode Island 02871. The handbook also provides general theoretical considerations, system selection guidance, and a performance prediction system that are applicable to most echo sounders.

AH.1.1.1. *DE-723 depth recorders.* Analog depth recorders for the Raytheon DE-723B and DE-723D echo sounders are essentially the same. To allow for portability or permanent mounting, the depth recorders are housed in separate cast-aluminum cases. Each opening surface is gasketed to ensure that the unit is splashproof when operated in an unprotected environment. (See figure AH-1.)

The analog recorder registers depths by means of a mark made on a dry electrosensitive calibrated paper by a stylus on a rotating arm that passes over the chart paper at a constant speed (600 rpm when sounding in feet and 100 rpm when sounding in fathoms). Sound energy is transmitted from the transducer when the stylus passes zero on the chart. During the round trip of the sound energy to the bottom and back, the stylus travels across the chart paper and makes a mark at the zero (or initial) point –then when the echo is received from the bottom and converted to electrical energy, additional marks are made that show a depth profile of the bottom.

The basic depth range of the recorder is 1 ft to 250 fm. Soundings can be recorded either in feet or in fathoms—a toggle switch on the recorder permits rapid and easy changing of the sounding unit. Six sounding ranges or phases can be selected on the ''**RANGE**'' switch. These phases are:

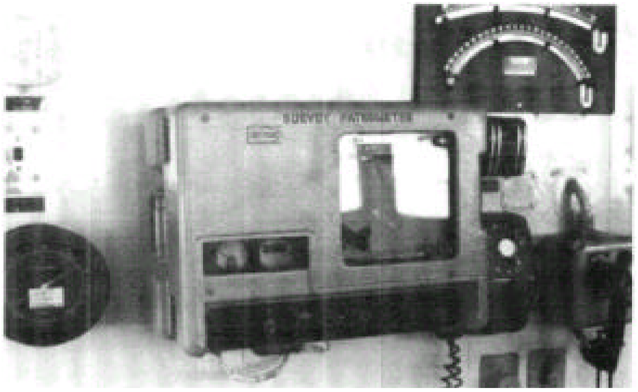


FIGURE AH-1. Raytheon DE-723 echo sounder recorder unit (courtesy of Raytheon Marine Co.)

A, 1 to 50 ft or fm;
B, 40 to 90 ft or fm;
C, 80 to 130 ft or fm;
D, 120 to 170 ft or fm;
E, 160 to 210 ft or fm; and
F, 200 to 250 ft or fm.

A 10-unit overlap in each range permits the hydrographer to change ranges without missing soundings and provides the means to determine phase corrections to soundings. Because the preprinted chart paper is not graduated for phases E and F, interpolation is necessary when scaling in those depth ranges. Chart paper is calibrated across a width of 6.25 in. Paper speed can be set at either 1 in/min or 2 in/min—use the lower speed if it gives adequate bottom definition.

To obtain the best depth profile, keep the **SENSITIVITY** setting at the minimum position that produces a good easy-to-read record. Hard bottoms reflect echoes stronger than do soft bottoms. A flat bottom composed of rock, sand, or packed mud should produce a sharp, clear, dark trace. Hard bottoms often create multiple echoes in shallow water because the sound waves reverberate between the bottom and the water surface. Such echoes are recorded as multiples of the actual depth — the actual depth is always the shoalest reading. Multiple echoes usually can be eliminated by reducing the **SENSITIVITY** setting. Soft muddy bottoms produce broad echoes of lighter intensity because the signal is reflected from both the top and bottom of mud surfaces. Mud thickness can often be determined from the characteristics of the recorded echo.

AH.1.1.2. *Electronics cabinet unit.* This contains the transmitter, receiver, keyer, and a 12- and 24-V d.c. power inverter. (See figure AH-2.) Units for both the DE-723B and the DE-723D systems can also be operated on 120-V a.c. power — regardless of type of power, the accuracy of recorded depths depends primarily on the frequency stability of the 60 Hz power input because a synchronous type motor drives the stylus arm.

Additional characteristics of the electronics cabinet unit are described in table AH-1.

AH.1.1.3. *Digital depth monitor*. This is a separate cabinet containing the digital display circuitry and the tide and draft preset controls. (See echo pulse at a depth selected by the operator. The figure AH-3.) Both of these controls shall be set at zero while conducting hydrographic surveys. Digital depth values are shown in a four-digit segmented display to the nearest tenth of a unit.

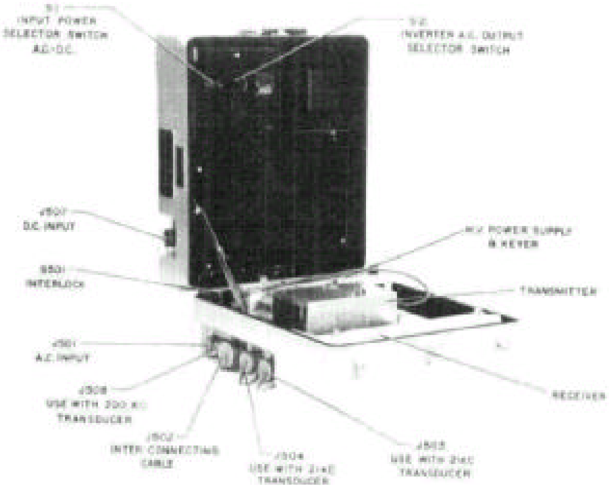


FIGURE AH–2. — Raytheon DE-723 echo sounder electronics cabinet unit (courtesy of Raytheon Marine Co.)

AH.1.1.4. *Digital phase checkers.* These checkers, designed at the Pacific Marine Center (Seattle, Washington), are used to check the mechanical functions of Raytheon DE-723 systems analog depth recorders (Raytheon Marine Co., Manchester, New Hampshire). The phase checker simulates

TABLE AH–1. — *Some characteristics of the Raytheon sounders*

Characteristic	DE-723B	DE-723D
Operating frequency	21 kHz	90 kHz
Transmitted pulse length	50	Same
Sounding rate	In ft: 10/s In fm: 1 2/3/s	Same Same
Accuracy*		
To depths of 100 ft	± 0.25 ft	0.25% of depth ± 0.1 ft or fm
100 ft to 240 fm	± 0.25% of indicated	Same
Minimum sounding	2 ft	5 ft
Phase position shift error	± 0.1 ft	Zero
Environmental specificationst†		
Operating temperature range	0º to 50ºC	Same
Storage temperature	-55º to 100ºC	Same
Maximum relative humidity	95%	Same
Digital logic output	None	Four bytes in 0.1 unit increments

*Accuracy figures are based on a velocity of sound in water of exactly 4,800 ft/s and a line frequency of exactly 60 Hz.

†When in the Tropics, never allow direct sunlight to fall on the electronics cabinet because the resulting internal temperature may exceed safe limits. Do not operate this equipment below freezing temperatures as this may cause damage to the components.

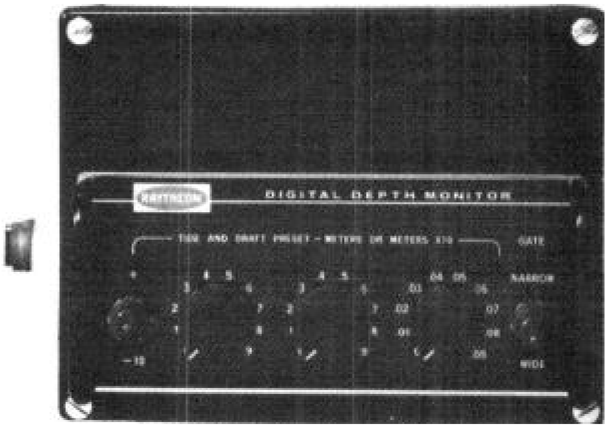


FIGURE AH–3.— Raytheon DE-723D digital depth monitor (courtesy of Raytheon Marine Co.)

an echo pulse at a depth selected by the operator. The simulated pulse is recorded on the analog record. Comparison of exact simulated depths with the corresponding values scaled from the record permits an accurate determination of phase errors. Recorded values of the simulated pulses are based on a velocity of sound of exactly 4,800 ft/s.

AH.1.2. ROSS DEPTH–SOUNDING SYSTEM. The basic Ross depth-sounding system consists of several units, including a transducer, a transmitter-receiver, and a chart recorder. (See figure AH-4.) In addition to the basic units, a digitizer is used to acquire depth data in digital form for the **NOS** automated system. Under ideal conditions, Ross systems can sound in depths up to slightly greater than 150 fm. For a more detailed technical discussion of the Ross depth sounder than is contained in the following sections, see the Ross Laboratories (1975) *Automated Hydrographic Survey System Operating and Maintenance Manual* and the Ross Laboratories (1972) Technical Bulletin, System 1 package. Their address is Ross Laboratories, Inc., 3138 Fairview Avenue East, Seattle, Washington 98102.

AH.1.2.1. *Ross depth recorder.* This depth recorder displays soundings on electrosensitive **NDK**-type chart paper (Ross Laboratories, Inc., Seattle, Washington). An endless rubber belt moves a stylus across the chart paper. As the stylus makes contact with a trolley rail, the signal from the transmitter-receiver is transferred through the stylus to the chart paper. These signals are "burned" on the chart paper to provide the graphic record of the bottom profile.

Soundings can be recorded in feet, fathoms, or meters. Chart paper graduated to increments of 100 units is used to record soundings in feet, 50 units for soundings in fathoms and 50 or 100 units for metric soundings. Four recorder ranges can be selected: (1) 0 to 100 ft or 0 to 50 fm, (2) 100 to 200 ft or 50 to 100 fm, (3) 200 to 300 ft or 100 to 150 fm, and (4) 300 to 400 ft or 150 to 200 fm. A slight overlap between range settings is printed on the chart paper to reduce the chance of missed soundings when changing scales over rapidly changing bottom.

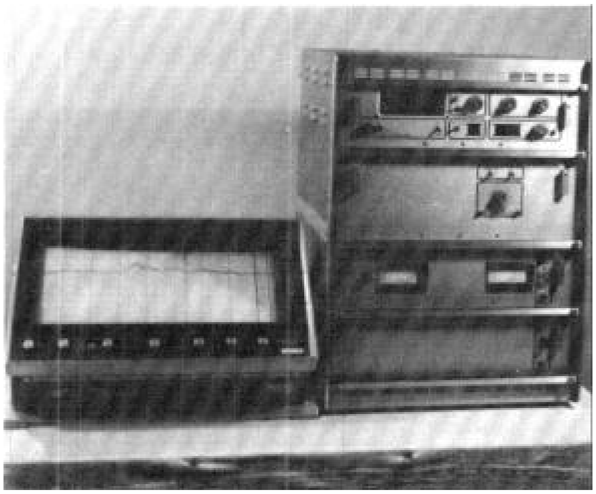


FIGURE AH–4. — Ross depth sounding system components, (left) analog recorder and (right) power supply topped by a digitizer (courtesy of Ross Laboratories, Inc., Seattle, Washington)

The endless belt is driven by a dual speed synchronous motor, which causes the recorded depth to be directly proportional to the power supply frequency. Thus, 115-V a.c. constant-frequency 60-Hz power must be used if the recorder is to operate at the proper calibrated speed of sound through water (4,800 ft./s). If the sounding vessel is not equipped with a constant-frequency power supply, an accurate d.c. to a.c. inverter must be used.

The recorder initiates all signal timing by generating a key pulse with a magnet that is riveted to the rubber belt and passes the pickup coils. The key pulse is delayed electronically to accommodate the various sounding ranges.

Chart paper speeds of 15, 30, 60, or 120 in/hr may be selected. Choice of paper speed is dictated by the bottom detail desired. Select the slowest speed that provides the necessary detail. A sensitivity switch on the recorder permits variation of the bottom trace density at different depths, and a fine line control switch can be used to produce a short dark mark at the leading edge of the echo for maximum definition of a soft bottom profile. A pulse length (AG.1.4) switch for use in varying depths is also available.

The Ross analog recording system is subject to three instrumental errors:

1. *Initial* where the leading edge of the outgoing pulse is not coincident with the zero line on the chart paper. This error is generally completely eliminated by operator adjustments; but on some models, the initial may record about 0.2 units high following the calibration phase check subsequently described.

2. *Stylus belt length* where calibration marks are recorded correctly at the top but not at the bottom of the graphic record. Hydrographers must be continually alert for the presence of this error by making frequent checks. When such errors are detected, belt lengths shall be adjusted as soon as possible.

3. *Phase* where disagreement exists between soundings on adjacent overlapping ranges when switching occurs between those ranges. This error is due to improper internal adjustments in the recorder and can be corrected only by a qualified electronics technician.

Calibration phase checks are performed on Ross analog depth recorders as follows:

1. Prior to beginning a new project.
2. At least once a day or if operations are conducted on a 24-hr basis, once each 4-hr watch.
3. Before and after changing recording paper.
4. Following a recorder malfunction and repair or adjustment.
5. At any time analog and digital depth values disagree by more than 0.5 ft, 0.2 fm, or by 1% of the depth, whichever is greater.
6. Following completion of a project or field season.

To perform a calibration phase check,

1. Set the digitizer function switch to "CAL."

2. Dial in the calibration depths, then scale the corresponding recorded depths as follows:

   a. If survey depths lie entirely on one scale such as 0 to 100 and 100 to 200, dial in depth increments of 10 units throughout the entire scale.

   b. If survey depths range over two or more scales, calibrate at three depths spaced equally throughout each scale; the greatest depth on each scale should be the least depth checked on each succeeding scale.

3. If an analog trace is not constant at each depth or varies by more than 0.5 ft, 0.2 fm, or by 1% of the depth, whichever is greater, survey operations should be suspended until a qualified electronics technician calibrates or checks the instrument.

4. Each calibration check shall be recorded on the graphic record and be filed as a permanent part of the survey records.

AH.1.2.2. *Ross Transceiver.* The echo-sounder transceiver, when keyed by a delayed pulse for the selected depth range, transmits electrical energy to the transducer. The transducer converts the electrical energy into acoustical energy at a frequency of 100 to 105 kHz. The transmitted echo beam is narrow and has distinct side lobes. Long or short pulse widths can be selected by the chart recorder operator. Short pulses (approximately 0.1 ms) are normally selected for shallower depths down to about 400 ft and for the necessity to interpret traces of fish or other small spurious targets. Long pulses (approximately 0.5 ms) are used to increase power as necessary to obtain stronger echoes when sounding in deeper waters. Long pulses cannot be used in depths less than 5 ft.

The transducer also functions as a receiver for return acoustical pulses that have been reflected by the bottom or by other objects; returning acoustical energy is reconverted into electrical energy by the transducer. The transceiver amplifies the returned electrical energy by the magnitude of the **SENSITIVITY** setting, then keys the chart recorder where depth is indicated.

AH.1.2.3. *Ross digitizer.* This provides depth values in the format necessary for automatic logging. Depth measuring by digital methods is an electronic process whereby the time it takes a sound pulse to travel to the bottom and return is measured by an accurate electronic clock. This time is divided by two and multiplied by the sound velocity (800 fm/s) to determine depth. Depth measurements by this process are inherently more accurate than those obtained from analog recording methods — mechanical instrument errors and human scaling errors are eliminated. In addition, digital depths are free of initial error. Both the Ross analog and digital recorders require a pulse to have a certain signal level before it will be recognized as a possible bottom return. The levels are, however, slightly different for the analog recorder and the digitizer.

Because the shape of the return signal pulse depends on the nature of the reflecting bottom, the analog signal level may be reached either slightly before or slightly after the digital signal level. Differences in these signal levels can result in the value of a digital depth varying from that of an analog depth. Such conditions become particularly apparent when sounding over soft bottoms, bottoms covered with a layer of silt, or steeply sloped bottoms.

Digitizers used by **NOS** are equipped with a four-digit readout that displays depths either in feet or in fathoms to the nearest tenth of a unit. (See figure AH-4.) Digital depth data is also transmitted in parallel binary coded decimal (BCD) form through an external connector for use as input to the **HYDROPLOT** system. The manufacturer's statement of accuracy of the digital readout and the BCD output is 0.01% ± 0.1 ft or fm, assuming a constant velocity of sound of 4,800 ft/s.

Ross digitizers feature a range gate that causes the unit to ignore echoes that are received outside a preset depth range. These digitizers also provide calibration pulses to permit precise adjustment of the chart recorder. Calibration pulses are derived by digital techniques from an internal crystal-controlled time base.

The digitizer can also be used to make a narrow dark mark on the analog depth record at the depth actually digitized. Such marks confirm proper digitizer operation and can be used to provide a clear profile of the bottom.

A missed soundings counter is used to reset the readout to zero after *n* consecutive soundings. Until *n* misses occur, the readout continues to display the last digital depth measurement. On each update of the readout, the decimal point flashes.

AH.1.3. RAYTHEON PORTABLE ECHO SOUNDER. This echo sounder, model DE-719 (figure AH-5), is a portable, precision, survey-type sounding instrument manufactured by Raytheon Marine Company, 676 Island Pond Road, Manchester, New Hampshire 03103.

FIGURE AH–5. — Raytheon Echo Sounder Model DE-719 (courtesy of Raytheon Marine Co.)

Depths from 2 ft to 410 ft are recorded analogically on electrosensitive straight-line chart paper by a flexible belt-mounted stylus. The recording rate is 534 soundings per minute. The operating range of the instrument through four overlapping depth phases (0-55, 50-105, 100-155, and 150-205 ft) is controlled by a selector switch. In addition, the "X2" range control switch doubles all range scales. Four paper speeds of 1 through 4 in/min may be selected.

The model DE-719 is designed to operate

from a 12-V d.c source; however, it can be furnished with a built-in power converter to operate from a 115/230 V a.c. 50-60 Hz power source. (See Raytheon Marine Co. 1976.) This conversion does not affect the ability to operate from a 12-V d.c. power source. The power requirement is 30 W.

A barium titanate transducer that is furnished as standard equipment can be installed permanently or temporarily. The transmitting beam width is 8º at the half power points and will not exceed 18º at the – 10 dB points at an operating frequency of 208 kHz. An optional narrow beam transducer with the following characteristics is also available; operating frequency of 204 to 210 kHz and a beam width of 2.75º at – 3 dB points, 3.5º at – 6 dB points, and 4º at – 10 dB points. Minor side lobes for both transducers are at least 11 dB down from maximum acoustic level. These narrow beam characteristics combined with the operating frequency make this instrument particularly well suited to record small depth changes and accurately define rates of change in steeply sloped and irregular bottoms.

When operating the depth sounder with standard chart paper, fixed reference marks are generated by a stable time base circuit that produces two sharp pulses spaced exactly 20.833 ms apart. These pulses are electrically superimposed on the analog output to the recording stylus and will fall exactly 50 ft apart on the chart paper when the stylus drive motor speed is adjusted to the speed of sound in water of 4,800 ft/s. The sharp line inscribed on the chart by the transmitted pulse is adjustable to the zero depth calibration on the chart by the **CAL ZERO** control, and the line initiated by the second pulse will fall on the 50-ft chart "calibrate" line.

The second mark (calibrated) will be interrupted periodically to indicate the phase on which the recording was made. For example, two interruptions with one solid mark indicates operation on phase 1 (0-55 ft), and three interruptions with two solid marks indicates operation on phase 2. The calibrate lines (at 0-50 ft) are not present when operating on the X2 range. No adjustments shall be made to compensate for variations in the temperature and salinity content of the water or to force agreement between recorded soundings and bar check results.

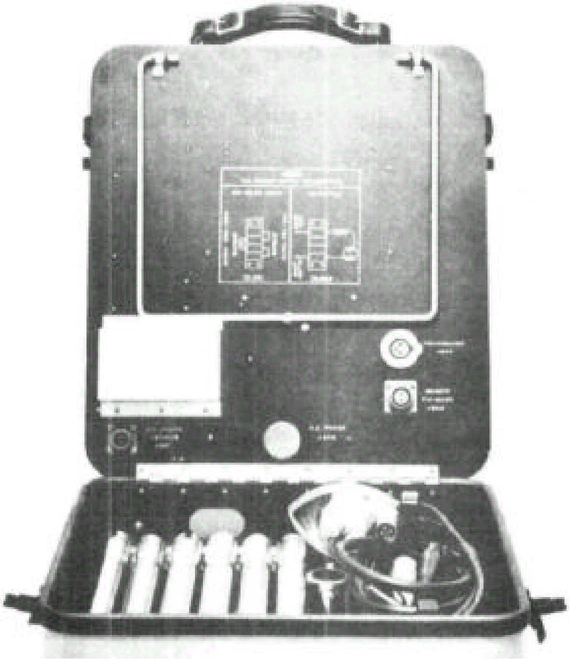


FIGURE AH–6. — Raytheon Echo Sounder Model DE-719 aluminum housing with rear storage area (courtesy of Raytheon Marine Co.)

The **FIX-MARK** switch when pressed to the right will inscribe a mark on the chart paper for time and/or position reference. Annotations can be made adjacent to the fix mark by opening the hinged window in the front of the recorder. A guard prevents accidental contact with the rotating stylus and belt assembly.

The Raytheon DE-719 depth recorder utilizes completely solid-state circuitry, magnetic keying, and electronically controlled chart speed. The equipment is housed in a splash-proof aluminum case to assure maximum protection when operated under adverse conditions. For optional 115/230 V a.c. operation, the power supply is designed to mount on the main chassis below the platen assembly. Space is also provided in the rear half of the case for storing the transducer, rigging, and power cable (figure AH-6). The entire package weighing 47 lb is provided with a zippered canvas cover for protection during handling and transportation. Claimed accuracy of the sounder is ± 0.5% ± 1 unit of indicated depth.

AI. Side Scan Sonar Equipment

AI.1. Introduction

Two basic acoustic approaches are used to distinguish topographic features of the sea floor and objects on or above the sea floor. The conventional method of echo sounding employs a vertical axis acoustic beam. The alternate methods, called side looking or side scanning sonar, requires an acoustic beam whose main axis is slightly below horizontal.

AI.2.1. GENERAL PRINCIPLES. As with most other underwater sonar devices, side scan sonar derives its information from reflected acoustic energy. In operation, however, it bears a marked similarity to radar, in that it produces a continuous, coherent plan view of a relatively broad scanned area. A set of transducers mounted in a compact towfish generate the high-power, short duration acoustic pulses required for the extremely high resolution of the system. The pulses are emitted in a fan-shaped pattern that spreads downward to either side of the fish in a plane perpendicular to its path. As the Fish follows the tow vessel's track, the beam scans a bottom segment ranging from the point directly beneath the fish outward as far as 500 meters to each side depending on the towed depth and frequency. Acoustic energy reflected from bottom (and waterborne) discontinuities is received by a set of transducers, amplified, and transmitted as electric energy to the towing vessel. There it is amplified, processed, and converted to hard copy by the side scan recorder. The resulting output is essentially a detailed representation of ocean floor features and characteristics. Good acoustic reflectors—rocks, ledges, metal objects, and sand ripples —are represented by darkened areas on the record. Depressions and other features scanned from the acoustic beam are indicated by light areas. An experienced observer can interpret most records at a glance, recognizing not only significant features and objects, but often more subtle data such as the composition and relative hardness of the bottom and the shape and condition of submerged objects.

AI.2.2. SIDE SCAN SONAR APPLICATIONS. Side scan sonar is used in a wide variety of applications in many phases of undersea endeavor. Those of interest to the National Ocean Survey include:

1. General searching. Because it highlights objects which protrude above the surrounding ocean floor, side scan sonar has proven to be a most effective means for bottom search. The fine resolution in the system recordings enables users to identify aircraft parts, small vessels, well heads, shipwrecks, and numerous other submerged objects.

2. Bathymetry and hydrography. The sonar can be used to give detailed topography of the bottom not only below the towfish, but out to both sides as well. This gives a much more rapid coverage than a standard depth sounder and it helps prevent "holidays" or skips of important targets between sounding lines. The system can also provide the very high probability of detection required in channel clearance surveys.

3. Sea floor geology. By comparing the intensity and shape of recorded echoes, the side scan operator can differentiate between various bottom materials. In most cases, sand, mud, rock outcrops, shell beds, gravel, coral, and other materials can be readily differentiated from each other.

AI.2.3. SYSTEM DESCRIPTION. The basic components of a side scan sonar system are a dual channel graphic recorder, a transducer towfish, and associated cables. Most units are capable of a.c. or d.c. (battery) operation.

Side scan sonar systems employ a stable, towed transducer (as opposed to a hull-mounted transducer) to minimize distortion of recorded data by allowing the transducer to be used below the thermocline. Also, the towed transducer is not attached to the hull, thus reducing distortion caused by vessel roll, pitch, and yaw. The towfish is usually towed to one side or astern of a vessel and can be launched or retrieved by one person. It contains two sets of transducers which aim fan-shaped beams to either side of the towfish perpendicular to the direction of fish motion. In addition, the towfish contains the transducer driver and preamplifiers for received signals. Breakaway tail fins are provided to minimize the possibility of snagging the fish on an obstruction. The towfish is usually operated at a distance above the sea floor equal to 10% to 20% of the range scale in use.

The towfish is towed by one of a choice of several cable lengths. The tow cable is connected to the recorder by a second covered cable. Short rubber-covered tow cables (in the range of 50 m to 100

m) are useful in shallow waters and where mechanical cable handling equipment is not available. Longer tow cables (200 m to 10,000 m) are steel armored, high-density cables designed to achieve maximum tow depth and minimum noise interference at given tow speeds.

Depth of the transducer towfish is controlled by the length of cable deployed, vessel towing speed, and vessel course. Tow depths can be increased by the use of a depressor or suitable weights.

The graphic recorder contains most of the electronics for the system as well as the graphic mechanism. Most recorders are designed to operate from 24 V d.c. or 110 to 220 V a.c. power supply. (See figure AI-1.)

AI.3. Side Scan Sonar

The following discussion is limited to a description of the side scan sonar system currently used by the National Ocean Survey for hydrographic and bathymetric surveying. The technical manual published by the manufacturer is a necessity for satisfactory operation and maintenance of the system.

A1.3.1. KLEIN ASSOCIATES, INC., SIDE SCAN SONAR SYSTEM. The Klein side scan sonar system consists of the following components:

1. Dual Channel Hydroscan Recorder
2. 50-kHz Dual Channel Towfish.
3. 100-kHz Dual Channel Towfish.
4. Lightweight Tow Cable - 300 feet.
5. Lightweight Tow Cable - 600 feet.
6. Armored Tow Cable - 2,000 feet.
7. Towfish Stablizer Depressor.
8. Operation and Maintenance Manual, Recording Paper, Breakaway Tail Assemblers, and Spare Parts.

The Klein side scan system can be operated from both small and large ships. The system is impervious to marine environments including temperatures of 0°C to 50°C. The equipment will operate from both 24 V d.c. ±10% and 120 V a.c. 60 Hz ± 10%. The service manual (Klein Associates, Inc.-1977) includes all necessary instructions, schematics, parts lists, troubleshooting, and general maintenance instructions. This manual is available as Klein Part No. 521-01 from Klein Associates, Inc., Route 111, RFD 2, Salem, New Hampshire 03079.

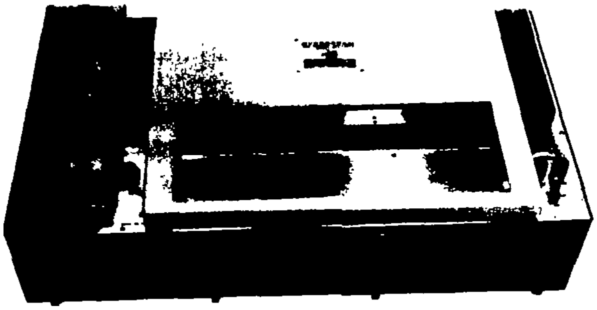


FIGURE AI–l.— Klein Hydroscan Dual Channel Side Scan Sonar Recorder (courtesy of Klein Associates, Inc., Salem, New Hampshire)

AI.3.1.1. *Side Scan Recorder.* The Klein recorder contains the patented Hands-Off-Tuning Ⓡ feature which provides automatic adjustment, making uniform results across the sonar chart. Switches are provided for each channel to additionally permit manual selective tuning. Three event mark features are included: an internally generated 2-minute mark, a pushbutton on the recorder control panel, and a remote event mark pushbutton.

Both recording channels print simultaneously, reading outward from the center of the record in true left/right perspective. The range of the system using the 100-kHz towfish is at least 1,500 feet port and starboard at speeds up to 6 knots. At a 5-knot tow speed the 50-kHz towfish range is at least 2,000 feet. The range of the side scan system is also dependent on the operational environment, target, and the tow speed.

AI.3.1.2. *Side Scan Transducers.* The towfish consists of individual modular port and starboard transducers whose vertical beam may be varied in 10° ± 2° increments from 0° to 20° by means of minor external mechanical adjustments to the transducer modules. (See figure AI-2.) The tail fin assembly consists of two individual breakaway tail fins, separating when they strike a submerged object. The towfish parts are capable of operation in water depths to 7,500 feet. Separate identical left and right channel plug-in circuit boards are housed in the nose of the towfish.

AI.3.1.3 *Tow Cable Assemblies.* Lightweight tow cable assemblies consisting of a polyurethane jacket and a Kevlar strength member are provided. The minimum breaking strength is 6,000 pounds. The core consists of four conductors, two of which are individually shielded and used for the right and left channel signal returns, while the other two are for power and trigger pulses. The entire core is additionally shielded. A 300-foot and a 600-foot lightweight cable are provided. The 2,000-foot cable has the same core as the lightweight cable and uses a dual-armored steel jacket providing a breaking strength in excess of 15,000 pounds.

AI.3.1.4. *Operations Considerations.* Although automatic tuning is available in the control circuitry manual tuning is superior when employed by a trained operator. Experience has shown that properly adjusted, manual controls strongly print a known target which might have been entirely overlooked among other returns on automatic tuning. Herein lies a problem, for if the manual tuning is not properly adjusted, it is worse than the automatic tuning for search. Manual tuning requires constant attention, and some skill to know, or feel, when proper tuning has been achieved. It is important to develop skill in hand tuning by working near a known target for a short period of time. This known target may be attached to an implanted buoy anchor line.

Environmental conditions limit the use of the sonar. The pulse repetition frequency is limited by the time required for the acoustic signal to reach the limit of the search band and return to the towfish. This physical limitation is in direct conflict with the desire to gain resolution on a target by getting as many separate pulses as possible to bounce off the target. There are two solutions to this problem: First, limit search path width; second, move at very slow speed. Both of these decrease the area which can be searched in a given period of time. It should be pointed out that speed over the ground is very important in side scan operations. Slow, constant speed can often be maintained by moving into the current.

Another environmental factor limiting use of side scan is sea state. This factor is most influential in water under 40 feet, but decreases with depth. Sea surface return is so strong with waves of only 2 and 3 feet in less than 40 feet, that it cannot be completely tuned out. As a result, targets on the bottom may be lost. One recourse is to lower the towfish below the interference. This would, of course, endanger the towfish in shallow water. Another means is by use of a recently developed towfish with a variable vertical beam (20° or 40°). The 20° setting is useful to minimize sea clutter.

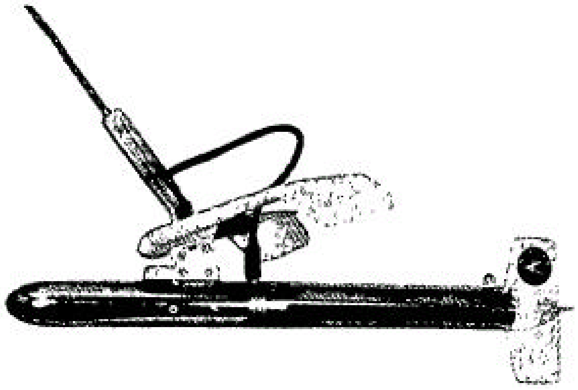


FIGURE AI–2.— Klein Side Scan Sonar Towfish (courtesy of Klein Associates, Inc., Salem, New Hampshire)

AJ NOS HYDROPLOT SYSTEM

This is **NOS's** hydrographic survey automated data acquisition and processing system. Figure AJ-1 is a block diagram of the system. **HYDROLOG** is a slight variation of the **HYDROPLOT** acquisition program in that an incremental plotter is not used. The **HYDROPLOT** system is capable of plotting hydrographic data on an on-line basis as the data are acquired and on an off-line basis after the data have been adjusted and corrected. See also figures AJ-2 and AJ-3.

The computer is a **DEC PD**(–8/E with 12K, 12-bit words of memory (Digital Equipment Cor-

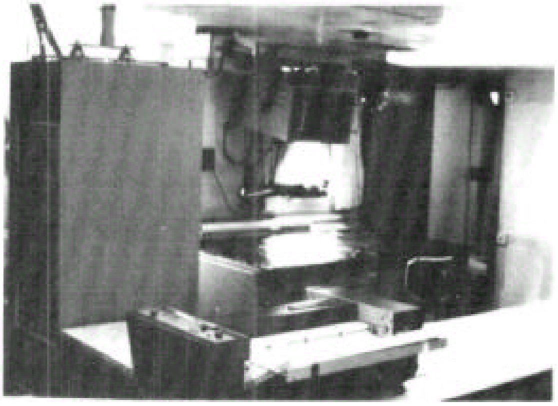


FIGURE AJ-2.—**HYDROPLOT** installation aboard the **NOAA** ship *Mt Mitchell*

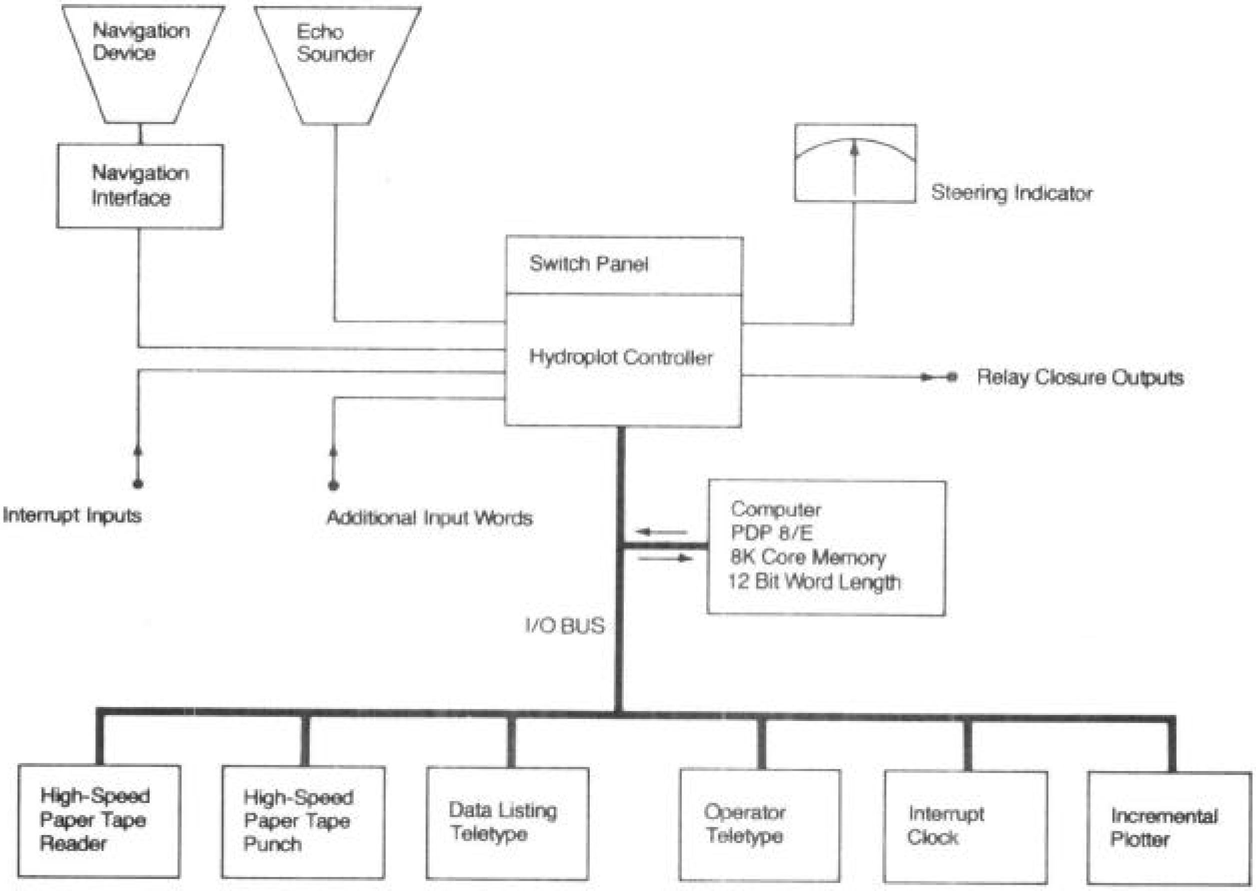


FIGURE AJ–1—**HYDROPLOT** system block diagram poration, Maynard, Massachusetts). System peripherals, all of which share a common input-output bus, include:

1. An eight-channel paper tape read and punch unit (reads 300 characters per second and punches 50 characters per second).

2 Two model ASR-33 teletypewriters that provide additional keyboard and paper tape input as well as paper tape and hard copy output.

3. A crystal controlled frequency interrupt clock located within the computer.

4. A Houston Instrument Company (Austin, Texas) **COMPLOT DP-3** incremental roll plotter. The plotter has a 22-in-wide plotting surface and, in effect, an unlimited plotting surface length. The maximum plotting speed is 300 increments per second at 0.005-in increments.

The **HYDROPLOT** Controller, a special purpose input-output interface, is the nucleus of the system hardware. This unit, manufactured by DEC to NOS specifications, provides these functions:

1. A digital multiplexer for up to 32 data input words, each 12 bits long.

2. An interrupt system for 12 input sources.

3. Four relay closures.

4. Analog output to activate a left/right steering indicator.

5. Two pulse outputs.

All data from the echo sounder, positioning equipment, and 49 controller panel thumbwheel switches enter the system under program control through the 32-word multiplexer. Hydrographers can select either of two echo sounders, one of several positioning systems, and various survey parameters; enter data using the panel switches. The operation of the system and software applications are thoroughly documented in *NOS Technical Manual* No. 2, "**HYDROPLOT/HYDROLOG** Systems Manual" (Wallace 1971).

FIGURE AJ-3. — Complete **HYDROPLOT** system launch installation

The interrupt system, which includes seven hand-operated momentary contacts on the controller front panel and five electrical connections on the rear panel, provides the means by which a hydrographer and the sensing equipment can communicate with the computer. Interrupts are used for such events as time synchronization, periodic inputs from sensors, and system starts and stops. Four relay closures are used to generate visual or audible alarm signals and to put timing marks on analog records such as graphic depth profiles.

The controller also contains a digital to analog coverter. Computer-controlled output of the converter activates a meter-type left/right steering indicator. Helmsmen keep the sounding vessel on a predefined line by following the steering indicator. The two pulse outputs from the controller inhibit changing of depth and position data while being sampled by the computer.

An echo sounder used with a **HYDROPLOT** system is a complete subsystem that provides an analog depth record, a visual digital depth display, and parallel binary coded decimal **(BCD)** depth input to the computer. Echo sounders used by **NOS** are discussed in section **AH**.

The navigation interface converts the outputs of an electronic positioning system (AC and AD) or the digital sextant (AE.2.) to parallel **BCD** information that is acceptable to the system. Any navigational or positional device to which an incremental encoder can be attached can be used as an input to the navigation interface.

Approximately 55 computer programs are available for use with the **HYDROPLOT** system. Most are in assembly language. These programs can be categorized into three basic groups: (1) preliminary and utility programs, (2) data-acquisition programs, and (3) off-line data editing and plotting programs.

The first group of programs are used for the following purposes: (a) to construct the modified transverse Mercator **(MTM)** grid (in both plane and geographic coordinates); (b) to construct range-range and hyperbolic lattice plots for the positioning system in use; (c) to convert electronic line-of-position values to plane and geographic coordinates, and vice versa; (d) to convert three-point sextant fixes to plane and geographic coordinates; (e) to generate predicted and actual tidal reduction values; (f) to calculate direct and inverse position computations; (g) to compile parameter inputs (based on the **MTM** projection) for real-time data acquisition; and (h) other utility programs designed to save time and labor from the preliminary phases of a survey to final data processing.

The second group encompasses **HYDROPLOT** data-acquisition programs. These programs permit either manual or automated real-time inputs of depth, position, and predicted tide or water level correction information. Acceptable positional data modes are range-range or hyperbolic electronic positioning values and three-point sextant fixes. Each program permits the input of actual tidal or water level stages by digital radio telemetry link when available. Echo sounder transducer draft, electronic position corrections, position fix interval, sounding interval, and other similar variables are entered manually on the controller thumbwheels. Velocity corrections to soundings are not applied on a real-time basis, but are compiled in digital format for application in a subsequent processing phase. Other data, such as sounding line spacing, coordinates of the starting point for the first line, heading of the first line, and orientation of the sounding numeral, are entered through the teletypewriter keyboard. System outputs include an on-line plot of positions and depths, analog left/right steering directions to the helmsman, digital hydrographic: data file on both punched paper tape and hard copy, and a listing of operator messages to the system. Positional information is acquired and listed for each sounding. Skewed projections may be used for both on-line and off-line plots.

The third group of programs permits a hydrographer to edit raw survey data, to compute and compile final corrections to positions and soundings, and to prepare final field sheets that are needed to evaluate the work prior to leaving the area. Off-line plotting programs will accommodate hybrid control systems, such as the combination of a sextant angle with a circular or hyperbolic line of position. (See 4.4.4.)

Off-line plotting programs of the **HYDROPLOT** system will also accept as input format-modified output of hydrographic data loggers. Hydrographic data loggers (figure AJ-4) are used aboard **NOAA** vessels to manually or automatically sample and log sounding information onto punched paper tape and provide a hard-copy listing. Time, position, and depth information from peripheral equipment, thumbwheel switches, or keyboard is logged in **ASCII** code in fixed formats. Data can be logged in real time or from manually kept sounding records after the hydrography has been run.

The semiautomatic hydrographic data loggers now in use were designed by **NOS** and are manufactured by Aircraft Standards, Inc. **(ASI)**, Seattle, Washington.

ASI logger electronics are entirely solid state consisting of integrated circuits on interchangeable modules. A memory unit stores input data before it is printed on a model **ASR-33** teletype. For operator convenience, a keyboard is used to enter data in the manual mode. A real-time clock with visual display is available for automatic logging.

The logger operates in any of three modes selected by the operator — automatic electronic, automatic visual, or manual. In the automatic mode, position and depth are taken from a digital source, such as a Ross digitizer and navigation interface, then logged automatically at preselected time intervals. Intervals are selected with a front panel thumbwheel and vary from 6 s to 99 min 59 s. The word length is set at medium for all data logged in

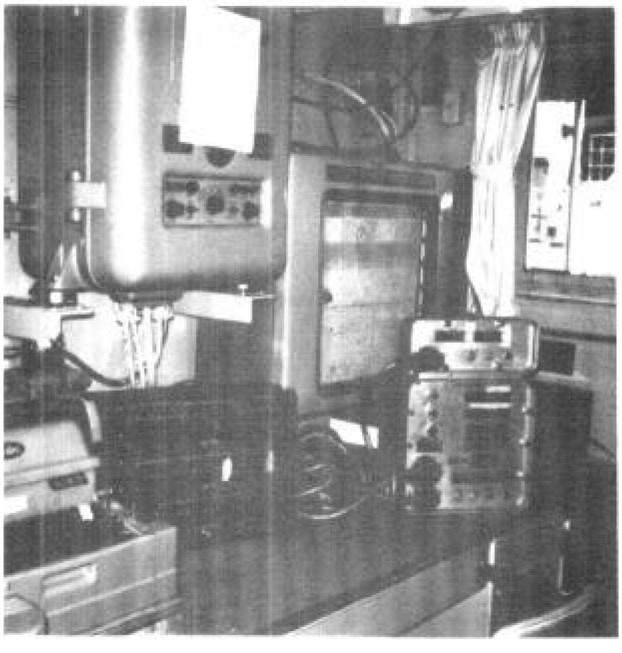


FIGURE AJ–4. — Hydrographic data logger aboard the **NOAA** ship *Davidson* this mode. In the automatic visual mode, position and depth data are taken from a source such as a Ross depth digitizer and a digital sextant (Ross Laboratories, Inc., Seattle, Washington). The word length varies between short and long, with a long word printed for every position update.

When in the manual mode, the operator keys in all depth and position data; time and position are automatically updated by the increment set in the time and position thumbwheels.

AK. TIDE AND WATER LEVEL GAGES

Tidal and water level gages are used to measure water surface heights and the times at which the heigths occur. These measurements are used to reduce observed soundings, taken at various tidal or water level stages, to the appropriate reference datum for the area. (See 1.5.4 1.) In areas where charted depths are referenced to tidal datums, the tidal datums are also determined from the water surface measurements.

Gages used exclusively to support hydrographic surveys shall conform to the requirements of this manual; however, gages to be used for both the **NOS** water levels program and hydrographic surveys shall conform to section 3.2 of the "Standing Project Instructions: Great Lakes Water Levels" (National Ocean Survey 1977*b*).

Gages that automatically record tidal or water level variations and corresponding time references are used for most **NOS** operations. Such data are recorded either graphically (marigram) or on punched paper tape. The gages most frequently used include (1) the analog to digital recording **(ADR)** gage (AK.1.2), (2) the gas-purging pressure gage, commonly called a "bubbler" gage (AK.1.3), and (3) the analog electric, weight, or spring-driven gage (AK.1.4).

Tide gages and water level recorders are similar instruments in that both rely on a float, float cable or float tape, and a float wheel as the basic measuring device. Because greater fluctuations of the water surface occur over shorter periods of time in tidal areas than in lakes, tide gages use a counterbalance spring in the measuring system. The spring takes up float-cable slack that is caused by sudden surges. Water level recorders are generally designed to measure more gradual changes in water surface heights.

Nonrecording gages include the simple staff (AK.2.1) and the electric tape gage (AK.2.2). Because observers are needed to record water heights and times, nonrecording gages are used only for short-term observations and as reference standards for automatic gages. Additional information on gages can be found in the Integrated Logistics Support Plan available from the Office of Oceanography, OA/C231.

AK.l. Automatic Gages

AK.1.1. STANDARD GAGES. These automatic gages used by the National Ocean Survey measure and record water levels by means of a float that is contained inside a stilling well. Use of a stilling well diminishes the effects of horizontal water movement and, by using a small intake opening, greatly reduces the effects of rapid changes in water level, such as surges generated by wind waves. A line attached to the float operates a worm screw on the gage—the worm screw drives a recording stylus across a strip of paper, and the paper is advanced at a uniform rate by a clock motor. The combined motion of the stylus and the paper produces a graphic or analog record (marigram) of the rise and fall of the tide or of variations in water level. (See figures AK-1 and AK-2.)

Standard automatic gages usually are installed only at control tide stations or at water level gaging control stations (i.e., stations that are maintained over a period of many years). Standard automatic gages are being phased out of use by **NOS** and few gages are now in operation. Because the records from control stations provide basic tidal and water level data of such importance, installation and maintenance procedures must meet rigorous standards to ensure the highest degree of reliability and precision of data. Essential equipment for a control station includes an automatic gage, a stilling well, a shelter, and a graduated staff or reference gage. A system of bench marks (AK.4) is established at each station. See U.S. Coast and Geodetic Survey (1965*a*) *Publication* 30—1, "Manual of Tide Observations."

AK.1.2. FISCHER AND PORTER ANALOG TO DIGITAL RECORDING (ADR) GAGE. The following information was extracted from the Fischer and Porter Co. (1972) *Instruction Bulletin for Type 1550 and 1551 Punched Tape Level Recorder (Spring Counter Balance Type), Design Level "C.*" Their complete address is Fischer and Porter Company, Warminster, Pennsylvania 18974.

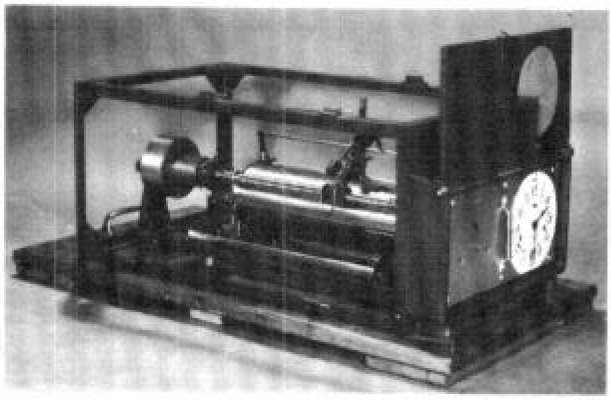


FIGURE AK–1. — Standard tide gage

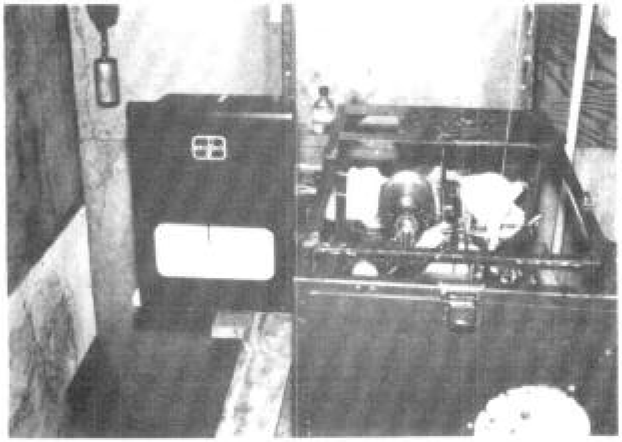


FIGURE AK–2.—Standard tide gage installation

Fischer and Porter (ADR) water level recorders, figures AK–3 and AK–4, mechanically convert angular positions of a rotating shaft into coded digital output, then punch these digital values on paper tape at selected time intervals. These instruments are designed specifically to measure liquid level by means of a cable, drum, and float assembly. This measurement source can be geared to the instrument to obtain any convenient ratio between rotation of the recorder input shaft and rotation of the primary actuating unit shaft.

The type 1550 recorder is contained in a weatherproof housing and is mounted on a 4-in pipe. The type 1551 recorder is flat, surface mounted in a dust-tight housing. Both instruments use a 7.5-V d.c. battery for power. A push button on the front plate initiates a tape punch on demand.

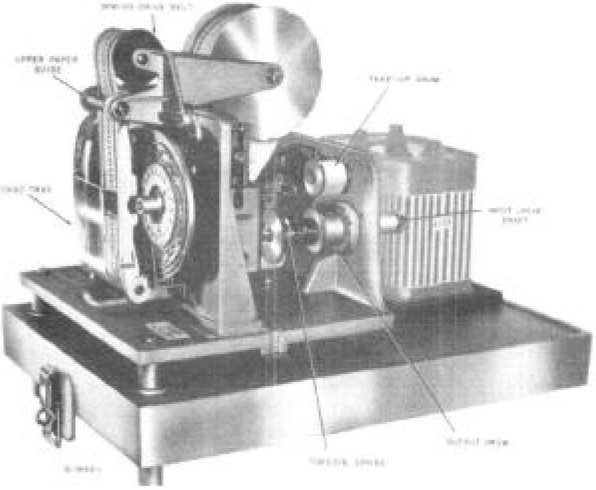


FIGURE AK–3. — Front view of a Fischer and Porter water level recorder (courtesy of Fischer and Porter, Warminster, Pennsylvania)

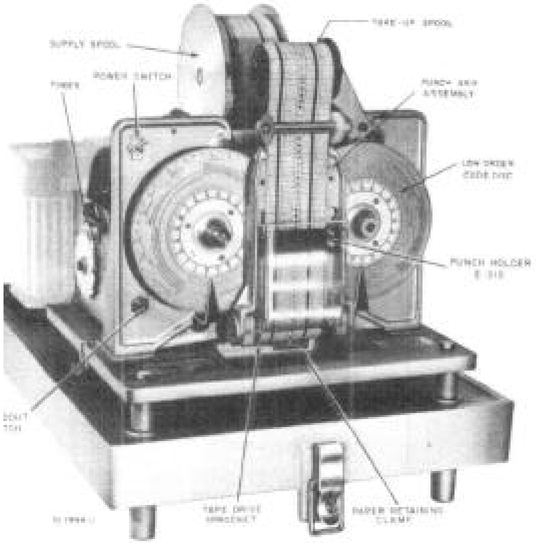


FIGURE AK–4. — Side view of a Fischer and Porter water level recorder (courtesy of Fischer and Porter, Warminster, Pennsylvania)

The measuring device consists of a float in a vertical stilling well or pipe, a float cable, a float wheel, and a spring counterbalance. Use of the spring counterbalance eliminates the need for counterweights, thus permitting a smaller well; however, on the Great Lakes, the Fischer and Porter Model 1542 is often used (counterweight vice spring counterbalance).

Fischer and Porter ADR gages have a maximum operating range of 50 ft. Water level heights are measured to the nearest hundredth of a foot. Ocean tides are recorded at 6-min intervals—Great Lakes water levels are recorded at 5-, 6-, and 15-min intervals.

Although the punched tape record is intended to be processed by high-speed mechanical scanning methods, time and height values can be decoded easily. (See figure AK-5.) Each horizontal row of punched holes represents, in digital form, the total amount of shaft rotation. The row is divided into four sections that represent, in binary coded decimal form, the tens, units, tenths, and hundredths digits of the value — a quick mental summation of the bit values provides the digital value. Each gage is also equipped with graduated disks for direct reading of times and heights. A combination of electrical connections are available to permit data telemetry.

The punched tape recorder mechanism is sequentially and mechanically interlocked, thus making it impossible for a function or action to be out of phase with the others. The operation of a

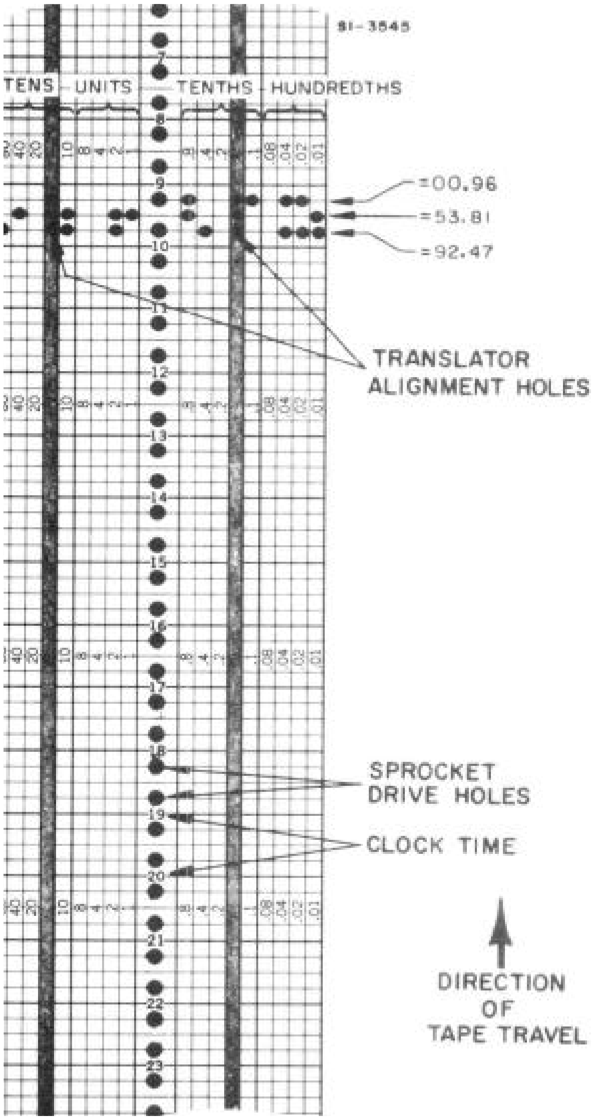


FIGURE AK–5. — Fischer and Porter punched tape record (courtesy of Fischer and Porter, Warminster, Pennsylvania)

punched tape recorder is best described as an interrelated function of two separate mechanisms — the input gearing-count memory system and the punch programming cycle system. The input system detects shaft rotation, then converts the amount of rotation to successive positions of the memory code disks. By means of a timing device, the punch-programming system initiates the punch demand, then triggers the proper punching and reset operations required to record the measured values on tape.

Fischer and Porter recording gages are rug- design and are mounted in weatherproof cases that make tape changing and routine maintenance easy.

AK.1.3. GAS-PURGED PRESSURE GAGE. These pressure-recording gages (commonly called "bubbler" gages) are used to obtain tidal or water level data in areas where the installation of structure-supported gages would be impractical. (See figure AK-6.) Detailed procedures for installation, operation, and maintenance are contained in the "User's Guide for the Gas-Purged Pressure Recording Bubbler Tide Gage" (Young 1976).

Bubbler gages are portable pressure-recording instruments that produce a continuous strip chart record of water level changes. (See figure AK-7.) The underwater part of the gage consists of a small bubbler orifice chamber attached to a gas supply tube. The shore end of the tubing is connected to the gas system (pressure-regulating mechanism and gas storage tank) and to the transducer (temperature-compensated pressure bellows) of a strip chart

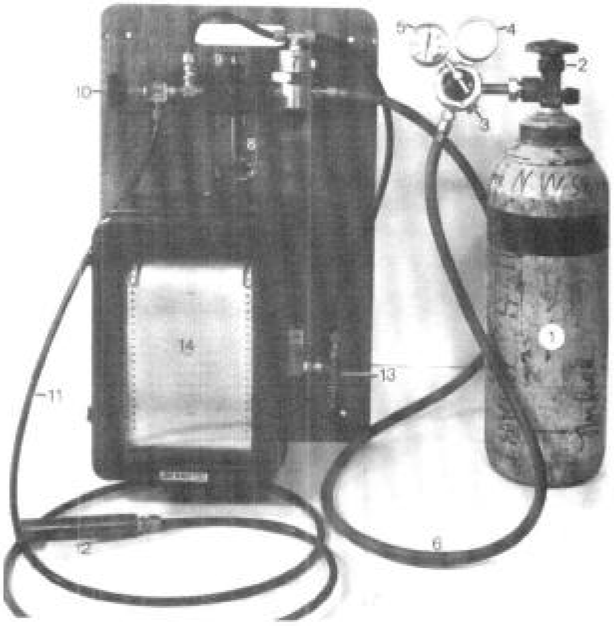


FIGURE AK–6.— Gas-purged pressure (bubbler) gage components 1, nitrogen tank; 2, high-pressure valve; 3, pressure-reducing valve; 4, high-pressure gage; 5, low-feed pressure gage; 6, supply hose; 7, pressure differential regulator; 8, transparent bubble chamber; 9, adjustable needle valve; 10, shut-off valve; 11, orifice supply line; 12, orifice; 13, dampening valve; and 14 recorder

recorder. Nitrogen gas is used because it is inert, dry, inexpensive, and readily available. Gas cylinders are available in three sizes. The smallest cylinder, 35 ft³, supplies the system for about 3 mo of normal use. Figure AK–8 shows the gas flow system

The operating principles of a bubbler gage system are simple and straightforward. When gas is bubbled freely into a liquid from the fixed end of a tube, the pressure in the entire length of the tube is approximately equal to the the pressure head of the liquid over the bubble orifice. Any change in the hydrostatic pressure, such as that caused by a change of water level, is transmitted by gas pressure through the tubing to the transducer bellows of the recorder where pressure variations are recorded. Use of a specially designed bubbler orifice chamber at the underwater end of the tube prevents rapid expulsion of gas and rise of water level in the tube, which would result from large waves if only a tube of fixed open end were used. Thus, errors caused by wave action are reduced to within practical limits of accuracy. The required rate of gas supply is determined by the maximum rate of water height increase and the volume of the system, including the orifice chamber, supply lines, and bellows. The rate of supply can be measured by counting the bubbles as the

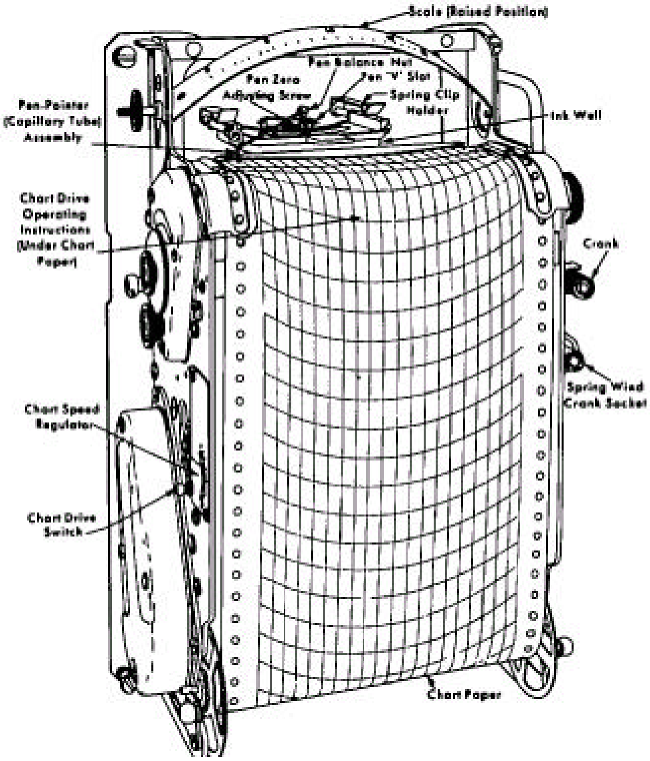


FIGURE AK–7.— Bubbler gage strip chart recorder (cover removed)

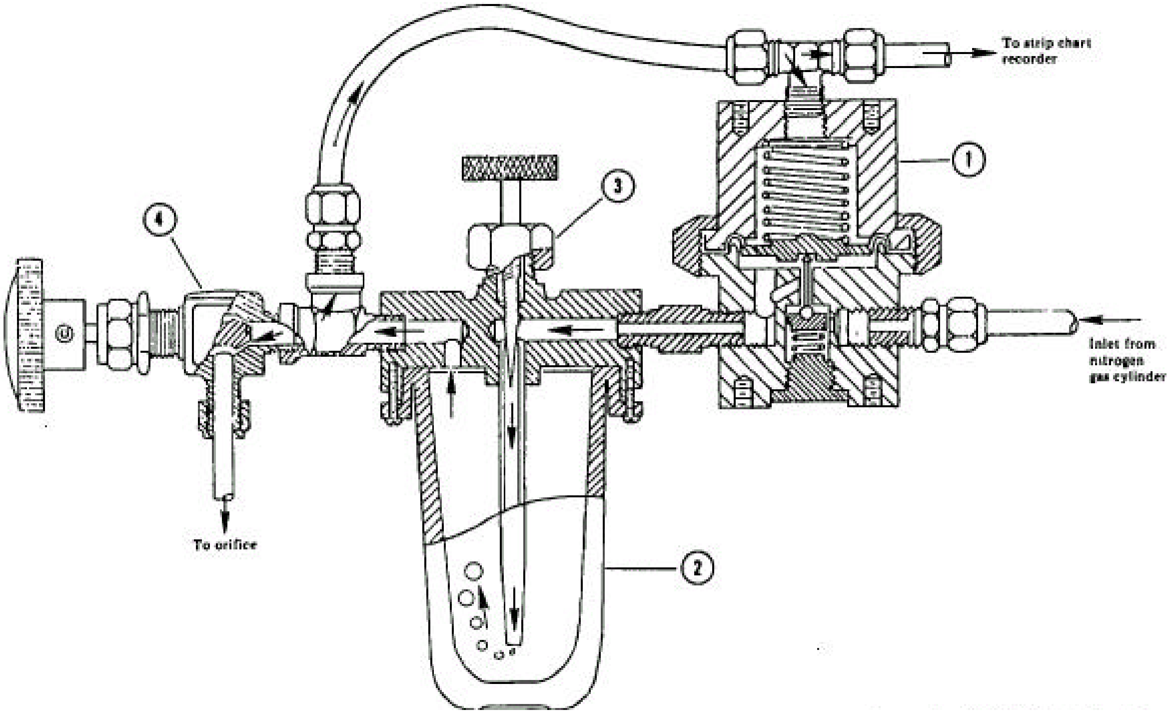


FIGURE AK–8.— Bubbler gage gas flow system components 1, constant differential pressure regulator; 2, oil-filled sight jar flow meter; 3, flow-regulating needle valve; and 4, shut-off valve gas is released through oil in a transparent bubble chamber and can be regulated by an adjustable needle valve.

The pressure sensing and recording elements of the bubbler gage are designed and calibrated to register depth with an error less than 1% of the full-scale values. Temperature-induced water density changes are not measurable. Errors caused by variations in salinity are usually so small that they may be ignored, but in extreme cases may become significant. Changes in atmospheric pressure do not affect water level records because the atmospheric effects on the bellows and on the surface of the water are equal. Pressure errors caused by friction of flowing nitrogen in the orifice tubing can be great. Such errors occur when high purging rates or excessive lengths of tubing are used. Pressure errors are minimized by maintaining recommended purge rates and limiting orifice tubing lengths to 800 m.

The gas-purging pressure-recording gage does not require a supporting structure. It can be used on open beaches, on shoals, at sites where it is impractical to install or use other types of tide gages, and where distances up to 800 m separate the orifice chamber and the recorder. The recorder can be placed in a buoy, on an offshore platform, or ashore. It also can be adapted to telemetering from remote and inaccessible areas. When installing a gage, the orifice chamber should be secured to a pipe that is driven into the ocean bottom or be embedded in a block of concrete. The tubing from the orifice chamber to the recorder may be lashed to a weighted cable, must be securely fastened at the inshore end. If the installation of a staff is impractical, datums for the observations may be established by referencing the elevation of the orifice chamber to the top of the pipe, which in turn is referenced to the elevation of bench marks.

AK.1.4. STEVENS WATER LEVEL RECORDER. The Stevens Type A, Model 71, Water Level Recorder (figure AK-9), currently in use at many Great Lakes water level gaging stations, provides data essential for hydrographic surveys and provides hydrologic and hydraulic information needed for engineering studies, water resources development research, publication of water levels data, and many other purposes. The following description of the system was extracted from Leupold and Stevens (1976) *Bulletin* 12, 24th Edition. Their address is Leupold & Stevens, Inc., P.O. Box 688, Beaverton, Oregon 97005.

Water level sensing is accomplished by a float, enclosed in a stilling well, and a beaded float line or float tape passing over a spined float pulley. A counterweight keeps the float line or float tape taut. As water levels change, the pulley rotates. By mechanical gearing, pulley rotation is translated to horizontal movement of a recording stylus. The stylus records the water levels on a strip chart that moves at a predetermined rate controlled by a clock movement. A 12-lb weight on a cable drives the clock.

The recording mechanism is precision made and ball bearing equipped and will respond to a 0.01-ft change in water level on a 1:6 recording ratio with a 10-in float. Interchangeable gears and pulleys permit easy changes to strip chart advancement rate and vertical motion scale. The instruments can be quickly converted in the field from English to metric measurements and vice versa. Strip charts graduated in metric units are available.

AK.2. Nonrecording Gages

These gages, such as the tide or water level staff and the electric tape gage, are used for (1) short-term tidal or water level observations for hydrographic surveys and (2) as a reference standard for comparative observations at automatic gage sites.

AK.2.1. TIDE STAFF. The simplest tide or water level gage is a plain staff or board, 1 or 2 in thick, 4 to 6 in wide, and graduated in feet and tenths. Staffs are normally secured vertically to pilings or other suitable supports and must be long enough to permit observations throughout the full range of tides or water levels. Because painted graduations on boards become illegible after short periods in salt water, **NOS** uses scales that are made by baking a vitrified coating onto wrought iron strips. The strips are about 2.5 in wide and 3 ft long and when placed end to end form a continuous scale. (See figure AK–10.) Each strip is secured to a wooden staff, using brass screws and lead washers. Graduated aluminum staffs are generally used at Great Lakes hydrographic water-gaging stations.

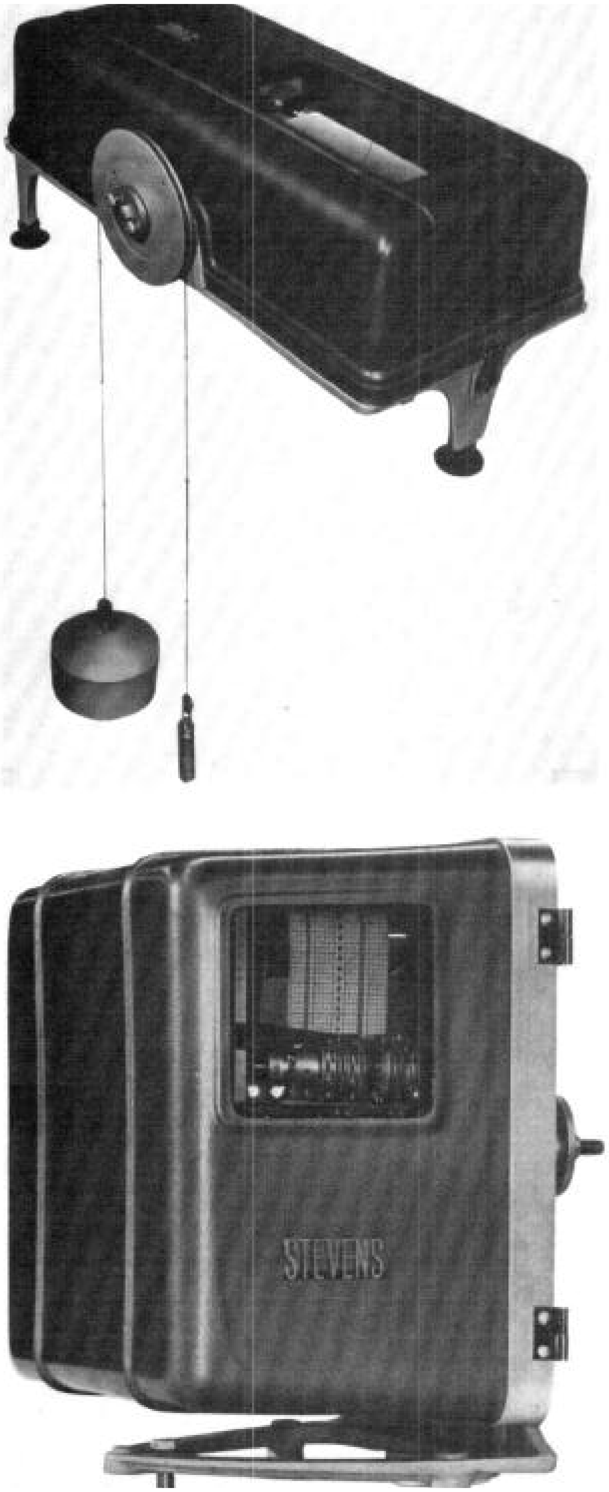


FIGURE AK–9. — (Top) Stevens water level recorder and (bottom) digital recorder (courtesy of Leupold and Stevens, Inc., Beaverton, Oregon)

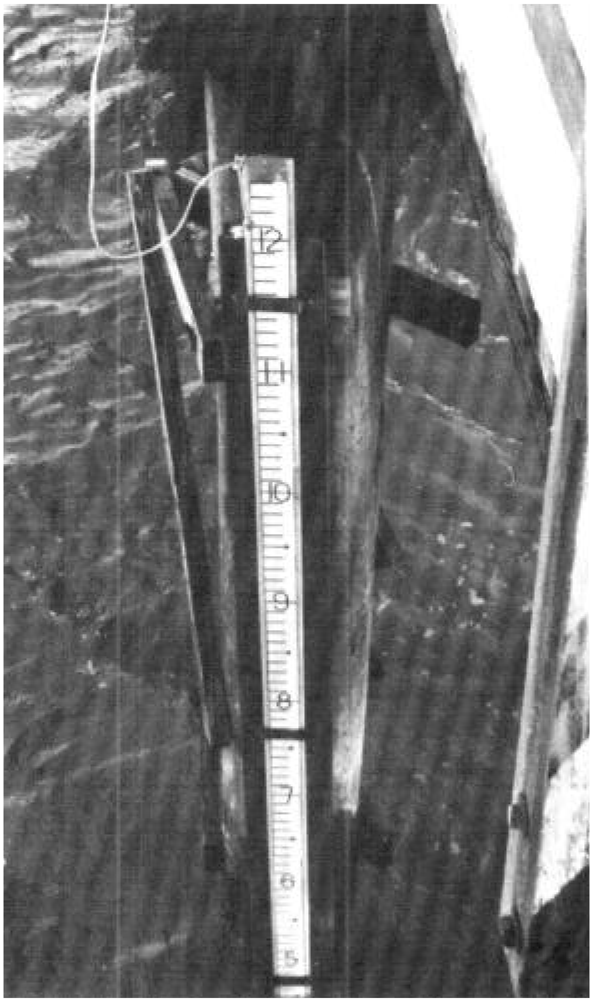


FIGURE AK–10. — Tide or water level staff installation

Observations of tides or water levels on simple staffs are often used by hydrographers in small areas where anomalies caused by meteorological conditions or landmass configuration are suspected and when the length of observations will not be more than a few days.

For obtaining accurate values for reducing soundings to the datum of reference, temporary staffs must be installed as near as possible to the sounded area. In tidal waters, observations are recorded continuously throughout the portion of the day that soundings are taken, and are extended each day as necessary to include at least one high water and one low water value on the staff. In nontidal waters, observations need be recorded only during sounding operations. Staff observations are entered at 15-min intervals in **NOAA** Form 77-53, "Tides — Location of Tide Staff."

Tidal staff observations are correlated to the sounding datum by one of the following methods: (1) an automatic recording gage is nearby and operating simultaneously—the automatic gage must have been operating continuously or is scheduled to operate for at least 30 days; or (2) levels are run between the staff and nearby existing bench marks—elevations of the bench marks with respect to the sounding datum must be known. Water level gages or staffs must always be tied to a reference datum by leveling.

For detecting lifting or settling of a temporary staff, levels are run between the staff and three nearby recoverable points prior to beginning observations, then again after all observations have been completed. These recoverable points need not be marked by survey disks but should be described. The leveling data can also be used to reestablish the sounding datum should the staff site be reactivated after discontinuance. See AK.4 for specifications and guidance on leveling procedures.

Accurate staff observations are difficult to obtain when the water is rough. One satisfactory and proven solution is to attach a clear glass or plastic tube (about 0.5 in in diameter) next to the staff graduations using spring clips or other suitable fasteners. Partially close the lower end of the tube with a notched cork or rubber plug to damp wave surges. Leave the upper end of the tube open. Water level heights in the tube are read from the graduated scale.

When a staff remains in the water for long periods, particularly in harbors where refuse and oil contaminants are present, graduation markings rapidly become illegible. In such cases, a portable staff, which is easily removed from a permanent support, is often used. Such staffs may be hinged in sections for convenient storage. The permanent staff support must be rigidly secured so that zero on the graduated scale will always be at the same elevation when placed in the water for use. Staff supports are usually planks, 2 in wide and nearly as long as the staff. Protect the wood from teredos and other marine borers by a cover of copper sheathing. The staff is held to the support in a vertical position by metal guides at intervals along the support. To keep the zero point of the staff at a fixed elevation, mount a metal plate shoulder at the top of the support. When the staff is inserted in the metal guides, the metal stop that is secured to the back of the staff rests firmly on the metal shoulder of the support.

AK.2.2. TAPE GAGES. These are often used in place of staffs at exposed locations where staff cannot be read conveniently or if the water is too rough for accurate readings.

The *electric* tape gage **(ETG)** (figure AK-11) consists of a Monel metal tape conductor attached to a metal drum and supporting frame, a voltmeter, and a 4.5- or 6-V battery. The tape, which is graduated in hundredths of feet, is connected through the frame to one of the terminals of the battery. The other terminal is grounded to the water in the stilling well by a connecting wire that leads either to the metal wall of the well or directly to the water in the well if the well is made of nonconducting material. The electric circuit is completed when the weight at the free end of the tape strikes the water surface. Contact is indicated by a movement of the needle on the voltmeter dial. At that instant, the graduated tape is read at the reading mark (zero electric tape gage) of the gage to give the distance of the water surface below the reading mark. The reading mark is referenced in elevation by differential levels to local bench marks.

AK.2.3. COMPARATIVE OBSERVATIONS. These are required to determine the relationship between the staff or tape gage and the height datum of the gage continuous record. This relationship should remain stable throughout the operation of a tide or water level station. If a new staff or tape gage is installed during the series, the original index setting of the automatic recording gage should neither be altered nor be reset to new staff values. Corrections to the data are applied by using the difference in elevation between the old staff and the new staff as determined by differential levels. If a recording gage is replaced, the index of the new gage shall be reset to a value which will make the gage-to-staff difference approximately 5 feet greater or less than the previous gage-to-staff difference. Any disturbance of an electric tape gage will necessitate releveling to determine the new zero electric tape gage elevation. Tidal analog to digital recorders should be set to read 10 ft above the staff reading to avoid negative values. At the time of leveling, concluding establishment of a gage, or before dismantling any gage or station, careful simultaneous water level readings shall be taken on all gages and staffs.

Five comparative observations per week are needed to obtain a statistically significant number of staff readings that will precisely relate the

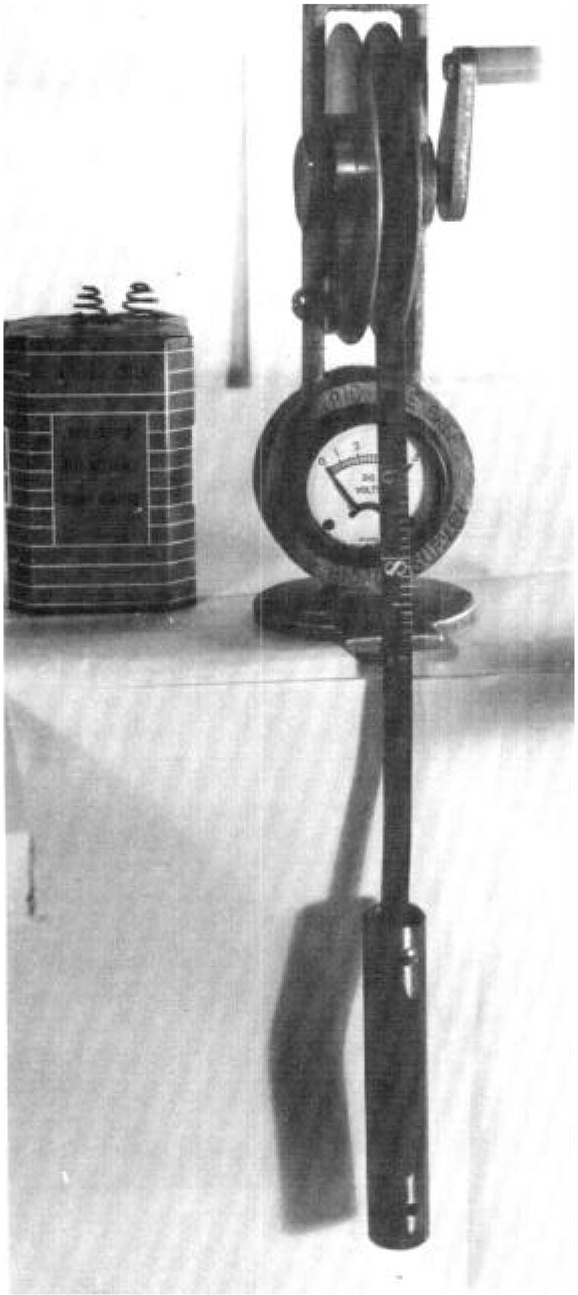


FIGURE AK–11.— Tide or water level electric tape gage

gage datum to the staff. Fewer readings reduce the degree of accuracy of datum determination. See U.S. Coast and Geodetic Survey (1965*a*) *Publication* 30-1 for detailed instructions on comparative observations.

AK.4. Bench Marks and Leveling

Five recoverable bench marks shall be established within a 1-mi (1.6-km) radius of each continuous recording tide station or water level reference gage. Each of the bench marks must be connected to the gage staff (or measuring mark) by third-order leveling. These marks are estabished to: (1) protect against the loss of the vertical datum, once determined, (2) provide a reference to which tide and water level observations are ulimately correlated, and (3) detect settlement or lift of the gage and staff.

A bench mark is a marked vertical control point on a relatively permanent object, natural or cultural; its elevation with respect to a datum is known. Bench marks established in the vicinity of a tide station for the reasons stated above are called "tidal bench marks"—those in the vicinity of a Great Lakes water level gaging station are simply called "bench marks."

Tidal bench marks shall be connected by levels to any other bench marks within 1 mi (1.6 km) of the tide station that have been adjusted into the National Geodetic Vertical Network (formerly the Sea Level Datum of 1929). To determine whether there are any such bench marks in the vicinity, consult the appropriate **NOS** State Map for Control Leveling or the Geodetic Control Diagram for the area. (Horizontal control stations are often included in the vertical network as well.) A network bench mark or horizontal control station that is included in a tidal bench mark level circuit is considered to be one of the required five marks. Include bench marks established by other organizations, if practical. Tidal bench mark elevations are referenced to **MLLW**. In the Great Lakes, lake levels are referred to bench marks on the International Great Lakes Datum (**IGLD**) of 1955.

Standard National Ocean Survey disks are used to identify bench marks established at tide stations or gage sites. Each disk has a long shank for cementing the mark into a structure, concrete surface, or survey monument. Bench mark identification numbers are assigned by the Office of Oceanography, **NOS**, and included in the project instructions; tidal bench mark numbers are assigned by the Tidal Requirements and Acquisition Branch (OA/C231) and Great Lakes bench mark numbers are assigned by the Water Levels Branch (OA/C234). Tidal bench marks are identified by a four-digit number and letter with the number representing the tide station and the letter indicating the established sequence of the bench mark. This identification number and the year the bench mark was established is stamped with a die set on each disk. Duplication of numbers and letters must always be avoided. For example, five new tidal bench marks set at tide station 924–1234 would be identified and stamped 1234A, 1234B, 1234C, 1234D, and 1234E, along with the year established. If a new mark is set, this identification sequence would be retained (i.e., 1234F, even if this new mark was set to replace a previously established and numbered mark).

The principal qualities of a good bench mark are permanence, stability, and recoverability. In settled areas, substantial building foundations are excellent bench mark sites. In undeveloped areas, rock ledges or partially buried masses of concrete are suitable foundations for bench mark disks. Permanent bench marks should not be located on hydrants, trees, curbstones, or structures vulnerable to change. Such objects may, however, be used as temporary bench marks for expedience during a leveling run. *Coast and Geodetic Survey Special Publication* No. 239, "Manual of Geodetic Leveling" (Rappleye 1949) and U.S. Coast and Geodetic Survey (1965*a*) *Publication* 30–1, "Manual of Tide Observations," and "Users Guide for the Establishment of Tidal Bench Marks and Leveling Requirements for Tide Stations" (1977) contain detailed guidance and standards for bench mark placement and leveling.

A complete description for each bench mark established must be prepared to accompany **NOAA** Form 76–77, "Leveling Record—Tide Station," each time differential levels are run for a tide or water level gage station. Descriptions must be clear, distinct, and detailed enough to permit easy recovery and identification. If a disk is used, the description must state whether the number and establishment year are stamped on the mark. If a bench mark is located on a building, give the street and number—otherwise, indicate the owner's name. When a bench mark is not on a prominent structure, reference it by distance and direction to several prominent nearby objects. Draw a sketch to help future location and identification of the mark.

Third–order levels must be run between the gage staff and the bench marks whenever a tide or water level gaging station is established. Levels are run again when station observations are terminated. Gages scheduled to continue operating after a hydrographic party leaves an area are leveled prior to departure. Before using data from such a gage at a later date, levels must be run to detect any change in the elevation of the staff.

The graduated lines on vitrified staffs are about 0.01 ft wide. The middle of each line is the reference for heights. If a portable staff is used, the leveling rod should be held on the flat top of the staff support (i.e., the lower staff stop). The staff reading at the staff support must be entered in the record. This value is easily determined from the position of the upper metal stop attached to the back of the staff. Be sure to place the staff in its support to ensure that the upper staff stop comes in actual contact with the lower staff stop on the support without interference. When a tape gage is used, third-order levels are run from the reading mark of the gage to the bench marks. The relation of the reading mark to the tape-gage datum is determined from the value of the plane of flotation.

Levels between marks must be checked by a forward and a backward run. The closing error, in feet, must not exceed $\pm 0.035 \pm M$ where M is the distance in statute miles over which levels were run between adjacent bench marks. Table AK-1 based on the formula,

$$\text{maximum error} = \pm 0.035 \sqrt{M},$$

gives the maximum allowable closures for selected distances in feet between bench marks.

If the difference between the results from the forward and backward lines between any two bench marks exceeds the allowable error, the section shall be rerun until a forward and backward difference falls within the allowable error limits. Questionable values from previous runs should not be used with new levels to obtain agreement.

TABLE AK–1.— *Maximum allowable leveling error between bench marks*

Distance between bench marks	Maximum error allowed
(feet)	(foot)
One setup	0.006
500	.011
1,000	.015
2,000	.021
3,000	.027
4,000	.030
5,000	.034

AL. MISCELLANEOUS EQUIPMENT

AL.1. Protractors

AL.1.1. PLASTIC THREE-ARM PROTRACTORS. Three-point sextant fixes can be plotted using a plastic three-arm protractor. Although automation has nearly eliminated the drudgery of hand plotting every position taken during a survey, the three-arm protractor remains a versatile and indispensable tool of the hydrographer. Plastic protractors are transparent and are available in several arm lengths for plotting convenience.

One fixed arm and two movable arms each contain an etched line that is radial with the center of the protractor. Each movable arm has a vernier graduated in 2-min intervals—angles can be estimated to the nearest minute. Plastic protractors are available with arms either 13.5 or 24 in long. (See figure AL–1.)

Plastic protractors cannot be adjusted, but must be tested for index correction and warping. The radial lines on the arms are checked for straightness by superimposing them over a steel straightedge. To determine index correction, place the protractor on a test plate, match the etched lines with the lines on the test plate at 30%, 60%, and 90%, then read the angles on the protractor. Differences, if any, represent index corrections.

Plastic protractors used during verification to plot final positions are calibrated as follows: draw a straight line on stable-base drafting film; then carefully construct a perpendicular to that line. (See figure AL-2.) From point *A*, measure off 50 cm to point *B*. From the same point, measure 18.2 cm (50 cm x tan 20°) along each perpendicular to points *C* and *C'*. Center the protractor over point *B* and aline the fixed arm through point *A*. The angles through *C* and *C'* should read exactly 20°. Any differences are applied to scaled angles as index corrections. Plastic protractors used for smooth plotting should be compared daily against a standard.

AL.1.2. ODESSEY PROTRACTORS. Positions determined from electronic ranging systems can be quickly and accurately hand plotted using an Odessey protractor (figure AL–3) provided that lattice lines have been drawn on the survey sheet. (See 4.5.5.) The protractor is simply a series of graduated closely spaced concentric circles etched on clear plastic. The circles represent distances from the template center in the output units of the electronic positioning system used. The protractor is maneuvered until the difference in distance between each observed range value and the plotted lattice line closest to that value is in register with the concentric distance circles. A small hole in the center of the, protractor permits a pinhole to be pricked at the plotted position.

Each protractor is especially constructed for the scale of the plotting sheet and measuring units

FIGURE AL–1.— Plastic three-arm protractors

AC and AC' = tan 20° x 50 cm

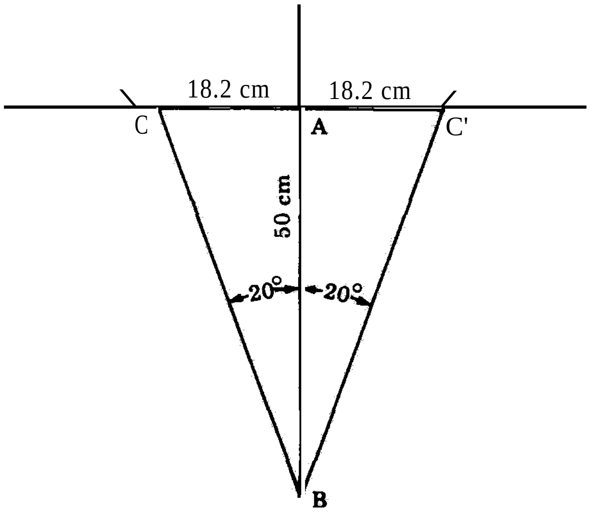


FIGURE AL-2.— Calibration of a three-arm protractor

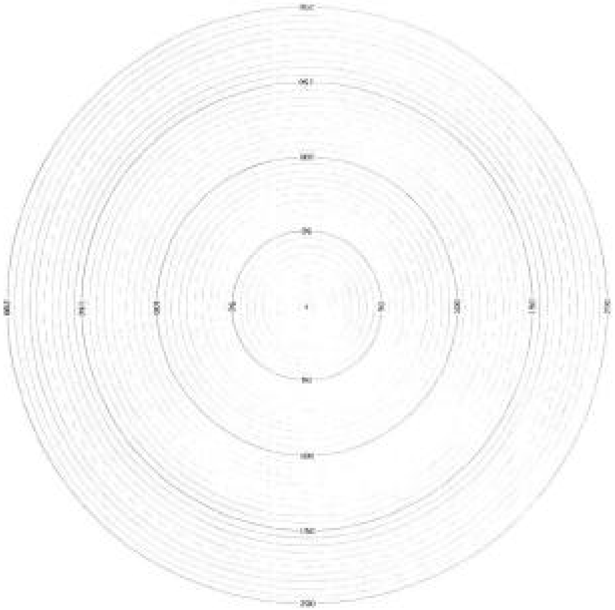


FIGURE AL–3. — Odessey protractor

of the electronic positioning system. The largest distance circle on the protractor is usually made to be twice the interval of the lattice lines on the survey sheet.

AL.1.3. DRAFTING MACHINE. Mechanical drafting machines are used to hand plot vessel positions and soundings on surveys controlled by the theodolite intersection method. (See 4.4.2.2.) When properly used with geometrically strong control, positions can be rapidly and accurately plotted with the instrument. The engineer's drafting machine is a refinement of the parallel motion protractor. (See figure AL-4.)

The two basic components of a drafting machine are an azimuth circle or protractor and an azimuth-measuring arm. The azimuth circle is 10 to 12 cm in diameter, is graduated to the nearest 0.5° of arc from 0° to 360°, and can be set and locked in any azimuthal orientation. The azimuth-measuring arm has a double vernier graduated to the nearest minute of arc and can be locked to permit an angle or azimuth to be moved across the plotting surface while maintaining positive directional orientation of the instrument. A variety of plain or graduated straightedges 15 to 36 cm long can be rigidly attached to the arm for projecting directional measurements.

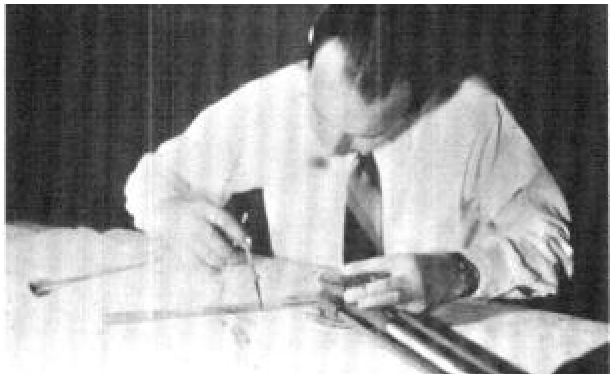


FIGURE AL–4. — Engineer's drafting machine

The azimuth circle and arm are mounted on the working end of a jointed arm or carrier. The reversible joint or elbow at the midpoint of the arm provides lateral folding and corresponding extension capability of the instrument. The stationary end of the arm pivots laterally on a vise clamp that is attached to the plotting board or drafting table.

After the control stations have been plotted and the azimuthal orientations of the theodolites are established on a hydrographic sheet, the machine is clamped to the plotting board.

The azimuth circle is then properly oriented and locked. An orientation reference line is drawn on the sheet for occasional checks to guard against slippage. Observed theodolite or transit directions are duplicated on the azimuth circle by setting and locking the values on the measuring arm of the protractor. The inner end of the protractor straightedge is aligned over the proper "cutoff" stations and the line of position indicated by a short pencil line drawn across the approximate track of the sounding vessel. Intersecting lines or "cuts" observed simultaneously establish the position.

Engineers' drafting machines are lightweight portable instruments that can also be used to manually plot and verify plotted control stations, landmarks, and aids to navigation.

AL.2. Oceanographic Equipment

AL.2.1. NANSEN BOTTLE. This bottle (figure AL-5) is the senior member of a rapidly growing family of devices used to obtain water samples from various depths for the measurement of their physical properties. Although many more modern and versatile devices are available, the Nansen bottle remains the classical standby for gathering temperature and salinity data needed to determine sound velocity corrections and for field checking the accuracy of more sophisticated electronic sensors.

The Nansen bottle is a cylindrical metal reversing water sampler with a 1.25 L (2.25-pint) capacity. Each end of the bottle is fitted with a slit valve. The slit valves are joined by a connecting rod that controls the opening and closing mechanism. The bottom of each bottle is clamped firmly to the lowering cable; the top of each bottle is connected to the cable by a mechanical tripping device. When a bottle is lowered to the desired depth, the valves are opened, permitting contaminants to be flushed out and an in situ sample to flow through the bottle. A mechanical messenger device slides down the cable, releases the tripping device at the top of the bottle, and causes the bottle to become upended or reversed. When reversed, the bottle is suspended from the cable by the bottom clamp. When the bottle is tripped, two other events occur: (1) the connecting rod shifts and closes the end valves causing the in situ sample to be trapped in the bottle and (2) a messenger attached to the bottom of the bottle is released and begins its travel down the cable to trip the next bottle.

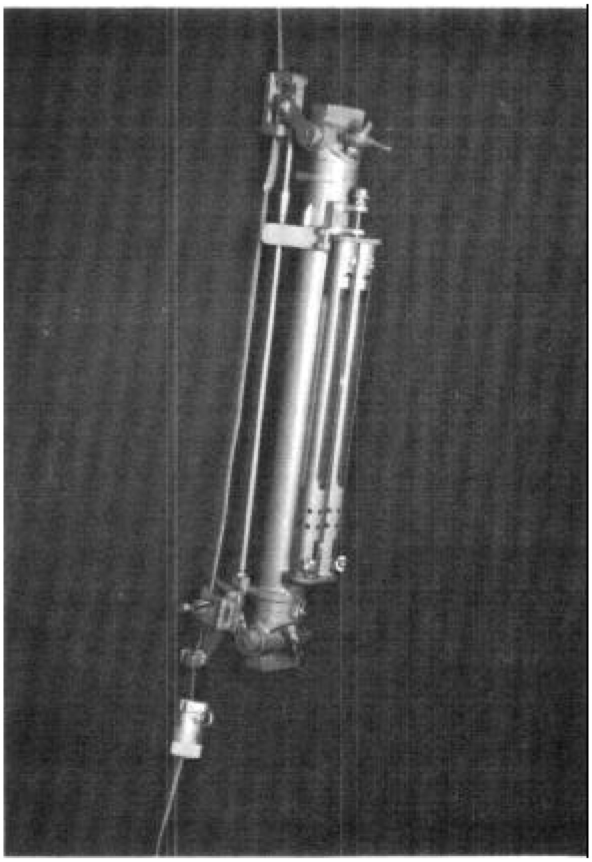


FIGURE AL–5.— Nansen bottle

Each bottle is equipped with a frame designed to hold two protected and one unprotected deep sea reversing thermometers. (See AL.2.2.) Brass tubes in the frame are slotted for easy reading of thermometer scales. One end of the tube is perforated to permit water circulation around the thermometer. The large reservoir end of the thermometer is placed at this end of the tube. Rubber pads backed by helical springs are fitted in each end of the tube to hold the thermometer securely in place and to protect it against shock.

Nansen bottles must be carefully checked before use to ensure that all moving parts are lubricated and move freely. Close the air vent and draincock; then secure the bottle to the wire with the clamp and fulcrum assembly at the bottom. A messenger is attached to all but the lowest bottle on the cast. Before lowering a bottle, be sure that the mercury in each thermometer has drained down to the main reservoir.

Not more than 12 Nansen bottles should be used on a cast with 5/32-in wire; not more than 5 should be used with standard bathythermograph winch cable. As the bottles are lowered, a flushing action of their contents occurs; however, flushing is incomplete when the bottles reach the sampling depths. Before releasing a messenger down the cable, let the bottles stand open at the sampling depths for at least 6 min to ensure complete flushing of their contents and registration of correct thermometer temperatures. The wire angle is measured and recorded immediately before or after releasing the messenger. Messengers fall at rates from 150 to 200 m/min, depending on the angle of the wire. Do not haul in the cast until the bottom bottle has been reversed. On shallower casts, the release of each bottle can be detected by a slight vibration of the cable.

Always use the oceanographic winch cautiously and give consideration to the sea state—never begin paying out or brake rapidly. Sudden jolts or excessive strain can part the cable or cause the string of bottles to be tripped before the proper time.

When the cast is hauled aboard, each Nansen bottle is detached from the cable as it reaches the surface and is placed in a specially constructed rack. Water samples are drawn into glass bottles, and the thermometer temperatures are recorded. Water samples may be analyzed for such properties as salinity, dissolved oxygen content, or various nutrients. Detailed instructions for drawing and preserving water samples are contained in the U.S. Naval Oceanographic Office (1968) *Publication* No. 607. When sample analysis is limited to determining salinity for echo-sounding corrections, each sample may be drawn in a hydrometer jar for a measurement of specific gravity (AL.2.4). Salinometers are usually used aboard larger vessels for salinity determinations. (See AL.2.3.) When samples are titrated to determine chlorinity, salinity values may be determined by using table 16 in U.S. Naval Oceanographic Office (1968) *Publication* No. 607 or by the formula,

salinity = 0.03 + 1.805 x chlorinity ‰.

AL.2.2. REVERSING THERMOMETERS. Precision reversing thermometers used for Nansen bottle casts are graduated to 0.1°C and are accurate to a few hundredths of a degree. (See figure AL-6.)

Reversing thermometers are delicate instruments and must be handled with extreme care at all times, A protected reversing thermometer and its auxiliary thermometer are enclosed in a heavy glass case that is sealed at both ends for protection against pressure at the depths at which they are used. The special features of a reversing thermometer include a knife edge in the capillary tube that is made by an appendage in the tube, a gooseneck (which may be a U-turn, S-turn, or a complete circle), and a supplemental mercury reservoir at the opposite end from the main reservoir.

FIGURE AL–6.— Reversing thermometers

When the protected thermometer is reversed or inverted, the extra weight of the mercury in the enlarged section of the capillary tube in the gooseneck breaks the mercury column at the knife edge. Mercury flows into the supplemental reservoir, then into the graduated stem where the temperature is read when the instrument is held in an inverted position. Thus when the thermometer is reversed, the temperature at the depth of reversal is obtained. Because the jacket protects the thermometer from hydrostatic pressure, a true temperature is registered. If there is no auxiliary thermometer, the protected reversing thermometer is allowed to come to thermal equilibrium in an enclosed thermally stable location. Use a good-quality laboratory thermometer to determine ambient air temperature when reading values from reversing thermometers. Air temperature is recorded as the auxiliary temperature.

An unprotected reversing thermometer, similar to the protected type in most respects, is open at one end of the glass jacket. This opening permits the thermometer to come in direct contact with the water and be subjected to hydrostatic pressure. The unprotected reversing thermometer has no mercury surrounding the reservoir as does the protected thermometer. Such instruments do not give true temperature readings. Registered temperatures increase with depth. By lowering a protected and an unprotected thermometer together, the depth at which the thermometers were reversed can be determined by the difference in thermometer readings.

AL.2.2.1. *Care* of *reversing thermometers.* Deep-sea reversing thermometers are expensive delicate instruments. Each thermometer is carefully calibrated at considerable expense. Unless they are properly handled, the mercury column can be separated by gas bubbles in the capillary tube with a resultant loss of calibration. Observe the following precautions when using these instruments:

1. Never lay a reversing thermometer in a horizontal position.

2. When a thermometer is not being used, put it in its protective cylindrical container; store the container in a padded carrying case with the large mercury reservoir in a down position; and stow the carrying case in an upright position.

3. All thermometers should be washed in fresh water and dried before being stored.

4. Handle the thermometers gently. If the mercury fails to return from the supplemental reservoir, a light tap with the finger will usually bring it down.

5. Never store thermometers in Nansen bottle frames for long periods. If thermometers are left in Nansen bottle frames during a brief run between stations, place the bottles in a storage rack with the large mercury reservoirs down.

AL.2.2.2. *Corrections to observed temperatures.* A calibration certificate is furnished with each reversing thermometer; from the calibration data, graphs are drawn from which corrections can be scaled as needed. Although temperatures of maximum precision are not required for computing corrections to echo soundings, corrected temperatures must be accurate to ± 0.1°C.

Observed temperatures often contain small errors. One is caused by minor irregularities in the capillary tube and slight errors in the graduation markings. When this condition exists, the calibration curve retains its shape; but over a period of time, shifts slightly with respect to the freezing point. Corrections for this error can be determined only by recalibrating the thermometer.

Another error is caused by a change in the volume of mercury in the capillary tube and in the small reservoir. Volume changes occur with temperature changes when a thermometer is brought to the surface. The magnitude of this error can be computed from auxiliary thermometer readings. Detailed discussions on methods to compute and apply temperature corrections are contained in *H.O. Pub.* No. 614, "Processing Oceanographic Data" (LaFond 1951).

New reversing thermometers generally exhibit a greater drift in calibration values than do older thermometers because of the aging process that the glass undergoes. As the glass is exercised and cycled through general usage, it eventually stabilizes to an acceptable level of change. Because temperature accuracy requirements for oceanographic research projects are generally much more rigorous (often to the nearest 0.02°C) than for hydrographic applications, reversing thermometers shall be assigned and calibrated as follows:

1. *New* reversing thermometers, after an initial calibration, shall be assigned to vessels engaged in hydrography— recalibrate after 1 yr and every 5 yrs thereafter unless the instrument has been damaged or obviously is in error.

2. *Seasoned* reversing thermometers with well-documented stable calibration histories shall be assigned to vessels engaged in oceanographic investigations—calibrate once each year and at other times that the instrument is suspect.

AL.2.3. SALINOMETERS. Portable laboratory salinometers are frequently used aboard **NOS** vessels to determine salinity percentages of acquired water samples. (See figure AL–7.) Most instruments of this type use an inductive coupling to sense and measure the conductivity ratio between an unknown sample and a standard sea water sample such as Copenhagen Standard Sea Water. Modern instruments of this type automatically compensate for temperature differences between the known and the unknown sample. Conductivity ratios are recorded from an instrument meter, then converted to salinity from standard tables. Some salinometers have circuitry that permits salinity values to be read directly. Salinometer data are of sufficient accuracy for hydrographic applications and for most oceanographic observations.

AL.2.4. HYDROMETERS. When in situ sensors or salinometers are not available, salinity determinations can be made by measuring the specific gravity of a water sample with a hydrometer. Water sample temperature and specific gravity are measured using a hydrometer set (i.e., a hydrometer jar, an accurate laboratory thermometer graduated in °C, and a set of three hydrometers for various ranges of specific gravity). (See figure AL-8.)

A glass hydrometer has a small graduated stem and a bulb counterweighted for the graduation range. It is a very fragile instrument and must be handled carefully. Hydrometers are furnished in sets of three and are graduated for the following ranges of specific gravity: 0.9960 to 1.0110, 1.0100 to 1.0210, and 1.0200 to 1.0310. Only hydrometers for which a calibration table is available are to be used for specific gravity measurements.

FIGURE AL–7.— Induction-type salinometer (courtesy of Plessey Environmental Systems, San Diego, California)

Hydrometers are calibrated and graduated to register specific gravity when the sample is at the temperature of 15°C. (The specific gravity of fresh water at 4°C is unity.) Salinity tables are computed on this basis.

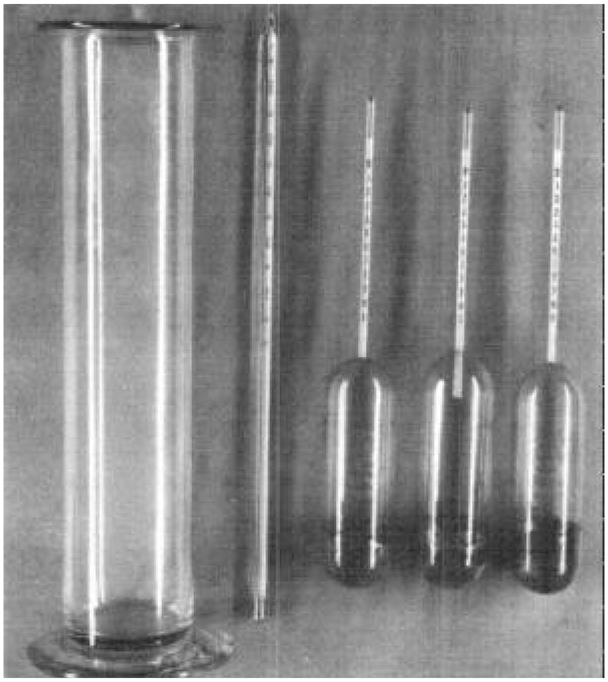


FIGURE AL–8.— NOS hydrometer set

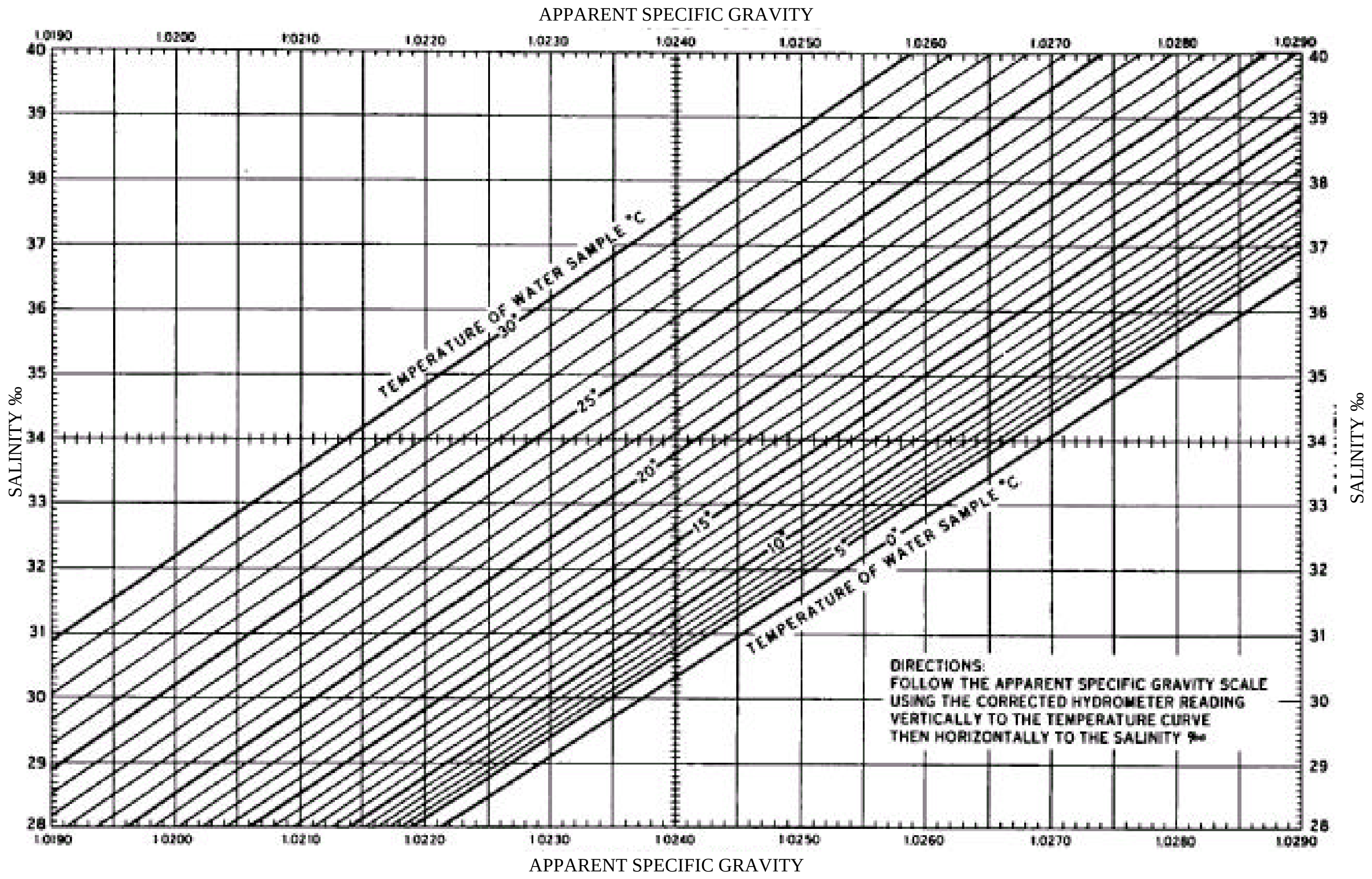
A sufficient quantity of a water sample is poured in a hydrometer jar so the hydrometer floats without touching bottom. Place the jar on a level bench or shelf—hold it in your hand if the vessel is rolling. Float the hydrometer and rotate it slowly; then insert the thermometer and wait until the mercury column comes to rest. To obtain accurate values, the hydrometer must float freely without touching the sides of the jar. Read the specific gravity of the water sample with the eye slightly below the water level in the jar. From this position, the water surface should appear as a straight line intersecting the graduations on the hydrometer stem. Observe and record the water temperature as soon as possible after reading the specific gravity. Disturb the hydrometer and repeat the observations as soon as it comes to rest.

Samples to be preserved for subsequent laboratory analysis are stored in properly labeled and identified citrate bottles. Observed densities and temperatures can be converted to salinities by using figure AL-9.

AL.2.5. TEMPERATURE, DEPTH, CONDUCTIVITY (TDC) SENSORS. Relatively inexpensive electronic sensors are available commercially that provide a more economic and efficient means of determining the velocity of sound through water for computing corrections to echo soundings. (See 4.9.) A number of firms manufacture light portable sensors for use aboard small hydrographic vessels that work in the lesser depth ranges. The sensor and conductor cables can be easily manhandled overboard in depths less than 100 fm, and observations can be easily read on data display modules with sufficient accuracy for hydrographic surveying. Tables and graphs to convert meter readings to sound velocities for various depth layers are included with the instruments.

When this type of instrument is used, the conductor cable should be graduated at intervals to help the observer. Periodic field checks must be made by comparing velocity and depth data obtained by the instrument with data determined by a classical method, such as a Nansen cast. Under no circumstances shall these instruments be used in depths greater than the recommended maximum.

An instrument of this type frequently used aboard **NOS** vessels is the Martek Model TDC Me-



DIRECTIONS:
FOLLOW THE APPARENT SPECIFIC GRAVITY SCALE
USING THE CORRECTED HYDROMETER READING
VERTICALLY TO THE TEMPERATURE CURVE
THEN HORIZONTALLY TO THE SALINITY ‰

FIGURE AL–9.— Conversion of apparent specific gravity to salinity tering System. (See figure AL–10.) Advertised capabilities of this instrument are:

1. Depth range of 0 to 100 m or 0 to 150 lb/in² with an accuracy of ± 1.5%.

2. Temperature range of 0°C to 40°C with an accuracy of ± 0.5°C.

3. Conductivity range of 0 to 40 ppt salinity with an accuracy of ± 2%.

AL.2.6. SALINITY, TEMPERATURE, DEPTH (STD) SENSORS. Modern sophisticated oceanographic instruments are available for in situ measurements of the parameters needed to compute velocity of sound corrections for surveys in deep waters. Most of these systems are unduly expensive if purchased only for routine hydrographic surveys. Deep ocean casts require heavy oceanographic winches; whether the data are obtained by classical methods or by an electronic sensor, costs are high in terms of vessel operating time; however, such equipment should be used when available.

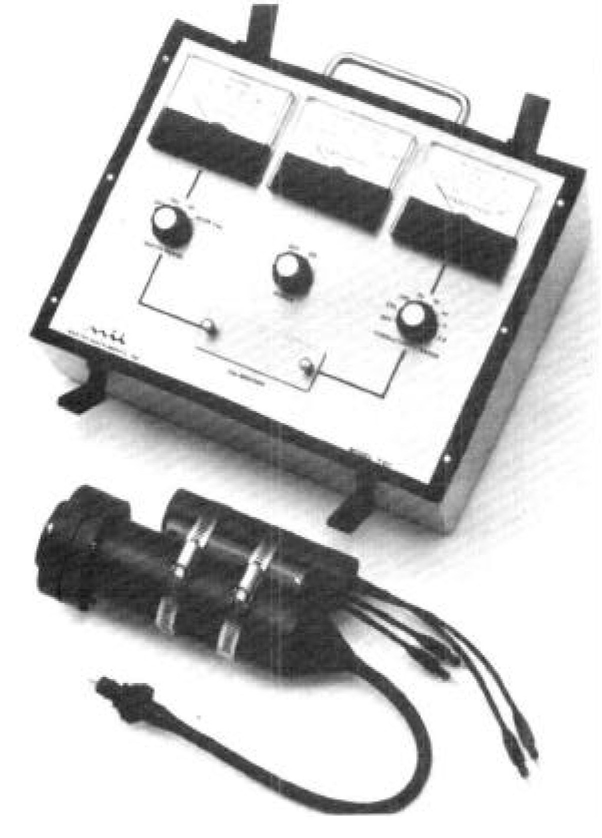


FIGURE AL–10.— Temperature, depth, and conductivity (TDC) metering system (courtesy of Martek Instruments, Inc., Newport Beach, California)

Deep ocean velocity corrections can be determined efficiently and economically by using an expendable salinity, temperature, depth **(XSTD)** system. Plessey Environmental Systems Model 9090 XSTD System (figure AL–11) has a standard depth range of 750 m. The system consists of an expendable probe or sensor that measures conductivity, temperature, and depth. The data are transmitted through a fine-wire link that connects the sensing probe to the shipboard recording and processing equipment. The probe is deployed through a simple deck- or hull-mounted launcher and has a drop rate of 6.1 m/s (20 ft/s). Measurement accuracies exceed those required for hydrographic survey sound velocity corrections.

When working in waters deeper than the maximum range of a sensor, historical oceanographic data for the area and time of year can be used to extend the observed data to the required depths.

AL.2.7. BOTTOM SAMPLERS. Equipment for bottom sampling used by **NOS** vessels to determine bottom characteristics for nautical charting are basically "snapper" type devices. Sampling devices must be capable of obtaining samples of sufficient volume to enable a hydrographer to readily determine the bottom characteristics of the surface layer and to provide a good representative sample of the bottom for submission to the Smithsonian Institution, Washington, D.C (See 4.7.1.)

One such device, frequently used aboard larger vessels, is the Shipek Sediment Sampler. (See figure AL–12.) This sampler is designed to obtain samples of unconsolidated sediment, from soft ooze to hard-packed sand and sizable rocks, from any depth. The sample size is approximately 400 cm² in surface area, and about 10 cm deep at the center.

Basically, the sampler is composed of two concentric half cylinders. The inner semicylinder or sample bucket is rotated at high torque to two helically wound external springs. A winch is needed to lower and hoist this sampler. Upon contact with the bottom, it is automatically triggered by the inertia of a self-contained weight upon a sear mechanism. At the end of its travel, the sample bucket is stopped and held in its closed position by residual spring torque.

Small clamshell snappers similar to those

FIGURE AL–12.— Shipek sediment sampler (courtesy of Hydro Products, San Diego, California)

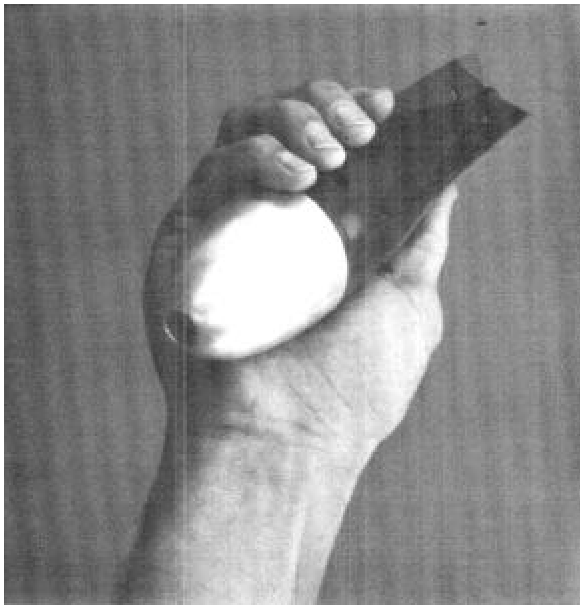


FIGURE AL–11. — Expendable salinity, temperature, and depth (XSTD) system (courtesy of Plessey Environmental Systems, San Diego, California)

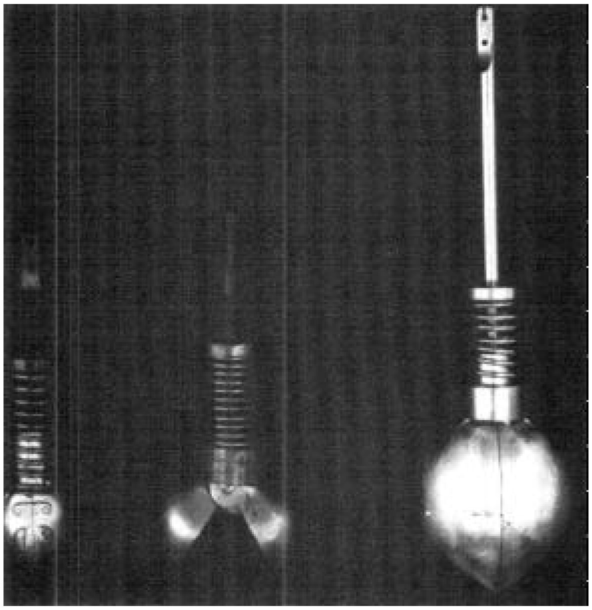


FIGURE AL–13.— Clamshell snappers for bottom sampling (Ballauf Mfg. Co., Inc., 619 H Street, N.W., Washington, D.C.)

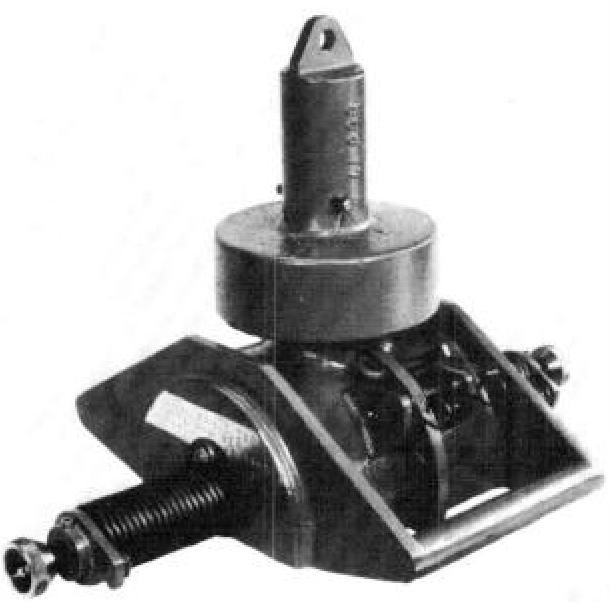


FIGURE AL.–14.— Hydrographic clock

shown in figure AL-13 are used for bottom sampling from smaller vessels.

AL.3. Hydrographic Clock

Accurate clocks are essential to correlate the various events of a hydrographic survey, particularly when the tidal ranges are large. For skiff hydrography and use on launches not equipped with a controlled frequency power source, an 8-day mechanical clock with a 6-in dial is used for timing. (See figure AL-14.) The clock must be sturdy and shock resistant; it must be housed in a waterproof casing and equipped with a battery-activated buzzer or bell that can be set to sound at intervals of 10, 15, 20, 30, or 60 s.

Clocks used for hydrographic survey timing shall be compared to a reliable standard at the beginning and at the end of each workday and must be adjusted to keep the best time possible. Clocks that cannot maintain time accurate to within ± 5 min a day shall not be used.

B. CARTOGRAPHIC CODES AND SYMBOLS

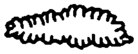
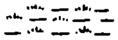
The cartographic codes and symbols shown in tables B-1 through B-9 shall be used to identify hydrographic information on final master data tapes and to represent features and data on survey sheets. Control station codes are entered by hydrographers in the field; the rest of the codes are entered during verification. Code entry methods and formats are specified in the "**HYDROPLOT/HYDROLOG** Systems Manual" (WALLACE 1971) and in "Specifications for Automated Hydrographic Survey Magnetic Tapes and Listings" (Office of Marine Technology 1973). For the meanings of most abbreviations in the tables, see *Chart No. 1, United States of America Nautical Chart Symbols and Abbreviations* (National Ocean Survey and Hydrographic Center 1975); and for the conversion of measurements, see appendix C.

TABLE B–1.— *Control stations**

Cartographic codes	Descriptions	Symbols and examples
139	Basic or supplemental control station. Use of this symbol shall be limited to described, marked, recoverable stations, and intersection stations of third-order class-II or higher accuracy. (See sections 3. 1.1 and 3.1.2.)	◬ 101 MORTON, 1959
250	Basic or supplemental control station (recoverable) used as electronic positioning system antenna site	 102 SANDY, 1973
243	Hydrographic station located by traverse, plane table, or photogrammetric methods—or undescribed, nonrecoverable stations of third-order or lower accuracy. (See 3.1.3.)	⊙ 213 TRAV-1, 1975
254	Undescribed, nonrecoverable station used as electronic positioning system antenna site	◎ 117 AA - 74, 1974
252	Hydrographic station located by sextant fixes or cuts	⊙ 319 (chy)
253	Hydrographic station located by unconventional methods (e.g., by spotting its position on a topographic map or aerial photograph for transfer to the hydrographic sheet)	⊙ 327 (cup)

* Station names and numbers of tanks, gables. chimneys, piles, rocks, and similar recoverable objects used as signals shall he accompanied by a brief description in black ink in parentheses, unless described in the control station name. Signals in water areas always shall be described fully; temporary signal descriptions are accompanied by the note "(temp)."

TABLE B–2— *Low water line and associated features**

Cartographic codes	Descriptions	Symbols and examples
013	Contour of zero depth drawn from corrected soundings	
188	Contour of zero depth estimated and sketched from hydrographic data	
008	Contour of zero depth from photogrammetric shoreline maps or topographic surveys	
009	Ledge†	
009	Reef	
None	Grass	

* See also section 1.6.1.

†See also figure B-4 for more detailed ways to depict ledges and reefs.

TABLE B–3.— *Dangers to navigation*

Cartographic codes	Descriptions	Symbols and examples
056*	Oil or gas well	∘ *subm well*
094	Rock awash	✱ *covers 1 ft at MLW*
099	Wreck, mast(s) visible	+++ *masts*
100	Wreck	+++
104†	Rock (no depth)	+
107	Ruins	[ ] *subm ruins*
108	Crib	□ *subm crib*
233	Dolphin	∘ *subm dol*
234	Pile	∘ *subm pile*
235	Pipe	∘ *subm pipe*
236	Stake	∘ *subm stake*
237	Stump	∘- *subm stump*
238	Snag	∘ *subm snag*
287	Obstruction	∘ *subm obstr*
094‡	Rock awash (no elevation determined)	✱
098	Wreck	
278	Dolphin	∘ *dol*
279	Pile	∘ *pile*
280	Pipe	∘ *pipe*
281	Stake	∘ *stake*
282	Stump	∘ *stump*
283	Snag	∘ *snag*
284	Obstruction	∘ *obstr*
285	Ruins	[ ] *ruins*
286	Crib	□ *crib*
291†	Rock awash (elevation in feet above datum)	✱ *($\underline{3}$)*
010§	Dolphin	∘ dol
085	Obstruction	∘ obstr
097	Islet (if impractical at survey scale, actual size and shape need not be shown)	• (3)
098	Wreck	

TABLE B-3.– *Concluded*

Cartographic codes	Descriptions	Symbols and examples
105	Pipe	○ pipe
106	Stake	○ stake
109	Crib	▣ crib
110	Pile	○ pile
111	Platform (oil or gas)	□ platform
230	Stump	○ stump
231	Snag	○ Snag
232	Deadhead (usually one end afloat)	○ deadhead
241	Duck blind	▣ duck blind
242	Duck blind ruins	⛶ duck blind ruins
248	Platform, survey	□ survey platform
249	Platform, lighted	□ platform (lighted)
260	Ruins	⛶ ruins
103¶	Kelp (symbol not to be used for bottom characteristic but to indicate small isolated patches visible on the surface)	
599	Kelp (limit lines not shown-used to indicate extensive kelp beds visible on the surface)	*kelp*
146	Tide rips (limit lines not shown)	*tide rips*
533	Spoil area (limit lines not shown)	*spoil*
534	Waterfall	*walerfall*
535	Rapids	*rapids*
536	Eddies	*eddies*
537	Shoal (limit lines not shown)	*shoal*
538	Foul (limit lines not shown)	*foul*
539	Breakers (limit lines not shown)	*breakers*

* Features in the 14 codes 056 through 287 do not uncover at the sounding datum prescribed for the area. (See section 1.5 4.1.)

†See figures B-1 through B-3 for additional information on rock symbolization.

‡Features in the 12 codes 094 through 291 uncover at the sounding datum but are covered at mean high water (not applicable to surveys of the Great Lakes).

§Features in the 17 codes 010 through 260 are visible at mean high water for surveys in tidal waters or are visible at shoreline datum in the Great Lakes.

¶Symbols in the 10 codes 103 through 539 are used to depict miscellaneous dangers that do not fall into any of the preceding categories.

TABLE B-4.–*Soundings*

	Descriptions	Symbols and examples
129	Sounding (whole fathoms)	56
130	Sounding (fathoms and tenths)	9^6
131	Sounding (fathoms and fraction)	$7\frac{1}{4}$ or $\frac{1}{2}$
148	Minus sounding (whole fathoms)	-1
137	Minus sounding (fathoms and tenths)	-0^2
142	Minus sounding (fathoms and fraction)	$-1\frac{1}{2}$ or $-\frac{1}{2}$
265	Sounding on rock (whole fathoms)	4 *Rk*
262	Sounding on rock (fathoms and tenths)	6^2 *Rk*
270	Sounding on wreck (whole fathoms)	1 *wk*
267	Sounding on wreck (fathoms and tenths)	3^5 *wk*
274	Sounding on obstruction (whole fathoms)	3 *obstr*
275	Sounding on obstruction (fathoms and tenths)	4^2 *obstr*
126	Sounding (whole feet)	15
127	Sounding (feet and tenths)	4^2
128	Sounding (feet and fraction)	$6\frac{1}{2}$ or $\frac{1}{2}$
135	Minus sounding (whole feet)	-3
141	Minus sounding (feet and tenths)	-0^2
136	Minus sounding (feet and fraction)	$-1\frac{1}{2}$ or $-\frac{1}{2}$
290	Sounding on rock (whole feet)	5 *Rk*
264	Sounding on rock (feet and tenths)	3^2 *Rk*
101	Sounding on wreck (whole feet)	10 *wk*
269	Sounding on wreck (feet and tenths)	2^7 *wk*
272	Sounding on obstruction (whole feet)	5 *obstr*
273	Sounding on obstruction (feet and tenths)	7^2 *obstr*

CARTOGRAPHIC CODES AND SYMBOLS

TABLE B-4.— *Concluded*

Cartographic codes	Descriptions	Symbols and examples
132	Sounding (whole meters)	47
133	Sounding (meters and tenths)	13^2
149	Minus sounding (whole meters)	-2
138	Minus sounding (meters and tenths)	-0^4
266	Sounding on rock (whole meters)	2 *Rk*
263	Sounding on rock (meters and tenths)	4^8 *Rk*
271	Sounding on wreck (whole meters)	2 *wk*
268	Sounding on wreck (meters and tenths)	1^6 *wk*
276	Sounding on obstruction (whole meters)	2 *obstr*
277	Sounding on obstruction (meters and tenths)	1^6 *obstr*
134	Unqualified sounding (final corrections will not be applied, plot in whole units)	31
251	Miss (no sounding)	*(No symbol)*
090	Wreck (wire drag clearance)	42 *wk - cleared by 40 ft*
091	Rock (wire drag clearance)	18 *Rk - cleared by 15 ft*
092	Obstruction (wire drag clearance)	18 *obstr - cleared by 18 ft*
095	Coral (wire drag clearance)	16 *Co-cleared by 14 ft*
239	Shoal (wire drag clearance)	12 *cleared by 9 ft*
240	Hard (wire drag clearance)	25 *hrd-cleared by 23 ft*

TABLE *B-5-Shoreline and alongshore features*

Cartographic codes	Descriptions	Symbols and examples
007*	Fast solid land (0.4 mm)	
003	Marsh, swamp, and mangrove (0.2 mm)	
001	Approximate shoreline (HWL)	
None	Piers and waterfront areas (0.4 mm and 0.2 mm)	
144†	Fast solid land (0.4 mm)	
190	Marsh, swamp. and mangrove (0.2 mm)	
145‡	Fast solid land (0.4 mm)	
189	Marsh, swamp. and mangrove (0.2 mm)	

* Features in codes 007, 003, 001, and none are from photogrammetric shoreline maps and topographic surveys or other method of equivalent accuracy Measurements in parentheses are line widths

†Features in codes 144 and 190 are shoreline revisions sketched bv the hydrographer using fixes or other methods of equivalent accuracv.

‡Features in codes 145 and 189 are shoreline revisions sketched by the hydrographer using estimated positions.

TABLE B–6.—*Buoys**

Cartographic codes	Descriptions	Symbols and examples
255	Red buoy (e.g., red nun buoy, number 32)	 N "32"
256	Black buoy (e.g., black can buoy, number 33)	 C "33"
257	Red buoy (lighted – e.g., bell buoy, number 4)	 BELL "4"
258	Black buoy (lighted – e.g., bell buoy, number 5)	 BELL "5"
214	Vertically striped buoy (e.g., black and white mid-channel can buoy, unnumbered)	 BW C
216	Horizontally banded buoy (e.g., red and black junction can buoy, unnumbered)	 RB C
217	Checkered buoy	 (Enter appropriate descriptions for all other buoy Symbols.)
218	Diagonally banded buoy	
212	Open buoy symbol (color to be added by hand)	
259	Open buoy symbol (lighted – color and/or striping to be added by hand)	
215	Mooring buoy	

* For buoys not shown, use symbols prescribed in *Chart No. 1 . United State of America Nautical Chart* ***Symbols*** and *Abbreviations* (National Ocean Survey and Hydrographic Center 1975).

TABLE B–7.— ***Bottom characteristics***

Carto-graphic codes	Nouns	Symbols and examples	Carto-graphic codes	Adjectives	Symbols and examples	Carto-graphic codes	Colors	Symbols and examples
550	Ooze	Oz	545	Gritty	gty	569	Black	bk
551	Clay	Cl	548	Rocky	rky	570	White	wh
552	Silt	Slt	555	Fine	fne	571	Gray	gy
553	Mud	M	557	Coarse	crs	577	Brown	br
558	Sand	S	572	Soft	sft	581	Red	rd
559	Gravel	G	573	Hard	hrd	582	Yellow	yl
560	Shingle	Sn	574	Sticky	stk	584	Blue	bu
562	Coral head	Co Hd	576	Broken	brk	586	Orange	or
566	Pebbles	P	578	Speckled	spk	587	Green	gn
567	Stones	St	579	Light	lt	589	Violet	vi
568	Boulders	Blds	583	Dark	dk			
575	Shells	Sh	597	Small	sml			
580	Coral	Co	598	Large	lrg			
594	Seaweed	Wd						
595	Grass	Grs						

TABLE B-8.— *Nonfloating aids to navigation and landmarks*

Cartographic codes	Descriptions	Symbols and examples
219	Day beacon	▲ "33" A '32*
223	Day beacon, front range	▲ *F Range Bn*
224	Day beacon, rear range	▲ *R Range Bn*
261	Marker (privately maintained)	⊙ priv marker
221	Marker, front mile*	⊙ marker (mile)
222	Marker, rear mile	⊙ marker (mile)
246	Marker, front dredging range	⊙ marker (dredging range)
247	Marker, rear dredging range	⊙ marker (dredging range)
139	Structure, of third-order or better accuracy, used as a signal. Give station name and year, and U.S. Coast Guard (1976) *Light List* name, if different.	△ 108 SAND POINT LIGHTHOUSE, 1887 *(Bay Shaft Light)*
139	Structure, † third-order accuracy, no longer in service, used as a signal	△ 117 BIRD ISLAND LIGHTHOUSE, 1857 (abandoned)
070	Lighted structure, not used as a signal and located by less than third-order methods. Give U.S. Coast Guard *Light List* name.	⊙ *Bald Pt Lt*
112	Landmark, ‡ less than third-order accuracy (not used as a signal)	⊙ TANK, ELEVATED (Country Club Hills) (landmark: 60 ft obove ground. 245 ft above MHW
139	Radio tower, § located previously by third-order intersection methods, not used during the survey, but suitable for use as a landmark	△ RADIO TOWER, WNOR, 1972 (landmark: 620 ft above ground, 705 ft above MHW)
243	Black day beacon, number 33, located photogrammetrically and used as a hydrographic signal	⊙ 187 *(B Bn "33")*

* All mileages are in nautical miles unless otheriser specified

†If structures of this type were not used to control the surve). omit the signal number (e.g., cartographic code 070)

‡Landmarks of third order or better accuracy that were not used to control the survey are shown using the control station symbol and the land mark description (e.g., cartographic code 139).

§If an aid to navigation or landmark was located by less than third-order methods for use as a signal during the survey, the appropriate control station symbol takes precedence (e.g. cartographic code 243).

TABLE B-9.— *Miscellaneous features*

	Descriptions	Symbol& and examples
244	Tide or water level gaging station	○ Tide Station
245	Current station	○ Current Station
011	Limit lines	┄┄┄┄
078	Feature for which an individual cartographic code has not been assigned. Code 078 also may be utilized for detached positions used to delineate features.	*(No symbol)*

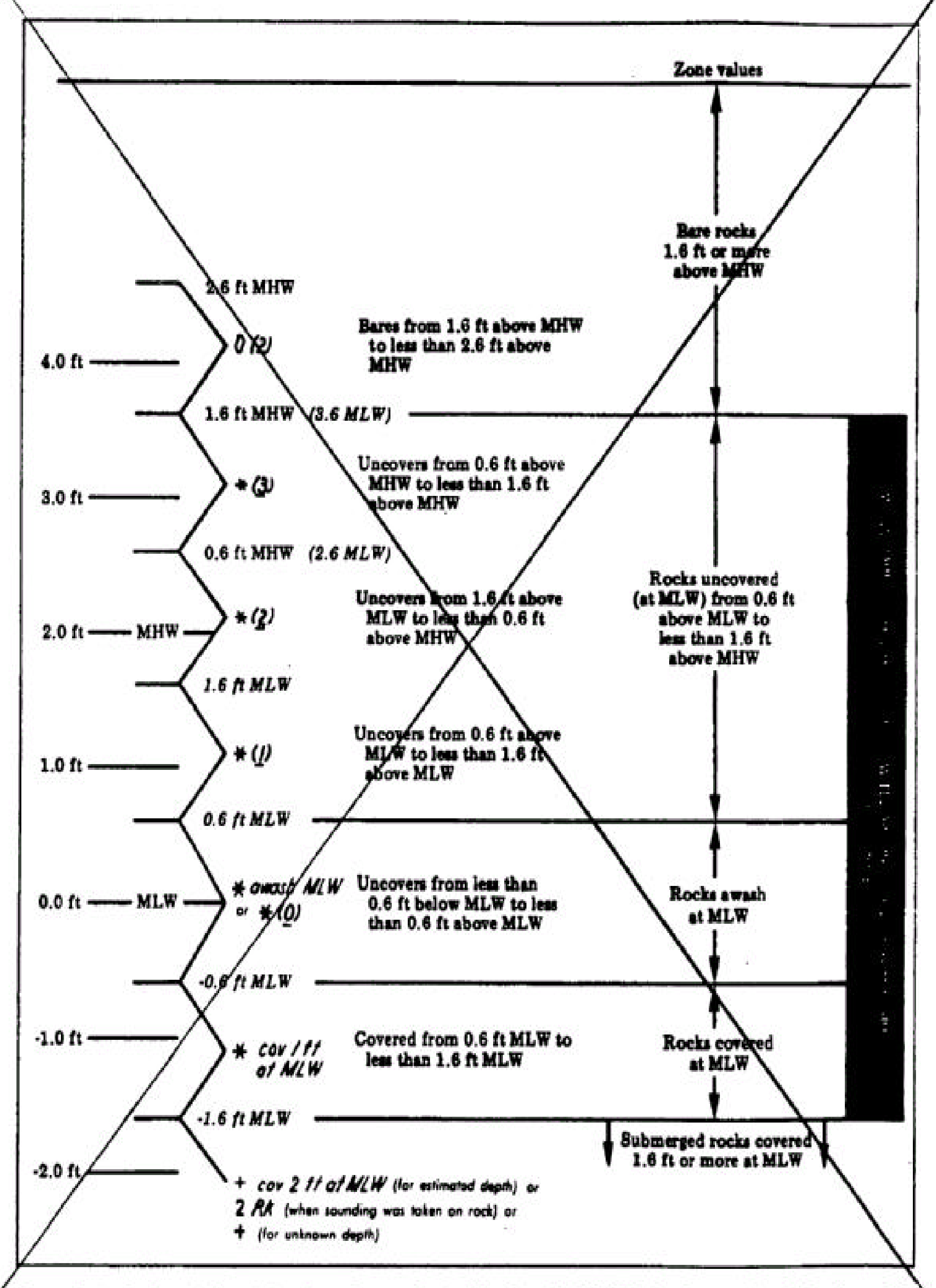


FIGURE B-1.—Rock symbols and elevation references for the Atlantic and Gulf of Mexico Coasts. Although based on a 2-ft range of tide, the zone values are valid for any tide range. See also "Photogrammetric Instruction No. 70, Rocks, Reefs, and Ledges Shown on Photogrammetric Maps" (National Ocean Survey 1975).

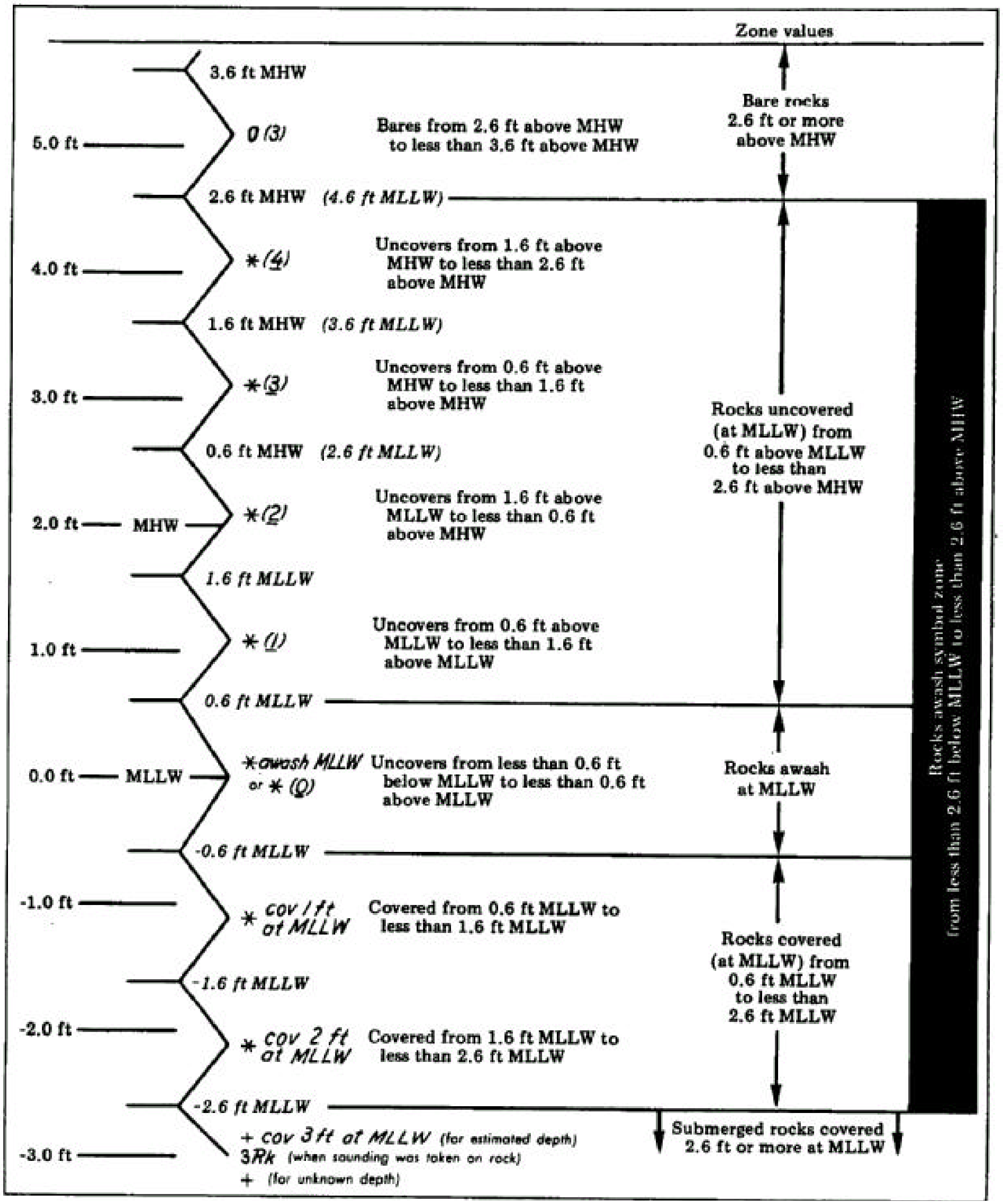


FIGURE B–2.—Rock symbols and elevation references for the Pacific Coast. Although based on a 2-ft range of tide, the zone values are valid for any tide range. See also "Photogrammetric Instruction No. 70, Rocks, Reefs, and Ledges Shown on Photogrammetric Maps" (National Ocean Survey 1975).

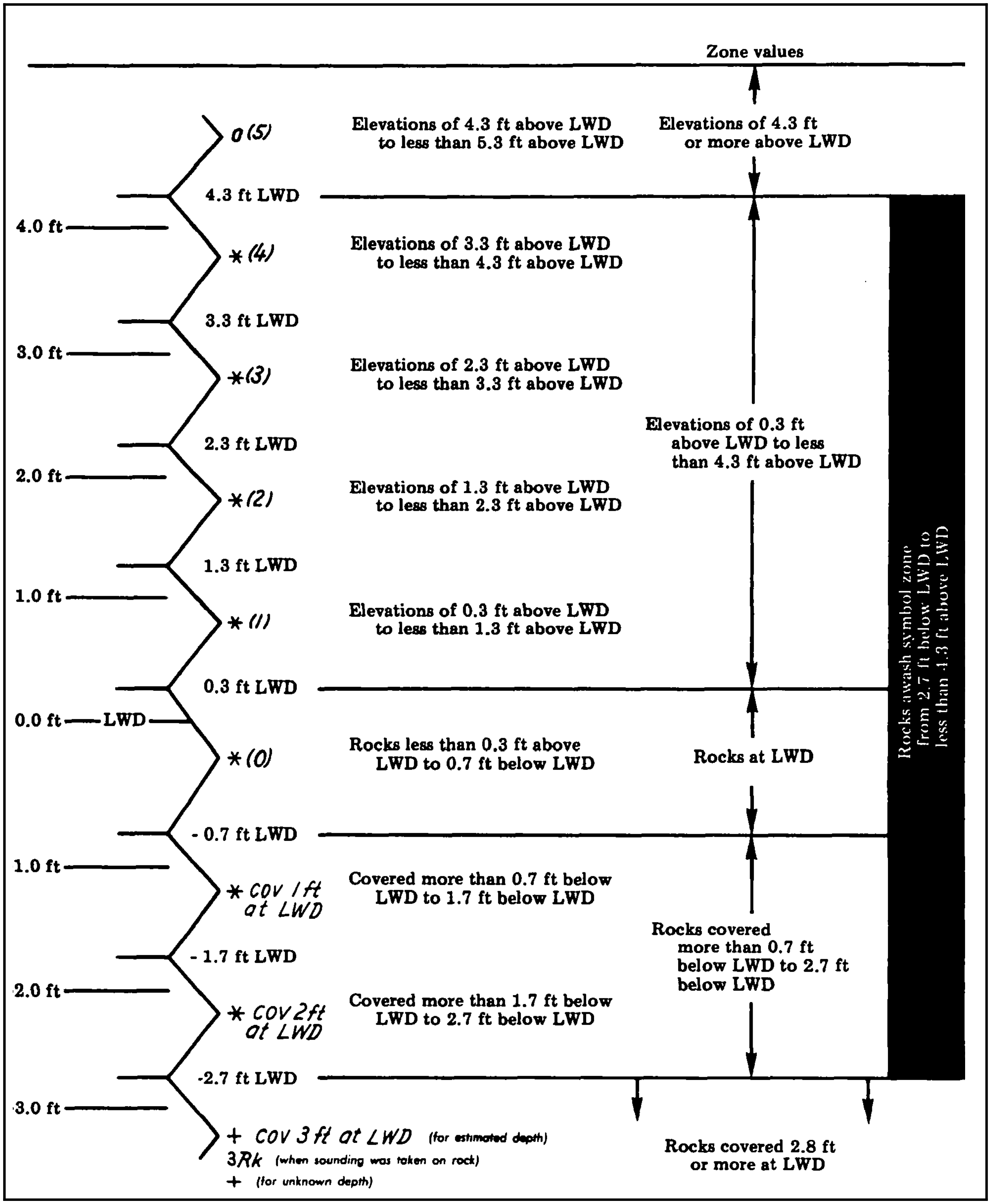


FIGURE B-3.— Rock symbols and elevation references for the Great Lakes. See also "Photogrammetric; Instruction No. 70, Rocks, Reefs, and Ledges Shown on Photogrammetric Maps" (National Ocean Survey 1975).

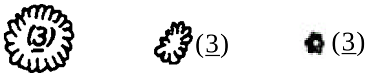
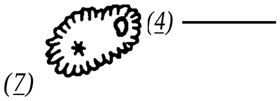
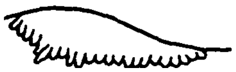
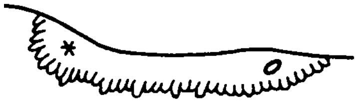
	Reef uncovers at rounding datum.
	Reef uncovers 3 ft at sounding datum.
	Rocks (high points) top reef.
 Elevations of bare rocks from topographic source are shown in red on hydrographic survey	Elevations of rocks and reef are known.
	Ledge uncovers at sounding datum.
	Ledge indicates foreshore characteristic only; dotted line is low water line.
	Rocks (high points) top ledge.
 Bare rocks from hydrographic sources are shown in red on hydrographic survey	Elevations of rocks are known.
Co	Add this abbreviation if the features are coral.
*	Reef is smaller than 1.5 x 1.5 mm.

FIGURE B–4.— Symbols and elevation references for reefs and ledges

C. MISCELLANEOUS CONVERSIONS, TABLES, AND GRAPHS

Since 1893, the basis of length measurement throughout the United States has been derived from metric standards. In 1959, a small refinement was made in the definition of the yard to resolve discrepancies both in this country and abroad. This refinement changed the length of 1 yd from 3600/3937 m (approximately 0.914402 m) to 0.9144 m, exactly. The new value became shorter than the old by two parts in a million. The foot defined by this newer yard is equal to 0.3048 m, exactly. and is called the "International Foot."

At the same time, it was decided that data derived from and published as a result of geodetic surveys within the United States would continue to be based upon the old standard (1 ft = 1200/3937 m). This foot is named the "U.S. Survey Foot."

As a result, all land measurements in the United States will relate to the meter by the old standard. The U.S. Survey Foot is also the unit adopted by the National Ocean Survey for its mapping and charting measurements; hence, linear and areal conversion factors in this appendix are based on the U.S. Survey Foot rather than the International Foot. See tables C-1 through C-7 and figure C-1.

TABLE C–1.— ***Conversion Factors (U.S. Survey Foot)***

Area	
1 square inch (in^2)	=6.45162581 square centimeters (cm^2)
1 square foot (ft^2)	=0.09290341 square meter (m^2)
1 square statute mile (mi^2)	=2.58999847 square kilometers (km^2)
1 square centimeter (cm^2)	=0.15499969 square inch (in^2)
1 square meter (m^2)	= 10.76386736 square feet (ft^2)
1 square kilometer (km^2)	=0.38610061 square statute mile (mi^2) =0.29155335 square nautical mile (nmi^2)
1 hectare (ha)	= 10,000 square meters (m^2) =2.471 acres
Mass	
1 ounce(oz)	=28.34952673 grams (g) =0.02834953 kilogram (kg) =0.0625 pound (lb)
1 pound (lb)	=453.59242768 grams (g) =0.45359243 kilogram (kg)
1 short ton	=2,000 pounds (lb) =907.1848554 kilograms (kg) =0.90718486 metric ton =0.89285714 long ton
1 kilogram (kg)	=2.20462234 pounds (lb) =1000 grams
Mathematics	
π	=3.1415926535897932
1 radian (rad)	=206,264."80625 =57°17'44."80625
1 degree (1°)	=0.0174532925199433 radian (rad)
360 degrees (360°)	= 2 π radians (rad) =400 grads
Length	
1 inch (in)	= 25.4000508 millimeters (mm) = 2.54000508 centimeters (cm)
1 foot (ft)	= 12 inches (in) = 0.30480061 meter (m)
1 yard (yd)	= 36 inches (in) = 3 feet (ft) = 0.91440183 meter (m) = 91.4401829 centimeters (cm)
1 fathom (fm)	= 6 feet (ft) = 2 yards (yd) = 1.82880366 meters (m) = 182.890366 centimeters (cm)
1 statute mile (mi)	= 5,280 feet (ft) = 1,760 yards (yd) = 1609,34721869 meters (m) = 0.86897798 nautical mile (nmi)
1 nautical mile (nmi)	= 6,076.10333333 feet (ft) = 2,025.36777777 yards (yd) = 1852 meters (m) = 1.15077715 statute miles (mi)
1 meter (m)	= 100 centimeters (cm) = 39.37 inches (in) = 3.28083333 feet (ft) = 0.54680556 fathom (fm) = 0.00062137 statute mile (mi) = 0.00053996 nautical mile (nmi)
1 kilometer (km)	=3,280.83333333 feet (ft) =1000 meters (m) =0.62136995 statute mile (mi) =0.53995680 nautical mile (nmi)

TABLE C-1.— *Continued*

Speed	
1 Knot (kn)	= 1 nautical mile per hour (nmi/hr) = 101.26838879 feet per minute (ft/min) = 30.87666667 meters per minute (m/min) = 1.852 kilometers per hour (km/hr) =1.15077715 statute miles per hour (mi/hr) =0.51444444 meter per second (m/s)
Temperature	
Celsius to Fahrenheit	°F = (9/5 x °C) + 32°
Fahrenheit to Celsius	°C = 5/9(°F–32°)
Volume	
1 cubic inch (in³)	=16.38716233 cubic centimeters (cm³) =0.01638670 liter (1) =0.00432900 gallon (gal)
1 cubic foot (ft³)	= 1,728 cubic inches (in³) = 28.31622363 liters (l) = 7.48051948 U.S. gallons (gal) = 0.02831702 cubic meter (m³)
1 cubic centimeter (cm³)	= 0.06102338 cubic inch (in³) = 0.00026417 U.S. gallon (gal)
1 cubic meter (m³)	= 264.17046733 U.S. gallons (gal) =35.31445483 cubic feet (ft³)
1 quart (qt, U.S.)	= 57.75 cubic inches (in³) = 0.94633213 liter (l)
1 gallon (gal, U.S.)	= 3785.43449592 cubic centimeters (cm³) = 231 cubic inches (in³) = 0.13368056 cubic foot (ft³) = 3.78532851 liters (l)
1 liter (l)	= 1000.028 cubic centimeters (cm³) = 61.02508662 cubic inches (in³) = 1.05671146 quarts (qt) = 0.26417786 gallon (gal)

TABLE C-2.— ***Linear distance conversion (fathoms, meters, feet, and yards)***

	Fathoms to		Meters to			Feet to		Yards to
	feet	meters	fathoms	yards	feet	meters	fathoms	meters
1	6	1.82880	0.54681	1.09361	3.28083	0.30480	0.16667	0.91440
2	12	3.65761	1.09361	2.18722	6.56167	0.60960	0.33333	1.82880
3	18	5.48641	1.64042	3.28083	9.84250	0.91440	0.50000	2.74321
4	24	7.31521	2.18722	4.37444	13.12333	1.21920	0.66667	3.65761
5	30	9.14402	2.73403	5.46806	16.40417	1.52400	0.83333	4.57201
6	36	10.97282	3.28083	6.56167	19.68500	1.82880	1.00000	5.48641
7	42	12.80163	3.82764	7.65528	22.96583	2.13360	1.16667	6.40081
8	48	14.63043	4.37444	8.74889	26.24667	2.43840	1.33333	7.31521
9	54	16.45923	4.92125	9.84250	29.52750	2.74321	1.50000	8.22962

MISCELLANEOUS CONVERSIONS, TABLES, AND GRAPHS

TABLE C–3.— *Linear distance conversion (nautical miles, statute miles, and kilometers)*

	Nautical miles to		Statute miles to		Kilometers to	
	statute miles	kilometers	nautical miles	kilometers	statute miles	nautical miles
1	1.15078	1.85200	0.86898	1.60935	0.62137	0.53996
2	2.30155	3.70400	1.73796	3.21869	1.24274	1.07991
3	3.45233	5.55600	2.60693	4.82804	1.86411	1.61987
4	4.60311	7.40800	3.47591	6.43739	2.48548	2.15983
5	5.75389	9.26000	4.34489	8.04674	3.10685	2.69978
6	6.90466	11.11200	5.21387	9.65608	3.72822	3.23974
7	8.05544	12.96400	6.08285	11.26543	4.34959	3.77970
8	9.20622	14.81600	6.95182	12.87478	4.97096	4.31965
9	10.35699	16.66800	7.82080	14.48412	5.59233	4.85961

TABLE C–4.—*Temperature conyersion (Celsius to Fahrenheit and Fahrenheit to Celsius)*

Celsius to Fahrenheit

℃	°F	℃	°F	℃	°F	℃	°F	℃	°F
-2	28.4	5	41.0	12	53.6	19	66.2	26	78.8
-1	30.2	6	42.8	13	55.4	20	68.0	27	80.6
0	32.0	7	44.6	14	57.2	21	69.8	28	82.4
1	33.8	8	46.4	15	59.0	22	71.6	29	84.2
2	35.6	9	48.2	16	60.8	23	73.4	30	86.0
3	37.4	10	50.0	17	62.6	24	75.2	31	87.8
4	39.2	11	51.8	18	64.4	25	77.0	32	89.6

Fahrenheit to Celsius

°F	℃	°F	℃	°F	℃	°F	℃	°F	℃
28	- 2.2	41	5.0	54	12.2	67	19.4	80	26.7
29	- 1.7	42	5.6	55	12.8	68	20.0	81	27.2
30	- 1.1	43	6.1	56	13.3	69	20.6	82	27.8
31	- 0.6	44	6.7	57	13.9	70	21.1	83	28.3
32	0.0	45	7.2	58	14.4	71	21.7	84	28.9
33	+0.6	46	7.8	59	15.0	72	22.2	85	29.4
34	1.1	47	8.3	60	15.6	73	22.8	86	30.0
35	1.7	48	8.9	61	16.1	74	23.3	87	30.6
36	2.2	49	9.4	62	16.7	75	23.9	88	31.1
37	2.8	50	10.0	63	17.2	76	24.4	89	31.7
38	3.3	51	10.6	64	17.8	77	25.0	90	32.2
39	3.9	52	11.1	65	18.3	78	25.6	91	32.8
40	4.4	53	11.7	66	18.9	79	26.1	92	33.3

TABLE C–5.— *Microwave horizon distance, range versus antenna height (kilometers). * See also table C–6. (Courtesy of Del Norte Technology, Inc. Euless, Texas.)*

Kilometers range	Minimum necessary height (m)	Kilometers range	Minimum necessary height (m)
1	0.06	41	103
2	.27	42	108
3	.55	43	113
4	.98	44	119
5	1.5	45	124
6	2.2	46	130
7	3.0	47	135
8	3.9	48	141
9	5.0	49	147
10	6.1	50	153
11	7.4	51	159
12	8.8	52	166
13	10	53	172
14	12	54	179
15	14	55	185
16	16	56	192
17	18	57	199
18	20	58	206
19	22	59	213
20	25	60	220
21	27	61	228
22	30	62	235
23	32	63	243
24	35	64	251
25	38	65	259
26	41	66	267
27	45	67	275
28	48	68	283
29	51	69	292
30	55	70	300
31	59	71	309
32	63	72	317
33	67	73	326
34	71	74	335
35	75	75	344
36	79	76	354
37	84	77	363
38	88	78	373
39	93	79	382
40	98	80	392

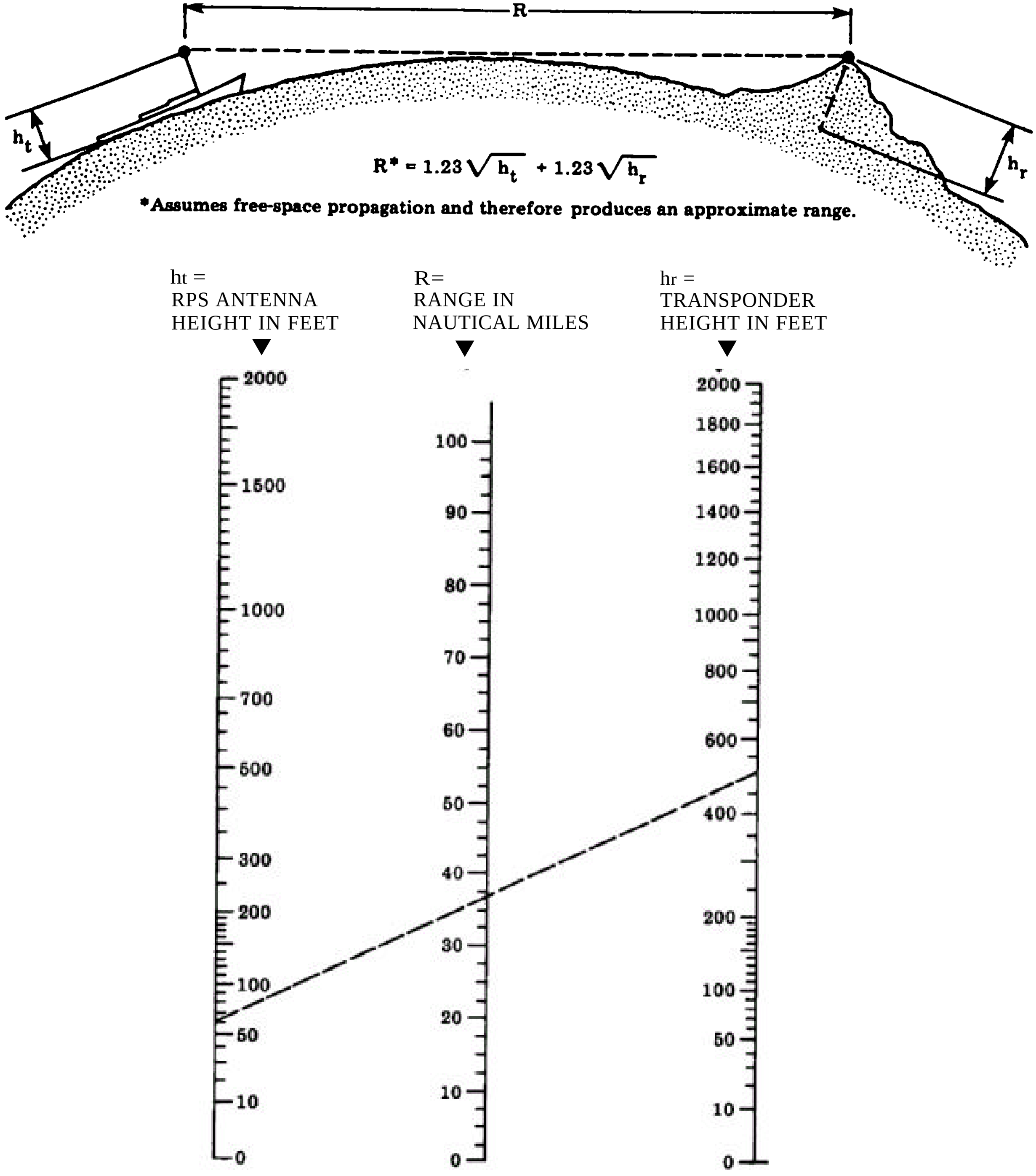
*This table shows the distance to the radar horizon for various antenna heights Enter the table with the master station antenna height and note the range to the radar horizon; then repeat using the remote station height. Add the two ranges just determined to find the maximum range possible for the given combination of antenna height [e.g. an antenna height of 16 m at a master station would result in a horizon range of 16 km—while an antenna height of 1.5 m at a remote station would result in a borizon range of 5 km; the theoretical maximum range of this antenna combination would be 21 km].

TABLE C–6.— *Microwave horizon distance, range versus antenna height (nautical miles and statute mile). See also table C–5. (Courtesy of Del Norte Technology, Inc, Euless, Texas.)*

Nautical miles range	Minimum necessary height (ft)	Statute miles	Minimum necessary height (ft)
1	0.7	1	0.7
2	2.7	2	2.1
3	6.0	3	4.7
4	10.7	4	8.3
5	16.8	5	13.0
6	24.2	6	18.7
7	32.9	7	25.5
8	43.0	8	33.3
9	54.4	9	42.1
10	67.2	10	52.0
11	81.3	11	63.0
12	96.7	12	74.9
13	113.5	13	87.9
14	131.7	14	102.0
15	151.2	15	117.0
16	172.0	16	133.2
17	194.2	17	150.4
18	217.7	18	168.6
19	242.5	19	187.8
20	268.7	20	208.1
21	296.3	21	229.4
22	325.2	22	251.8
23	355.4	23	275.2
24	387.0	24	299.7
25	420.0	25	325.2
26	454.2	26	351.7
27	489.8	27	379.3
28	526.7	28	407.9
29	565.0	29	437.6
30	604.7	30	468.3
31	645.7	31	500.0
32	688.0	32	532.8
33	731.7	33	566.6
34	776.7	34	601.5
35	823.0	35	637.4
36	870.7	36	6743
37	919.8	37	712.3
38	970.2	38	751.3
39	1,021.9	39	791.4
40	1,075.0	40	832.5
41	1,129.4	41	874.6
42	1,185.2	42	917.8
43	1,242.3	43	962.0
44	1,300.7	44	1,007.3
45	1,360.5	45	1,053.6
46	1,421.7	46	1,100.9
47	1,494.1	47	1,149.3
48	1,548.1	48	1,198.7
49	1,613.1	49	1,249.2
50	1,679.7	50	1.300.7

TABLE C–7.— *Velocity correction factors for a calibration velocity of 800 fm/ s*

Actual velocity (m/ s)	Factors
1,460	– 0.00205
61	– .00137
62	– .00068
63	.00000
64	+ .00068
65	+ .00137
66	+ 0.00205
67	+ .00273
68	+ .00342
69	+ .00410
1,470	+ .00478
71	+ 0.00547
72	+ .00615
73	+ .00684
74	+ .00752
75	+ .00820
76	+ 0.00889
77	+ .00957
78	+ .01025
79	+ .01094
1,480	+ .01162
81	+ 0.01230
82	+ .01299
83	+ .01367
84	+ .01435
85	+ .01504
86	+ 0.01572
87	+ .01640
88	+ .01709
89	+ .01777
1,490	+ .01846
91	+ 0.01914
92	+ .01982
93	+ .02051
94	+ .02119
95	+ .02187
96	+ 0.02256
97	+ .02324
98	+ .02392
99	+ .02461
1,500	+ .02529
1,501	+ 0.02597
02	+ .02666
03	+ .02734
04	+ .02802
05	+ .02971
06	+ 0.02939
07	+ .03008
08	+ .03076
09	+ .03144
1,510	+ .03213
11	+ 0.03281
12	+ .03349
13	+ .03418
14	+ .03486
15	+ .03554
16	+ 0.03623
17	+ .03691
18	+ .03759
19	+ .03828
1,520	+ .03896
21	+ 0.03964
22	+ .04033
23	+ .04101
24	+ .04170
25	+ .04238
26	+ 0.04306
27	+ .04375
28	+ .04443
29	+ .04511
1,530	+ .04580
31	+ 0.04648
32	+ .04716
33	+ .04785
34	+ .04853
35	+ .04921
36	+ 0.04990
37	+ .05058
38	+ .05126
39	+ .05195
1,540	+ .05263



EXAMPLE: HEIGHT OF MRS (TRANSMITTING) ANTENNA 60 FEET; HEIGHT OF TRANSPONDER (RECEIVING) ANTENNA 500 FEET: MAXIMUM, FREE-SPACE LINE-OF-SIGHT TRANSMISSION IS APPROXIMATELY 37 NAUTICAL MILES.

FIGURE C–1.— Line-of-sight nomograph (courtesy of Motorola, Inc., Scottsdale, Arizona)

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This manual is one of a series of **NOAA** publications designed to state the requirements for various survey operations and to describe the methods and equipment used. This manual emphasizes proper or recommended techniques and procedures for conducting hydrographic surveys. The hydrographer should consult the following technical publications, for they may be needed during combined operations projects. Note that the dates of publication of the references cited in the text appear in boldface type.

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E. GLOSSARY OF ABBREVIATIONS AND ACRONYMS

The abbreviations in table B–7 in appendix B shall be used to record data obtained by bottom sampling. See also *Chart No. 1, United States of America Nautical Chart Symbols and Abbreviations* (National Ocean Survey and Hydrographic Center 1975). Table E–1 below is a listing of most abbreviations and acronyms used in this manual. Some, such as in-house usage and trademarks, have not been included—if the interested reader desires this information, write to Requirements Branch (**OA/C351**); Hydrographic Surveys Division, Office of Marine Surveys and Maps, 6001 Executive Boulevard, Rockville, Maryland 20852. This branch will also welcome written matter to correct and update the manual.

TABLE E–1.— *Abbreviations and acronyms used in this manual**

A	ampere(s)
a.c.	alternating current
ASCII	American National Standard Code for Information Interchange
adj	adjusted
ADR	Analog to Digital Recording; Automatic Digital Recording
AGC	Automatic Gain Control
ahd	ahead
AMC	Atlantic Marine Center
ASI	Aircraft Standards, Inc.
ARGO	Automatic Ranging Grid Overlay
assy	assembly
avg	average
batt	battery
BC	Bathymetric Chart
BCD	Binary Coded Decimal
bldg(s)	building(s)
Bn	beacon
BS	Bottom Sample
BT	bathythermograph
C	can; center; core
° C	Celsius (degrees)
C&GS	Coast and Geodetic Survey
cal	calibration
C/C	change course
CF	Constant Frequency
chan	channel
chy	chimney
CL	checklist
cm	centimeters(s)
complot	computer plotted
con.	continued
cont	control
cor	corner; correction
corr	correction
cov	covered
C/S	change speed
csc	cosecant
CSS	Coastal Survey Ship
CTRL	control
CUP	cupola
D	depth; dredge
dB	decibel(s)
d.c.	direct current
DEC	Digital Equipment Corporation
dec	decrease
dir	direction
dist	distance
Div	division
dm's	differences along meridians
DMU	Distance Measuring Unit
dol	dolphin
DP	Detached Positions
dp's	differences along parallels
DR	Dead Reckoning
ECC	eccentric
ED	Existence Doubtful
EDM	Electronic Distance Measuring
EDP	Electronic Data Processing
elev	elevation
FSSA	Environmental Science Services Administration
ETG	electric tape gage
F	field; frequency
• F	Fahrenheit (degrees)
FM	Frequency Modulation
fm	fathom(s)
fm/s	fathom(s) per second
F/S	Full Speed
ft	foot (feet)
ft/fm	feet or fathoms
FWD	forward
GCLWD	Gulf Coast Low Water Datum
GMT	Greenwich Mean Time
G.P.O.	Government Printing Office
grp	group
gyro	gyroscope; gyroscopic
H	Hydrographic
H.O.	Hydrographic Office
horiz	horizontal
hr	hour(s)
H/S	Half Speed
ht	height
H/V	hyperbolic-visual
hyd	hydrography
hydro	hydrographic
HYDROPLOT	Hydrographic data system
Hydrotrac	Hydrographic tracking
HYP	hyperbolic
HYPLOT	HYDROPLOT
Hz	hertz
I(s)	island(s)
ID	identification
IGLD	International Great Lakes Datum
in	inch(es)
info	information
instr	instrument
I/S	Increased Speed
JD	Julian date
kHz	kilohertz
km	kilometer(s)
km/s	kilometer(s) per second
kn	knot(s)
L	lane; left; location
I	liter(s)
LAJ	Lane Jump
Lat.	latitude
LB	Line Begins
lb	pounds(s)
LBDB	Line Begins, Day Begins
lb/in^2	pound(s) per square inch
LBL	Line Bends Left
LBR	Line Bends Right
L Brks	Line Breaks
LE	Line Ends
LEDE	Line Ends, Day Ends
LJL	Line Jogs Left
LJR	Line Jogs Right
LL	Lead Line
LNM	Lineal Nautical MiWs)
long.	Longitude
LORAN	Long Range Aid to Navigation
LR	Line Resumes
LSC	Lake Survey Center
Lt	light

* Continued on next 2 pages; see also table B-5 in appendix B

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

TABLE E–1.— *Continued*

LTL	Line Turns Left
LTLA	Line Turns Left About
LTR	Line Turns Right
LTRA	Line Turns Right About
LWD	Low Water Datum
M	mark; middle; missed
m	meter(s)
MDU	Master Drive Unit
mer	meridian
MHz	megahertz
MHW	Mean High Water
mi	Mile(s) statute
min	*minute(s)*
misc	miscellaneous
MLLW	Mean Lower Low Water
MLW	Mean Low Water
mm	millimeter(s)
mo	month(s)
MRV	Middle Reed Vibrating
ms	millisecond(s)
MSS	Medium Survey Ship
Mt	Mount
MTM	Modified Transverse Mercator
µs	microsecond(s)
N	nitrates; north; nun
NA	North America
na	not applicable
NAD	North American Datum
NGS	National Geodetic Survey
nmi	nautical mile(s)
No(s).	number(s)
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Survey
NP	Not Plotted
O	oxygen
obj	object
obstr	obstruction
O/C	on course
ODESSA	Ocean Data Environmental Science Services Acquisition
opr	operator; operational
ortho-photo	orthographic-photographic
OSS	Ocean Survey Sheets; Ocean Survey Ship
P	pattern; phosphate
p(p).	page(s)
PA	Position Approximate
P/C	Partly Cloudy
PD	Position Doubtful
PDR	Precision Depth Recorder
pge	per gyro compass
photo	photogrammeric; photograph
photo-hydro	photogrammetric- photographic
PMC	Pacific Marine Center
pmc	per magnetic compass
PN	Position Number
pos	position
ppm	parts per million
ppt (‰)	parts per thousand
presc	prescribed
priv	private
PS	Pole Sounding
PSC	Per Steering Compass
PT	part
Pt.	point
pub	publication
R	rejected; report; right
RCVD	received
rdg	reading
rec	recorder
recov	recovered
Red	reduction
REF	reflected
ref	reference
reg	registry; regulation
rev(s)	revolution(s)
rmse	root mean square error
rpm	revolutions per minute
R/R	Range-Range
R/S	Reduced Speed
R/V	Range-Visual
S	same (fix)
S	salinity; snapper; south; speed
S	Special Project
s	second(s)
S&S	Settlement and Squat
SB	Side Band
sdr	sounder
sext	sextant
SF	scoopfish
SFS	See Field Sheet
SL	shoreline
S/N	Serial Number
sndg	sounding
S1	station 1
spd	speed
sq	square
S/S	Slow Speed; Standard Speed
SSS	Side Scan Sonar
sta	station
stbd	starboard
STD	Salinity, Temperature, and Depth
subm	submerged
T	TICUS (System)
T(A,B)	true (azimuth, bearing)
T+C	Time and Course
TDC	Temperature, Depth, and Conductivity
temp	temperature; temporary
TG	Tide Gage
TICUS	Tidal and Current Survey
TM	Technical Manual; Technical Memorandum
TRA	transducer
TRAV	traverse
triang	triangulation
unadj	unadjusted
uncov	uncovered
V	volt(s)
VC	Vertical Cast
vhf	very high frequency
vic	vicinity
vis	visual
vlf	very low frequency
vol(s).	volume(s)
V-VIS	Verified Visually

TABLE E-1. — *Continued*

W	watt(s); west
WD	Wire Drag
Wk	wreck
WL	Water Level
Xpndr	transponder
XSTD	expendable, Salinity, Temperature, Depth
yr	year(s)
Z	GMT
ZETG	zero electric tape gage

INDEX