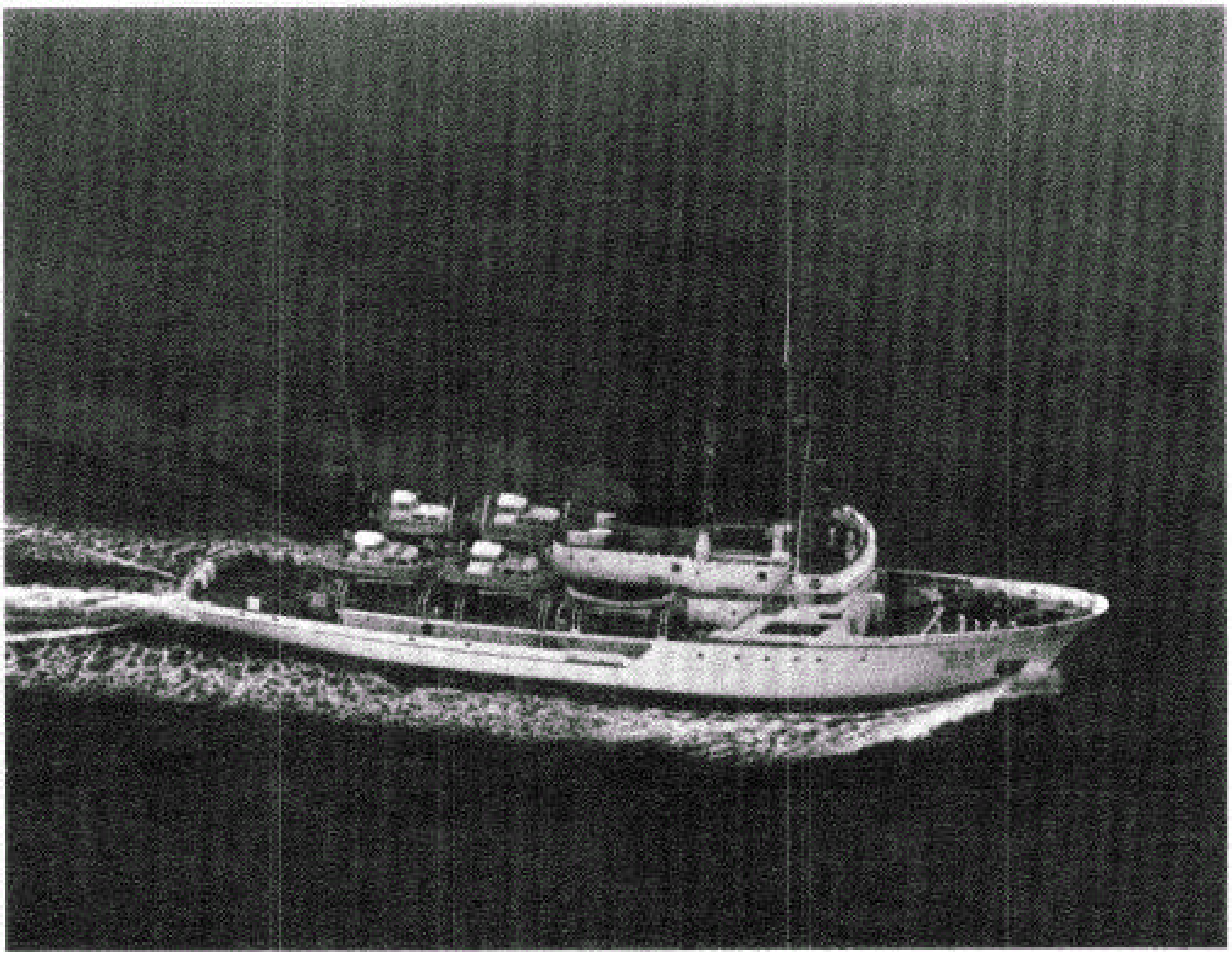
PART ONE

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 (1 975) *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 $\pm$ 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 45º. 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 90º 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.

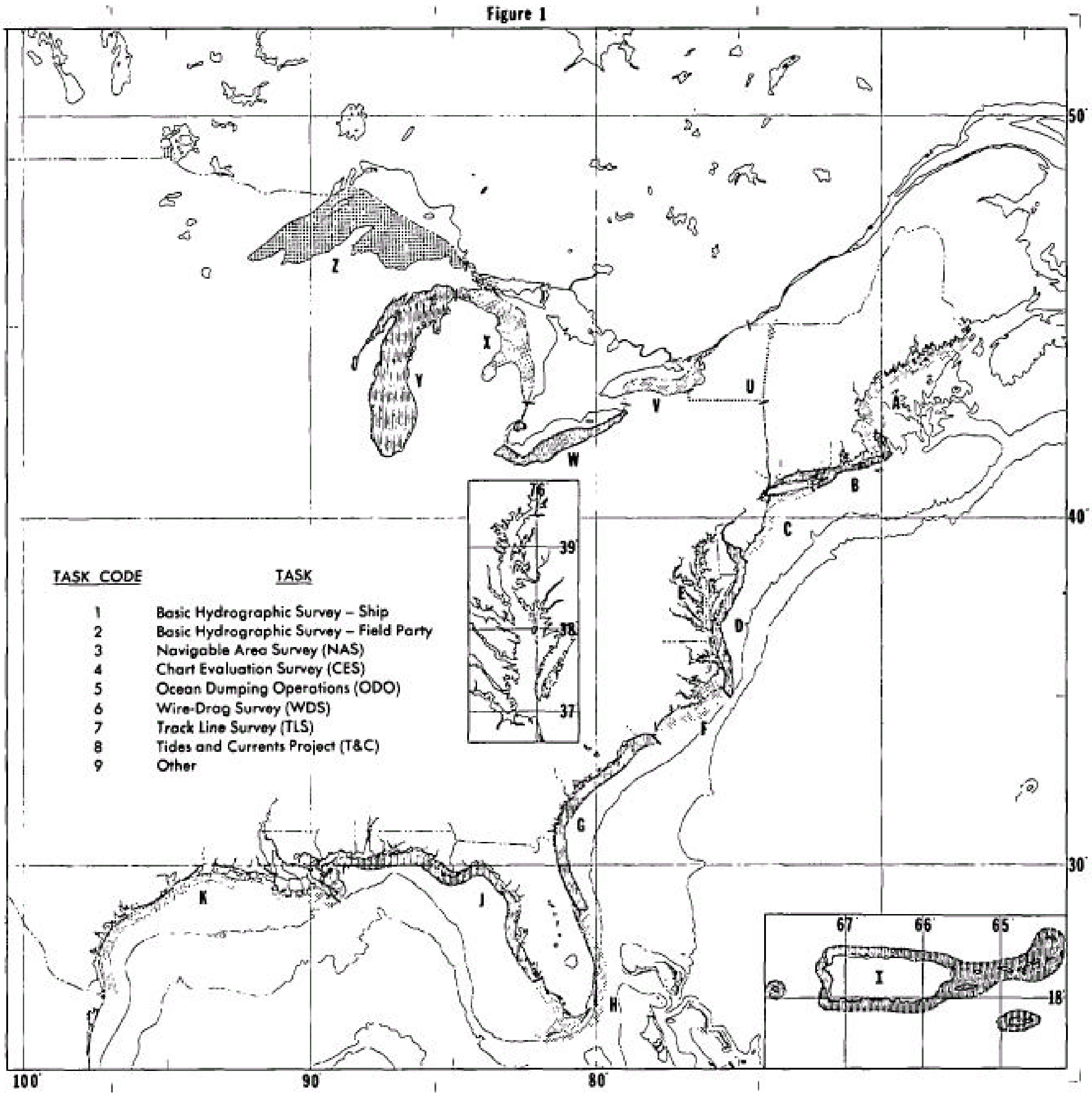
Charted features that will require special investigation. (See 2.3.3.)

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.



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

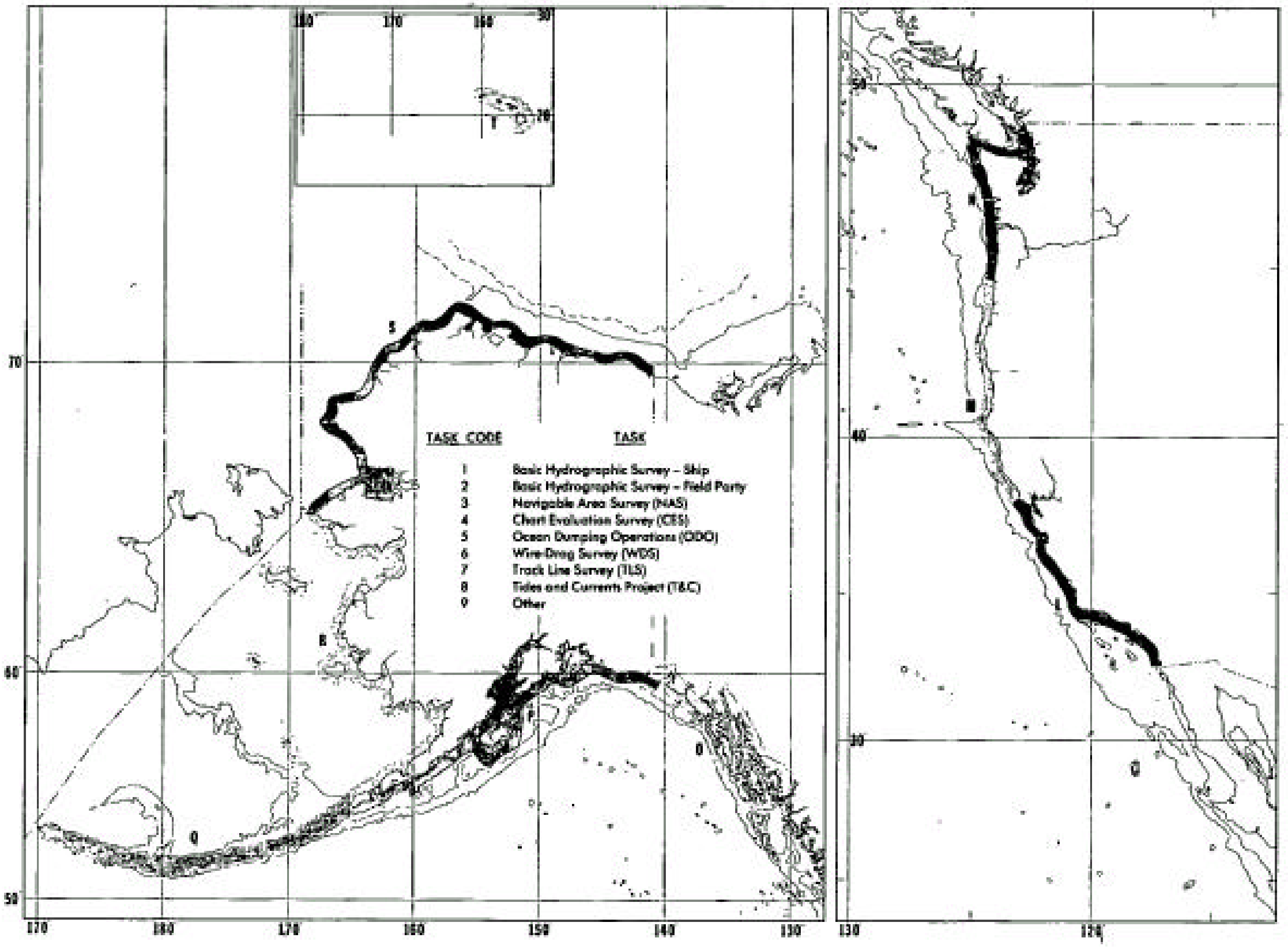


FIGURE 2-2 — Geographic designations for project numbering for the Pacific Coast, Alaska, and the Pacific Islands.

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.

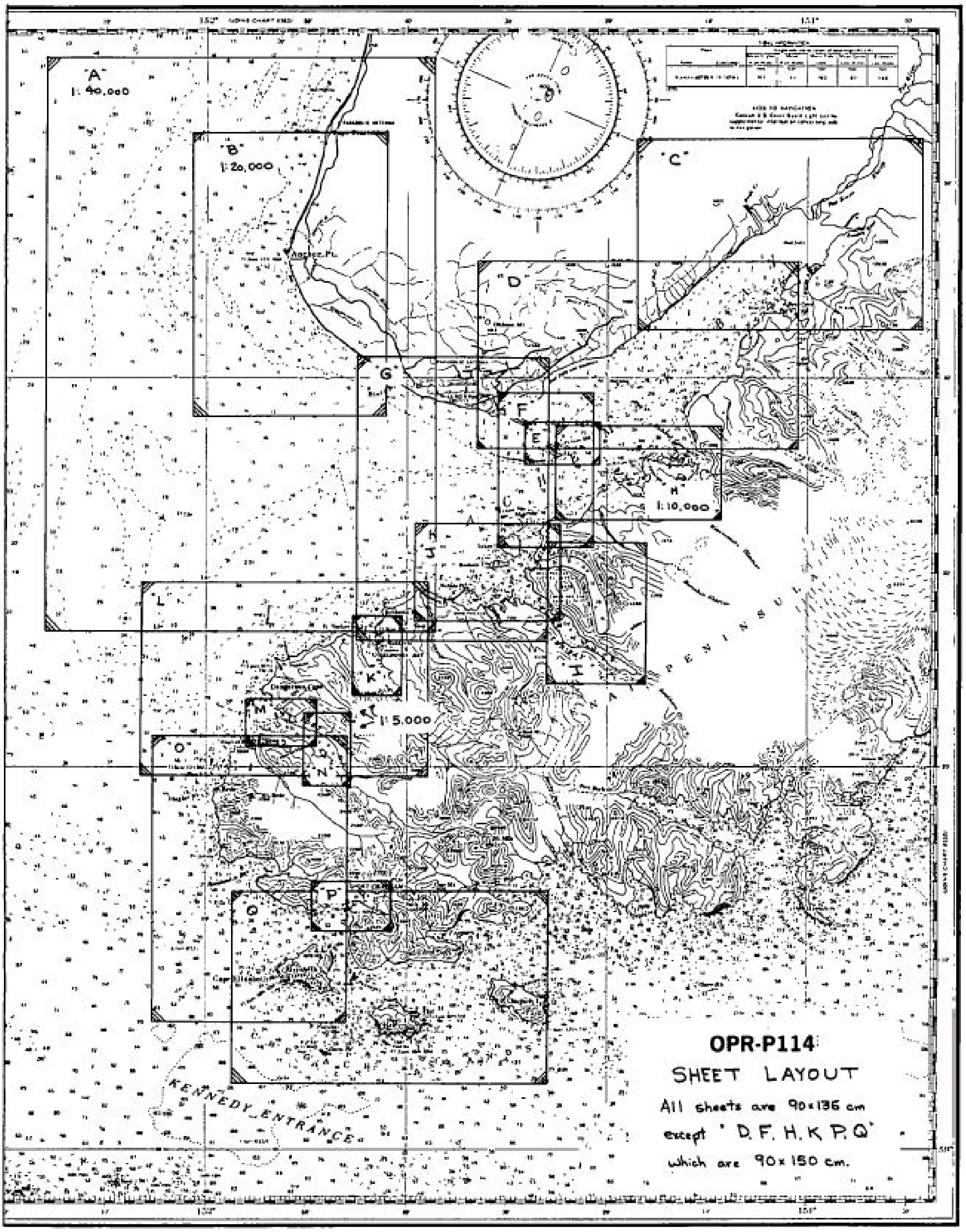


FIGURE 2.3 — Typical layout of hydrographic survey sheets showing reference letters, scales, and dimensions

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 360º 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 $10''\sqrt{N}$, 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 $10''\sqrt{N}$, 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.

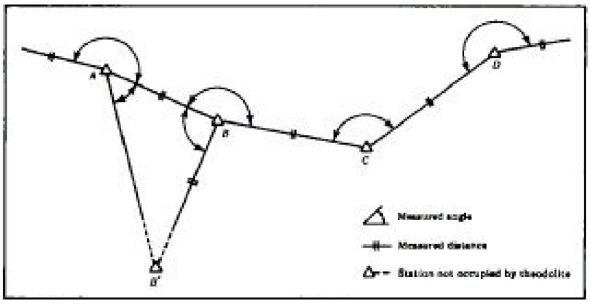


FIGURE 3-1. — Traverse with a checked spur point.

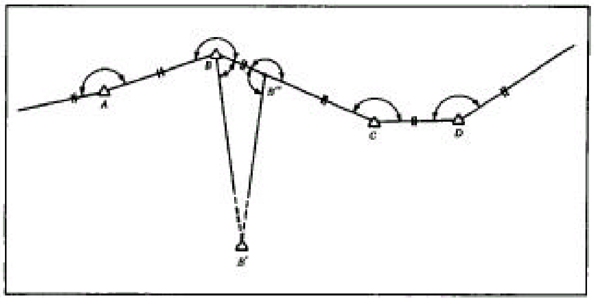


FIGURE 3-2. — Short base method for checking a traverse spur point.

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''*.

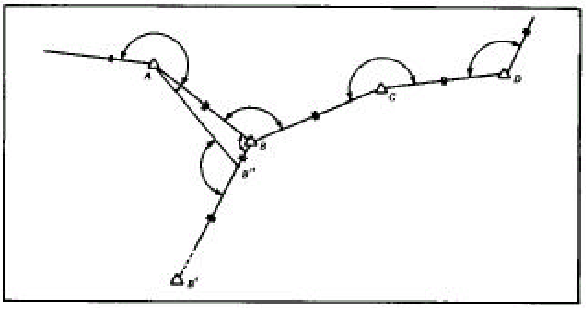


FIGURE 3-3. — Offset method for checking a traverse spur point

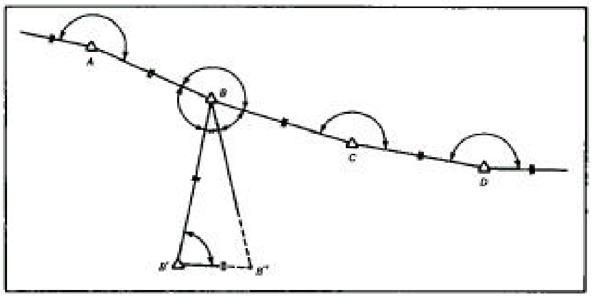


FIGURE 3-4. — Wing point method for checking a traverse spur point

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 360º 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 2º

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.