# NOS HYDROGRAPHIC SURVEYS SPECIFICATIONS and DELIVERABLES

**June 2006**

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# SPECIFICATIONS AND DELIVERABLES

## 1. Introduction

These technical specifications detail the requirements for hydrographic surveys to be undertaken either by National Oceanic and Atmospheric Administration (NOAA) field units or by organizations under contract to the Director, Office of Coast Survey (OCS), National Ocean Service (NOS), NOAA, U.S. Department of Commerce.

The specifications described herein are based in part on the International Hydrographic Organization's Standards for Hydrographic Surveys, Special Publication 44, Fourth Edition, April 1998, specifically for Order 1 surveys. Hydrographic surveys classified as Order 1 are intended for harbors, harbor approach channels, recommended tracks, inland navigation channels, coastal areas of high commercial traffic density, and are usually in shallower areas less than 100 meters water depth. Additional details for the specific project areas, including any modifications to the specifications in this manual, will be provided in Hydrographic Survey Letter Instructions for NOAA field units or the Statement of Work for contractors.

If a hydrographer has any questions on the interpretation of these Specifications or feels that there may be a "better way" to provide a deliverable, they should contact the COTR or appropriate NOAA Program Office to discuss and clarify the issue. The Specifications will continue to evolve and can only improve with the input of all users.

## 1.1. Definition

The term "hydrographer" as used through this document, refers to: (a) the chief of party or officer in charge, when the survey is being conducted by NOAA field units, or (b) the contractor where the work is being performed for NOAA under contract.

## 1.2 Changes From March 2003 Edition

Chapter 4, "Tides and Water Level Requirements" was not changed in any way.

The 2006 edition of the "NOS Hydrographic Surveys Specifications and Deliverables" includes two major changes:

1. The preliminary smooth sheet has been eliminated.
2. Depth data shall be submitted as a Bathymetric Attributed Grid (BAG).

The deliverables from Contractors and NOAA field units should be:

1. Features contained in an S-57 .000 feature file,
2. A collection of BAGs, and
3. Metadata in the form of reports.

The International Hydrographic Organization (IHO) Special Publication 57 (IHO S-57) is the IHO Transfer Standard for Digital Hydrographic Data (current version is edition 3.1). The IHO intends for the standard to be used for the exchange of digital hydrographic data between hydrographic offices, and for the distribution of hydrographic data to manufacturers, mariners and other data users. It was developed so that the transfer of all forms of hydrographic data would take place in a consistent and uniform manner.

IHO Special Publication 57 may be downloaded free of charge at "www.iho.shom.fr". Section 8.2 of the "NOS Hydrographic Surveys Specifications and Deliverables" provides additional details on the attributions required for the NOAA "features" survey deliverable.

Historically, a final product of a hydrographic survey would be a shoal-biased sounding set, reduced so that individual soundings do not overlap at a specific scale. This process severely reduces the usefulness of the data beyond nautical charting as resolution to define small features is lost.

Research at the Center for Coastal and Ocean Mapping and Joint Hydrographic Center (CCOM/JHC) resulted in the development of the Navigation Surface concept. The distinguishing feature of the Navigation Surface is that the horizontal and vertical uncertainty for each sounding is used in a weighting scheme to create a digital terrain or elevation model of the seafloor. The Navigation Surface processing workflow offers a new approach to managing, archiving, and creating multiple products from hydrographic survey data. NOAA has adopted the Navigation Surface concept into its hydrographic survey and nautical charting process. The algorithms have been made freely available for technology transfer and several vendors have commercialized the concept by incorporating it into their hydrographic and charting software. The intent of the process is to preserve a higher resolution version of the data, even if such resolution will never appear on a navigational or charting product. Charting products such as paper charts, Electronic Navigational Charts (ENC) and preliminary smooth sheets are created from scale-appropriate generalizations of the elevation model.

The Navigation Surface requires that each sounding have a horizontal and vertical uncertainty. To do this effectively, an error model is needed for all systems supplying measurements to compute the sounding; including not only the multibeam echosounder, but the GPS sensors, the heave, pitch, and roll sensors, the sound velocity measuring devices, tide gages, draft measurements, dynamic draft, or anything else that contributes to the calculation of a sounding. Once this comprehensive error model is assembled, then all the inherent errors in each measurement can be propagated from the measurement platform to each individual sounding. Only when each sounding has an associated Total Propagated Error (TPE), can we combine the soundings into a Navigation Surface with each node having a depth and uncertainty attribute.

NOAA field units typically process hydrographic data using CARIS HIPS software. CARIS' format for the Navigation Surface is a Bathymetry Associated with Statistical Error (BASE) surface. Non-CARIS users may submit their Navigation Surfaces as a Bathymetric Attributed Grid (BAG).

The BAG format was developed to create an open source exchange format for gridded data. The Open Navigation Surface Working Group (ONSWG) was formed to develop the format. ONSWG is comprised of government and private sector groups. The primary goals of the ONSWG are to define an open, platform independent, grid database file format suitable for access, archival, and interchange of Navigation Surface results, and to develop an open source software access library to operate on this format. For more information see http://www.opennavsurf.org.

Chapters 5 and 8 provide additional details on the formats and information required for the new Navigation Surface deliverables.

# 2. Datums

## 2.1. Horizontal Datum

All positions will be referenced to the North American Datum of 1983 (NAD 83). This datum must be used throughout a survey project for everything that has a geographic position or for which a position is to be determined. Those documents used for comparisons, such as charts, junctional surveys, and prior surveys, must be referenced or adjusted to NAD 83. In addition, all software used on a survey must contain the correct datum parameters.

The only exception for the NAD83 datum requirement, is that the S-57 feature file will be in the WGS84 datum to comply with the international S-57 specifications (see Section 8.2). All data shall be collected in the NAD83 datum and then transformed to the WGS84 datum in the S-57 feature file.

## 2.2. Sounding Datum

All sounding data will be reduced to Mean Lower Low Water (MLLW). Heights of bridges and overhead cables will be referenced to Mean High Water (MHW).

## 2.3. Time

Coordinated Universal Time (UTC) will be used for all time records.

# 3. Hydrographic Position Control

## 3.1. Horizontal Position Accuracy

The NOS specification for hydrographic positioning is that the total error in position of soundings, at the 95 percent confidence level, will not exceed 5 meters + 5 percent of the depth. This accuracy requirement is independent of survey scale.

For hydrographic surveys using single-beam echosounders, the accuracy of the vessel position can be considered the accuracy of the sounding obtained by that vessel, taking into account transducer offsets. However, for multibeam surveys, due to the oblique sounding pattern, the position of a sounding may be at some distance from the vessel position. The accuracy requirement for the vessel position will depend upon how accurately the sounding is positioned relative to the vessel. That, in turn, will depend upon the characteristics of the multibeam system, depth of water, the accuracy with which heave, roll, pitch, heading, and latency are accounted for and applied, and the reliability with which the speed of sound profile is known.

## 3.2. Differential Global Positioning System (DGPS)

DGPS is the primary positioning system currently used for hydrographic surveys. DGPS correctors can be obtained either through the U.S. Coast Guard (USCG) Maritime DGPS Service or other differential services provided they meet the accuracy requirement in Section 3.1.

### 3.2.1. DGPS Specifications

Unless specified otherwise in the Hydrographic Survey Letter Instructions or Statement of Work, the following specifications are recommended when DGPS is used as the primary positioning system:

- GPS receiver(s) aboard the vessel will be configured such that satellites below 8 degrees above the horizon will not be used in position computations.

- The age of pseudo-range correctors used in position computation should not exceed 20 seconds; and any horizontal positioning interpolation must not exceed the accuracy requirement in Section 3.1.

- Horizontal Dilution of Precision (HDOP) will be monitored and recorded, and should not exceed 2.5 nominally. Satellite geometry alone is not a sufficient statistic for determining horizontal positioning accuracy. Other variables, including satellite pseudorange residuals can be used in conjunction with HDOP to estimate DGPS horizontal accuracy.

- A minimum of four satellites will be used to compute all positions.

- Horizontal and vertical offsets between the GPS antenna and transducer(s) will be observed and applied in no coarser than 0.1 m increments.

Any deviations from the above specifications shall be clearly documented in the Descriptive Report with an explanation and supporting data to show that the resulting positions meet the accuracy requirement in Section 3.1

### 3.2.2. DGPS Site Confirmation

The hydrographer will conduct a 24-hour certification of all non-USCG differential reference stations prior to use for positioning control. The purpose of this certification is to ensure that no multipath or other site specific problems exist. Once the differential station is set up at the site and configured for survey operations, differential corrections will be broadcast and received at a remote site. This remote site may be within 2 meters of the differential reference station control point or over a second control point (third order or better) at another location. The remote site will receive correctors, compute a final position at a rate of not less than once per second, and compare that position to the control point position. A position plot will be constructed comparing the known position and the differentially computed position. An analysis of the data must prove that the position accuracy requirement of Section 3.1 is met. Certification for any non-USCG differential station is valid for one year only. All related position accuracy plots will be included in the Horizontal and Vertical Control Report for each project.

### 3.2.3 Other GPS Techniques

Real Time Kinematic (RTK) and Post Processed Kinematic (PPK) may be used for positioning during hydrographic surveys. If RTK or PPK techniques are used, the hydrographer must ensure that all positions meet the accuracy requirements of section 3.1.

Many vessels receive survey positions from a DGPS aided inertial navigation system (e.g. POS MV). A high quality inertial system may be able to maintain accurate positions for several minutes after loss of differential correctors. Also, age of correctors, satellite elevation variables, etc., may not be configurable. When using DGPS aided inertial navigation systems, the DGPS recommended configurations of section 3.2.1 may not apply. However, whatever positioning system is used, the hydrographer must always ensure that positions meet the accuracy requirements of section 3.1.

The hydrographer must describe the quality control checks used to ensure positional accuracy was met in the Data Acquisition and Processing Report (DAPR) and/or Descriptive Report (DR).

# 4. Tides and Water Levels Requirements

No changes in content have been made to Chapter 4 since the March 2003 edition. The 2006 edition may have some formatting issues with some of the tables and figures. Users may choose to refer back to the 2003 edition for clearer reading of the tables/figures.

## 4.1. General Project Requirements and Scope

### 4.1.1. Scope

The requirements and specifications contained in this section cover the water level and vertical datum requirements for operational support of hydrographic surveys conducted as part of the NOAA Nautical Charting Program. The scope of this support comprises the following functional areas:

1. Tide and water level requirement planning
2. Preliminary tidal zoning development
3a. Control water level station operation;
3b. Supplemental water level station installation, operation and removal
4. Data quality control, processing, and tabulation
5. Tidal datum computation and tidal datum recovery
6. Generation of water level reducers and final tidal zoning

For in-house surveys, personnel from the National Ocean Service (NOS) Center for Operational Oceanographic Products and Services (CO-OPS) are responsible for functional areas 1, 2, 4, 5, and 6. NOS hydrographers and CO-OPS Field Operations Division will be responsible for functional area 3 above.

For contract surveys, CO-OPS personnel are responsible for functional areas 1, 2 and 3a. NOS contract hydrographers will be responsible for functional areas 3b through 6 above. NOS continues to be responsible for operating, maintaining, and processing data from the control stations (e.g., the NWLON).

### 4.1.2. Objectives

The work performed under the requirements and specifications of this section is required for NOS major program areas of navigational products and services. The first objective for the support detailed in this section is to provide time series of water level reducers that can be applied to hydrographic soundings so that they can be corrected to chart datum. A second objective is to establish and/or recover tidal datums relative to local benchmarks at each station that can be used for continuing and future hydrographic surveys in the area. A third objective is to provide new or updated information that can be used to update NOAA tide prediction products and tidal zoning for promoting safe navigation applications.

### 4.1.3. Planning and Preliminary Tidal Zoning

CO-OPS is responsible for all planning of tide requirements for NOS hydrographic surveys. CO-OPS will analyze historical data and tidal characteristics for each project area, specify operational

NOS control stations, specify subordinate tide station locations to be installed, and provide the preliminary tidal zoning to be used during survey operations. CO-OPS will provide 6-minute interval tide predictions relative to chart datum for appropriate NOS control stations prior to each survey and will also provide historical published bench mark information available for all historical tide stations specified for reoccupation. If CO-OPS provides a new preliminary tidal zoning scheme, the contractor must use that zoning scheme first for each project, and then, may generate a new scheme if the one provided is not adequate. At the conclusion of the survey, the contractor shall suspend the use of preliminary zoning scheme and develop final zoning scheme using correctors derived from the subordinate stations installed during the survey. Refer to Section 4.5.2 for further details.

### 4.1.4. NOS Control Stations and Data Quality Monitoring

National Water Level Observation Network

CO-OPS manages the National Water Level Observation Network (NWLON) of approximately 175 continuously operating water level observation stations in the U.S. coastal zone, including the Great Lakes. As most of these stations are equipped with satellite radios, near real-time (within about 3 hours of collection) raw data are made available to all users through the interface to the CO-OPS Home Page on the Web. Verified products, such as edited 6-minute data, hourly heights, high and low waters, and monthly means are made available over the Web within one to four weeks after data collection. NWLON data and accepted tidal datums are used in hydrographic surveys either to provide tide reducers directly or for control for datum determination at subordinate (short-term) stations. Preliminary and verified data are made available over the Web relative to MLLW datum, station datum, or special water level datum (such as Columbia River datum) as a user option in the interface.

Data Quality Monitoring

CO-OPS has an in-place Continuous Operational Real-Time Monitoring System (CORMS) that provides quality control and system monitoring functions on a 24 hour/day, 7 days/week, all year around basis. CORMS will monitor the status and performance of all hydro gauges equipped with satellite radios using the NOS satellite message format installed by the hydrographer, and once listed on the hydro hot list by CO-OPS, as it does for all other NOS water level systems, including all NWLON stations. The CORMS system description can be found in System Development Plan, CORMS. CORMS is a NOS provided support function to the operational field parties and does not relieve the hydrographer of responsibility for performing QC and ensuring proper gauge operation.

### 4.1.5. General Data and Reference Datum Requirements

The present NOAA Nautical Chart Reference Datum for tidal waters is Mean Lower Low Water (MLLW) based on the NOAA National Tidal Datum Epoch (NTDE) of 1983-2001 as defined in the Tide and Current Glossary. All tidal datum computations and water level reductions shall be referenced to this datum. In non-tidal areas, including the Great Lakes, special low water datums have been defined for specific areas and are used as chart datum in these locations.

In some cases where historical sites are re-occupied, site datum shall be zeroed to a pre-established MLLW datum held on a bench mark. In that case, data can be acquired relative to

MLLW for immediate application during the survey. At present, in Great Lakes areas, a special Low Water Datum relative to IGLD 85 is the reference datum.

### 4.1.6. Error Budget Considerations

The water level reducers can be a significant corrector to soundings to reduce them relative to chart datum especially in shallow water areas with relatively high ranges of tide. The errors associated with water level reducers are generally not depth dependent, however. The portion of the error of the water level reducers must be balanced against all other sounding errors to ensure that the total sounding error budget is not exceeded. The allowable contribution of the error for tides and water levels to the total survey error budget falls between 0.20 m and 0.45 m (at the 95% confidence level) depending on the complexity of the tides.

The total error of the tides and water levels can be considered to have component errors of:

1) the measurement error of the gauge/sensor and processing error to refer the measurements to station datum. Gauges/sensors need to be calibrated, and sensor design and data sampling need to include strategies to reduce measurement errors due to waves, currents, temperature and density effects. The measurements need to be properly referenced to the bench marks and tide staffs, as appropriate and monitored for vertical stability. The measurement error, including the dynamic effects, should not exceed 0.10 m at the 95% confidence level. The processing error also includes interpolation error of the water level at the exact time of the soundings. A estimate for a typical processing error is 0.10 m at the 95% confidence level.

2) the error in computation of tidal datums for the adjustment to an equivalent 19-year National Tidal Datum Epoch (NTDE) periods for short term stations. The shorter the time series, the less accurate the datum, i.e. bigger the error. An inappropriate control station also decreases accuracy. The NTDE does not apply in the Great Lakes, however the accuracy of datum based on shorter time series is analogous. The estimated error of an adjusted tidal datum based on one month of data is 0.08 m for the east and west coasts and 0.11 m for the Gulf coast (at the 95% confidence level).

3) the error in application of tidal zoning. Tidal zoning is the extrapolation and/or interpolation of tidal characteristics from a known shore point(s) to a desired survey area using time differences and range ratios. The greater the extrapolation/interpolation, the greater the uncertainty and error. Estimates for typical errors associated with tidal zoning are 0.20 m at the 95% confidence level. However, errors for this component can easily exceed 0.20 m if tidal characteristics are very complex, or not well-defined, and if there are pronounced differential effects of meteorology on the water levels across the survey area.

Project planning by NOS attempts to minimize and balance these potential sources of errors through the use and specification of accurate reliable water level gauges, and optimization of the mix of zoning required, the number of station locations required, and the length of observations required within practical limits of the survey area and survey duration. The practical limits depend upon the tidal characteristics of the area and suitability of the coastline for the installation and operation of appropriate water level stations.

## 4.2. Data Collection and Field Work

The hydrographer shall collect continuous and valid data series. Accurate datums cannot be computed for a month of data with a break in the water level measurement series in excess of three days. Even breaks of significantly less than three days duration will not allow for interpolation during times when strong meteorological conditions are present and in areas with little periodic tidal influence. Any break in the water level measurement series affects the accuracy of datum computations. Breaks in data also result in increased error in the tide reducers when interpolation is required to provide data at the time of soundings. At a critical measurement site where the water level measurement data cannot be transmitted or monitored during hydrographic operations, an independent backup sensor or a complete redundant water level collection system shall be installed and operated during the project.

### 4.2.1. Water Level Station Requirements

Data from NOS National Water Level Observation Network (NWLON) stations will be provided to support hydrographic survey operations where appropriate. Data provided are relative to Chart Datum which is Mean Lower Low Water for the 19-year National Tidal Datum Epoch (NTDE).

The acquisition of water level data from subordinate locations may be required for hydrographic surveys and if so shall be specified by NOS in each individual set of Project Instructions or Statement of Work. These stations shall be used to provide 6-minute time series data, tidal datum references and tidal zoning which all factor into the production of final tide reducers for specific survey areas. Station locations and requirements may be modified after station reconnaissance or as survey operations progress. Any changes shall be made only after consultation between the CO-OPS and the hydrographer (and COTR if contract survey) as moving required stations to new locations may require new seven-digit station identifier numbers and new/historical station and bench mark information.

The duration of continuous data acquisition shall be a 30-day minimum except for zoning stations. Data acquisition shall be from at least 4 hours before the beginning of the hydrographic survey operations to 4 hours after the ending of hydrographic survey operations, and/or shoreline verification in the applicable areas. Stations identified as “30-day” stations are the “main” subordinate stations for datum establishment, providing tide reducers for a given project and for harmonic analysis from which harmonic constants for tide prediction can be derived. At these stations, data must be collected throughout the entire survey period in specified areas for which they are required, and not less than 30 continuous days are required for accurate datum determination. Additionally, supplemental and/or back-up gauges may also be necessary based upon the complexity of the hydrodynamics and/or the severity of environmental conditions of the project area.

In non-tidal areas the correctors for hydrographic soundings are simply water level measurements relative to a specified local low water level datum established for navigational purposes. Laguna Madre and parts of Pamlico Sound are examples of such areas classified as non-tidal which have special low water datums. Some river areas also have special datums due to the effects of seasonal changes on the river, e.g., Columbia River Datum, Hudson River datum, and Mississippi River Low Water are examples of this case. Great Lakes NWLON permanent stations will provide water level data referenced to an established Low Water Datum relative to International Great Lakes Datum of 1985 (IGLD '85) (see Standing Project Instructions: Great Lakes Water Levels, June 1978).

### 4.2.2. Water Level Measurement Systems and Data Transmissions

### Water Level Sensor and Data Collection Platform

The water level sensor shall be a self-calibrating air acoustic, pressure (vented), or other suitable type. The sensor measurement range shall be greater than the expected range of water level. Gauge/sensor systems shall be calibrated prior to deployment, and the calibration shall be checked after removal from operations. The calibration standard's accuracy must be traceable to National Institute of Standards and technology (NIST). The required water level sensor resolution is a function of the tidal range of the area in which hydrographic surveys are planned. For tidal range less than or equal to 5 m, the required water level sensor resolution shall be 1 mm or better; for tidal range between 5 m and 10 m, the required water level sensor resolution shall be 3 mm or better; and for tidal range greater than 10 m, the required water level sensor resolution shall be 5 mm or better.

The Data Collection Platform (DCP) shall acquire and store water level measurements at every 6-minutes. The water level measurements shall consist of an average of at least three minutes of discrete water level samples with the period of the average centered about the six minute mark (i.e. :00, :06, :12, etc.). In addition to the average measurement, the standard deviation of the discrete water level samples which comprise the 6-minute measurements shall be computed and stored. The 6-minute centered average water level data is required for compatibility with the NWLON stations, and the standard deviation provides valuable data quality information regarding each measurement. The clock accuracy of a satellite radio system shall be within 5 seconds per month so that channel "stepping" does not occur. Non-satellite radio systems shall have a clock accuracy of within one minute per month. Known error sources for each sensor shall be handled appropriately through ancillary measurements and/or correction algorithms. Examples of such errors are water density variations for pressure gauges, sound path air temperature differences for acoustic systems, and high frequency wave action and high velocity currents for all sensor types.

The NOS is currently using the Aquatrak® self-calibrating air acoustic sensors at the majority of the NWLON stations. (For further information refer to Next Generation Water level Measurement System (NGWLMS) Site Design, Preparation, and Installation Manual, NOAA/NOS, January 1991 and User's Guide for 8200 Acoustic Gauges, NOAA/NOS, Updated August 1998). At stations where the acoustic sensor can not be used due to freezing or the lack of a suitable structure, either a ParoScientific intelligent pressure (vented) sensor incorporated into a gas purge system, or a well/float with absolute shaft angle encoder (Great Lakes Stations) are used for water level measurements. (For further information refer to User's Guide for 8200 Bubbler Gauges, NOAA/NOS, Updated February 1998).

In each and any case, the water leveling sampling/averaging scheme shall be as described above. For short term subordinate stations which are installed to support NOS hydrographic surveys, the use of air acoustic sensor is preferred over pressure sensor whenever possible. Where the air acoustic sensor can not be installed, NOS uses a vented strain gauge pressure sensor in a bubbler configuration (Refer to User's Guide for 8200 Bubbler Gauges, NOAA/NOS, updated February

1998). When using the vented pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle shall be required (1) at the start, (2) at frequent intervals during deployment, and (3) at the end of a deployment. Frequent gauge/staff comparisons (at least two times per week or minimum eight times per month) during deployment shall be required to assist in assuring measurement stability and minimizing processing type errors. The staff to gauge observations shall be at least three hours long at the beginning and end of deployment and the periodic observations during deployment shall be 1 hour long. Along with the averaging procedure described above which works as a digital filter, NOS uses a combination protective well/parallel plate assembly on the acoustic sensor and a parallel plate assembly (with 2" orifice chamber) on the bubbler orifice sensor to minimize systematic measurement errors due to wave effects and current effects, as shown in figure 4.1.

## Data Transmissions

The ability to monitor water level measurement system performance for near real-time quality assurance is essential to properly support hydrographic survey operations. Therefore, it is required that, where access to the satellite is available, the measurement system shall be equipped with a GOES transmitter to telemeter the data to NOS every three hours. The data transmissions must use a message format identical to the format as currently implemented in NOS' Next Generation Water Level Measurement Systems (NGWLMS). This is required to assure direct compatibility with the NOS Data Management System (DMS). This data format is detailed in the reference document "NGWLMS GOES MESSAGE FORMATTING" (refer to Section 4.7 for References). Once station and gauge information is configured in DMS and station listed on the Hydro Hot List (HHL), the NOS Continuous Operational Real-Time System (CORMS) will monitor all water level measurement system GOES transmissions to assure they are operating properly, provided that the GOES data transmitted is compatible with NOS format. Data that is not transmitted by GOES, or data transmitted but not in NOS compatible GOES format, or is submitted to CO-OPS via diskette, CD-ROM, or such other digital media, must also conform to the format specified in the above document so that data can be loaded properly into DMS software. Refer to Section 4.6.3 for further details about the water level data format specifications.

Close coordination is required between hydrographer and Requirements and Development Division (RDD) of CO-OPS for all hydrographic water level installations with satellite transmission capability. NOS will assist in acquiring assigned platform ID's, time slots, etc. At least three business days prior to the initiation of GOES data transmission in the field, information about the station number, station name, latitude, longitude, platform-ID, transmit time, channel, and serial numbers of sensors, and DCP shall be faxed, phoned, or sent to RDD. Test transmissions conducted on site are outside this requirement. This station and DCP information must be configured in DMS before data transmissions begin so that the data will be accepted in DMS. The documentation required prior to transmission in field is defined in the NGWLMS Site

Report, Field Tide Note, or Water Level Station Report, as appropriate. (Refer to Section 4.6 Data Submission Requirements).

### 4.2.3. Station Installation, Operation and Removal

Hydrographers shall obtain all required permits and permissions for installation of the water level sensor(s), Data Collection Platforms (DCP), bench marks, and utilities, as required. The hydrographer shall be responsible for security and/or protective measures, as required. The hydrographer shall install all components in the manner prescribed by manufacturer, or installation manuals. The hydrographer or contractor shall provide CO-OPS of the position of all tide gauges installed before hydrography begins, including those that were not specified in the Statement of Work or Project Instructions, as appropriate. The positions of bench marks and stations installed or recovered shall be obtained as latitudes and longitudes (degrees, minutes, and hundredths of seconds).

The following paragraphs provide general information regarding requirements for station installation, operations and maintenance, and station removal.

## Station Installation

A complete water level measurement gauge installation shall consist of the following:

(A) The installation of the water level measurement system (water level sensor(s), DCP, and satellite transmitter) and its supporting structure and a tide staff if required.

(B) The recovery and/or installation of a minimum number of bench marks and a level connection between the bench marks and the water level sensor(s), and tide staff as appropriate.

(C) The preparation of all documentation and forms.

## Operation and Maintenance

When GOES telemetry and NOS satellite message format is used, the hydrographer shall monitor the near-real time water level gauge data daily for indications of sensor malfunction or failure, and for other causes of degraded or invalid data, such as marine fouling. This monitoring can be performed by accessing the COOPS web page (http://www.CO-OPS.NOS.NOAA.GOV) The data over this system are typically available for review within three to four hours after collection.

All repairs, adjustments, replacements, cleaning, or other actions potentially affecting sensor output or collection of data shall be documented in writing using appropriate maintenance forms (see section on water level station documentation below) and retained as part of the water level data record. This documentation shall include, but not be limited to, the following information: date and time of start and completion of the maintenance activity; date and time of adjustments in sensor/DCP, datum offset, or time; personnel conducting the work; parts or components replaced; component serial numbers; tests performed; etc.

## Removal

A complete removal of the water level measurement gauge shall consist of the following:

(A) Closing levels - a level connection between the minimum number bench marks and the water level sensor(s) and tide staff as appropriate.

(B) Removal of the water level measurement system and restoration of the premises, reasonable wear and tear excepted.

(C) The preparation of all documentation, forms, data, and reports.

## 4.2.4. Tide Staffs

### Staff

The hydrographer shall install a tide staff at a station if the reference measurement point of a sensor (zero of a gauge) cannot be directly leveled to the local bench marks, e.g. orifice is laid over sea floor in case of pressure based bubbler gauges. Even if a pressure gauge can be leveled directly, staff readings are still required for assessment of variations in gauge performance due to density variations in the water column over time. The tide staff shall be mounted independent of the water level sensor so that stability of the staff or sensor is maintained. Staff shall not be mounted to the same pile on which the water level sensor is located. The staff shall be plumb. When two or more staff scales are joined to form a long staff, the hydrographer shall take extra care to ensure the accuracy of the staff throughout its length. The distance between staff zero and the rod stop shall be measured before the staff is installed and after it is removed and the rod stop above staff zero height shall be reported on the documentation forms.

In areas of large tidal range and long sloping beaches (i.e. Cook Inlet and the Gulf of Maine), the installation and maintenance of tide staffs can be extremely difficult and costly. In these cases, the physical installation of a tide staff(s) may be substituted by systematic leveling to the water's edge from the closest bench mark. The bench mark becomes the "staff stop" and the elevation difference to the water's edge becomes the "staff reading".

### Staff Observations

When using the vented pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle shall be required (1) at the start, (2) at frequent intervals during deployment, and (3) at the end of a deployment. Frequent gauge/staff comparisons (at least three times per week or minimum eight times per month) during deployment shall be required to assist in assuring measurement stability and minimizing processing type errors. The staff to gauge observations at the start and end of deployment shall be at least each three hours long and the periodic observations during the deployment shall be 1 hour long.

If a gauge requiring independent staff readings is installed, the installation report must be accompanied by a 3-hour set of staff-to-gauge observations documenting the proper operation of the gauge. During the first or second day of gauge operations, the gauge and staff must be read simultaneously and recorded every 6 minutes for a 3-hour period. The staff-to-gauge differences should remain constant throughout the set of observations and show no increasing or decreasing trends. Gauge time should be set to Coordinated Universal Time (UTC). The gauge and staff shall be read simultaneously and recorded once a day (minimum of three days in each seven day period) for the duration of the water level measurements. The average staff-to-gauge difference shall be applied to water level measurements to relate the data to staff zero. A higher number of independent staff readings decreases the uncertainty in transferring the measurements to station datum and the bench marks. Refer to Figure 4.2 for an example pressure tide gauge record.

If the old staff is found destroyed by elements during the deployment, then a new staff shall be installed for the remainder period of the deployment and a new staff to gauge constant needs to be derived by new sets of staff to gauge observations. Also when a staff or an orifice is replaced or re-established, check levels shall be run to minimum of three bench marks including the PBM. Refer to Section 4.2.5 for leveling frequency and other leveling requirements. Bubbler Orifice and Parallel Plate Assembly

This bottom assembly is made of red brass, its chemical properties prevent the growth of marine life by the slowly releasing copper oxide on its metal surface. A Swagelok® hose fitting is screwed into the top end cap and is used to discharge the Nitrogen gas. The Nitrogen gas flows through the bottom of the orifice at a rate sufficient to overcome the rate of tidal change and wave height. This opening establishes the reference point for tidal measurements. The parallel plates produce a laminar flow across the orifice to prevent venturi effect. A two inch by eight inch pipe provides the correct volume gas for widest range of surf conditions encountered by most coastal surveys.

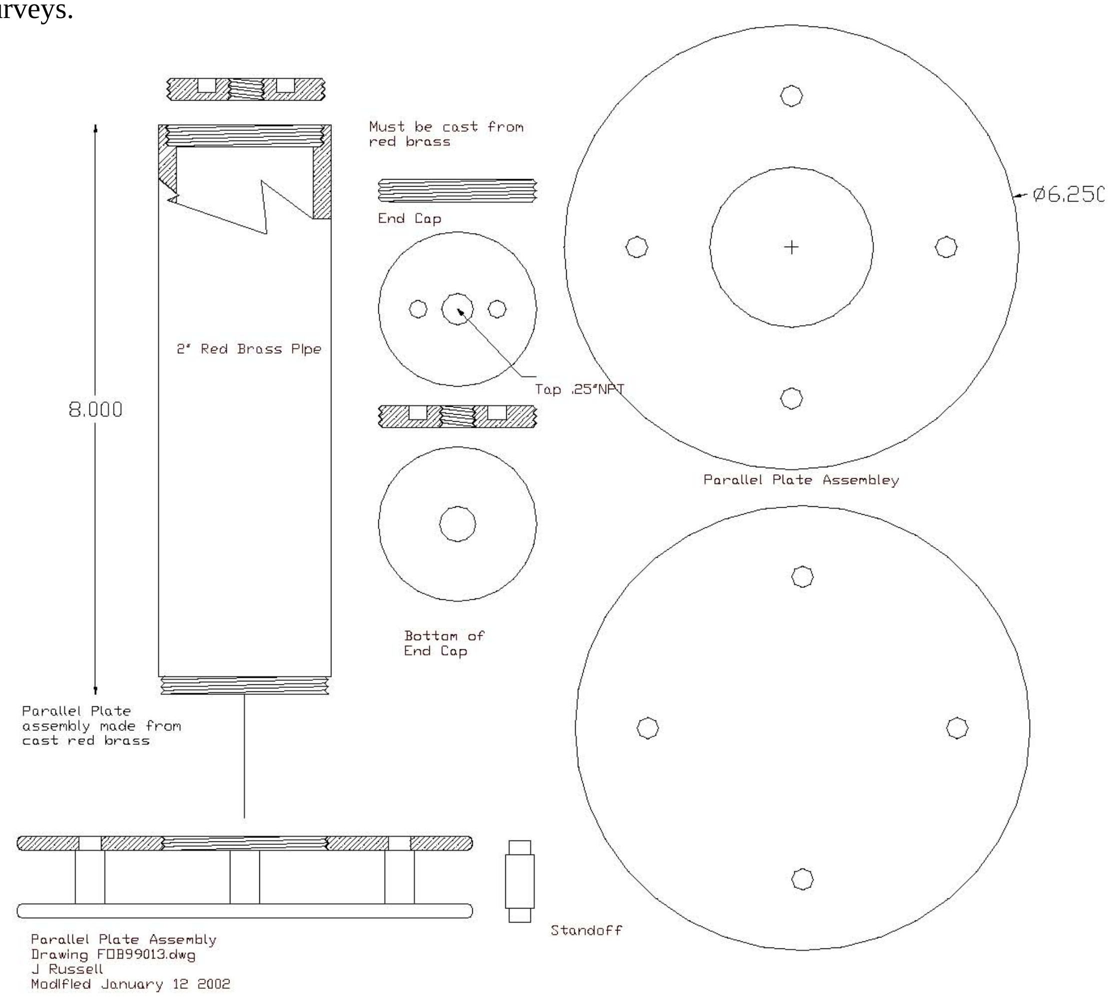


**Figure 4.1 : Bubbler orifice bottom assembly**

**Figure 4.2 Example - Pressure Tide Gauge Record**

**PRESSURE TIDE GAUGE RECORD**

**Station Name:** **Station No. (7 digit #)**

| Date | Time | | Staff Reading | | Gage/Staff Difference | Gas Pressure | | Wind (Dir/Spd) | Air Temp. | |
|---|---|---|---|---|---|---|---|---|---|---|
| (M,D,Y) | Gage | Correct | High | Low | | Cyln | Feed | | | Remarks |
| | | | | | | | | | | |
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### 4.2.5. Bench Marks and Leveling

## Bench Marks

A bench mark is a fixed physical object or marker (monumentation) set for stability and used as a reference to the vertical and/or horizontal datums. Bench marks in the vicinity of a water level measurement station are used as the reference for the local tidal datums derived from the water level data. The relationship between the bench marks and the water level sensor or tide staff shall be established by differential leveling.

## Number and Type of Bench Marks

The number and type of bench marks required depends on the duration of the water level measurements. The User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, dated October 1987, specifies the installation and documentation requirements for the bench marks. Each station will have one bench mark designated as the primary bench mark (PBM), which shall be leveled to on every run. The PBM is typically the most stable mark in close proximity to the water level measurement station. The contractor shall select a PBM at sites where the PBM has not already been designated. For historic NOS station reoccupations, CO-OPS will furnish the name of the PBM and PBM elevation above station datum, as appropriate and if available.

The most desirable bench mark for GPS observations will have 360 degrees of horizontal clearance around the mark at 10 degrees and greater above the horizon and stability code of A or B. Refer to Section 4.2.8 GPS Observations, and User’s Guide for GPS Observations, Updated January 2003, for further information.

If the PBM is determined to be unstable, another mark shall be designated as PBM. The date of change and the elevation difference between the old and new PBM shall be documented. NOAA will furnish the individual NOS standard bench mark disks to be installed. Bench mark descriptions shall be written according to User’s Guide for Writing Bench Mark Descriptions, updated January 2003.

## Leveling

At least third-order levels shall be run at short-term subordinate stations operated for less than one-year. Requirements for higher order levels will be specified in individual project instructions, as appropriate. Standards and specifications for leveling are found in Standards and Specifications for Geodetic Control Networks and Geodetic Leveling (NOAA Manual NOS NGS 3). Additional field requirements and procedures used by NOS for leveling at tide stations can be found in the User’s Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations. Electronic digital/barcode level systems are acceptable. Specifications and standards for digital levels can be found in Standards and Specifications for Geodetic Control Networks and additional field requirements and procedures used by NOS for electronic leveling at water level stations can be found in the User’s Guide for Electronic Levels, updated January 2003.

### Leveling Frequency

Levels shall be run between the water level sensor(s) or tide staff and the required number of bench marks when the water level measurement station is installed, modified (e.g., water level sensor serviced, staff, or orifice replaced), for time series bracketing purposes, or prior to removal. In any case, levels are required at a maximum interval of six (6) months during the station's operation, and are recommended after severe storms, hurricanes, earthquakes to document stability (see stability discussed below).

Bracketing levels to appropriate number of marks (five for 30-day minimum stations) are required (a) if smooth tides are required 30 days or more prior to the planned removal of a applicable gauge(s), or (b) after 6 months for stations collecting data for long term hydrographic projects.

### Stability

If there is an unresolved movement of the water level sensor or tide staff zero relative to the PBM, from one leveling to the next of greater than 0.010 m, the hydrographer shall verify the apparent movement by rerunning the levels between the sensor zero or tide staff to the PBM. This threshold of 0.010 m should not be confused with the closure tolerances used for the order and class of leveling.

### 4.2.6. Water Level Station Documentation

The field team shall maintain a documentation package for each water level measurement station installed for hydrographic projects. The documentation package shall be forwarded to CO-OPS within 10 business days of a) installation of a station, b) performance of bracketing levels, c) gauge maintenance and repair, or d) removal of the station.

Generally, all documentation submitted (see Section 4.6 for Data Submission Requirements) shall be forwarded to CO-OPS when a station is installed. For other situations, only information that has changed shall be submitted (e.g., levels and abstract for bracketing or removal levels, NGWLMS Site Report for maintenance and repair or station removal, etc.)

### 4.2.7. Additional Field Requirements

(A) Generally upon completion of the data acquisition for each gauge installed, the data must be sent all together for 30-day minimum stations unless the data are transmitted via satellite. For long term stations running more than three months, the data shall be sent periodically (monthly) unless the data are transmitted via satellite.

(B) All water level data from a gauge shall be downloaded and backed up at least weekly on diskettes whether the gauge data are sent via satellite or not.

(C) For new stations that do not have station numbers assigned, once the location of the gauge has been finalized then contact CO-OPS and provide latitude and longitude of the gauge site at least three business days prior to actual installation of the gauge in field. CO-OPS will assign a new station number within three business days and inform the hydrographer.

(D) The progress sketch shall show the field sheet, layout, area of hydrography, gauge locations, and other information as appropriate. Verify the location of the gauge as shown on the progress sketch, bench mark and tide station location sketch, field tide note, NGWLMS Site Report (or Tide Station Report or Great Lakes Water Level Station Report, as appropriate).

### 4.2.8. GPS Observations

GPS observations are required to obtain elevation ties between the tidal datums and GPS derived datums.

(A) High accuracy static differential GPS surveys require a geodetic quality, dual frequency, full-wavelength GPS receiver with a minimum of 10 channels for tracking GPS satellites.

A choke ring antenna is preferred, however, any geodetic quality ground plane antenna may be used. More important than antenna type, i.e. choke ring or ground plane, is that the same antennas or identical antennas should be used during the entire observing sessions. If not, a correction for the difference in antenna phase patterns (modeled phase patterns) must be applied. This is extremely critical for obtaining precise vertical results. The antenna cable length between the antenna and receiver should be kept to a minimum when possible; 10 meters is the typical antenna cable length. If a longer antenna cable is required, the cable must be fabricated from low loss coaxial cable ( RG233 for up to 30 meters and RG214 over 30 meters).

(B) A fixed height precise GPS antenna tripod is required for this type of a survey. This is a fixed height, 2 meter pole with three adjustable legs, a bulls eye bubble to plumb the antenna, and a magnetic compass to align the antenna to North. These fixed height tripods reduce the chance of introducing an Height of Instrument (HI) “blunder” during the post-processing of the data.

(C) The manufacturer, model, and complete serial numbers of all receivers and antennas must be included for each occupation on each station/bench mark observation log sheet as shown in Figure 4.18

(D) The station bench mark selected for GPS observations shall have stability code either an A or B. GPS observations on the PBM are preferred if the PBM has the stability code of A or B and also if it is suitable for satellite observations. Stability code C and D bench marks shall not be used for GPS observations. Generally once a mark is selected for GPS observations, future GPS observations shall be done on the same mark. It may be necessary to select new GPS marks, or set new marks, at some stations to ensure stability over time as the case may be.

(E) Additional GPS suitable marks shall also be connected during the static survey using rapid static GPS procedures to verify bench mark stability, if time and personnel resources are available. Priority shall be given to connecting to the NSRS, particularly to the North American Vertical Datum of 1988 (NAVD 88) bench marks.

(F) All existing station bench marks at operating stations shall be assessed for feasibility of GPS observations, as time and resources permit. A note shall be made, either in the APP field of the electronic leveling HA file, if electronic levels are used, or on the bench mark descriptions sheet, stating the suitability of GPS observations for each mark. GPS visibility obstruction diagram shall also be completed for each mark observed as shown in Figure 4.20.

(G) The most desirable bench mark for GPS observations will have 360 degrees clearance around the mark at 10 degrees and greater above the horizon. Newly established marks shall be set in locations that have the required clearances, if at all possible. Public property is usually a good location choice. If a station does not have any marks suitable for GPS observations, and it has been selected as needing GPS observations, a new 3-D rod mark or a mark installed in rock outcrop with stability A shall be established according to NOS standard procedure. This new mark shall be connected to the station bench mark network through conventional geodetic leveling, and then GPS observations shall be made.

(H) Static GPS surveys shall be conducted on a minimum of one bench mark, preferably two marks if time and resources permit, at each subordinate water level station installed/occupied for hydrography.

(I) Static GPS surveys shall be conducted at water level stations concurrently with the occupation of NAVD 88 marks, if possible, to accomplish water level datum transfers using GPS-derived orthometric heights.

(J) A digital photo of the stamping of the bench mark occupied must be made as shown in Figure 4.22. If digital photo is not available, then a rubbing of the bench mark must be done as shown in Figure 4.21. A digital photo of the stamping is preferred over rubbing of the mark.

(K) Set the epoch update or recording interval (REC INT) for 15-seconds, which should agree with the recording interval of the reference stations (IGS or CORS) used to post-process the data. For GPS sessions greater than 30 minutes, collect data at 15-second epoch intervals, starting at an even minute. The elevation mask (ELEV MASK) is typically set for 10 degrees for static surveys; low angle satellites can degrade the final solution. Set the minimum number of satellites to four. For static surveying, setting the minimum number of satellites (MIN SV) is not as critical as for kinematic surveying. However, if the number of satellites tracked drops below four, it could be an indication of other problems, such as an antenna or antenna cable connection problem, RF interference, or an obstruction from traffic (vehicle or vessel). The GPS signal from the satellite is not very strong when entering the receiver, so anything that produces further attenuation of the signal can cause the receiver to stop tracking satellites

(L) The length of GPS observation sessions depends upon the length of the time field crew has available for GPS observations, number of satellites available at a site, number of bench marks available for GPS observations, etc. The basic requirement for GPS observations on a bench mark is minimum two sessions of 6 hours each and both sessions should begin with proper antenna setup.The two GPS observation sessions on the same bench mark shall be done on the same day or on two different days. When two sessions are done (whether on the same day or on two different days), then close down the antenna at the end of the first session and re-setup the antenna at the beginning of the second session. If two sessions are done on the same day, then start the second session at least after ½ hour after the completion of the first session. If two GPS observation sessions are selected on two different days, then ideally the second session should start 28 hours after the beginning of the first session so that a different set of GPS satellites are available for the second session. When two sessions are done on the same day, the gap between the end of the first session and the beginning of the second session can be, or need to be increased if PDOP is not suitable for observations, this is applicable only if PDOP information is available to the field crew.

For contract and NOAA hydrographic surveys and special projects three GPS observation sessions of 6 hours each on two or three different days are recommended, if time and resources permit. If three GPS sessions are done then they should be spread over minimum two different days. Two GPS sessions can be done the same day, or on two different days.

If only one GPS observation session is possible for the available time, then record minimum of 24 hours of GPS observations on a bench mark. Minimum two GPS observation sessions of 6 hours each are preferred over one long 24 hour GPS session.

Always collect a little bit of extra data if time and schedule permit, so that blunders or invalid data, if any, can be removed during processing still leaving minimum of 24 hours of valid data for one GPS session, or 6 hours of valid data for each session for two (or three as the case may be) GPS sessions.

(M) It is recommended that after the session is complete, two independent downloads be done from the GPS receiver to the laptop computer, so that if one downloaded file gets corrupted, the other file may have good data. Since two downloads of the GPS observation file is a requirement, do not make copy of the downloaded file twice to the laptop instead, as both the files will have the same problem, if there exists a problem. Send both copies of digital GPS data so that one copy of the data can be forwarded to NGS and other copy will be kept for record in CO-OPS.

(N) Meteorological data (air temperature, barometric pressure, and relative humidity) need to be collected, if available, during the GPS observations. Collect appropriate meteorological data at the beginning, middle, and at the end of each GPS session, if a sensor is available and GPS session length is greater than 2 hours. If a sensor is available, then air temperature must be observed and recorded to the nearest 1E Celsius, and barometer must be observed and recorded to at least nearest 1 millibar. Meteorological data should be collected at or near the antenna phase center. All equipment should be checked for proper calibration periodically.

If none of the meteorological sensors (air temperature, barometric pressure, and relative humidity) are available for recording observations, then note any change in the atmospheric conditions on the GPS station/bench mark observation log form under Remarks section.

(O) GPS (horizontal) positions (latitude and longitude) of each bench mark installed or recovered shall be listed on the HA files for laser levels, if used, or on the bench mark descriptions sheet for optical leveling, as applicable, at each subordinate water level station occupied for hydrography.

(P) Refer to Section 4.6.2. for GPS Project Documentation requirements later in this document.

## 4.3. Data Processing and Reduction

### 4.3.1. Data Quality Control

The required output product used in generation of tide reducers and for tidal datum determination is a continuous time series of 6-minute interval water level data for the desired time period of hydrography and for a specified minimum time period from which to derive tidal datums. CO-OPS will monitor the installed system operation information for all gauges equipped with GOES satellite radios. The 6-minute interval water level data from the water level gauges shall be quality controlled to NOS standards by the contractor for invalid and suspect data as a final review prior to product generation and application. This includes checking for data gaps, data discontinuities, datum shifts, anomalous data points, data points outside of expected tolerances such as expected maximum and minimum values and for anomalous trends in the elevations due to sensor drift or vertical movement of the tide station components and bench marks.

Quality control shall include comparisons with simultaneous data from backup gauges, predicted tides or data from nearby stations, as appropriate. Data editing and gap filling shall use documented mathematically sound algorithms and procedures and an audit trail shall be used to track all changes and edits to observed data. All inferred data shall be appropriately flagged. Water level measurements from each station shall be related to a single, common datum, referred to as Station Datum. Station Datum is an arbitrary datum and should not be confused with a tidal datum such as MLLW. All discontinuities, jumps, or other changes in the gauge record (refer to the specific gauge user's guide) that may be due to vertical movement of any the gauge, staff, or bench marks shall be fully documented. All data shall be recorded on UTC and the units of measurement shall be properly denoted on all hard-copy output and digital files. Refer to Section 4.6 Data Submission Requirements for details.

### 4.3.2. Data Processing and Tabulation of the Tide

The continuous 6-minute interval water level data are used to generate the standard tabulation output products. These products include the times and heights of the high and low waters, hourly heights, maximum and minimum monthly water levels, and monthly mean values for the desired parameters. Examples of these tabulation products are found in Figures 4.3 and 4.4 for tide stations and 4.5 for Great Lakes stations. The times and heights of the high and low waters shall be derived from appropriate curve-fitting of the 6-minute interval data. For purposes of tabulation of the high and low tides and not non-tidal high frequency noise, successive high and low tides shall not be tabulated unless they are greater than 2.0 hours apart in time and 0.030 meters different in elevation. Hourly heights shall be derived from every 6-minute value observed on the hour. Monthly mean sea level and monthly mean water level shall be computed from the average of the hourly heights over each calendar month of data. Data shall be tabulated relative to a documented consistent station datum such as tide staff zero, arbitrary station datum, MLLW, etc.. over the duration of the data observations. Descriptions of general procedures used in tabulation are also found in the *Tide and Current Glossary, Manual of Tide Observations,* and *Tidal Datum Planes.*

## 4.3.3. Computation of Monthly Means

Monthly means are derived on a calendar month basis in accordance with the definitions for the monthly mean parameters as found in the Tide and Current Glossary. Examples of the desired monthly means are found in figures 4.4 and 4.6. For purposes of monthly mean computation, monthly means shall not be computed if gaps in data are greater than three consecutive days.

### 4.3.4. Data Editing and Gap Filling Specifications

When backup sensor data are not available, data gaps in 6-minute data shall not be filled if the gaps are greater than three consecutive days in length. Data gap filling shall use documented mathematically and scientifically sound algorithms and procedures and an audit trail shall be used to track all gap-fills in observed data. Data gaps of less than 3-hours can be inferred using interpolation and curve-fitting techniques. Data gaps of longer than three hours shall use external data sources such as data from a nearby station. All data derived through gap-filling procedures shall be marked as inferred. Individual hourly heights, high and low waters, and daily means derived from inferred data shall also be designated as inferred.

**Figure 4.3**

TIDES, HIGH AND LOW WATERS July 1998
National Ocean Service (NOAA)
Water Level Heights in meters on Station Datum

Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY , CA
Time Meridian: 0 W Tide Type: Mixed

| | HIGH | LOW | HIGH | LOW |
|---|---|---|---|---|
| DAY | TIME HEIGHT | TIME HEIGHT | DAY TIME HEIGHT | TIME HEIGHT |
| 1 > | 1.4 3.337 | 6.8 2.521 | 16 > 0.6 3.550 | 6.2 2.343 |
| | 12.62.996 | > 18.5 2.253 | 12.6 3.187 | > 18.1 2.195 |
| 2 > | 2.0 3.393 | 7.8 2.434 | 17 > 1.4 3.654 | 7.4 2.205 |
| | 13.92.950 | > 19.4 2.406 | 14.1 3.096 | 19.0 2.335 |
| 3 > | 2.6 3.458 | > 9.1 2.367 | 18 > 2.2 3.725 | > 8.6 2.054 |
| | 15.2 2.941 | 20.1 2.498 | 15.6 3.132 | 20.2 2.504 |
| 4 > | 3.2 3.524 | > 9.7 2.210 | 19 > 3.1 3.819 | > 9.7 1.891 |
| | 16.5 2.988 | 21.1 2.612 | 16.9 3.188 | 21.5 2.586 |
| 5 > | 4.0 3.584 | > 10.3 2.018 | 20 > 4.1 3.899 | >10.7 1.763 |
| | 17.6 3.054 | 22.0 2.644 | 18.0 3.267 | 22.5 2.597 |
| 6 > | 4.6 3.656 | > 11.1 1.913 | 21 > 4.9 3.903 | >11.6 1.654 |
| | 18.3 3.124 | 22.7 2.682 | 18.8 3.309 | 23.4 2.583 |
| 7 > | 5.1 3.711 | > 11.8 1.812 | 22 > 6.0 3.884 | |
| | 19.1 3.194 | 23.4 2.697 | 19.6 3.347 | >12.4 1.587 |
| 8 > | 5.8 3.754 | | 23 > 6.4 3.880 | 0.2 2.587 |
| | 19.7 3.223 | > 12.4 1.730 | 20.3 3.390 | >13.1 1.611 |
| 9 > | 6.3 3.789 | 0.1 2.703 | 24 > 7.4 3.833 | 1.1 2.586 |
| | 20.4 3.285 | > 13.1 1.669 | 20.9 3.409 | > 13.9 1.659 |
| 10 > | 7.3 3.795 | 0.9 2.709 | 25 > 8.1 3.780 | 1.7 2.562 |
| | 21.1 3.306 | > 13.7 1.627 | 21.6 3.445 | > 14.5 1.719 |
| 11 > | 8.0 3.712 | 1.6 2.614 | 26 > 8.7 3.668 | 2.6 2.564 |
| | 21.7 3.302 | > 14.4 1.579 | 22.2 3.437 | > 14.9 1.826 |
| 12 > | 8.8 3.639 | 2.5 2.584 | 27 > 9.3 3.510 | 3.2 2.549 |
| | 22.3 3.356 | > 15.1 1.609 | >22.8 3.416 | > 15.6 1.932 |
| 13 > | 9.3 3.547 | 3.1 2.530 | 28 10.1 3.356 | 4.1 2.538 |
| | 23.1 3.419 | > 15.6 1.692 | >23.5 3.430 | > 16.1 2.042 |
| 14 | 10.1 3.443 | 4.1 2.522 | 29 10.9 3.202 | 5.0 2.495 |
| | > 23.9 3.484 | > 16.5 1.800 | | > 16.6 2.199 |
| 15 | 11.3 3.282 | 5.1 2.422 | 30 > 0.1 3.432 | 5.9 2.492 |
| | | > 17.0 1.967 | 12.0 3.099 | >17.3 2.402 |
| | | | 31 > 0.8 3.472 | > 6.9 2.431 |
| | | | 13.1 3.018 | 18.5 2.513 |

HIGHEST TIDE: 3.903 4.9 HRS Jul 21 1998
LOWEST TIDE: 1.579 14.4 HRS Jul 11 1998
MONTHLY MEANS FOR July 1998
HWL 3.903
MHHW 3.641 DHQ 0.208
MHW 3.433 GT 1.720
MTL 2.832 MN 1.203
DTL 2.781
MSL 2.816
MLW 2.230 DLQ 0.309
MLLW 1.921
LWL 1.579
HWI 7.570 HRS
LWI 0.760 HRS

> higher high/lower low waters [ ] denotes inferred water level values Data Status: Verified

## Figure 4.4

HOURLY WATER LEVELS
Water Level Heights in meters on Station Datum

Station: 9414290 SAN FRANCISCO, SAN FRANCISCO BAY , CA Time Meridian 0 W Tide Type: Mixed

| HOUR | Jul 1 | Jul 2 | Jul 3 | Jul 4 | Jul 5 | Jul 6 | Jul 7 | Jul 8 | Jul 9 | Jul 10 | Jul 11 | Jul 12 | Jul 13 | Jul 14 | Jul 15 | Jul 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | 3.247 | 3.183 | 3.119 | 3.052 | 2.936 | 2.837 | 2.770 | 2.724 | 2.717 | 2.763 | 2.814 | 2.960 | 3.152 | 3.354 | 3.481 | 3.529 |
| 01 | 3.329 | 3.333 | 3.319 | 3.274 | 3.157 | 3.066 | 2.972 | 2.851 | 2.762 | 2.694 | 2.637 | 2.723 | 2.901 | 3.162 | 3.365 | 3.517 |
| 02 | 3.311 | 3.391 | 3.449 | 3.437 | 3.378 | 3.293 | 3.173 | 3.060 | 2.913 | 2.799 | 2.627 | 2.602 | 2.653 | 2.868 | 3.123 | 3.395 |
| 03 | 3.164 | 3.312 | 3.463 | 3.526 | 3.526 | 3.504 | 3.423 | 3.298 | 3.171 | 2.988 | 2.750 | 2.618 | 2.529 | 2.621 | 2.792 | 3.103 |
| 04 | 2.948 | 3.158 | 3.338 | 3.469 | 3.595 | 3.629 | 3.617 | 3.555 | 3.420 | 3.261 | 2.985 | 2.755 | 2.606 | 2.523 | 2.523 | 2.741 |
| 05 | 2.725 | 2.914 | 3.091 | 3.304 | 3.474 | 3.628 | 3.714 | 3.707 | 3.652 | 3.519 | 3.247 | 3.012 | 2.757 | 2.576 | 2.423 | 2.459 |
| 06 | 2.558 | 2.651 | 2.811 | 3.012 | 3.209 | 3.430 | 3.640 | 3.740 | 3.782 | 3.711 | 3.508 | 3.252 | 2.986 | 2.745 | 2.472 | 2.302 |
| 07 | 2.528 | 2.451 | 2.531 | 2.651 | 2.833 | 3.112 | 3.342 | 3.580 | 3.746 | 3.785 | 3.668 | 3.485 | 3.217 | 2.954 | 2.619 | 2.399 |
| 08 | 2.581 | 2.453 | 2.387 | 2.366 | 2.448 | 2.653 | 2.915 | 3.225 | 3.496 | 3.677 | 3.715 | 3.628 | 3.433 | 3.155 | 2.804 | 2.480 |
| 09 | 2.648 | 2.510 | 2.375 | 2.228 | 2.133 | 2.243 | 2.435 | 2.701 | 3.060 | 3.348 | 3.540 | 3.626 | 3.535 | 3.354 | 2.997 | 2.651 |
| 10 | 2.778 | 2.568 | 2.400 | 2.229 | 2.017 | 1.994 | 2.057 | 2.236 | 2.477 | 2.819 | 3.159 | 3.410 | 3.510 | 3.444 | 3.185 | 2.870 |
| 11 | 2.890 | 2.696 | 2.494 | 2.280 | 2.057 | 1.909 | 1.859 | 1.919 | 2.081 | 2.327 | 2.576 | 2.970 | 3.257 | 3.389 | 3.283 | 3.040 |
| 12 | 2.976 | 2.813 | 2.643 | 2.431 | 2.159 | 1.972 | 1.826 | 1.719 | 1.774 | 1.922 | 2.101 | 2.422 | 2.818 | 3.165 | 3.248 | 3.162 |
| 13 | 2.995 | 2.917 | 2.750 | 2.581 | 2.327 | 2.124 | 1.913 | 1.756 | 1.674 | 1.667 | 1.781 | 2.000 | 2.350 | 2.735 | 3.051 | 3.175 |
| 14 | 2.904 | 2.945 | 2.897 | 2.760 | 2.559 | 2.338 | 2.117 | 1.908 | 1.744 | 1.633 | 1.588 | 1.706 | 1.946 | 2.305 | 2.737 | 3.069 |
| 15 | 2.742 | 2.903 | 2.922 | 2.898 | 2.778 | 2.611 | 2.387 | 2.154 | 1.944 | 1.759 | 1.625 | 1.612 | 1.732 | 1.965 | 2.365 | 2.831 |
| 16 | 2.505 | 2.783 | 2.909 | 2.986 | 2.937 | 2.862 | 2.683 | 2.455 | 2.260 | 2.014 | 1.791 | 1.690 | 1.697 | 1.794 | 2.053 | 2.492 |
| 17 | 2.359 | 2.594 | 2.814 | 2.976 | 3.040 | 3.034 | 2.954 | 2.786 | 2.585 | 2.366 | 2.084 | 1.911 | 1.852 | 1.854 | 1.971 | 2.258 |
| 18 | 2.250 | 2.473 | 2.649 | 2.915 | 3.028 | 3.137 | 3.124 | 3.015 | 2.936 | 2.739 | 2.449 | 2.242 | 2.074 | 1.986 | 2.020 | 2.177 |
| 19 | 2.272 | 2.401 | 2.550 | 2.773 | 2.960 | 3.099 | 3.190 | 3.187 | 3.141 | 3.021 | 2.814 | 2.618 | 2.419 | 2.256 | 2.193 | 2.269 |
| 20 | 2.336 | 2.413 | 2.484 | 2.647 | 2.812 | 2.990 | 3.149 | 3.215 | 3.271 | 3.239 | 3.094 | 2.975 | 2.797 | 2.595 | 2.462 | 2.415 |
| 21 | 2.508 | 2.514 | 2.527 | 2.637 | 2.690 | 2.843 | 2.999 | 3.128 | 3.251 | 3.310 | 3.275 | 3.220 | 3.131 | 2.954 | 2.781 | 2.677 |
| 22 | 2.736 | 2.685 | 2.631 | 2.636 | 2.634 | 2.709 | 2.835 | 2.982 | 3.130 | 3.233 | 3.280 | 3.369 | 3.339 | 3.242 | 3.104 | 2.961 |
| 23 | 2.965 | 2.912 | 2.814 | 2.752 | 2.703 | 2.700 | 2.688 | 2.779 | 2.916 | 3.063 | 3.177 | 3.322 | 3.422 | 3.417 | 3.336 | 3.284 |
| Mean | 2.761 | 2.791 | 2.807 | 2.826 | 2.808 | 2.822 | 2.824 | 2.820 | 2.829 | 2.819 | 2.762 | 2.755 | 2.755 | 2.767 | 2.766 | 2.802 |

| HOUR | Jul 17 | Jul 18 | Jul 19 | Jul 20 | Jul 21 | Jul 22 | Jul 23 | Jul 24 | Jul 25 | Jul 26 | Jul 27 | Jul 28 | Jul 29 | Jul 30 | Jul 31 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | 3.514 | 3.373 | 3.180 | 2.993 | 2.778 | 2.625 | 2.586 | 2.678 | 2.821 | 3.048 | 3.228 | 3.317 | 3.411 | 3.444 | 3.438 | |
| 01 | 3.654 | 3.617 | 3.485 | 3.264 | 3.035 | 2.810 | 2.649 | 2.586 | 2.613 | 2.749 | 2.951 | 3.122 | 3.270 | 3.357 | 3.466 | |
| 02 | 3.620 | 3.720 | 3.720 | 3.573 | 3.322 | 3.071 | 2.848 | 2.682 | 2.573 | 2.590 | 2.680 | 2.834 | 3.030 | 3.195 | 3.394 | Monthly |
| 03 | 3.427 | 3.686 | 3.818 | 3.785 | 3.641 | 3.379 | 3.133 | 2.884 | 2.694 | 2.576 | 2.550 | 2.625 | 2.735 | 2.937 | 3.148 | Max HWL |
| 04 | 3.111 | 3.433 | 3.737 | 3.907 | 3.840 | 3.659 | 3.444 | 3.201 | 2.926 | 2.761 | 2.591 | 2.538 | 2.547 | 2.704 | 2.888 | 04:54/21 |
| 05 | 2.704 | 3.048 | 3.487 | 3.775 | 3.898 | 3.849 | 3.697 | 3.460 | 3.206 | 2.978 | 2.759 | 2.586 | 2.487 | 2.523 | 2.660 | 3.903 |
| 06 | 2.398 | 2.607 | 3.017 | 3.452 | 3.745 | 3.887 | 3.866 | 3.717 | 3.505 | 3.247 | 2.976 | 2.757 | 2.553 | 2.486 | 2.467 | |
| 07 | 2.215 | 2.254 | 2.539 | 2.948 | 3.376 | 3.678 | 3.851 | 3.828 | 3.704 | 3.501 | 3.210 | 2.928 | 2.697 | 2.545 | 2.448 | |
| 08 | 2.255 | 2.073 | 2.167 | 2.436 | 2.810 | 3.269 | 3.593 | 3.770 | 3.778 | 3.652 | 3.390 | 3.150 | 2.860 | 2.659 | 2.477 | Monthly |
| 09 | 2.319 | 2.064 | 1.953 | 2.018 | 2.299 | 2.662 | 3.083 | 3.430 | 3.637 | 3.659 | 3.504 | 3.302 | 3.031 | 2.809 | 2.571 | Min LWL |
| 10 | 2.483 | 2.155 | 1.884 | 1.806 | 1.896 | 2.146 | 2.526 | 2.942 | 3.284 | 3.486 | 3.479 | 3.358 | 3.144 | 2.948 | 2.725 | 14:24/11 |
| 11 | 2.691 | 2.304 | 1.993 | 1.757 | 1.696 | 1.794 | 2.071 | 2.397 | 2.758 | 3.107 | 3.252 | 3.294 | 3.203 | 3.055 | 2.856 | 1.579 |
| 12 | 2.876 | 2.544 | 2.195 | 1.877 | 1.664 | 1.603 | 1.743 | 1.981 | 2.282 | 2.618 | 2.907 | 3.090 | 3.119 | 3.107 | 2.975 | |
| 13 | 3.037 | 2.784 | 2.453 | 2.094 | 1.808 | 1.637 | 1.621 | 1.723 | 1.924 | 2.215 | 2.471 | 2.741 | 2.953 | 3.037 | 3.031 | |
| 14 | 3.088 | 2.995 | 2.738 | 2.387 | 2.076 | 1.816 | 1.662 | 1.644 | 1.740 | 1.919 | 2.149 | 2.402 | 2.658 | 2.905 | 2.975 | Monthly |
| 15 | 3.038 | 3.104 | 2.978 | 2.738 | 2.434 | 2.122 | 1.918 | 1.797 | 1.762 | 1.827 | 1.956 | 2.144 | 2.396 | 2.676 | 2.908 | Mean |
| 16 | 2.880 | 3.119 | 3.134 | 3.028 | 2.790 | 2.510 | 2.249 | 2.056 | 1.942 | 1.882 | 1.950 | 2.016 | 2.231 | 2.493 | 2.725 | MSL |
| 17 | 2.621 | 3.011 | 3.191 | 3.220 | 3.078 | 2.887 | 2.646 | 2.422 | 2.219 | 2.117 | 2.061 | 2.118 | 2.218 | 2.398 | 2.595 | 2.816 |
| 18 | 2.400 | 2.812 | 3.107 | 3.284 | 3.266 | 3.162 | 3.018 | 2.791 | 2.604 | 2.412 | 2.302 | 2.244 | 2.299 | 2.432 | 2.508 | |
| 19 | 2.323 | 2.600 | 2.938 | 3.179 | 3.300 | 3.316 | 3.273 | 3.162 | 2.978 | 2.775 | 2.615 | 2.496 | 2.465 | 2.490 | 2.527 | |
| 20 | 2.402 | 2.513 | 2.731 | 3.013 | 3.210 | 3.336 | 3.394 | 3.345 | 3.271 | 3.109 | 2.939 | 2.795 | 2.688 | 2.663 | 2.620 | |
| 21 | 2.554 | 2.550 | 2.605 | 2.755 | 3.012 | 3.214 | 3.345 | 3.401 | 3.415 | 3.335 | 3.215 | 3.075 | 2.963 | 2.884 | 2.766 | |
| 22 | 2.789 | 2.698 | 2.619 | 2.612 | 2.735 | 2.975 | 3.189 | 3.316 | 3.427 | 3.428 | 3.369 | 3.310 | 3.184 | 3.109 | 2.984 | |
| 23 | 3.073 | 2.920 | 2.760 | 2.631 | 2.613 | 2.707 | 2.912 | 3.118 | 3.300 | 3.400 | 3.407 | 3.429 | 3.373 | 3.308 | 3.178 | |
| Mean | 2.811 | 2.833 | 2.851 | 2.855 | 2.847 | 2.838 | 2.847 | 2.847 | 2.848 | 2.850 | 2.830 | 2.820 | 2.813 | 2.840 | 2.847 | |

[ ] denotes inferred water level values Data Status: Verified

## Figure 4.5

HOURLY WATER LEVELS
Water Level Heights in meters IGLD (1985)

Station: 9052030 Oswego, Lake Ontario , NY    Time Meridian: 75 W Data Type: Great Lakes

| HOUR | Jul 1 | Jul 2 | Jul 3 | Jul 4 | Jul 5 | Jul 6 | Jul 7 | Jul 8 | Jul 9 | Jul 10 | Jul 11 | Jul 12 | Jul 13 | Jul 14 | Jul 15 | Jul 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 75.21 | 75.21 | 75.19 | 75.18 | 75.19 | 75.17 | 75.15 | 75.17 | 75.17 | 75.20 | 75.21 | 75.21 | 75.20 | 75.17 | 75.17 | 75.17 |
| 02 | 75.25 | 75.21 | 75.19 | 75.19 | 75.22 | 75.14 | 75.17 | 75.16 | 75.19 | 75.19 | 75.20 | 75.22 | 75.18 | 75.17 | 75.18 | 75.16 |
| 03 | 75.26 | 75.21 | 75.19 | 75.17 | 75.19 | 75.18 | 75.18 | 75.16 | 75.16 | 75.19 | 75.21 | 75.19 | 75.18 | 75.18 | 75.15 | 75.17 |
| 04 | 75.25 | 75.20 | 75.19 | 75.20 | 75.21 | 75.18 | 75.17 | 75.16 | 75.17 | 75.20 | 75.21 | 75.18 | 75.17 | 75.18 | 75.16 | 75.16 |
| 05 | 75.25 | 75.21 | 75.20 | 75.19 | 75.21 | 75.18 | 75.17 | 75.20 | 75.20 | 75.18 | 75.21 | 75.20 | 75.19 | 75.17 | 75.19 | 75.16 |
| 06 | 75.25 | 75.21 | 75.19 | 75.20 | 75.20 | 75.19 | 75.17 | 75.16 | 75.19 | 75.20 | 75.20 | 75.20 | 75.17 | 75.17 | 75.14 | 75.15 |
| 07 | 75.25 | 75.20 | 75.19 | 75.19 | 75.19 | 75.17 | 75.18 | 75.20 | 75.20 | 75.19 | 75.21 | 75.20 | 75.18 | 75.17 | 75.14 | 75.17 |
| 08 | 75.24 | 75.21 | 75.19 | 75.21 | 75.20 | 75.17 | 75.17 | 75.14 | 75.19 | 75.20 | 75.22 | 75.20 | 75.19 | 75.15 | 75.18 | 75.15 |
| 09 | 75.24 | 75.21 | 75.19 | 75.20 | 75.19 | 75.19 | 75.16 | 75.17 | 75.18 | 75.18 | 75.22 | 75.20 | 75.19 | 75.18 | 75.16 | 75.14 |
| 10 | 75.24 | 75.20 | 75.19 | 75.18 | 75.19 | 75.18 | 75.16 | 75.20 | 75.17 | 75.20 | 75.22 | 75.22 | 75.18 | 75.18 | 75.17 | 75.16 |
| 11 | 75.23 | 75.19 | 75.17 | 75.18 | 75.20 | 75.18 | 75.15 | 75.15 | 75.19 | 75.20 | 75.22 | 75.20 | 75.19 | 75.18 | 75.16 | 75.15 |
| 12 | 75.22 | 75.21 | 75.18 | 75.18 | 75.17 | 75.17 | 75.17 | 75.16 | 75.17 | 75.19 | 75.22 | 75.20 | 75.18 | 75.18 | 75.17 | 75.16 |
| 13 | 75.22 | 75.20 | 75.18 | 75.19 | 75.18 | 75.16 | 75.16 | 75.15 | 75.17 | 75.18 | 75.21 | 75.19 | 75.19 | 75.17 | 75.16 | 75.16 |
| 14 | 75.23 | 75.20 | 75.19 | 75.21 | 75.18 | 75.19 | 75.14 | 75.15 | 75.16 | 75.18 | 75.20 | 75.22 | 75.17 | 75.17 | 75.18 | 75.17 |
| 15 | 75.22 | 75.21 | 75.17 | 75.19 | 75.17 | 75.15 | 75.14 | 75.18 | 75.17 | 75.19 | 75.20 | 75.18 | 75.18 | 75.17 | 75.17 | 75.17 |
| 16 | 75.21 | 75.20 | 75.19 | 75.18 | 75.19 | 75.16 | 75.18 | 75.18 | 75.17 | 75.19 | 75.19 | 75.19 | 75.17 | 75.16 | 75.16 | 75.16 |
| 17 | 75.21 | 75.20 | 75.20 | 75.21 | 75.20 | 75.17 | 75.17 | 75.18 | 75.17 | 75.19 | 75.20 | 75.18 | 75.17 | 75.17 | 75.17 | 75.15 |
| 18 | 75.22 | 75.20 | 75.20 | 75.21 | 75.21 | 75.20 | 75.18 | 75.18 | 75.15 | 75.17 | 75.20 | 75.18 | 75.16 | 75.15 | 75.16 | 75.16 |
| 19 | 75.21 | 75.20 | 75.19 | 75.21 | 75.19 | 75.19 | 75.18 | 75.20 | 75.18 | 75.22 | 75.19 | 75.19 | 75.17 | 75.16 | 75.16 | 75.17 |
| 20 | 75.20 | 75.22 | 75.19 | 75.25 | 75.19 | 75.17 | 75.18 | 75.18 | 75.20 | 75.22 | 75.20 | 75.20 | 75.16 | 75.16 | 75.16 | 75.13 |
| 21 | 75.20 | 75.18 | 75.18 | 75.15 | 75.19 | 75.19 | 75.15 | 75.19 | 75.22 | 75.18 | 75.21 | 75.19 | 75.18 | 75.16 | 75.15 | 75.17 |
| 22 | 75.21 | 75.20 | 75.17 | 75.17 | 75.19 | 75.18 | 75.19 | 75.17 | 75.23 | 75.20 | 75.21 | 75.19 | 75.18 | 75.18 | 75.15 | 75.13 |
| 23 | 75.20 | 75.19 | 75.17 | 75.24 | 75.19 | 75.16 | 75.18 | 75.19 | 75.22 | 75.22 | 75.21 | 75.17 | 75.18 | 75.16 | 75.17 | 75.13 |
| 24 | 75.21 | 75.20 | 75.17 | 75.20 | 75.18 | 75.17 | 75.17 | 75.19 | 75.18 | 75.21 | 75.21 | 75.18 | 75.18 | 75.15 | 75.16 | 75.15 |
| Mean | 75.23 | 75.20 | 75.19 | 75.19 | 75.19 | 75.18 | 75.17 | 75.17 | 75.18 | 75.20 | 75.21 | 75.19 | 75.18 | 75.17 | 75.16 | 75.16 |

| HOUR | Jul 17 | Jul 18 | Jul 19 | Jul 20 | Jul 21 | Jul 22 | Jul 23 | Jul 24 | Jul 25 | Jul 26 | Jul 27 | Jul 28 | Jul 29 | Jul 30 | Jul 31 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 75.17 | 75.17 | 75.14 | 75.12 | 75.13 | 75.14 | 75.11 | 75.16 | 75.14 | 75.11 | 75.09 | 75.07 | 75.07 | 75.10 | 75.09 | |
| 02 | 75.17 | 75.18 | 75.14 | 75.16 | 75.12 | 75.16 | 75.12 | 75.16 | 75.14 | 75.10 | 75.08 | 75.09 | 75.06 | 75.11 | 75.08 | |
| 03 | 75.16 | 75.19 | 75.15 | 75.15 | 75.11 | 75.16 | 75.12 | 75.15 | 75.13 | 75.10 | 75.08 | 75.06 | 75.06 | 75.10 | 75.08 | Monthly |
| 04 | 75.17 | 75.18 | 75.14 | 75.14 | 75.13 | 75.15 | 75.10 | 75.14 | 75.14 | 75.10 | 75.07 | 75.09 | 75.02 | 75.09 | 75.08 | Max HWL |
| 05 | 75.16 | 75.18 | 75.16 | 75.13 | 75.14 | 75.13 | 75.14 | 75.16 | 75.13 | 75.10 | 75.06 | 75.11 | 75.07 | 75.08 | 75.08 | 03:00/01 |
| 06 | 75.17 | 75.16 | 75.15 | 75.16 | 75.10 | 75.17 | 75.12 | 75.16 | 75.12 | 75.10 | 75.06 | 75.07 | 75.16 | 75.07 | 75.08 | 75.259 |
| 07 | 75.16 | 75.16 | 75.17 | 75.14 | 75.12 | 75.13 | 75.14 | 75.14 | 75.13 | 75.10 | 75.07 | 75.06 | 75.14 | 75.07 | 75.07 | |
| 08 | 75.16 | 75.16 | 75.14 | 75.15 | 75.15 | 75.12 | 75.14 | 75.16 | 75.13 | 75.10 | 75.06 | 75.08 | 75.11 | 75.05 | 75.07 | |
| 09 | 75.15 | 75.15 | 75.11 | 75.14 | 75.12 | 75.20 | 75.15 | 75.17 | 75.13 | 75.11 | 75.06 | 75.06 | 75.10 | 75.08 | 75.07 | Monthly |
| 10 | 75.16 | 75.15 | 75.11 | 75.14 | 75.11 | 75.18 | 75.10 | 75.15 | 75.13 | 75.12 | 75.08 | 75.07 | 75.11 | 75.07 | 75.06 | Min LWL |
| 11 | 75.16 | 75.16 | 75.13 | 75.14 | 75.11 | 75.16 | 75.11 | 75.16 | 75.12 | 75.11 | 75.08 | 75.06 | 75.11 | 75.06 | 75.07 | 04:00/29 |
| 12 | 75.16 | 75.17 | 75.16 | 75.14 | 75.12 | 75.12 | 75.13 | 75.14 | 75.11 | 75.11 | 75.09 | 75.07 | 75.12 | 75.10 | 75.07 | 75.021 |
| 13 | 75.16 | 75.15 | 75.14 | 75.14 | 75.12 | 75.14 | 75.13 | 75.14 | 75.11 | 75.10 | 75.07 | 75.05 | 75.08 | 75.08 | 75.07 | |
| 14 | 75.16 | 75.17 | 75.13 | 75.15 | 75.10 | 75.11 | 75.14 | 75.14 | 75.10 | 75.11 | 75.06 | 75.08 | 75.08 | 75.08 | 75.06 | |
| 15 | 75.17 | 75.16 | 75.13 | 75.13 | 75.12 | 75.12 | 75.12 | 75.13 | 75.11 | 75.09 | 75.07 | 75.06 | 75.07 | 75.08 | 75.05 | Monthly |
| 16 | 75.16 | 75.16 | 75.13 | 75.13 | 75.13 | 75.14 | 75.14 | 75.13 | 75.12 | 75.09 | 75.08 | 75.05 | 75.09 | 75.05 | 75.06 | Mean |
| 17 | 75.18 | 75.16 | 75.13 | 75.13 | 75.08 | 75.11 | 75.16 | 75.13 | 75.10 | 75.07 | 75.08 | 75.07 | 75.08 | 75.09 | 75.06 | MSL |
| 18 | 75.17 | 75.15 | 75.14 | 75.16 | 75.12 | 75.13 | 75.13 | 75.13 | 75.10 | 75.07 | 75.08 | 75.06 | 75.08 | 75.09 | 75.06 | 75.152 |
| 19 | 75.16 | 75.16 | 75.13 | 75.14 | 75.11 | 75.11 | 75.10 | 75.14 | 75.10 | 75.08 | 75.06 | 75.05 | 75.07 | 75.09 | 75.06 | |
| 20 | 75.17 | 75.16 | 75.16 | 75.15 | 75.12 | 75.13 | 75.16 | 75.14 | 75.11 | 75.09 | 75.06 | 75.07 | 75.09 | 75.07 | 75.06 | |
| 21 | 75.18 | 75.14 | 75.11 | 75.13 | 75.16 | 75.12 | 75.17 | 75.14 | 75.11 | 75.08 | 75.07 | 75.05 | 75.09 | 75.07 | 75.04 | |
| 22 | 75.18 | 75.15 | 75.14 | 75.13 | 75.10 | 75.15 | 75.17 | 75.14 | 75.11 | 75.08 | 75.07 | 75.06 | 75.09 | 75.08 | 75.06 | |
| 23 | 75.18 | 75.14 | 75.14 | 75.12 | 75.09 | 75.14 | 75.18 | 75.14 | 75.11 | 75.08 | 75.09 | 75.05 | 75.10 | 75.08 | 75.05 | |
| 24 | 75.19 | 75.14 | 75.11 | 75.11 | 75.09 | 75.12 | 75.17 | 75.15 | 75.11 | 75.09 | 75.10 | 75.08 | 75.09 | 75.09 | 75.06 | |
| Mean | 75.17 | 75.16 | 75.14 | 75.14 | 75.12 | 75.14 | 75.14 | 75.15 | 75.12 | 75.10 | 75.07 | 75.07 | 75.09 | 75.08 | 75.07 | |

[ ] denotes inferred water level values    Data Status: Verified

## 4.4. Computation of Tidal Datums and Water Level Datums

### 4.4.1. National Tidal Datum Epoch

Tidal datums must be computed relative to a specific 19 year tidal cycle adopted by the National Ocean Service (NOS) called the National Tidal Datum Epoch (NTDE). The present NTDE is the period 1983 through 2001. A primary datum determination is based directly on the average of tide observations over the 19 year Epoch period at NOS permanent long term primary control stations in the National Water Level Observation Network (NWLON). The data from NOS primary stations are used to compute datums at short term subordinate stations by reducing the data from those subordinate stations to equivalent 19 year mean values through the method of comparison of simultaneous observation.

### 4.4.2. Computational Procedures

The equivalent 19 year tidal datums for subordinate stations are computed for certain phases of the tide using tide-by-tide comparisons or monthly mean comparisons with an appropriate NOS long term control station. Accepted 19 year mean values of mean tide level (MTL), mean range (Mn), diurnal high water inequality (DHQ), diurnal low water inequality (DLQ), diurnal tide level (DTL), and great diurnal range (Gt) are required in the reduction process in which a "short series" of tide observations at any location are compared with simultaneous observations from an NOS control station. Datums are computed by the "standard" method of range ratio comparison generally on the West coast and Pacific Islands where there exists a large diurnal inequality in the low and high waters. The "modified" method of range ratio comparison is generally used on the East coast and Caribbean where small differences exist in the low and high water diurnal inequalities. For stations requiring a datum determination, at least 30 continuous days of tide observations are required for stations where adequate primary datum control exists. For error budget purposes, one month of data results in a datum accuracy of 0.11 m (95% confidence level) for Stations in the Gulf of Mexico and 0.08 m (95% confidence level) for east and West Coast stations. Examples of a tide by tide and a monthly mean simultaneous comparison for datum determination are found in Figures 4.6 and 4.7. Descriptions of the tidal datum computational procedures are found in the *Tide and Current Glossary, Tidal Datum Planes, Manual of Tide Observations, NOAA Special Publication NOS CO-OPS 1Tidal Datums and Their Applications and Computational Techniques for Tidal Datums.*

### 4.4.3. Tidal Datum Recovery

Whenever tide stations are installed at historical sites, measures shall be taken to "recover" the established tidal datums through leveling which shall be accomplished by referencing the gauge or tide staff zero "0" to more than one existing bench mark (three bench marks are preferred) with a published tidal elevation. Through this process, the published MLLW elevation is transferred by level differences to the "new" gauge or tide staff and compared to the MLLW elevation computed from the new data on the same zero "0". Factors affecting the datum recovery (i.e. differences between old and newly computed datums) include the length of each data series used to compute the datums, the geographical location, the tidal characteristics in the region, the length of time between reoccupations, the sea level trends in the region, and the control station used. Based on all of these factors, the datum recovery can be expected to vary from +/- 0.03 m to +/- 0.08 m. Hence, this process also serves as a very useful quality control procedure. After a successful datum recovery is performed and benchmark stability is established, the historical value of Mean Lower Low Water (MLLW) shall be used as the operational datum reference for data from the gauge during hydrographic survey operations. An example of a published tidal datum sheet for a station for which a datum recovery could be made is found in Figure 4.8.

**Figure 4.6**

COMPARISON OF SIMULTANEOUS OBSERVATIONS FOR 98 6 15 TO 98 7 14 9/11/1998
1960-1978 TIDAL EPOCH (EXPECTED DIFFERENCE (STATION A - STATION B) = .0 HOURS)

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER ACCEPTED TM ( 0W) TIDE TYPE (M)
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY ACCEPTED TM ( 0W) TIDE TYPE (M)

(A) STATION TIME OF HW LW (B) STATION TIME OF HW LW (A) - (B) TIME DIFFERENCE HW LW (A) STATION HEIGHT OF HW LW (B) STATION HEIGHT OF HW LW (A) - (B) HEIGHT DIFFERENCE HW LW

DATE HOURS HOURS DATE HOURS HOURS HOURS HOURS METERS METERS METERS METERS METERS METERS
JUN 15 10.6 15 5.2 JUN 15 10.4 .2 5.248 4.455 3.459 1.789
17.5 16.7 .8 3.553 1.858 1.695
16 1.0 16 6.4 16 .6 5.5 .4 . 9 5.225 4.469 3.420 2.750 1.805 1.719
11.9 18.4 11.5 17.7 .4 . 7 5.169 3.694 3.391 2.019 1.778 1.675
17 1.6 17 7.6 17 1.4 6.6 .2 1.0 5.304 4.304 3.509 2.638 1.795 1.666
13.1 19.3 12.6 18.7 .5 .6 5.057 3.841 3.285 2.185 1.772 1.656
18 2.5 18 8.6 18 2.1 7.6 .4 1.0 5.378 4.112 3.585 2.411 1.793 1.701
14.3 20.2 14.0 19.3 .3 .9 4.948 3.887 3.162 2.229 1.786 1.658
19 3.3 19 9.6 19 2.8 8.7 .5 .9 5.450 3.911 3.653 2.197 1.797 1.714
15.9 21.2 15.6 20.6 .3 .6 4.972 4.041 3.173 2.326 1.799 1.715
20 4.0 20 10.6 20 3.6 9.9 .4 .7 5.581 3.698 3.786 1.955 1.795 1.743
17.2 22.2 16.7 21.5 .5 .7 5.009 4.157 3.208 2.423 1.801 1.734
21 4.7 21 11.6 21 4.4 10.9 .3 .7 5.677 3.495 3.870 1.762 1.807 1.733
18.2 23.1 17.8 22.6 .4 .5 5.072 4.195 3.261 2.450 1.811 1.745
22 5.5 22 12.6 22 5.2 11.8 .3 .8 5.725 3.362 3.935 1.635 1.790 1.727
19.2 23 .1 18.8 23.5 .4 .6 5.102 4.258 3.290 2.505 1.812 1.753
23 6.2 13.6 23 6.0 12.5 .2 1.1 5.748 3.257 3.943 1.550 1.805 1.707
20.3 19.8 .5 5.144 3.329 1.815
24 7.2 24 1.0 24 6.8 .3 .4 .7 5.759 4.339 3.951 2.587 1.808 1.752
21.1 14.3 20.6 13.3 .5 1.0 5.198 3.249 3.371 1.514 1.827 1.735
25 7.7 25 1.8 25 7.5 1.1 .2 .7 5.708 4.355 3.892 2.625 1.816 1.730
22.0 15.0 21.5 14.1 .5 .9 5.198 3.246 3.366 1.540 1.832 1.706
26 8.7 26 2.6 26 8.4 2.1 .3 .5 5.559 4.363 3.763 2.625 1.796 1.738
22.6 15.6 22.4 14.6 .2 1.0 5.158 3.236 3.343 1.536 1.815 1.700
27 9.3 27 3.6 27 9.0 2.9 .3 .7 5.432 4.360 3.625 2.629 1.807 1.731
23.5 16.2 23.1 15.4 .4 .8 5.195 3.350 3.382 1.625 1.813 1.725
28 10.1 28 4.4 28 9.7 3.7 .4 .7 5.293 4.389 3.494 2.661 1.799 1.728
29 . 2 16.7 23.8 16.1 .4 .6 5.190 3.487 3.376 1.762 1.814 1.725
10.9 29 5.6 29 10.6 4.7 .3 .9 5.105 4.360 3.315 2.649 1.790 1.711
17.6 16.8 .8 3.605 1.907 1.698
30 1.0 30 6.6 30 .6 5.7 .4 .9 5.150 4.288 3.354 2.589 1.796 1.699

12.0 18.5 11.6 17.9 .4 .6 4.897 3.738 3.120 2.077 1.777 1.661

JUL 1 1.6 1 7.8 JUL 1 1.4 6.8 .2 1.0 5.123 4.195 3.337 2.520 1.786 1.675
13.1 19.2 12.6 18.5 .5 .7 4.764 3.899 2.995 2.253 1.769 1.646
2 2.4 2 8.8 2 2.0 7.8 .4 1.0 5.161 4.112 3.392 2.434 1.769 1.678
14.3 20.0 13.9 19.4 .4 .6 4.713 4.078 2.950 2.406 1.763 1.672
3 3.1 3 9.9 3 2.6 9.1 .5 .8 5.232 4.036 3.458 2.366 1.774 1.670
15.6 20.8 15.2 20.1 .4 .7 4.697 4.200 2.940 2.498 1.757 1.702
4 3.7 4 10.4 4 3.2 9.7 .5 .7 5.301 3.895 3.524 2.209 1.777 1.686
16.7 21.8 16.5 21.1 .2 .7 4.751 4.326 2.987 2.612 1.764 1.714
5 4.2 5 11.1 5 4.0 10.3 .2 .8 5.365 3.737 3.584 2.017 1.781 1.720
17.9 22.7 17.6 22.0 .3 .7 4.833 4.384 3.053 2.644 1.780 1.740
6 4.8 6 11.8 6 4.6 11.1 .2 .7 5.442 3.620 3.656 1.913 1.786 1.707
18.7 23.5 18.3 22.7 .4 .8 4.905 4.418 3.124 2.681 1.781 1.737
7 5.6 7 12.6 7 5.1 11.8 .5 .8 5.506 3.532 3.710 1.812 1.796 1.720
19.5 8 .2 19.1 23.4 .4 .8 4.991 4.434 3.193 2.697 1.798 1.737

COMPARISON OF SIMULTANEOUS OBSERVATIONS FOR 98 6 15 TO 98 7 14 9/11/1998
1960-1978 TIDAL EPOCH (EXPECTED DIFFERENCE (STATION A - STATION B) = .0 HOURS)

(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY

(A) STATION (B) STATION TIME OF TIME OF
HW LW HW LW
DATE HOURS HOURS DATE HOURS HOURS
JUL 8 6.0 8 13.2 JUL 8 5.8 12.4
20.2 19.7 9 6.7 9 .7 9 6.3 .1
20.8 13.9 20.4 13.1 10 7.6 10 1.6 10 7.3 .9
21.5 14.5 21.1 13.7 11 8.4 11 2.2 11 8.0 1.6
22.1 15.2 21.7 14.4 12 8.8 12 3.2 12 8.8 2.5
22.7 15.8 22.3 15.1 13 9.6 13 3.8 13 9.3 3.1
3.5 16.6 23.1 15.6 14 10.6 14 4.7 14 10.1 4.1

17.1 23.9 16.5
(A) - (B) (A) STATION TIME DIFFERENCE HEIGHT OF HW LW HW LW HOURS HOURS METERS METERS.2 .8 5.568 3.463 .5 5.024 .4 .6 5.589 4.445 .4 .8 5.092 3.402 .3 .7 5.605 4.442 .4 .8 5.120 3.349 .4 .6 5.527 4.342 .4 .8 5.112 3.294 .0 .7 5.445 4.309 .4 .7 5.163 3.334 .3 .7 5.354 4.264 .4 1.0 5.243 3.438
.5 .6 5.235 4.262 .6 3.521
ACCEPTED ACCEPTED

(B) STATION HEIGHT OF HW LW METERS METERS3.754 1.729 3.222 3.789 2.702 3.285 1.6693.794 2.709 3.306 1.6273.712 2.613 3.302 1.5783.638 2.584 3.355 1.6083.547 2.529 3.419 1.691
3.443 2.521 3.483 1.800
HHW HLW HHW HLW HHW
TM ( 0W) TIDE TYPE (M ) TM ( 0W) TIDE TYPE (M )
(A) - (B) HEIGHT DIFFERENCE HW LW METERS METERS1.814 1.734 1.802 1.800 1.743 1.807 1.733 1.811 1.733 1.814 1.722 1.815 1.729 1.810 1.716 1.807 1.725 1.808 1.726 1.807 1.735 1.824 1.747
1.792 1.741
1.721

HLW

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SUMS | | | 152.420 | 120.010 | 102.090 | 71.841 | 50.330 | 48.169 | |
| ITEMS | | | 28 | 28 | 28 | 28 | 28 | 28 | |
| MEANS | | | 5.444 | 4.286 | 3.646 | 2.566 | 1.797 | 1.720 | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LHW LLW | LHW | LLW | LHW | LLW |
| SUMS | 20.6 | 43.5 | 146.092 | 103.320 | 93.990 | 53.800 | 52.102 | 49.520 | | |
| ITEMS | 57 | 57 | 29 | 29 | 29 | 29 | 29 | 29 | | |
| MEANS | .36 | .76 | 5.038 | 3.563 | 3.241 | 1.855 | 1.797 | 1.708 | | |

COMPARISON OF SIMULTANEOUS OBSERVATIONS FOR 98 6 15 TO 98 7 14 9/11/1998
1960-1978 TIDAL EPOCH (EXPECTED DIFFERENCE (STATION A - STATION B) = .0 HOURS)
(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER ACCEPTED TM ( 0W) TIDE TYPE (M )
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY ACCEPTED TM ( 0W) TIDE TYPE (M )

ERROR SCAN FOR TIME DIFFERENCE OF HW STANDARD DEVIATION= .111 ERROR IN 98 7 12 88 (SUBORDINATE STATION) .0 ERROR SCAN FOR TIME DIFFERENCE OF LW STANDARD DEVIATION= .141 ERROR IN 98 6 23 136 (SUBORDINATE STATION) 1.1 ERROR SCAN FOR HEIGHT DIFFERENCE OF HHW STANDARD DEVIATION= .013 ERROR IN 98 7 2 24 (SUBORDINATE STATION) 1.769 ERROR SCAN FOR HEIGHT DIFFERENCE OF LHW STANDARD DEVIATION= .020 ERROR SCAN FOR HEIGHT DIFFERENCE OF HLW STANDARD DEVIATION= .026 ERROR IN 98 6 17 76 (SUBORDINATE STATION) 1.666 ERROR IN 98 6 18 202 (SUBORDINATE STATION) 1.658 ERROR SCAN FOR HEIGHT DIFFERENCE OF LLW STANDARD DEVIATION= .027 ERROR IN 98 7 1 192 (SUBORDINATE STATION) 1.646
COMPARISON OF SIMULTANEOUS OBSERVATIONS FOR 98 6 15 TO 98 7 14 9/11/1998
1960-1978 TIDAL EPOCH (EXPECTED DIFFERENCE (STATION A - STATION B) = .0 HOURS)
(A) SUBORDINATE STATION 9414863 RICHMOND, CHEVRON OIL PIER ACCEPTED TM ( 0W) TIDE TYPE (M )
(B) STANDARD STATION 9414290 SAN FRANCISCO, SAN FRANCISCO BAY ACCEPTED TM ( 0W) TIDE TYPE (M )

MEAN DIFFERENCE IN HIGH ( .36) AND LOW ( MEAN HHW HEIGHT AT (A) = 5.444 MEAN LHW HEIGHT AT (A) = 5.038 DHQ AT (A) = .207 MEAN HW HEIGHT AT (A) = 5.237 MN AT (A) = 1.319 GT AT (A) = 1.881
.76) WATER INTERVALSMEAN HLW HEIGHT AT (A) = 4.286MEAN LLW HEIGHT AT (A) = 3.563 DLQ AT (A) = .355
MEAN LW HEIGHT AT (A) = 3.918 MTL AT (A) = 4.578DTL AT (A) = 4.503

MEAN HHW DIFFERENCE = 1.797 MEAN HLW DIFFERENCE = 1.720 MEAN LHW DIFFERENCE = 1.797 MEAN LLW DIFFERENCE = 1.708 DHQ DIFFERENCE = .000 DLQ DIFFERENCE = .006 MEAN HW DIFFERENCE = 1.797 MEAN LW DIFFERENCE = 1.714 MN DIFFERENCE = .083 MTL DIFFERENCE = 1.755 GT DIFFERENCE = .090 DTL DIFFERENCE = 1.753 MN RATIO = 1.067 DHQ RATIO = 1.002 GT RATIO = 1.050 DLQ RATIO = 1.018 MSL AT (A) = 4.570 MSL AT (B) = 2.804 MSL DIFFERENCE = 1.766

HWI LWI MTL MN DHQ DLQ
HOURS HOURS METERS METERS METERS METERS ACCEPTED FOR B 7.56 .83 2.728 1.250 .183 .344 DIFFERENCES AND RATIOS .36 .76 1.755 1.067 1.002 1.018 CORRECTED FOR A 7.92 1.59 4.483 1.334 .183 .351

MSL DTL GT
METERS METERS METERS ACCEPTED FOR B 2.713 2.646 1.777 DIFFERENCES AND RATIOS 1.766 1.753 1.050 CORRECTED FOR A 4.479 4.398 1.866

MRR METHOD

MHHW= 5.331 MLLW= 3.465
DHQ = .181 DLQ = .351

SRANDARD METHOD

MHHW= 5.334 MLW = 3.816
MHW = 5.150 MLLW= 3.466

DIRECT METHOD

MHHW MHW MLW MLLW

METERS METERS METERS METERS ACCEPTED FOR B 3.536 3.353 2.103 1.759 DIFFERENCES AND RATIOS 1.797 1.797 1.714 1.708 CORRECTED FOR A 5.333 5.150 3.817 3.466

MN = 1.333
GT = 1.867

**Figure 4.7 – Monthly Mean Simultaneous Comparison Example**

COMPARISON OF MONTHLY MEANS ( JAN-98 - JUN-98) 1960-78 TIDAL EPOCH
(A) SUBORDINATE: 9414863 RICHMOND, CA TM (000W) TIDE TYPE:MIXED
(B) CONTROL: 9414290 SAN FRANCISCO, CA TM (000W) TIDE TYPE:MIXED

| month/year | | MTL | | | MSL | | | HWI | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | A - B | A | B | A - B | A | B | A - B |
| | meters | meters | meters | meters | meters | meters | hours | hours | hours |
| Jan-98 | 4.736 | 3.001 | 1.735 | 4.726 | 2.981 | 1.745 | 7.900 | 7.510 | 0.390 |
| Feb-98 | 4.841 | 3.103 | 1.738 | 4.839 | 3.082 | 1.757 | 7.900 | 7.580 | 0.320 |
| Mar-98 | 4.624 | 2.883 | 1.741 | 4.615 | 2.859 | 1.756 | 7.840 | 7.520 | 0.320 |
| Apr-98 | 4.542 | 2.798 | 1.744 | 4.532 | 2.776 | 1.756 | 7.880 | 7.530 | 0.350 |
| May-98 | 4.562 | 2.811 | 1.751 | 4.547 | 2.787 | 1.760 | 7.890 | 7.540 | 0.350 |
| Jun-98 | 4.600 | 2.849 | 1.751 | 4.588 | 2.826 | 1.762 | 7.930 | 7.570 | 0.360 |

| month/year | | LWI | | | MN | | | DHQ | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | A - B | A | B | A/B | A | B | A/B |
| | hours | hours | hours | meters | meters | ratio | meters | meters | ratio |
| Jan-98 | 1.460 | 0.790 | 0.670 | 1.367 | 1.287 | 1.062 | 0.207 | 0.213 | 0.972 |
| Feb-98 | 1.570 | 0.820 | 0.750 | 1.208 | 1.101 | 1.097 | 0.161 | 0.183 | 0.880 |
| Mar-98 | 1.430 | 0.660 | 0.770 | 1.321 | 1.215 | 1.087 | 0.118 | 0.125 | 0.944 |
| Apr-98 | 1.450 | 0.660 | 0.790 | 1.309 | 1.210 | 1.082 | 0.111 | 0.117 | 0.949 |
| May-98 | 1.460 | 0.690 | 0.770 | 1.306 | 1.217 | 1.073 | 0.155 | 0.158 | 0.981 |
| Jun-98 | 1.490 | 0.720 | 0.770 | 1.292 | 1.205 | 1.072 | 0.194 | 0.196 | 0.990 |

| month/year | | DLQ | | | MHW | | | MLW | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | A/B | A | B | A - B | A | B | A - B |
| | meters | meters | meters | ratio | meters | meters | meters | meters | meters |
| Jan-98 | 0.331 | 0.337 | 0.982 | 5.420 | 3.644 | 1.776 | 4.053 | 2.357 | 1.696 |
| Feb-98 | 0.251 | 0.261 | 0.962 | 5.445 | 3.653 | 1.792 | 4.237 | 2.552 | 1.685 |
| Mar-98 | 0.210 | 0.207 | 1.014 | 5.284 | 3.490 | 1.794 | 3.983 | 2.275 | 1.708 |
| Apr-98 | 0.279 | 0.268 | 1.041 | 5.196 | 3.403 | 1.793 | 3.887 | 2.193 | 1.694 |
| May-98 | 0.336 | 0.328 | 1.024 | 5.215 | 3.420 | 1.795 | 3.909 | 2.203 | 1.706 |
| Jun-98 | 0.360 | 0.352 | 1.023 | 5.246 | 3.452 | 1.794 | 3.954 | 2.247 | 1.707 |

| month/year | | DRL(TL) | | | GT | | | MHHW | |
|---|---|---|---|---|---|---|---|---|---|
| | A | B | A - B | A | B | A/B | A | B | A - B |
| | meters | meters | meters | meters | meters | ratio | meters | meters | meters |
| Jan-98 | 4.675 | 2.939 | 1.736 | 1.905 | 1.837 | 1.037 | 5.627 | 3.857 | 1.770 |
| Feb-98 | 4.806 | 3.063 | 1.743 | 1.640 | 1.545 | 1.061 | 5.626 | 3.836 | 1.790 |
| Mar-98 | 4.578 | 2.841 | 1.737 | 1.649 | 1.547 | 1.066 | 5.402 | 3.615 | 1.787 |
| Apr-98 | 4.458 | 2.723 | 1.735 | 1.699 | 1.595 | 1.065 | 5.307 | 3.520 | 1.787 |
| May-98 | 4.471 | 2.726 | 1.745 | 1.797 | 1.703 | 1.055 | 5.370 | 3.578 | 1.792 |
| Jun-98 | 4.517 | 2.772 | 1.745 | 1.846 | 1.753 | 1.053 | 5.440 | 3.648 | 1.792 |

| month/year | | MLLW | |
|---|---|---|---|
| | A | B | A - B |
| | meters | meters | meters |
| Jan-98 | 3.722 | 2.020 | 1.702 |
| Feb-98 | 3.986 | 2.291 | 1.695 |
| Mar-98 | 3.753 | 2.068 | 1.685 |
| Apr-98 | 3.608 | 1.925 | 1.683 |
| May-98 | 3.573 | 1.875 | 1.698 |
| Jun-98 | 3.594 | 1.895 | 1.699 |

COMPARISON OF MONTHLY MEANS ( JAN-98 - JUN-98) 1960-78 TIDAL EPOCH

(A) SUBORDINATE: 9414863 RICHMOND, CA TM (000W) TIDE TYPE:MIXED

(B) CONTROL: 9414290 SAN FRANCISCO, CA TM (000W) TIDE TYPE:MIXED

| | MTL | MSL | HWI | LWI | MN | DHQ | DLQ |
|---|---|---|---|---|---|---|---|
| | A - B | A - B | A - B | A - B | A/B | A/B | A/B |
| | meters | meters | hours | hours | ratio | ratio | ratio |
| months | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| sums | 10.460 | 10.536 | 2.090 | 4.520 | 6.473 | 5.825 | 6.046 |
| means | 1.743 | 1.756 | 0.348 | 0.753 | 1.079 | 0.971 | 1.008 |
| accepted B | 2.728 | 2.713 | 7.560 | 0.830 | 1.250 | 0.183 | 0.344 |
| corrected A | 4.471 | 4.469 | 7.908 | 1.583 | 1.349 | 0.178 | 0.347 |

| | MHW | MLW | DRL(TL) | GT | MHHW | MLLW |
|---|---|---|---|---|---|---|
| | A - B | A - B | A - B | A/B | A - B | A - B |
| | meters | meters | meters | ratio | meters | meters |
| months | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 | 6.000 |
| sums | 10.744 | 10.176 | 10.441 | 6.337 | 10.718 | 10.162 |
| means | 1.791 | 1.696 | 1.740 | 1.056 | 1.786 | 1.694 |
| accepted B | 3.353 | 2.103 | 2.646 | 1.777 | 3.536 | 1.759 |
| corrected A | 5.144 | 3.799 | 4.386 | 1.877 | 5.322 | 3.453 |

| METHOD | DATUM | VALUE meters |
|---|---|---|
| MRR | MHHW | 5.325 |
| MRR | MLLW | 3.448 |
| MRR | DHQ | 0.179 |
| MRR | DLQ | 0.349 |
| STANDARD | MHW | 5.146 |
| STANDARD | MLW | 3.797 |
| STANDARD | MHHW | 5.323 |
| STANDARD | MLLW | 3.450 |
| DIRECT | MN | 1.345 |
| DIRECT | GT | 1.870 |
| DIRECT | DHQ | 0.179 |
| DIRECT | DLQ | 0.346 |

FINAL/PRELIMINARY DATUMS

METHOD : STANDARD 1960-78 EPOCH

| DATUM | VALUE meters |
|---|---|
| MHHW | 5.323 |
| MHW | 5.146 |
| MTL | 4.471 |
| MSL | 4.469 |
| DRL(TL) | 4.386 |
| MLW | 3.797 |
| MLLW | 3.450 |
| MN | 1.349 |
| GT | 1.873 |
| DHQ | 0.178 |
| DLQ | 0.347 |

COMPARISON OF MONTHLY MEANS ( JAN-98 - JUN-98) 1960-78 TIDAL EPOCH
(A) SUBORDINATE: 9414863 RICHMOND, CA TM (000W) TIDE TYPE:MIXED
(B) CONTROL: 9414290 SAN FRANCISCO, CA TM (000W) TIDE TYPE:MIXED

OUTLIER REPORT: MAXIMUMS AND MINIMUMS WHEN INDIVIDUAL MONTHLY MEAN DIFFERENCE EXCEEDS TWO STANDARD DEVIATIONS FROM OVERALL MEAN

| | MTL | MSL | HWI | LWI | MN | DHQ | DLQ |
|---|---|---|---|---|---|---|---|
| STD.DEV. | 0.004 | 0.003 | 0.018 | 0.019 | 0.008 | 0.012 | 0.017 |
| MAXIMUM | 1.752 | 1.762 | 0.384 | 0.791 | 1.095 | 0.994 | 1.041 |
| MINIMUM | 1.734 | 1.750 | 0.313 | 0.715 | 1.062 | 0.948 | 0.974 |
| month/year | | | | | | | |
| Jan-98 | | 1.745 | 0.390 | 0.670 | 1.062 | | |
| Feb-98 | | | | | 1.097 | | 0.962 |
| Mar-98 | | | | | | 0.944 | |
| Apr-98 | | | | | | | 1.041 |
| May-98 | | | | | | | |
| Jun-98 | | | | | | | |

| | MHW | MLW | DTL | GT | MHHW | MLLW |
|---|---|---|---|---|---|---|
| STD.DEV. | 0.003 | 0.006 | 0.003 | 0.006 | 0.004 | 0.004 |
| MAXIMUM | 1.796 | 1.708 | 1.746 | 1.068 | 1.794 | 1.703 |
| MINIMUM | 1.785 | 1.684 | 1.734 | 1.045 | 1.779 | 1.685 |
| month/year | | | | | | |
| Jan-98 | 1.776 | | | 1.037 | 1.770 | |
| Feb-98 | | | | | | |
| Mar-98 | | | | | | |
| Apr-98 | | | | | | 1.683 |
| May-98 | | | | | | |
| Jun-98 | | | | | | |

## Figure 4.8 Published Bench Mark Sheet

PUBLICATION DATE: 06/06/1996 Page 1 of 5
CALIFORNIA 941 4290
U.S. DEPARTMENT OF COMMERCE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE TIDAL BENCH MARKS THE PRESIDIO, SAN FRANCISCO
LATITUDE: 37E 48.4' N LONGITUDE: 122E 27.9' W NOAA CHART: 18649 USGS QUAD: SAN FRANCISCO NORTH

TO REACH TIDE STATION: To reach the tide station from the intersection of U.S. Highway 101 (north) and Lincoln Boulevard (last exit before the Golden Gate toll plaza), proceed NE on Lincoln Boulevard approximately 1.6 km (1.0 mile) to Cowles Street, turn left onto Cowles Street and proceed
0.8 km (0.5 mile) to McDowell Avenue, turn left onto McDowell Avenue and proceed 0.5 km (0.3 mile) to Crissey Field Avenue, turn left onto Crissey Field Avenue and proceed 0.3 km
(0.2 mile) to a stop sign, turn right and then immediately left onto Mason street, proceed along the National Parks Service parking lot fence where Mason Street turns into Hamilton Street, and proceed
0.5 km (0.3 mile) to a parking lot at the end of the street. The tide station is located in the 2nd building on the L-shaped wooden pier formerly owned by the U.S.Coast Guard, now owned by the National Park Service
. ...............................................................................

BENCH MARK STAMPING: 180 1936 MONUMENTATION: Survey Disk AGENCY/DISK TYPE: USC&GS Tidal Bench Mark SETTING CLASSIFICATION: Concrete Seawall The primary bench mark is set in the top of a 0.9-m (3') high concrete seawall at the NW end of Crissy Field on the Coast Guard property, 15 m (49') east of the NE corner of the crews quarters building, 6 m (20') south of the south side of the garage building, and 1.1 m (3.5') north of an angle in the seawall.

BENCH MARK STAMPING: 181 1945 MONUMENTATION: Survey Disk AGENCY/DISK TYPE: USC&GS Tidal Bench Mark SETTING CLASSIFICATION: Concrete Seawall The bench mark is set in the top of the NW corner of a seawall at the Fort Point Coast Guard Station, 62 m (204') west of the inshore end of the Coast Guard wharf, 46 m (151') NW of a flagpole, 22 m (71') NE of the north corner of Building S.F. 19.4 (paint shop and storage building), and 1.2 m (4.0') above grade.

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CALIFORNIA 941 4290
THE PRESIDIO, SAN FRANCISCO

BENCH MARK STAMPING: 4290 J 1976 MONUMENTATION: Survey Disk AGENCY/DISK TYPE: NOS Tidal Bench Mark SETTING CLASSIFICATION: Copper Clad Steel Rod The bench mark is in an elevated beach area midway between the Fort Point Coast Guard pier and the engineer's dock, 133 m (435') WNW of the west end of the seawall surrounding the Coast Guard crews quarters, 27 m (89') SW of the shoreward end of the old seaplane ramp, 18.3 m (60.0') SE of the shoreward end of the concrete discharge pipe, and 0.8 m (2.5') north of a chain link fence surrounding U.S. Army Field Maintenance Building #937. The mark is crimped to a copper-clad steel rod driven 15 m (48'), encased in a 4-inch diameter PVC pipe, and marked by a witness post.

BENCH MARK STAMPING: 4290 K 1976 MONUMENTATION: Survey Disk AGENCY/DISK TYPE: NOS Tidal Bench Mark SETTING CLASSIFICATION: Bedrock The bench mark is set vertically in bedrock on the south side of Marine Drive, 24 m (79') SSW of the SE corner of National Park Service building #T989, 14.7 m (48.2') SW of Bench Mark 174 1925, and
2.4 m (8.0') south of the south curb of Marine Drive.

BENCH MARK STAMPING: BM 174 1925 MONUMENTATION: Survey Disk AGENCY/DISK TYPE: USC&GS Tidal Bench Mark SETTING CLASSIFICATION: Concrete Monument The bench mark is set in a concrete monument level with the ground inside a brick circle in the pavement at the center of the Y-junction between Marine Drive and the road leading SE to Fort Winfield Scott, 38 m (125') west of the extension of the west edge of the engineer's dock where it crosses Marine Drive, 13.0 m (42.5') SW of a fire hydrant, and 8.7 m (28.5') south of the south edge of an iron manhole cover.

BENCH MARK STAMPING: BM 175 1925 MONUMENTATION: Survey Disk AGENCY/DISK TYPE: USC&GS Tidal Bench Mark SETTING CLASSIFICATION: Concrete Seawall The bench mark is set in the seawall near the National Park Service building, 62.2 m (214') NE of Bench Mark 4290 L 1976, 59 m (193') west of the NW corner of the park service building, 28.9 m (94.8') WNW of the northernmost post of a pedestrian gate, 6.9 m (22.5') north of the centerline of Marine Drive, and 0.7 m (2.4') south of the north edge of the seawall. (Note: The seawall was repaired in April 1981 and the elevation of the bench mark was changed after the repair, but the elevation seems stable since then.)

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CALIFORNIA 941 4290
THE PRESIDIO, SAN FRANCISCO

BENCH MARK STAMPING: BM 176 1925 MONUMENTATION: Survey Disk AGENCY/DISK TYPE: USC&GS Tidal Bench Mark SETTING CLASSIFICATION: Concrete Step The bench mark is set in the west end of the lowest concrete step at the main entrance to the porch of the U.S. Army Logistic Control office at #651 Mason Avenue, 30 m (98') SE of the intersection of Crissy Field and Mason Avenues, 15 m (50') south of the centerline of Mason Avenue, and about
0.2 m (0.7') above the sidewalk.

BENCH MARK STAMPING: CLARK 1948 MONUMENTATION: Survey Disk AGENCY/DISK TYPE: USC&GS Triangulation Mark SETTING CLASSIFICATION: Concrete Seawall The bench mark is set in the top of a concrete seawall, about 549 m (1800') NW of the Fort Point Coast Guard station, 24.2 m (79.5') west of the west edge of the engineer's dock, 6.9 m (22.5') NE of the NW corner of corrugated iron building #985, 3.0 m (10') west of the NW corner of a stucco paint locker building, and about 1.1 m (3.6') above ground.

BENCH MARK STAMPING: NO 2 1948 MONUMENTATION: Survey Disk AGENCY/DISK TYPE: USC&GS Reference Mark SETTING CLASSIFICATION: Concrete Seawall The bench mark is set flush in the top of a concrete seawall, 11.4 m (37.5') west of the west edge of the engineer's dock, 8.1 m (26.5') NE of the NE corner of corrugated iron building #985, and about
0.9 m (3.0') above ground.

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CALIFORNIA 941 4290 THE PRESIDIO, SAN FRANCISCO
Tidal datums at THE PRESIDIO, SAN FRANCISCO are based on the following: LENGTH OF SERIES = 19 YEARS TIME PERIOD = 1960-1978 TIDAL EPOCH = 1960-1978 CONTROL TIDE STATION =
Elevations of tidal datums referred to mean lower low water (MLLW) are as follows: HIGHEST OBSERVED WATER LEVEL (01/27/1983) = 8.87 FEET MEAN HIGHER HIGH WATER (MHHW) = 5.83 FEET MEAN HIGH WATER (MHW) = 5.23 FEET MEAN TIDE LEVEL (MTL) = 3.18 FEET MEAN SEA LEVEL (MSL) = 3.13 FEET MEAN LOW WATER (MLW) = 1.13 FEET *NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) = 0.14 FEET MEAN LOWER LOW WATER (MLLW) = 0.00 FEET LOWEST OBSERVED WATER LEVEL (12/17/1933) = -2.67 FEET
*NAVD is based on elevations published in Quad 371221, 1993, and NOS leveling of
1995.
Bench mark elevation information:

ELEVATION IN FEET ABOVE:

| BENCH MARK STAMPING | MLLW | MHW |
|---|---|---|
| 180 1936 | 13.24 | 8.01 |
| 181 1945 | 13.29 | 8.06 |
| 4290 J 1976 | 11.18 | 5.95 |
| 4290 K 1976 | 19.31 | 14.08 |
| BM 174 1925 | 16.65 | 11.42 |
| BM 175 1925 | 13.84 | 8.61 |
| BM 176 1925 | 15.99 | 10.76 |
| CLARK 1948 | 14.08 | 8.85 |
| NO 2 1948 | 14.04 | 8.81 |

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CALIFORNIA 941 4290 THE PRESIDIO, SAN FRANCISCO
MSL is the local mean sea level and should not be confused with the fixed datums of NGVD (sometimes referred to as Sea Level Datum of 1929) or NAVD 88. NGVD is a fixed datum adopted as a standard geodetic reference for heights. It was derived from a general adjustment of the first order leveling nets of the

U.S. and Canada. Mean sea level was held fixed as observed at 26 stations in the U.S. and Canada. Numerous adjustments have been made since originally established in 1929.
NAVD 88 involved a simultaneous, least squares, minimum-constraint adjustment of Canadian-Mexican-United States leveling observations. Local mean sea level at Father Point/Rimouski, Canada was held fixed as the single constraint. These fixed datums do not take into account the changing stands of sea level and because they represent a "best" fit over a broad area, their relationship to local mean sea level is not consistent from one location to another.

### 4.4.4. Quality Control

It is essential for tidal datum quality control to have data processing and leveling procedures carried out to the fullest extent. Caution must also be used in computing tidal datums in riverine systems or in regions of unknown tidal regimes. Tide-by-tide comparisons between subordinate and control station data will often detect anomalous differences which should be investigated for possible gauge malfunction or sensor movement. Datums shall be established from more than one bench mark. Differences in elevations between bench marks based on new leveling must agree with previously established differences from the published bench mark sheets. Any changes in the elevation differences must be reconciled before using in any datum recovery procedure. Datum accuracy at a subordinate station depends on various factors, but availability and choice of an adequate control station of similar tidal characteristics, similar daily mean sea level and seasonal mean sea level variations, and similar sea level trends are the most important. The length of series will also determine accuracy. The longer the series, the more accurate the datum and the greater quality control and confidence gained from analyzing numerous monthly mean differences between the subordinate and control station. At reoccupied historical stations for which datum recoveries are made, updated datums shall be computed from the new time series and compared with the historical datums as the survey progresses.

### 4.4.5. Geodetic Datum Relationships

Tidal datums are local vertical datums which may change considerably within a geographical area. A geodetic datum is a fixed plane of reference for vertical control of land elevations. The North American Vertical Datum of 1988 (NAVD 88) is the accepted geodetic reference datum of the National Geodetic Spatial Reference System and is officially supported by the National Geodetic Survey (NGS) through a network of GPS continuously operating reference stations. The relationship of tidal datums to NAVD has many hydrographic, coastal mapping and engineering applications including monitoring sea level change and the deployment of GPS electronic chart display and information systems, etc.

Existing geodetic marks in the vicinity of a subordinate tidal station shall be searched for and recovered. A search routine is available at http://www.ngs.noaa.gov. An orthometric level connection and ellipsoidal GPS tie is required at a subordinate tide station which has geodetic bench marks located nearby. NAVD 88 height elevations for published bench marks are given in Helmert orthometric height units by NGS. The GPS ellipsoid network height accuracies are classified as conforming to 2 cm or 5 cm standards accuracies (Refer to *NOAA Technical Memorandum NOS NGS-58*). At the present time, GPS ellipsoid heights conforming to the 2 cm accuracy standards are required for contract hydrographic surveying projects. Refer to Section 4.2.8 GPS Observations and *User's Guide for GPS Observations, NOAA/NOS, Updated January 2003.*

An orthometric level connection is preferred over ellipsoidal GPS tie, where applicable, for deriving NAVD 88 heights. An orthometric level connection is required if any geodetic marks (up to five marks) are located within a radius of 0.8 km (0.5 mi) from the subordinate tide station location. If suitable marks are found in the NGS database, and are farther than 0.8 km (0.5 mi) but less than 10 km (6 mi) from a subordinate tide station, then a GPS tie is required to derive the ellipsoid heights. If a minimum of five existing tidal bench marks within 1 km of a subordinate tide station location are not found, or suitable geodetic marks are not found in the NGS database within 10 km (6 mi) of a subordinate tide station, then five new bench marks shall be installed, described, connected by levels, and GPS observations shall be done on at least one of the five marks. (Refer to *User's Guide for Writing Bench Mark Descriptions, NOAA/NOS, Updated January 2003, User's Guide for GPS Observations, NOAA/NOS, Updated January 2003*, and the Section 4.2.8 GPS Observations.) At least two geodetic bench marks should be used to validate the leveling or GPS ellipsoid height connection for quality control purposes.

## 4.5. Final Zoning and Tide Reducers

Data relative to MLLW from subordinate stations or from NWLON stations, as appropriate, shall be applied to reduce sounding data to chart datum, either directly or indirectly through a correction technique referred to as tidal zoning. Whether corrected or direct, time series data relative to MLLW or other applicable LWD applied to reference hydrographic soundings to chart datum are referred to as "tide reducers" or "water level reducers".

### 4.5.1. Water Level Station Summaries

Data are reduced to mean values and subsequently adjusted to National Tidal Datum Epoch (NTDE) values for tidal datums and characteristic tidal attributes as prescribed in Section 4.4. and 4.5. "Summary files" shall be created for each subordinate tide station occupied for the survey. These summary data facilitate the development of corange and cophase lines and final zoning schemes. They also provide input into the NOS tidal datum bench mark publication process which supports navigation, boundary and shoreline determination, coastal engineering and management. NTDE values for Greenwich high and low water intervals, mean and diurnal ranges and high and low water inequalities shall be tabulated in these summary files which also contain the datums, the time and length of the series and NOS control station which was used to compute 19year equivalent NTDE values. NTDE datums shall be tabulated in the summary file relative to a documented consistent station datum such as tide staff zero or arbitrary station datum. The elevation of the primary bench mark shall be provided in this summary relative to the same zero or station datum. Latitude and longitude positions shall also be provided. An example of a summary file is provided in Figure 4.9.

Summary file data from new station occupations and NOS provided summaries from historical occupations and control stations within the survey area shall be used as input data to the tidal zoning process.

### 4.5.2. Construction of Final Tidal Zoning Schemes

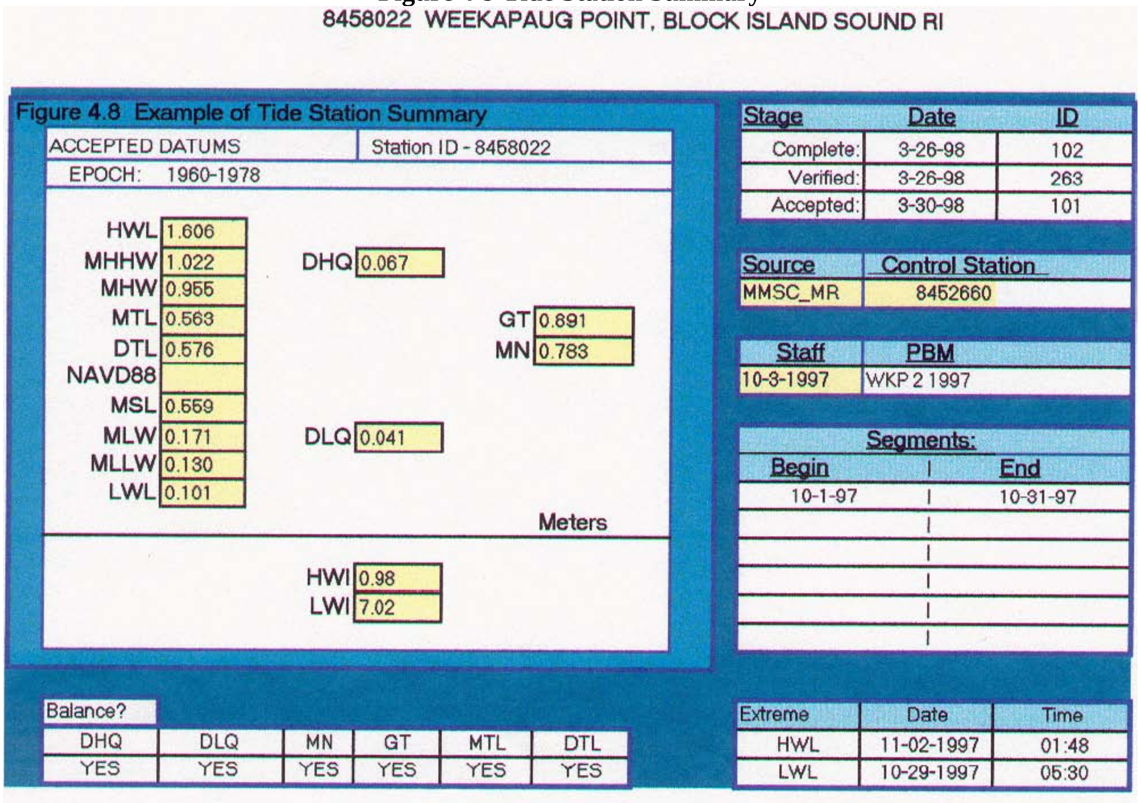
As tidal characteristics vary spatially, data from deployed water level gauges may not be representative of water levels across a survey area. Tidal zoning shall be implemented to facilitate the provision of time series water level data relative to chart datum for any point within the survey area such that prescribed accuracy requirements are maintained for the water level measurement component of the hydrographic survey. NOS currently utilizes the "discrete tidal zoning" method for operations, where survey areas are broken up into a scheme of zones bounding areas of common tidal characteristics. The minimum requirement is for a new zone for every 0.06 m change in mean range of tide and every 0.3 hour progression in time of tide (Greenwich high and low water intervals). Phase and amplitude corrections for appropriate tide station data shall be assigned to each zone.

As part of the process, tidal characteristics shall be accessed using geographic spacial placement of summary data in a commercial GIS compatible format to assess spatial variations in tidal characteristics. Corange and cophase maps shall be generated to provide the base for development of zoning schemes. Preliminary zoning, which is based on available historical tide station data and estuarine and global tide models, is referenced to an applicable predictions reference station for utilization during field work. For final processing, preliminary zoning shall be superseded by “final zoning” which is a refinement based on new data collected at subordinate stations during the survey. With the final zoning scheme, correctors for each zone shall be derived from a subordinate station specifically installed for the survey rather than the reference station used with preliminary zoning. For contract surveys, the contractor shall develop and utilize a zoning scheme to the specifications mentioned above such that water level reducers are within required accuracy across the entire survey area. Zoning errors shall be minimized such that when combined with errors from actual water level measurement at the gauge and errors in reduction to chart datum, the total error of the tide reducers is within specified tolerances. The final zoning scheme and all data utilized in its development shall be documented and submitted. Examples of zoning files and graphics are provided in Figures 4.10, 4.11, 4.12, 4.13 and 4.15.

### 4.5.3. Tide Reducer Files and Final Tide Note

Verified time series data collected at appropriate subordinate stations are referenced to the NTDE Mean Lower Low Water (Chart Datum) through datum computation procedures outlined in Section 4.4. Time series data collected in six-minute intervals and reduced to chart datum as specified, both from subordinate gauges operated by the contractor and from NWLON stations where appropriate, shall be used either directly or corrected through use of a zoning scheme as determined appropriate by the contractor such that tide reducers are within specified tolerances. A Final Tide Note shall be submitted for each hydrographic sheet with information as to what final tidal zoning should be applied to which stations to obtain the final tide reducers. An example Final Tide Note and final tidal zoning graphic is found in Figure 4.15.

**Figure 4-9 Tide Station Summary**



8458022 WEEKAPAUG POINT, BLOCK ISLAND SOUND RI

Figure 4.8 Example of Tide Station Summary

ACCEPTED DATUMS | Station ID - 8458022

EPOCH: 1960-1978

| | | | |
|---|---|---|---|
| HWL | 1.606 | | |
| MHHW | 1.022 | DHQ | 0.067 |
| MHW | 0.955 | | |
| MTL | 0.563 | GT | 0.891 |
| DTL | 0.576 | MN | 0.783 |
| NAVD88 | | | |
| MSL | 0.559 | | |
| MLW | 0.171 | DLQ | 0.041 |
| MLLW | 0.130 | | |
| LWL | 0.101 | | |

Meters

HWI 0.98

LWI 7.02

| Stage | Date | ID |
|---|---|---|
| Complete: | 3-26-98 | 102 |
| Verified: | 3-26-98 | 263 |
| Accepted: | 3-30-98 | 101 |

| Source | Control Station |
|---|---|
| MMSC_MR | 8452660 |

| Staff | PBM |
|---|---|
| 10-3-1997 | WKP 2 1997 |

Segments:

| Begin | End |
|---|---|
| 10-1-97 | 10-31-97 |

Balance?

| DHQ | DLQ | MN | GT | MTL | DTL |
|---|---|---|---|---|---|
| YES | YES | YES | YES | YES | YES |

| Extreme | Date | Time |
|---|---|---|
| HWL | 11-02-1997 | 01:48 |
| LWL | 10-29-1997 | 05:30 |

**Figure 4-10 GIS Summary Data File**

GIS Summary Data File

| STATION | NAME | ST | HWI | LWI | TCHHWI | TCLLWI | MN | DHQ | DLQ | GT | EPOCH | SERIES | HA_SERIES | COMP_STAT | COMMENTS | LATITUDE | LONGITUDE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9455176 | BURNT ISLAND, JURNALAIN ARM | AK | 3.67 | 10.25 | N/A | N/A | 28.0 | 0.8 | 2.4 | 31.2 | | 4H/L,1912 | N/A | Fire Island | | 60.950000000 | -149.883333333 |
| 9455182 | CAIRN POINT, KNIK HARBOR | AK | 3.69 | 10.35 | N/A | N/A | 26.97 | 0.76 | 2.38 | 30.11 | | 224H/L,1918 | N/A | Anchorage staff | | 61.233333333 | -149.916666667 |
| 9455697 | SISTERS ROCK, COOK INLET | AK | 0.31 | 6.85 | N/A | N/A | 16.31 | 0.85 | 2.02 | 19.18 | 41-59 | 34H/32L,Jul-Aug79 | N/A | Seldovia | | 60.301666667· | -151.455000000 |
| 9455711 | CAPE KASILOF, COOK INLET | AK | 0.43 | 6.80 | N/A | N/A | 17.66 | 0.60 | 2.08 | 20.34 | 41-59 | 60H/L,Jun-Aug74 | N/A | Seldovia | | 60.336666667 | -151.380000000 |
| 9455715 | KASILOF, KASILOF RIVER | AK | | | N/A | N/A | | | | | | 36H,Jul80 | N/A | | High waters only | 60.358333333 | -151.276666667 |
| 9455722 | KALGIN ISLAND (WEST) | AK | 0.36 | 6.71 | N/A | N/A | 15.63 | 0.71 | 1.90 | 18.24 | 41-59 | 128H/127L,Jun-Aug74 | N/A | Seldovia | mean of 2 series | 60.453333333 | -151.956666667 |
| 9455728 | LIGHT POINT, KALGIN ISLAND | AK | 0.70 | 7.13 | N/A | N/A | 15.95 | 0.70 | 2.00 | 18.65 | | 58H/L,Jul-Aug75 | N/A | Nikiski | | 60.486666667 | -151.835000000 |
| 9455735 | CHINULNA POINT, COOK INLET | AK | 0.68 | 7.22 | N/A | N/A | 17.89 | 0.74 | 2.02 | 20.65 | 60-78 | 1Mo,Jun95 | N/A | Seldovia | 3 series | 60.503333333 | -151.283333333 |
| 9455737 | KENAI RIVER | AK | 0.80 | | N/A | N/A | | 0.67 | | | 41-59 | 24Dy,Jul-Aug74 | N/A | Nikiski | high waters only | 60.521666667 | -151.206666667 |
| 9455741 | DRIFT RIVER | AK | 0.69 | 7.04 | N/A | N/A | 15.58 | 0.68 | 1.93 | 18.19 | | 64H/L,Jul-Aug74 | N/A | Seldovia | superceded | 60.555000000 | -152.133333333 |
| 9455742 | KENAI | AK | 0.78 | 7.75 | N/A | N/A | 14.49 | 0.73 | 1.64 | 19.86 | 41-59 | 2Mo,Jun-Jul76 | N/A | Seldovia | | 60.545000000 | -151.218333333 |
| 9455760 | NIKISKI | AK | 1.22 | 7.60 | N/A | N/A | 17.69 | 0.70 | 2.08 | 20.47 | 60-78 | 5Yr,1972-75&77 | N/A | Seldovia | | 60.683333333 | -151.396666667 |
| 9455768 | WEST FORELAND | AK | 1.53 | 7.56 | N/A | N/A | 13.30 | 0.68 | 2.23 | 18.21 | 60-78 | 1Mo,Jul76 | N/A | Seldovia | | 60.713333333 | -151.710000000 |
| 9455769 | NIKISHKA, 1ST EAST FURGUNA | AK | 1.43 | 8.03 | N/A | N/A | 18.05 | 0.49 | 2.11 | 20.65 | | 9H/L,1909 | N/A | Seldovia | | 60.733333333 | -151.333333333 |
| 9455771 | PLATFORM DILLON,T-39,COOK INLET | AK | 1.48 | 7.70 | N/A | N/A | 17.28 | | | | | | N/A | | CHART 16660 | 60.736666667 | -151.513333333 |
| 9455772 | NIKISHKA #2, COOK INLET | AK | 1.59 | 8.22 | N/A | N/A | 17.33 | 0.65 | 2.21 | 20.19 | 41-59 | 4Mo,Jul-Oct71 | N/A | Seldovia | | 60.743333333 | -151.308333333 |
| 9455779 | SHELL PLATFORM, GIDDLE GROUND | AK | 1.68 | 8.06 | N/A | N/A | 16.4 | | | | | 1Mo,1966 | N/A | | Chart 16660 | 60.795000000 | -151.495000000 |
| 9455781 | JUMBO ROCK, BOULDER POINT | AK | 1.83 | 8.48 | N/A | N/A | 18.02 | 0.68 | 2.06 | 20.76 | 41-59 | 15H/L,Sep76 | N/A | Nikiski | | 60.797000000 | -151.170000000 |
| 9455782 | DOLLY VARDEN PLATFORM,COOK INLET | AK | 1.68 | 8.14 | N/A | N/A | 16.22 | 0.68 | 2.11 | 19.01 | | 1Mo,Dec71 | N/A | Anchorage | | 60.808333333 | -151.636666667 |
| 9455783 | TRADING BAY, COOK INLET | AK | 1.47 | 7.88 | N/A | N/A | 16.5 | 0.8 | 2.20 | 19.50 | | 22H.12L,1910 | N/A | Seldovi/1st Red. | | 60.801666667 | -151.776666667 |
| 9455787 | GRAY CLIFFE | AK | 1.95 | 8.58 | N/A | N/A | 19.47 | 0.79 | 2.06 | 22.32 | 41-59 | 2Mo,Jul-Aug77 | N/A | Anchorage | | 60.833333333 | -150.971666667 |
| 9455799 | MIDDLE RIVER, COOK INLET | AK | | | N/A | N/A | | | | | | | N/A | | | 60.911666667 | -151.616666667 |
| 9455809 | T-37 PLATFORM (OPR 469) | AK | | | N/A | N/A | 16.82 | 0.63 | 2.15 | 19.60 | 60-78 | 24H/L,Jul75 | N/A | Nikiski | | 60.928333333 | -151.530000000 |
| 9455824 | MOOSE POINT | AK | 2.73 | 9.23 | N/A | N/A | 20.6 | 0.8 | 2.3 | 23.7 | | 4H/L,1910 | N/A | Chinulna Pt. | | 60.953300000 | -150.731600000 |
| 9455826 | MOOSE POINT T33 (OPR 469) | AK | | | N/A | N/A | | | | | | | N/A | | | 60.975000000 | -150.606666667 |
| 9455828 | T-29 CHICALOON BAY,TURNAGAIN ARM | AK | | | N/A | N/A | | | | | | | N/A | | | 60.966666667 | -149.850000000 |
| 9455845 | T-36 PLATFORM, OFF GRANITE POINT | AK | 2.25 | 8.68 | N/A | N/A | 16.73 | 0.65 | 2.08 | 19.46 | | 62h/l,Jul-Aug1975 | N/A | Nikiski | | 61.000000000 | -151.330000000 |
| 9455846 | T-29 RAINBOW (OPR-469) | AK | 3.59 | 11.28 | N/A | N/A | 27.51 | 0.59 | 1.56 | 29.66 | | 20H/L,Jul1975 | N/A | Anchorage | | 61.000000000 | -149.640000000 |
| 9455856 | TYONEK, COOK INLET | AK | 2.32 | 8.77 | N/A | N/A | 17.5 | 0.8 | 2.3 | 20.6 | | 4H/L,1910 | N/A | Chinulna Pt. | | 61.020000000 | -151.316666667 |
| 9455866 | T-39 POINT POSSESSION (OPR-469) | AK | 3.00 | 9.68 | N/A | N/A | 23.19 | 0.66 | 2.20 | 26.05 | 41-59 | 1Mo,Jul1975 | N/A | Anchorage | | 61.036666667 | -150.413000000 |
| 9455869 | NORTH FORELAND | AK | 2.71 | 9.03 | N/A | N/A | 17.88 | 0.61 | 2.08 | 20.57 | 41-59 | 107H/L,Jun-Aug1975 | N/A | Nikiski | GP changed 5/5/98 | 61.048300000 | -151.158300000 |
| 9455885 | PHILLIPS PLATFORM | AK | 2.79 | 9.21 | N/A | N/A | 19.20 | 0.64 | 2.19 | 13.04 | 60-78 | 1Mo,Jul1975 | N/A | Anchorage | not verified | 61.076700000 | -150.951666667 |
| 9455909 | THREE MILE CREEK, COOK INLET | AK | 2.68 | 9.18 | N/A | N/A | 19.2 | 0.8 | 2.3 | 22.3 | | 7H/8L,1919 | N/A | Chinulna Pt. | | 61.143333333 | -151.075000000 |
| 9455911 | FIRE ISLAND (WEST SIDE) | AK | | | N/A | N/A | 24.6 | 0.7 | 2.2 | 27.5 | | 22H/21L,May1941 | N/A | | | 61.156666667 | -150.240000000 |
| 9455912 | FIRE ISLAND | AK | 3.27 | 10.00 | N/A | N/A | 24.01 | 0.65 | 2.08 | 26.74 | 60-78 | 108H/107LMay-Jun1982 | N/A | Anchorage | | 61.173333333 | -150.213333333 |
| 9455915 | PT. WORONZOF | AK | 3.41 | 10.15 | N/A | N/A | 24.43 | 0.68 | 2.12 | 27.23 | 60-78 | 2Mo,Jul-Aug1971 | N/A | Anchorage | | 61.196666667 | -150.030000000 |
| 9455920 | ANCHORAGE, KNIK ARM, COOK INLET | AK | 3.72 | 10.42 | N/A | N/A | 26.25 | 0.71 | 2.28 | 29.24 | 60-78 | 8Yr,1984-91 | N/A | Seldovia | | 61.238333333 | -149.888333333 |
| 9455921 | ANCHORAGE (ADR) | AK | | | N/A | N/A | | | | | | | N/A | | | 61.238333333 | -149.888333333 |
| 9456043 | HARRIET POINT | AK | 0.50 | 6.72 | N/A | N/A | 14.19 | 0.70 | 1.95 | 16.84 | 41-59 | 100H/99L,Jun-Jul1974 | N/A | Seldovia | | 60.403333333 | -152.255000000 |
| 9456094 | REDOUBT PT | AK | 0.33 | 6.50 | N/A | N/A | 14.01 | 0.44 | 1.95 | 16.40 | 41-59 | 1Mo,Jul75 | N/A | Nikiski | | 60.301666667 | -152.385000000 |

**Figure 4-11 CORANGE LINE of GREENWICH**

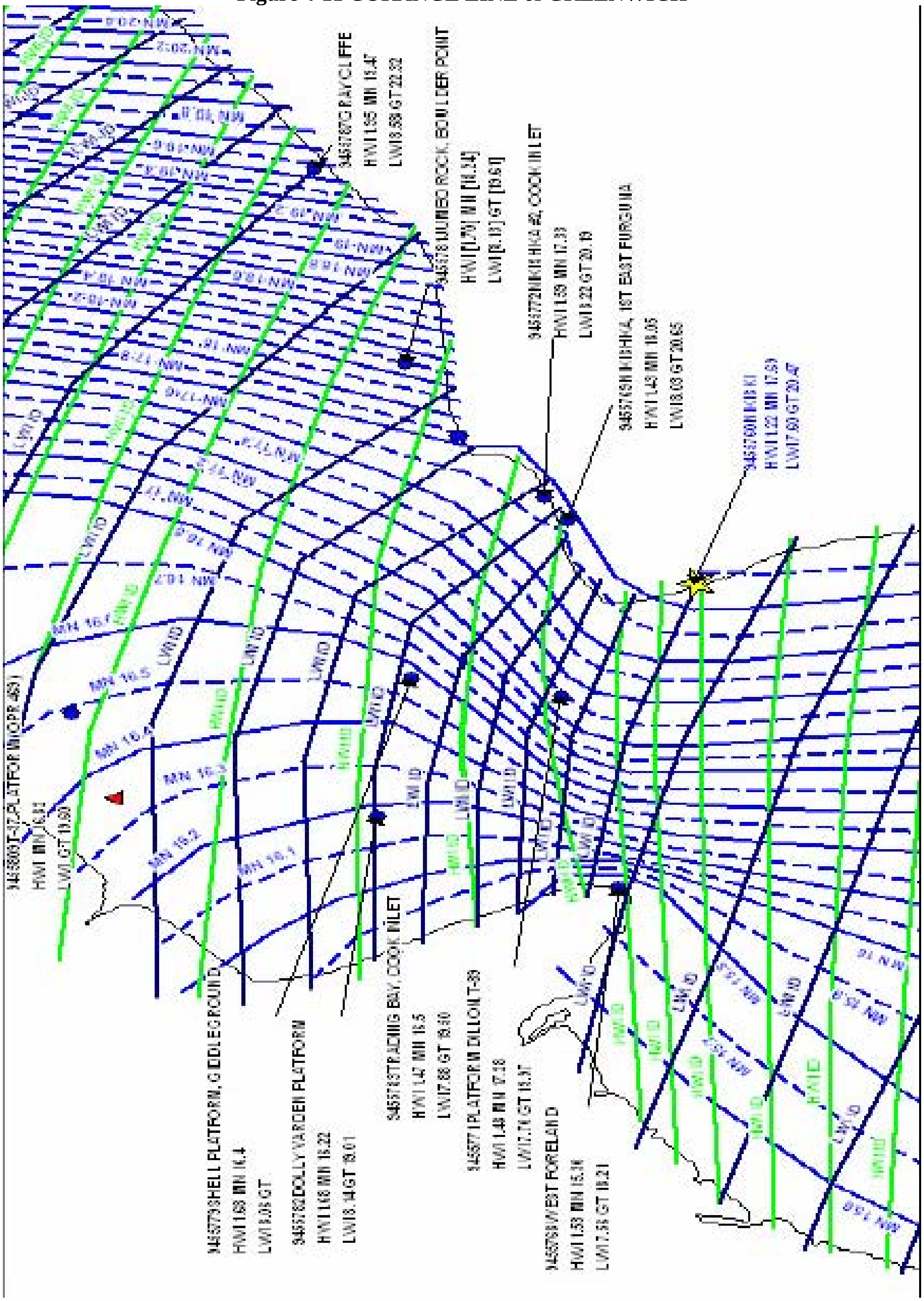


**Figure 4-12 TIDAL ZONING**

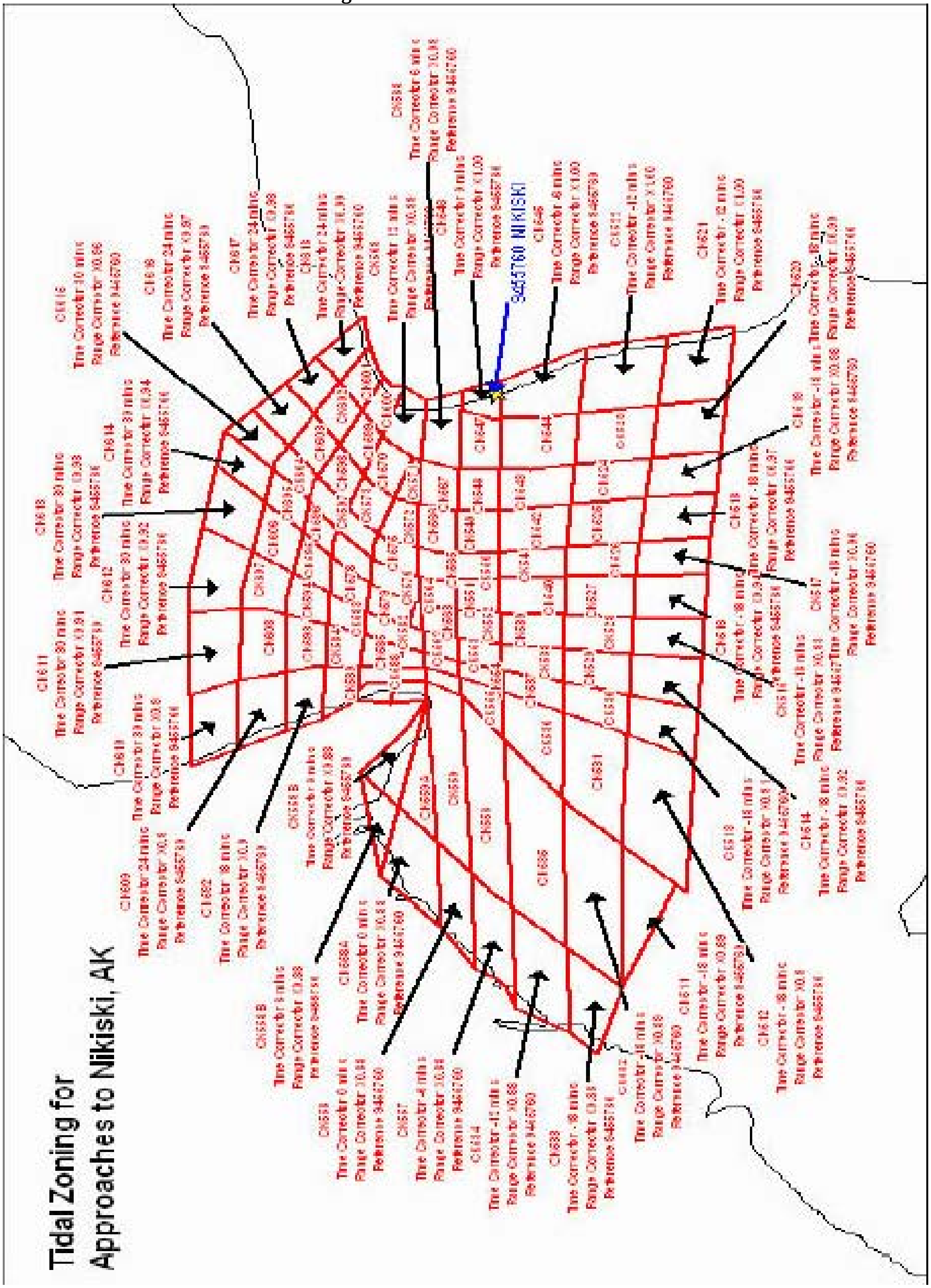


**Figure 4.13 Example Tide Reducer File from NOAA acoustic system**

| STATION | DATE/TIME utc | WL VALUE on MLLW meters | WL SIGMA meters | quality control flags: inferred | flat | rofc | temp |
|---|---|---|---|---|---|---|---|
| 9414290 | 10/1/98 0:00 | 1.373 | 0.042 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 0:06 | 1.390 | 0.043 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 0:12 | 1.403 | 0.036 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 0:18 | 1.424 | 0.039 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 0:24 | 1.426 | 0.033 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 0:30 | 1.436 | 0.034 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 0:36 | 1.458 | 0.032 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 0:42 | 1.489 | 0.035 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 0:48 | 1.507 | 0.032 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 0:54 | 1.520 | 0.038 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:00 | 1.533 | 0.042 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:06 | 1.537 | 0.029 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:12 | 1.541 | 0.033 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:18 | 1.548 | 0.032 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:24 | 1.572 | 0.033 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:30 | 1.596 | 0.037 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:36 | 1.609 | 0.039 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:42 | 1.624 | 0.036 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:48 | 1.639 | 0.040 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 1:54 | 1.638 | 0.036 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 2:00 | 1.649 | 0.032 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 2:06 | 1.658 | 0.036 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 2:12 | 1.659 | 0.033 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 2:18 | 1.660 | 0.041 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 2:24 | 1.671 | 0.029 | 0 | 0 | 0 | 0 |
| 9414290 | 10/1/98 2:30 | 1.669 | 0.039 | 0 | 0 | 0 | 0 |
| . | . | . | . | | | | |
| . | . | . | . | | | | |
| . | . | . | . | | | | |
| . | . | . | . | | | | |
| 9414290 | 11/30/98 23:00 | 0.350 | 0.120 | 0 | 0 | 0 | 0 |
| 9414290 | 11/30/98 23:06 | 0.342 | 0.124 | 0 | 0 | 0 | 0 |
| 9414290 | 11/30/98 23:12 | 0.343 | 0.090 | 0 | 0 | 0 | 0 |
| 9414290 | 11/30/98 23:18 | 0.359 | 0.106 | 0 | 0 | 0 | 0 |
| 9414290 | 11/30/98 23:24 | 0.389 | 0.079 | 0 | 0 | 0 | 0 |
| 9414290 | 11/30/98 23:30 | 0.412 | 0.087 | 0 | 0 | 0 | 0 |
| 9414290 | 11/30/98 23:36 | 0.446 | 0.128 | 0 | 0 | 0 | 0 |
| 9414290 | 11/30/98 23:42 | 0.459 | 0.102 | 0 | 0 | 0 | 0 |
| 9414290 | 11/30/98 23:48 | 0.399 | 0.089 | 0 | 0 | 0 | 0 |
| 9414290 | 11/30/98 23:54 | 0.463 | 0.136 | 0 | 0 | 0 | 0 |

## 4.6. Data Submission Requirements

Data submission requirements for water level measurement stations are comprised of both supporting documents for the installation, maintenance, and removal of stations, and the formatted digital water level data collected by the water level measurement system required for NOS quality control and ingestion into the NOS data base management system. In addition, documentation for processing and tabulation of the data, tidal datum computation, and final tidal zoning are required.

Data submission requirements for GPS project consists of project reports, station (bench mark) description or recovery notes, observation log sheets, station visibility diagrams, photographs or rubbings of station marks, raw GPS data, Rinex GPS data, and other info as pertinent.

### 4.6.1. Station Documentation

The documentation package shall be forwarded to CO-OPS within 10 business days of: a) installation of a station, b) performance of bracketing levels, c) gauge maintenance and repair, or d) removal of the station. Refer to Section 4.2.6 for general documentation requirements and Figure 4.14, Water Level Station Documentation Checkoff List. The station documentation generally includes, but is not limited to the following:

(a) Field Tide Note

(b) Calibration test documentation from an independent source other than the manufacturer for each sensor used to collect water level or ancillary data.

(c) NGWLMS Site Report (see *Next Generation Water level Measurement System Site Design, Preparation, and Installation Manual*) , and/or Tide Station Report (NOAA Form 77-12), or Great Lakes Water Level Station Report (NOAA Form 77-75) or equivalent. Contractor created Site Reports are acceptable as long as the reports provide same required information.

(d) New or updated Nautical chart section or U.S. Geological Survey quadrangle map indicating the exact location of the station, with chart number or map name and scale shown.

(e) Large-scale sketch of the station site and digital GIS compatible file provided on diskette showing the relative location of the water level gauge, staff (if any), bench marks, and major reference objects found in the bench mark descriptions. The sketch shall include an arrow indicating north direction, a title block, and latitude and longitude (derived from handheld GPS) of the gauge and all bench marks.

(f) New or updated description of how to reach the station from a major geographical landmark.

(g) Photographs of station components and bench marks. Digital photographs are preferred. As a minimum, photographs shall show a view of the water level measurement system as installed, including sensors and DCP; a front view of the staff (if any); multiple views of the surroundings and other views necessary to document the location; and photographs of each bench mark, including a location view and a close-up showing the bench mark stamping. All photographs shall be annotated and referenced with the station name, number, location, and date of the photograph.

(h) Description/Recovery Notes of Bench Marks (see *User's Guide for Writing Bench Mark Descriptions*, NOAA/NOS, Updated January 2003).

(I) Level records and level abstract, including level equipment information.

(j) Datum offset computation worksheet or Staff/Gauge difference work sheet as appropriate showing how sensor "zero" is referenced to the bench marks.

### 4.6.2. GPS Project Documentation

The following information shall be submitted to CO-OPS at the end of the project so that proper information can be forwarded to NGS.

This documentation is important because most of the information is used to submit the GPS data to NGS. In addition to the log, data must comply with the "Data Submission to NGS Section" of NGS-58 and the "Input Formats and Specifications of the National Geodetic Survey (NGS) Data Base" to become part of the NSRS.

GPS data collected by contractors or NOAA Ships for hydrographic survey support, or special projects shall be processed by the parties, and final data product - Receiver Independent Exchange Format (RINEX) data and appropriate forms - shall be submitted to CO-OPS which will be forwarded to NGS, as per the contracts, project instructions, statement of work, or as appropriate.

GPS forms in PDF format can be found at the following NGS Federal Base Network web site:

http://www.ngs.noaa.gov/PROJECTS/FBN/index.htm

Refer to Figures 4.16 through 4.22 for GPS projects submission checklist and sample package contents.

(A) Project report (Refer to Figure 4.16):
One project report per GPS project is required.

(B) Station (bench mark) description or recovery notes (Refer to Figure 4.17)
One per bench mark, for which GPS observations are submitted, is required.

(C) Observation log sheets (Refer to Figure 4.18 and 4.19)
One per each GPS observation session is required.

(D) Station/bench mark visibility diagrams (Refer to Figure 4.20)
One per each bench mark, for which GPS observations are submitted, is required.

(E) Photographs or rubbings of station (bench) marks (Refer to Figure 4.22 and 4.21)
One per each bench mark, for which GPS observations are submitted, is required.

(F) Raw GPS data

(G) Rinex GPS data

**Figure 4.14**

**I. For Each Water Level Station:**

**PROJECT DOCUMENTATION AND DATA CHECKOFF LIST**

Project Number: Locality:

Station Number: Station Name:

**A. Field Tide Note**

1.Verify latitude and longitude with handheld GPS.
2.Verify dates.

**B. Site Report (required for both installation and removal)**

1.All applicable information complete, especially serial numbers of DCP/sensors and dates of installation/removal of DCP/sensors and levels.
2.Verify latitude and longitude (ensure that this is the same as on the field tide note).
3.Denote latitude and longitude as NAD 83. Also note if position was derived from handheld GPS.

**C. Chart Section**

1.Ensure that station location is clearly depicted with circle and station number.
2.Note chart number, edition, date and scale.

**D. Bench Mark/Station Location Sketch**

1.Gage/staff and bench marks shown.
2.Title block provided (NOAA Form 76-199).
3.North arrow depicted.
4.Include hard copy sketch and GIS digital format on diskette.

**E. Photographs**

1.Digital photographs of gage, staff and surrounding area.

**F. Bench Mark Descriptions/Recovery Notes**

1.Stampings for new and recovered marks verified.

2.Descriptions for new marks provided in NOS format (WordPerfect).
3.Recovery notes provided for all historical marks.

**G. Levels**

1.Ensure all information written in ink.
2.Cover information complete; station name, number, instrument and rod type, serial numbers, date,personnel.
3.Note types of levels; installation, bracketing and closing.
4.Staff information complete (if applicable).
5.Collimation check shown.
6.Note that bench mark descriptions are submitted on separate sheets.
7.Headers on all applicable pages complete.

**H. Datum Offset Computation Worksheet**

1. Submit for stations using Vitel or Sutron 8200 DCP with Aquatrak sensor.

**I. Data Submitted on Diskettes**

1.Label diskettes with contractor name and list of files on each diskettes.
2.Data files should be named in the following format: xxxxxxx1.dat, where xxxxxxx = seven digit station number and 1 is the DCP designation. For multiple files from the same station, change the extension, i.e., xxxxxxx1.da1, da2, etc.
3.Check the begin and end dates of data submitted with dates of hydrographic operations. 4.Check data continuity.

**For the Project:**

**A. Files**

____ 1. GIS files for final zoning

____ 2. Final Tide Reducer Files for each H-Sheet

**B. Final Tide Notes**

____ 1.Final Tide Note for each H-Sheet

**C. Transmittal Letter**

1.Transmittal letter attached with current contractor address, phone number and email.

**D. All Documentation Enclosed in Tide Level Envelope (NOAA Form 75-29A)**

1.Leave "sheets" box blank, complete other information in title boxes.
2.Verified complete by Contractor and Include date.

## Figure 4.15 FINAL TIDE NOTE and FINAL TIDE ZONING CHART

**DATE:** December 22, 1999

**HYDROGRAPHIC BRANCH:** Pacific
**HYDROGRAPHIC PROJECT:**
OPR-P342-RA-99 **HYDROGRAPHIC**
**SHEET:** H-10910

**LOCALITY**: 6 NM Northwest of Cape Kasilof, AK

**TIME PERIOD:** July 22 - August 20, 1999

**TIDE STATION USED: 945-5711 Cape Kasilof, AK**
**Lat. 60° 20.2'N Lon. 151° 22.8'W PLANE OF REFERENCE (MEAN LOWER LOW WATER):** 0.000 meters **HEIGHT OF HIGH WATER ABOVE PLANE OF REFERENCE:** 5.850 meters

**REMARKS: RECOMMENDED ZONING**
Use zone(s) identified as: CK394, CK395, CK399, CK400, CK401,
CK407, CK408, CK409, CK434, CK435, CK441, CK442, CK443, CK467, CK468, CK469, CK470, CK477,
CK480, CK481, CK482, CK483, CK493 & CK494.

**Refer to attachments for zoning information.**

Note 1: Provided time series data are tabulated in metric units (Meters), relative to MLLW and on Greenwich Mean Time.

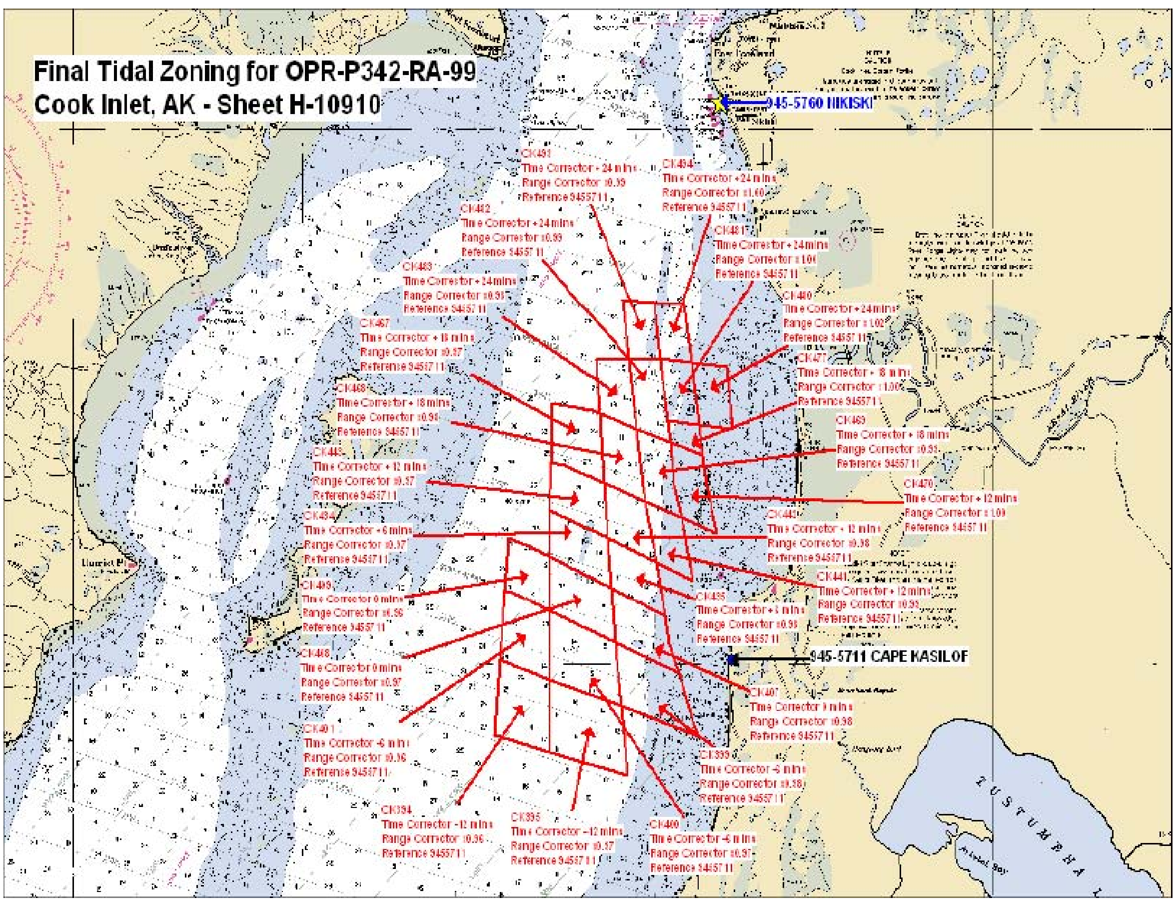
Note 2: Nikiski, AK served as datum control for subordinate tide stations and for tidal zoning in this hydrographic survey. Accepted datums for this station have been updated recently and have changed significantly from previous values.

The current National Tidal Datum Epoch (NTDE) used to compute tidal datums at tide stations is the 1960-78 NTDE. Traditionally, NTDEs have been adjusted when significant changes in mean sea level (MSL) trends were found through analyses amongst the National Water Level Observation Network (NWLON) stations. Epochs are updated to ensure that tidal datums are the most accurate and practical for navigation, surveying and engineering applications and reflect the existing local sea level conditions. For instance, analyses of sea level trends show that a new NTDE is necessary and efforts are underway to update the 1960-1978 NTDE to a more recent 19-

year time period.

Note: This example of Field Tide Note and Final Tidal Zoning Chart was written in December 1999, at that time NTDE was 1960-1978, now the new NTDE is 1983-2001.

However, analyses also show that there are several geographic areas whose sea level trends are strongly anomalous from the average trends found across the NWLON and thus, must be treated differently. One of these areas is in Cook Inlet, Alaska. Nikiski has shown a significant relative sea level change due to continued vertical land movement after the 1964 earthquake. NOS has adopted a procedure for computing accepted tidal datums for this anomalous region by using an MSL value calculated from the last several years of data rather than the 19-year NTDE. The accepted range of tide is still based on the 19-year NTDE and, when applied to the updated MSL, will result in updated values for Mean High Water (MHW) and Mean Lower Low Water (MLLW) derived through standard datum calculation procedures. For Nikiski, the MSL value was computed from the period of 1994-1998. This resulted in a lowering of the MLLW datums relative to land by approximately 1.0 ft at Nikiski compared to the previous MLLW elevations used in surveys prior to January 1, 1998. Subordinate tide stations in the area used for hydrographic surveys and controlled by Nikiski will be affected similarly. Accepted datums have been computed and may be accessed on the Internet through the URL specification **http://www.co-ops.nos.noaa.gov.**



## Figure 4.16 PROJECT SUBMISSION CHECKLIST

## GPS PROJECTS

Project Title_________________________________________________
SubmittingAgency:_____________________________________________
ObservingAgency:____________________________________________
ReceiverType:______________________________________________
AntennaType:________________________________________________

## PACKAGE CONTENTS

( ) Project Report

( ) Station Description or Recovery notes

( ) Observations Logs Sheets
Data which must be filled out: Station Designation, Date (UTC), General Location, Day of Year, Project Name, Session ID, Observation Session Times, Agency Full Name, Operator Full Name, Phone Number, GPS Receiver, GPS Antenna, Antenna Height, Data File Name
( ) Station Visibility Diagrams
( ) Photographs or Rubbings of Station Marks
( ) Raw GPS data
( ) Rinex GPS Data - See below
( ) Other

DATA REFORMATTING

Convert the raw GPS data to RINEX2 format with your manufacturer's software. The software should require you to enter the raw data filename, the output filenames, your name, the observer's name and agency, and the antenna type used.

The NGS-standard data filenames are as follows:

Raw GPS input files: aaaaddds.xxx
Where: aaaa = alphanumeric 4-character station identifier, ddd = day of year, s = session, yy = year of observations, and xxx is the receiver-dependent file extension (e.g., .DAT, .EPH, .ION, .MES, etc.)

RINEX2 Navigation File: aaaaddds.yyn
RINEX2 Observation File: aaaaddds.yyo

For example, RINEX2 filenames from station BALD 2 on session A of 12/31/98 are BALD365A.98o and BALD365A.98n Copy the raw GPS data files and the converted RINEX2 data files onto separate 3.5-inch diskettes or CD ROM.

**Figure 4.17 Station Description/Recovery Form**

--> Click here to clear the sample data <--

## NATIONAL GEODETIC SURVEY
## STATION DESCRIPTION / RECOVERY FORM

PID: QE2736 Designation & Alias: BALD 2 RESET

Country: (USA / USA) State: OR County: LINCOLN

Latitude: N 44 49 49.17802 " Longitude: W 124 03 56.23447 " Elevation: 17.0 (meter / ft)

| Original Description (check one): | |
|---|---|
| ☐ P | Preliminary (mark has not been set yet) |
| ☐ D | A newly set mark |
| ✔ R | A recovered mark |
| Established by: (NGS / CGS / Other:) Oregon DOT | |
| Date: | Chief of Party (initials): ??? |

| Recovery Description (check one): | |
|---|---|
| ☐ F | Full description of a station *not* in the database |
| ✔ T | Full description of a station *in* the database |
| ☐ M | *Partial* description of a station in the database |
| Recovered by: (NGS / Other:) Oregon DOT | |
| Date: | Chief of Party (initials): CFS |

| Monument Stability (check one): | |
|---|---|
| ✔ A | Of the most reliable nature; expected to hold well |
| ☐ B | Will probably hold position and elevation well |
| ☐ C | May hold well, but subject to ground movement |
| ☐ D | Of questionable or unknown reliability |

| Recovery Condition (check one): | |
|---|---|
| ✔ G | Recovered in good condition |
| ☐ N | Not recovered or not found |
| ☐ P | Poor, disturbed, or mutilated |
| ☐ X | Surface mark known destroyed |

| Setting Information: | |
|---|---|
| Marker Type: (Rod / Disk ✔ / Other) | |
| Setting Type: (Bedrock ✔ / Concrete / Other:) | |
| ✔ / N / ? | Monument contains magnetic material? |

| | |
|---|---|
| Stamping: | BALD 2 1991 |
| Agency Inscription: (NGS / CGS / Other:) | Oregon DOT |
| Rod Depth: (meter/ft), Sleeve Depth: (meter/ft) | |
| Monument is: (flush ✔ / projecting / recessed) (cm/inch) | |

| Special Type (check all applicable): | |
|---|---|
| ☐ F | Fault monitoring site |
| ☐ T | Tidal Station |
| ✔ -- | Control Station: ( FBN / CBN ✔ / Bench mark ✔ ) |
| ☐ -- | Airport Control Station: ( PACS / SACS ) |
| ✔ /N | Mark is suitable for GPS use? |

| Transportation (check one): | |
|---|---|
| ✔ C | Car |
| ☐ P | Light truck (pickup, carry-all, etc.) |
| ☐ X | Four-Wheel Drive Vehicle |
| ☐ __ | Other (SnowCat, Plane, Boat; describe) |
| ✔ /N | Pack Time (hike) to mark? (hh:mm): 00:03 |

**See Back of Form to add Text Description**

**General Station Location:** The station is located in about 10 km south from Lincoln Bay, 13 km north from Depoe Bay, and at the US101 Boiler Bay wayside rest area.

(Describe general location; include airline distances to three towns or mapped features.)

**Ownership:** The station is on the property of Oregon State Department of Parks and Recreation.

(name, address, phone of landowner)

**To Reach Narrative:** To reach the station from the intersection of US routes 5 and 101 in Depoe Bay, go north on US 101 for 1 km to the south entrance of the Boiler Bay wayside. Bear left on entrance road for 0.4 km to the parking area on the left. Pack northwest inside fence for about 90 meters to end of fence and the station on the right.

(Leg-by-leg distances and directions from major road intersection to mark)

**Monument Description and Measurements:** The station is set into drill hole in bedrock, 7.6 m south from the north fence corner, 8.8 m east from the west fence corner, and 3.6 m southeast from the northwest end of the outcrop.

(Add at least three measurements to permanent, identifiable, nearby objects; and a description of the monument size, shape, height, etc.)

**NOTE: - Include a pencil rubbing, sketch, or photographs of mark.**

Described by: John Q. Surveyor Phone: (301) 713-3194 e-mail: jqs@ordot.gov

**Figure 4.18 GPS Station Observation Log**

--> Click here to clear the sample data <--

GPS STATION OBSERVATION LOG (01-Nov-2000)

| | | | |
|---|---|---|---|
| Station Designation: (check applicable: FBN / ✔CBN / PAC / SAC / ✔BM) BALD 2 RESET | | Station PID, if any: QE2736 | Date (UTC): 31-Dec-98 |
| General Location: Boiler Bay Wayside | Airport ID, if any: --- | Station 4-Character ID: BALD | Day of Year: 365 |
| Project Name: Sample GPS, 1998 | Project Number: GPS- 1234 | Station Serial # (SSN): | Session ID:(A,B,C etc) A |

| | | | |
|---|---|---|---|
| NAD83 Latitude: 44° 49' 49.17802" | NAD83 Longitude: 124° 03' 56.23447" | NAD83 Ellipsoidal Height: -6.44 meters | Agency Full Name: Oregon DOT |
| Observation Session Times (UTC): Sched. Start 12:00 Stop 17:30; Actual Start 11:55 Stop 17:32 | Epoch Interval= 15 Seconds; Elevation Mask = 10 Degrees | NAVD88 Orthometric Ht. 17.0 meters; GEOID99 Geoid Height -23.52 meters | Operator Full Name: John Q. Surveyor; Phone #: (301) 713-3194; e-mail address: jqs@ordot.gov |

**GPS Receiver:**
Manufacturer & Model: Leica SR530
P/N: p/n 667122
S/N: s/n 0030354
Firmware Version: Version 3.0
✔CamCorder Battery, ▯ 12V DC, ▯ 110V AC, ▯ Other

**GPS Antenna:**
Manufacturer & Model: Trimble Choke Ring
P/N: p/n 29659-00
S/N: s/n 02200-63591
Cable Length, meters: 30 meters
Vehicle is Parked 25 meters N (direction) from antenna.

Antenna plumb before session? ✔(Y / N)
Antenna plumb after session? ✔(Y / N)
Antenna oriented to true North? ✔(Y / N)
Weather observed at antenna ht ✔(Y / N)
Antenna ground plane used? ✔(Y / N)
Circle Yes or No -If no, explain "

Antenna radome used? (Y / N)✔
Eccentric occupation (>0.5 mm)? (Y / N)✔
Any obstructions above 10°? (Y / N)✔
Radio interference source nearby (Y / N)✔
If yes, describe. Use Vis. form

**Tripod or Ant. Mount:** Check one: ✔Fixed-Height Tripod, ▯ Slip-Leg Tripod, ▯ Fixed Mount
Manufacturer & Model: SECO
P/N: none.
S/N: 97-G
Last Calibration date: 1998-11-01

**Tribrach:** Check one: ✔None, ▯ Wild GDF 22, ▯ Topcon, ▯ Other (describe)
Last Calibration date:

| ** ANTENNA HEIGHT ** (see back of form for measurement illustration) | Before Session Begins: Meters | Feet | After Session Ends: Meters | Feet |
|---|---|---|---|---|
| A= Datum point to Top of Tripod (Tripod Height) | 2.000 | | 2.000 | |
| B=Additional offset to ARP if any (Tribrach/Spacer) | -0.003 | | -0.003 | |
| H= Antenna Height = A + B = Datum Point to Antenna Reference Point (ARP) | | | | |

Note: Meters = Feet X (0.3048) Height Entered Into Receiver = 2.000 Meters.
Please note &/or sketch **ANY** unusual conditions. Be **Very Explicit** as to where and how Measured!

**Barometer:**
Manufacturer & Model: pretel altiplus A2
P/N: none.
S/N: J.Q.S.
Last Calibration or check Date: 11-Sep-01

**Psychrometer:**
Manufacturer & Model: Psychrodyne
S/N: J.Q.S.

| Weather DATA | Time (UTC) | Dry-Bulb Temp Fahrenheit | Dry-Bulb Temp Celsius | WetBulb Temp Fahrenheit | WetBulb Temp Celsius | Rel. % Humidity | Atm. Pressure inches Hg | Atm. Pressure millibar | Weather Codes * |
|---|---|---|---|---|---|---|---|---|---|
| Before | 12:00 | 74.0 | | 68.0 | | 74 | 29.4 | | 00000 |
| Middle | 14:45 | 77.0 | | 72.5 | | 81 | 29.6 | | 00001 |
| After | 17:30 | 82.5 | | 78.0 | | 82 | 29.7 | | 00102 |
| Average of Readings | | | | Calculate | | | | | * See back of form for codes |

**Remarks, Comments on Problems, Sketches, Pencil Rubbing, etc:**

1. Winds, calm at start, gradually increased to 20 knots by end of session.

2. Semi-trailer parked 12 meters SSE of antenna from 15:17 to 15:32 UTC, possibly blocking satellites and causing multipath environment.

3. Center pole of tripod projected 3 mm into dimple of disk.
Antenna height was therefore 2 m - 3 mm = 1.997 m

Note: Entries are Required in all Unshaded areas.

**Data File Name(s):** BALD365A.dat
(Standard NGS Format = aaaaddds.xxx)
where aaaa=4-Character ID, ddd=Day of Year, s=Session ID, xxx=file dependant extension

Updated Station Description: ✔Attached ▯ Submitted earlier
Visibility Obstruction Form: ✔Attached ▯ Submitted earlier
Photographs of Station: ✔Attached ▯ Submitted earlier
Pencil Rubbing of Mark: ✔Attached

LOG CHECKED BY: JGE

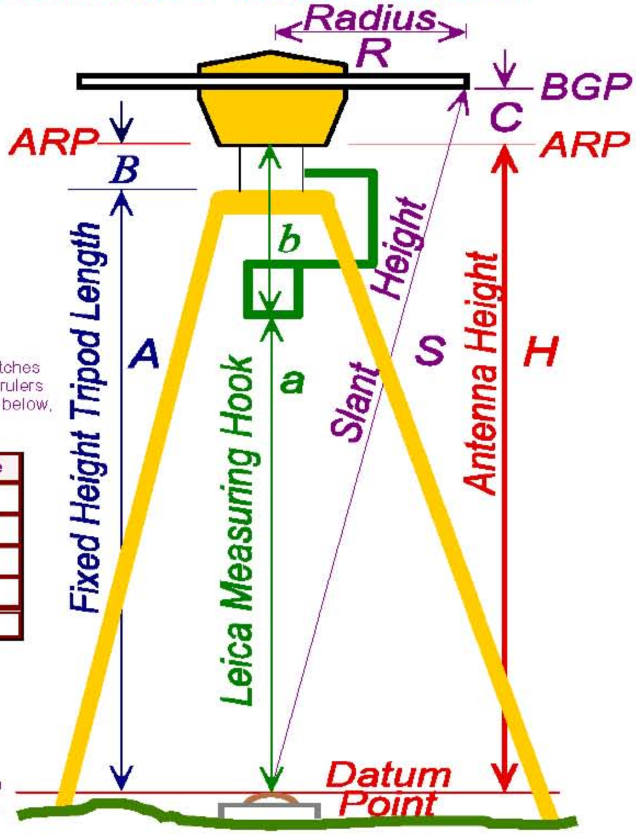
**Figure 4.19 GPS Antenna Height Measurements**

## ILLUSTRATION FOR ANTENNA HEIGHT MEASUREMENTS:

### I. Instructions for Fixed-Height Tripods:

Measure & record the fixed-height tripod length **(A)** and other offsets, if any, between the tripod and the Antenna Reference Point (ARP) **(B)**

$$Antenna.Height = H = A + B$$




### II. Instructions for Slip-Leg Tripods:

**1. Measure the Slant Height (S)**

Measure the slope distance from the mark to at least three notches on the Bottom of Ground Plane (BGP) using two independent rulers (e.g., metric and Imperial). Record measurements in the table below, and compute the average.

| Measure S | Notch #_ | Notch #_ | Notch #_ | Average |
|---|---|---|---|---|
| Before, cm | 223.40 | 223.30 | 223.30 | |
| Before, inch | 87.95 | 87.94 | 87.93 | |
| After, cm | 223.40 | 223.40 | 223.30 | |
| After, inch | 87.97 | 87.96 | 87.95 | |
| Note: cm= inch x (2.54) | | Overall average, cm | | |

S = ________________ cm

**2. Record the Antenna Radius (R) and the Antenna Constant (C)**

The antenna radius (R) is the horizontal distance from the center of the antenna to the measurement notch. The antenna constant (C) is the vertical distance from the ARP to the BGP. Consult your antenna users manual for exact measurements

R = ___19.05___ cm

C = ___3.50___ cm

**3. Compute Antenna Height (H)**

Use the following Pythagorean equation:

$$Antenna.Height = H = ((\sqrt{S^2 - R^2}) - C)$$

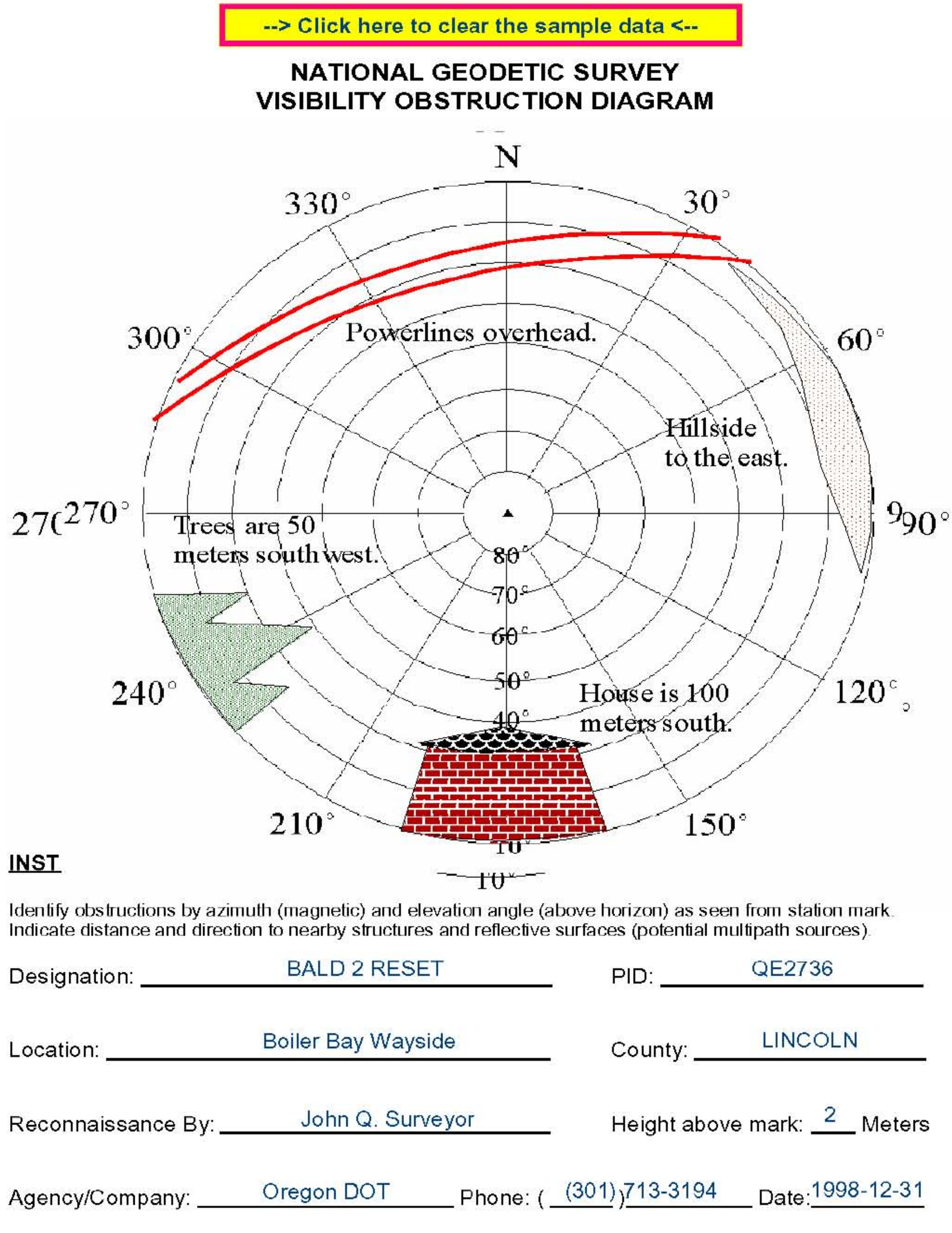
### III. Instructions for using the Leica Brand Measuring Hook:

Follow the Leica operating instructions, being sure to reduce the height to the Antenna Reference Point (ARP), NOT the L1 Phase Center.

$$Antenna.Height = H = a + b$$

| Table of Weather Codes -- for entry into Weather Data Table on front of form: | | | | | |
|---|---|---|---|---|---|
| CODE | PROBLEM | VISIBILITY | TEMPERATURE | CLOUD COVER | WIND |
| 0 | NO PROBLEMS encountered | GOOD More than 15 miles | NORMAL 32° F to 80°F | CLEAR Below 20% | CALM Under 5mph (8km/h) |
| 1 | PROBLEMS encountered | FAIR 7 to 15 miles | HOT Over 80°F (27 C) | CLOUDY 20% to 70% | MODERATE 5 to 15 mph |
| 2 | -- NOT USED -- | POOR Less than 7 miles | COLD Below 32° F (0 C) | OVERCAST Over 70% | STRONG over15mph (24km/h) |
| Examples: Code 00000 = Code 12121 = | 0 - No problems, 1 - Problems, | 0 - good visibility, 2 - poor visibility, | 0 - normal temperature, 1 - hot temperature, | 0 - clear sky, 2 - overcast, | 0 - calm wind 1 - moderate wind |

**Figure 4.20: Visibility Obstruction Diagram**


--> Click here to clear the sample data <--

**NATIONAL GEODETIC SURVEY**
**VISIBILITY OBSTRUCTION DIAGRAM**



**INST**

Identify obstructions by azimuth (magnetic) and elevation angle (above horizon) as seen from station mark. Indicate distance and direction to nearby structures and reflective surfaces (potential multipath sources).

Designation: BALD 2 RESET PID: QE2736

Location: Boiler Bay Wayside County: LINCOLN

Reconnaissance By: John Q. Surveyor Height above mark: 2 Meters

Agency/Company: Oregon DOT Phone: (301) 713-3194 Date: 1998-12-31

**Figure 4.21: Station Pencil Rubbing Form**

# Station Pencil Rubbing Form

--> Click here to clear the sample data <--

Location / Airport Name and ID: Boiler Bay Wayside  
Project: Sample GPS, 1998

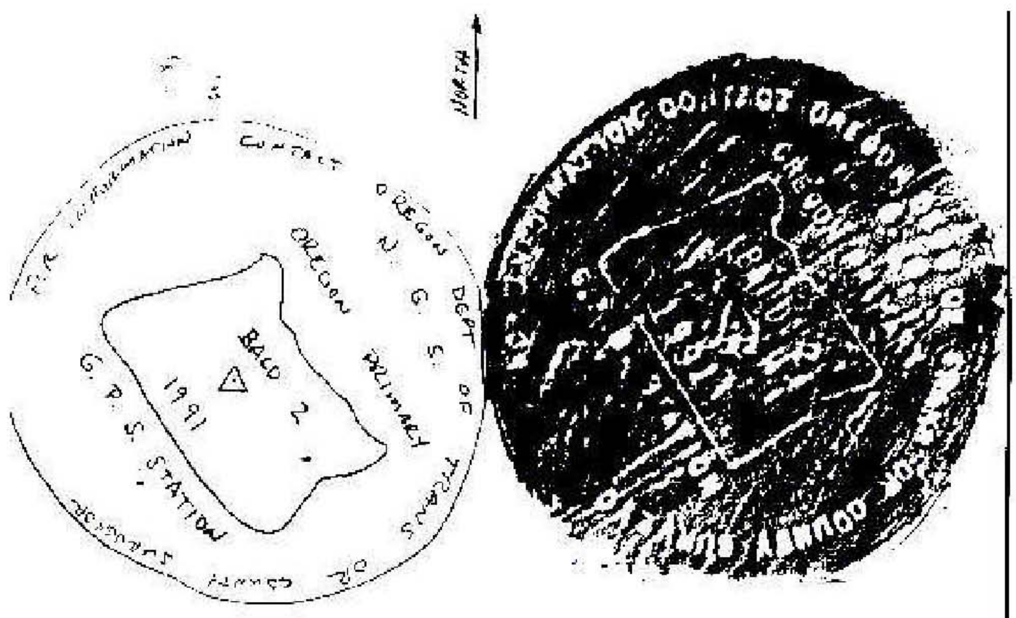
Station Designation: BALD 2 RESET  
PID: QE2736  
Date: 1998-12-31

Circle all applicable: PACS SACS BM ✓ FEN CBN ✓ OTHER____

Observer & Organization: John Q. Surveyor, ORDOT

**Station Pencil Rubbing**

Instructions: Place the blank form (or other blank paper) over the mark and rub over the entire disk with a pencil. For rod marks, rub only the designation and date stamping from the rim of the aluminum logo cap. If it is impossible to make a rubbing of the mark, or if the rubbing appears indistinct, a sketch and/or photograph may be substituted.




Remarks:  
This disk is reset into the same drill hole as the original station BALD 1962.

Monument Type: Brass Disk

Inscribed Agency: Oregon DOT

Stamping: BALD 2 1991

**Figure 4.22: Digital Photo of Stamping of Bench Mark**

## 4.6.3. Water Level Data

The final observed water level measurements shall be reported as heights in meters to three decimal places (i.e. 0.001 m). All heights shall be referenced to station datum and shall be referenced to UTC. The final tide reducer time series data shall be referenced to MLLW and shall be referenced to UTC. The contractor must provide CO-OPS with the water level data from all tide gauges installed with in 90 days of removal of stations/gauges.

The original raw water level data and also the correctors used to convert the data to chart datum shall be retained until notified in writing or at least two years after the survey is completed. All algorithms and conversions used to provide correctors shall be fully supported by the calibrations, maintenance documentation, leveling records, and sound engineering/oceanographic practices. Sensors for measurements used to convert data (e.g. pressure to heights) shall be calibrated and maintained for the entire water level collection period.

All digital water level and ancillary data shall be transmitted to CO-OPS in a format dependent on the DCP configuration. If GOES satellite is used, the data shall be transmitted and received using the NOS compressed pseudo binary format (see NGWLMS GOES Message Formatting, Libraro, 1998). These satellite messages are then decoded by NOS DMS upon receipt from NESDIS before further processing and review by CORMS can be completed. If satellite transmission configurations cannot be installed, the data shall be manually downloaded from the DCP and submitted to NOS, as shown in the format below, in a digital format, on 3.5 inch floppy disks, CD-ROM, or by email as an ASCII data attachment. It may be prudent to submit data at more frequent intervals under specific circumstances. Data download files shall be named in the following format: xxxxxxxy.DAZ, where xxxxxxx is the seven digit station number, y is the DCP number (usually 1), and DAZ is the extension (where Z = 1,2,3...if more than one file is from the same station and DCP). This is the format needed when the data is loaded into DMS.

The 6-minute interval data (acoustic sensor and pressure sensor examples follow) shall have the following format once decoded:

Acoustic Sensor Data (XXX.ACO format)

- Column 1-7 Station ID (assigned in the project instructions)
- Column 8 1 (DCP number, use 2, 3 , etc., for additional DCPs)
- Column 9-19 Date (MMM DD YYYY format, e.g. JAN 01 1998)
- Column 20 Blank
- Column 21-22 Hours in 24 hour format (i.e. 01, 01, ..., 23)
- Column 23 : (place a colon)
- Column 24-25 Minutes (00,06,12,etc..)
- Column 26-32 Data value in millimeters, right justified, (e.g. 1138)
- Column 33-38 Sigma (standard deviation in millimeters in integer format)
- Column 39-44 Outlier (integer format)
- Column 45-50 Temperature 1 (tenth of degrees C in integer format)
- Column 51-56 Temperature 2 (tenth of degrees C in integer format)
- Column 57-58 Sensor type (A1 for acoustic type)
- Column 59-60 blank
- Column 61-61 Data Source (S for Satellite, D for Diskette)

Sample Data:

85169901AUG 17 1993 05:00 1138 23 0 308 297A1 S
85169901AUG 17 1993 05:06 1126 26 0 308 298A1 S
85169901AUG 17 1993 05:12 1107 26 1 309 298A1 S

Pressure Sensor Data (XXX.BWL format)
Column 1-7 Station ID (assigned in the project instructions)
Column 8 1 (DCP number, use 2, 3 , etc., for additional DCPs)
Column 9-19 Date (MMM DD YYYY format, e.g. JAN 01 1998)
Column 20 Blank
Column 21-22 Hours in 24 hour format (i.e. 01, 01, ..., 23)
Column 23 : (place a colon)
Column 24-25 Minutes (00-59)
Column 26-32 Data value in millimeters, right justified, (e.g. 1138)
Column 33-38 Sigma (standard deviation in millimeters in integer format)
Column 39-44 Outlier (integer format)
Column 45-50 DCP temperature (tenth of degrees C in integer format)
Column 51-52 Sensor type (B1 for pressure type)
Column 53-53 blank
Column 54-54 Data Source (S for Satellite, D for Diskette)

85169901AUG 17 1993 05:00 1138 23 0 308B1 S
85169901AUG 17 1993 05:06 1126 26 0 308B1 S
85169901AUG 17 1993 05:12 1107 26 1 309B1 S

Note: pressure data must be accompanied by documented staff observations as listed in Section 4.2.2. and 4.2.4.

### 4.6.4. Tabulations and Tidal Datums

For contract surveys, the contract hydrographer shall provide digital and hard copies of tabulations of staff/gauge differences, hourly heights, high and low waters, and monthly means for the entire time series of observations from each station. Along with the final contractor computed tidal datums, the contractor shall provide copies of the tide-by-tide and/or monthly mean simultaneous comparison sheets from which the final tidal datums were determined. Audit trails of data edits and gap-filling shall be summarized and provided also.

The digital tabulation files for hourly heights and high and low waters shall have the following formats:

**Hourly height data**

COLUMN
1 -7 Station ID number
8 -11 Year
12 - 13 Month
14 - 15 Day
16 Line Number ( 1 = 1st line of day for 0 to 11 hours,
2 = 2nd line of day for 12 to 23 hours).
17 - 20 Time Meridian (Example: 000W)

21 - 26 0/12 Hourly height in meters (to millimeter resolution)
27 - 32 1/13 Hourly height in meters (to millimeter resolution)
33 - 38 2/14 Hourly height in meters (to millimeter resolution)
39 - 44 3/15 Hourly height in meters (to millimeter resolution)
45 - 50 4/16 Hourly height in meters (to millimeter resolution)
51 - 56 5/17 Hourly height in meters (to millimeter resolution)
57 - 62 6/18 Hourly height in meters (to millimeter resolution)
63 - 68 7/19 Hourly height in meters (to millimeter resolution)
69 - 74 8/20 Hourly height in meters (to millimeter resolution)
75 - 80 9/21 Hourly height in meters (to millimeter resolution)
81 - 86 10/22 Hourly height in meters (to millimeter resolution)
87 - 92 11/23 Hourly height in meters (to millimeter resolution)

**High and Low Water data**

COLUMN
1 -7 Station ID Number
8 -9 Year
10 - 11 Month
12 - 13 Day
14 - 17 Time Meridian (Example: 075W)
18 - 26 First Tide
18 1 = High
2 = Low
3 = Higher High
4 = Lower Low
19 0 Nothing unusual/Normal
1 If Inferred Tide
2 If Flat Tide
3 If Extra Tide
4 If Inferred and Flat Tide
5 If Extra and Flat Tide
20 - 22 Hour (Tenths of Hours)
23 - 27 Height (in meters to millimeter resolution)
28 - 37 Second Tide
38 - 47 Third Tide
48 - 57 Fourth Tide
58 - 67 Fifth Tide (If any)
68 - 77 Sixth Tide (If any)
78 - 87 Seventh Tide (If any)

### 4.6.5. Tide Reducers and Final Zoning and Final Tide Note

The final zoning scheme shall be fully supported by documentation of data and methodology which comprised the final zoning model. The contractor must provide CO-OPS with his/her final tidal zoning scheme digitally and it must be in the MAPINFO or ARCVIEW compatible format. Final tidal zoning scheme in AUTOCAD format is not acceptable.

Final tide reducers shall be submitted in the specified format.
All documentation listed below shall be forwarded to CO-OPS:

(a) Contractor created summary files.
(b) Documentation of NOS summary files utilized for final zoning
(c) GIS compatible zoning development steps including geographical presentation of summary data and cophase/corange maps
(d) GIS compatible digital final zoning files
(e) Final tide reducer data files
(f) Final Tide Note

The final zoning scheme shall be fully supported by documentation of data and methodology which comprised the final zoning model.

### 4.6.6. Submission

The check list in Figure 4.14 shall be used to check and verify the documentation that is required for submission. All documentation, water level data, GPS info and data, and other reports as required shall be forwarded to the following address:

NOAA, National Ocean Service
Thomas Mero
Chief, Requirements and Development Division
SSMC4 - Station 6531, N/OPS1
1305 East-West Highway
Silver Spring, MD 20910

Voice: 301-713-2897 ext. 145
Fax: 301 - 713-4436

## 4.7. Guidelines and References

References for the water level measurement and leveling requirements issued by the NOS Center of Operational Oceanographic Products and Services (CO-OPS) and the National Geodetic Survey (NGS) are listed below.

Some of these documents are available on CO-OPS web site at http://www.CO-OPS.nos.noaa.gov.

1. Next Generation Water Level Measurement System (NGWLMS) Site Design, Preparation, and Installation Manual, NOAA/NOS, January 1991.

2. User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, NOAA/NOS, dated October 1987.

3. User's Guide for Writing Bench Marks Descriptions, NOAA/NOS, Updated January 2003.

4. User's Guide for Electronics Levels, NOAA/NOS, updated January 2003.

5. User's Guide for 8200 Bubbler Gauges, NOAA/NOS, updated February 1998.

6. User's Guide for 8200 Acoustic Gauges, NOAA/NOS, updated August 1998.

7. User's Guide for 8210 Bubbler Gauges, NOAA/NOS, updated February 2001.

8. User's Guide for GPS Observations, NOAA/NOS, updated January 2003.

9. Tidal Datums and Their Applications, Special Publication No. CO-OPS 1, NOAA/NOS, June 2000.

10. Manual of Tide Observations, U.S. Department of Commerce, Publication 30-1, Reprinted 1965.

11. Tidal Datum Planes, U.S. Department of Commerce, Special Publication No.135, Marmer 1951.

12. Tide and Current Glossary, U.S. Department of Commerce, NOAA, NOS, October 1989.

13. Standing Project Instructions: Great Lakes Water Levels, June 1978.

14. NOAA Technical Report NOS 64 "Variability of Tidal Datums and Accuracy in Determining Datums from Short Series of Observations", Swanson, 1974.

15. Data Quality Assurance Guidelines for Marine Environmental Programs, Robert J. Farland, Office of Ocean Engineering, NOAA, March, 1980.

16. System Development Plan, CORMS: Continuous Operational Real-Time Monitoring System, NOAA Technical Report NOS OES 014, U.S. Department of Commerce, NOAA, NOS February, 1997.

17. NGWLMS GOES MESSAGE FORMATTING, Phil Libraro, 6/98.

18. Computational Techniques for Tidal Datums, NOAA Technical Report NOS CO-OPS 2, U.S. Department of Commerce, NOAA, NOS, DRAFT December 1998.

19. Standards and Specifications for Geodetic Control Networks, Federal Geodetic Control Committee, September 1984.

20. Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2CM and 5CM) Version 4.3, NOAA Technical Memorandum NOS NGS-58, November 1997.

21. Geodetic Leveling, NOAA Manual NOS NGS 3, U.S. Department of Commerce, NOAA, National Ocean Survey, August, 1981.

22. NOAA Special Publication NOS CO-OPS 1Tidal Datums and Their Applications, February 2001.

# 5. Depth Sounding

## 5.1. Sounding Units

Depths shall be recorded in meters, with a precision of at least centimeters. This precision shall be maintained throughout the processing pipeline and be maintained in the digital data.

Depths reported in the Descriptive Report (DR), other reports or correspondence should be rounded to the nearest decimeter and have the associated Total Propagated Error (TPE) or uncertainty of the depth listed to the nearest decimeter.

## 5.2. Accuracy and Resolution Standards

As mentioned in Section 1, the NOS Specifications are partly based on the IHO Standards for Hydrographic Surveys as outlined in Special Publication 44 (S-44). In the future, NOS Specifications will only define the requirements for grid accuracy and grid resolution, subjects not covered in the current version of S-44. As an interim step, sounding accuracy is still defined in the NOS Specifications, in addition to grid requirements. The IHO accuracy limit curves are used as a convenient point of reference (see section 5.2.1), however, NOS is not strictly following IHO S-44. The IHO Specifications are suggested minimum standards that member states may choose to follow.

When the NOS Specifications refer to an IHO Order, it is usually in terms of the final accuracy of a measurement. No other claim for “meeting” an IHO Order survey is implied.

### 5.2.1 Accuracy Standards

NOS standards for the accuracy of measured depths in hydrographic surveys apply to the systematic measurement of general water depths and to the least depths determined over wrecks and obstructions. By extension, they also apply to the elevations of rocks or other features which uncover at low water and to the measurement of overhead clearances. These standards apply regardless of the method of determination; whether by single beam echosounder, multibeam echosounder, lead line, lidar or diver investigation.

The total sounding error in a measured depth at the 95 percent confidence level, after systematic and system specific errors have been removed, shall not exceed:

$$\pm\sqrt{[a^2 + (b * d)^2]}$$

where in depths less than 100 meters, a = 0.5 meters and represents the sum of all constant errors, (b * d) represents the sum of all depth dependent errors, b = 0.013 and is a factor of depth dependent error, and d is depth (in meters) (IHO S-44, Order 1).

In depths greater than 100 meters, a =1.0, b=0.023, d=depth (IHO S-44, Order 2).

The maximum allowable error in measured depth includes all inaccuracies due to residual systematic and system specific instrument errors; the speed of sound in water; static vessel draft; dynamic vessel draft; heave, roll, and pitch; and any other sources of error in the actual measurement process, including the errors associated with water level (tide) variations (both tidal measurement and zoning errors).

### 5.2.2. Multibeam Resolution Standards

The hydrographer shall maintain and operate the multibeam sonar system, from data acquisition to processing, such that it detects shoals that measure 2 meters x 2 meters horizontally and 1 meter vertically in depths of 40 meters or less. For depths greater than 40 meters, the minimum size of detectable targets shall be 10 percent of the depth for horizontal dimensions and 5 percent of the depth for vertical dimensions. Depths shall be determined and recorded with a vertical resolution no coarser than 1 centimeter.

The ability to detect objects (multibeam resolution) is a function of the beam width, beam foot print on the bottom, bottom detection algorithms and the spacing of soundings on the seafloor, both across track and along track. Along track coverage is dependent on the sounding frequency and speed of the survey vessel. To ensure proper along track coverage, the hydrographer shall ensure that vessel speed is adjusted so that no less than 3.2 beam footprints, center-to¬center, fall within 3 m, or a distance equal to 10 percent of the depth, whichever is greater, in the along track direction.

### 5.2.3. Gridded Data Specifications

In the Navigation Surface approach, survey data are archived as a certified digital terrain model rather than as a set of verified or certified soundings. The archived elevation model could be saved at the highest resolution supported by the sounding data. That is to say, that if the beam footprint on the seafloor of a full-coverage multibeam survey is 0.5 meter, for example, the elevation model could be saved at a grid spacing of 0.5 meter. This practice has the advantage of preserving this high-resolution data for a variety of known and unknown future purposes, even if such resolution will never appear on a navigational or charting product. Charting products such as paper charts are created from scale-appropriate generalizations of the elevation model. In reality, the final resolution of the surface may be slightly coarser than “the highest resolution supported by the sounding data” due to depth ranges, bottom topography and other variables.

Individual soundings that do not meet the Horizontal Position Accuracy as defined in Section 3.1 or do not meet the Vertical Accuracy as defined in Section 5.2.1, shall not be applied to the grid.

Currently, the open source Bathymetric Attributed Grid (BAG) format does not support multi-resolution grids. The CARIS Bathymetry with Associated Statistical Error (BASE) surface has multi-resolution functionality; however, it is not presently approved for NOAA surveys. Therefore, the survey area will typically be required to be subdivided into several grids of varying resolution dependent on depth.

An **example** distribution of grid resolution;

- 0 to 15 meter depths; 0.5 meter grid resolution,
- 14 to 30 meter depths; 1.0 meter grid resolution,
- 29 to 60 meter depths; 2.0 meter grid resolution,
- 59 to 150 meter depths; 5.0 meter grid resolution,
- deeper than 149 meter depths; 10.0 meter grid resolution.

The hydrographer may adjust these values based on the bathymetry of the survey area, the type of multibeam sonar used and other factors. However, the grids should always have a depth overlap to ensure no gaps in coverage when switching from one depth grid to another.

The hydrographer shall also consider the size of objects that they are attempting to detect. Typically, a grid must have twice the resolution of the object (i.e. a 1 meter grid would be required to properly depict a 2 meter cube).

Lidar data is typically less dense then shallow water multibeam data. Therefore, grid resolutions for lidar data may differ from the example above. The data density and resulting grid resolutions created shall be discussed with the COTR during the project planning phase. Any deviations from the plan, project instructions or Specifications and Deliverables shall be discussed with the COTR and clearly described in the Descriptive Report (DR) and Data Acquisition and Processing Report (DAPR).

The hydrographer has the responsibility to review the surface and ensure that it truly reflects the conditions in the survey area. No algorithm will ever perfectly model the seafloor. Especially in the case of small diameter objects (pilings, small rocks, etc.), depending on the resolution of the gridded surface, it is unlikely that the surface will capture the absolute least depth on all features. An experienced hydrographer, therefore, must review the data and occasionally select “designated” soundings which override the gridded surface and force the model to recognize the shoal sounding.

DESIGNATED SOUNDINGS:
In depths less than 30 meters, a designated sounding shall be selected when the difference between the gridded surface and reliable shoaler sounding(s) are more than one-half the allowable IHO error budget for the depth.

In depths greater than 30 meters, a designated sounding shall be selected when the difference between the gridded surface and reliable shoaler sounding(s) are more than the allowable IHO error budget for the depth.

Additional designated soundings may be selected by the Hydrographer as deemed necessary.

Conversely, if noisy data, or ‘fliers’ are incorporated into the gridded solution, the surface may be shoaler than the true seafloor. In such cases the spurious soundings will need to be rejected and the surface recomputed. Therefore, if noisy data causes the surface to be shoaler than expected by an amount greater than the IHO error budget for depth, then the noisy data shall be rejected and the surface recomputed.

If an excessive number of designated soundings need to be selected, the hydrographer may need to reassess the grid resolution of the surface. If the data supports a higher resolution grid, the resultant surface may model the seafloor more accurately and result in fewer designated soundings being required.

UNCERTAINTY
By definition each node of the grid includes not only a depth value, but other attributes including “uncertainty”. The uncertainty value for the grid shall be the greater of the standard deviation and the a priori uncertainty at each node. The hydrographer shall include a discussion in the DAPR on how the uncertainty was computed on each individual sounding and how the uncertainty was computed on the grid, with a justification for that methodology.

The hydrographer shall examine the finalized grids and explain in the DR any areas of unusually high uncertainty.

## 5.3. Coverage

In general, there are three classifications of multibeam coverage: Complete Multibeam Coverage, Object Detection Multibeam and Set Line Spacing. The survey coverage technique will be specified in the Hydrographic Survey Letter Instructions or Statement of Work.

• *Complete Multibeam Coverage*
Field operations shall be conducted such that the accuracy and resolution requirements in Section 5.2 are met for the entire multibeam coverage area. Grid resolutions shall be appropriate to detect objects required of Section 5.2.2 for the entire multibeam coverage area, unless an exemption is approved by the COTR and/or HSD Operations. The resolution requirements may not be required in some areas due to bottom topography ("steep and deep"), or if side scan data is also collected, or other project specific reasons.

• *Object Detection Coverage*
Field operations shall be conducted such that the accuracy requirements in Section 5.2 are met for the entire multibeam coverage area. In addition, the multibeam shall be operated and the grid resolutions shall be appropriate, such that a 1 meter cube can be detected to 20 meter depths (for depths greater than 20 meters, the minimum size of detectable targets shall be 5 percent of the depth.)

• *Set Line Spacing*
The hydrographer shall conduct Multibeam operations at the line spacing specified in the Hydrographic Survey Letter Instructions or Statement of Work. This is usually associated with multibeam data collected concurrently with side scan sonar operations (sometimes referred to as "skunk stripe", where the side scan swath is wider than the multibeam swath). Field operations shall be conducted such that the accuracy requirements in Section 5.2 are met for the multibeam data.

In some cases a hybrid coverage technique may be used, such as, 100% side scan with Complete Multibeam Coverage. The requirements for any assigned hybrid coverage will be described in the Statement of Work or Project Instructions.

For lidar operations, all soundings shall meet the accuracy requirements of Section 5.2. Grid resolutions shall be appropriate for the spot spacing required in the Statement of Work.

### 5.3.1. Demonstration of Coverage

To demonstrate *Complete Multibeam Coverage*, a collection of BAGs or CARIS BASE surfaces covering the survey area shall be submitted which have the following characteristics:

- Grid resolution of 10 to 20% of the depth, to a minimum resolution of 1 meter.

If survey data can support higher resolutions, then use hydrographer discretion and submit a higher resolution, if appropriate.

- Maximum propagation distance of soundings to node of 20% of the depth or one grid resolution, whichever is greater.
- At least 95% of all nodes on the surface must be populated.
- Maximum surface uncertainty is IHO Order 1 for depths less than 100 meters (IHO Order 2 for depths greater than 100 meters).
- No holiday larger than 3 nodes across.

*Complete Multibeam* surveys are usually conducted in conjunction with side scan sonar operations or in areas where general bathymetric data is required and there is little risk of small man made hazards to navigation being present.

*Set Line Spacing* surveys will use the same grid characteristics of Complete Multibeam to show the areas where multibeam data was collected.

To demonstrate *Object Detection Multibeam* coverage, a collection of BAGs or CARIS BASE surfaces covering the survey area shall be submitted which have the following characteristics;

- Grid resolution of 2 to 4% of the depth, to a minimum resolution of 0.5 meters.

If survey data can support higher resolutions, then use hydrographer discretion and submit a higher resolution, if appropriate.

- Maximum propagation distance of soundings to node of 4% of the depth or one grid resolution, whichever is greater.
- At least 99% of all nodes on the surface must be populated.
- Maximum surface uncertainty is IHO Order 1 for depths less than 100 meters (IHO Order 2 for depths greater than 100 meters).
- No holiday larger than 3 nodes across.

In both cases, if a holiday occurs at the top of a rock, wreck or other significant feature, then the data gap must be filled, even if the gap is less than 3 nodes across. The hydrographer must ensure that accurate least depths are obtained on all significant features. Individual soundings that do not meet the Horizontal Position Accuracy as defined in Section 3.1 or do not meet the Vertical Accuracy as defined in Section 5.2.1, shall not be applied to the grid.

As always, the hydrographer must ensure that the data accurately reflects the condition of the seafloor at the time of the survey and adjust operations if required. **Any deviations from the specifications must be clearly explained in the Descriptive Report.**

The purpose of the above grid parameters is to "demonstrate coverage". Depending on the survey area and seafloor topography, a different grid resolution may be more appropriate to accurately depict the seafloor with a minimum amount of designated soundings. If needed, the hydrographer may submit two sets of grids. One set used solely to demonstrate coverage and a second set that is the final depiction of the seafloor with all appropriate designated soundings applied. However, in the DR and data submission transmittal, the hydrographer must clearly specify which set of grids are for the final depiction of the seafloor and which set of grids are merely to prove coverage.

Lidar projects will usually need to deviate from the requirements stated above. Typically a 4x4 meter spot spacing requirement will result in a 5 meter grid resolution. A 3x3 meter spot spacing will result in a 4 meter grid resolution and a 2x2 meter project in a 3 meter grid resolution. The final surface parameters shall be discussed with the COTR prior to data collection. Any deviations from the Specifications and Deliverables shall be discussed with the COTR and clearly described in the DR and DAPR.

## 5.4. Corrections to Echo Soundings

To meet the accuracy and resolution standards for measured depths specified in Section 5.2, and to create a BAG that includes an accurate uncertainty layer, the hydrographer should conduct an error analysis of their survey systems.

Precise measurements are fundamental to the field of hydrography. Synchronization of multiple sensors with the sonar system is essential for meaningful spatial analysis of the data. All measurements, however careful and scientific, are subject to some uncertainties. Error analysis is the study and evaluation of these uncertainties with the purpose of estimating the extent of the uncertainties and when necessary, reducing them.

Uncertainty-based processing has fundamentally altered bathymetric data processing and product creation. The validity and usefulness of the results are directly correlated to the accuracy of the individual estimates that compose the error model. The error model for CARIS is contained in the HIPS Vessel File (HVF). The HVF has entries for the uncertainties associated with the sensor and sonar, physical offsets, latency, draft, loading, tide and tidal zoning. Non-CARIS users must build a similar model of all the correctors to the depth measurement and the associated uncertainties.

In recognition of the possibility that some discrepancies in sounding may not be detected until the final processing phase of the survey, the determination and application of corrections to echo soundings must be accomplished and documented in a systematic manner. In addition, it is preferable that all corrections be applied in such a way that the on-line values may be removed and replaced with a revised set of correctors during office processing. Corrections to echo soundings are divided into five categories, and listed below in the sequence in which they are applied:

> *Instrument error corrections* account for sources of error related to the sounding equipment itself.
>
> *Draft corrections* shall be added to the observed soundings to account for the depth of the echosounder transducer below the water surface.
>
> *Appropriate corrections for settlement and squat* shall be applied to soundings to correct the vertical displacement of the transducer, relative to its position at rest, when a vessel is underway.
>
> *Speed of sound correctors* shall be applied to soundings to compensate for the fact that echosounders may only display depths based on an assumed sound speed profile while the true speed may vary in time and space.
>
> *Heave, roll, pitch, heading, and navigation timing error (latency) corrections* shall be applied to multibeam soundings to correct the effect of vessel motion caused by waves and swells (heave, roll, pitch), the error in the vessel’s heading, and the time delay from the moment the position is measured until the data is received by the data collection system (navigation timing error).

### 5.4.1. Instrument Error Corrections

In modern digital sounding instruments, instrument errors are generally small and of a fixed magnitude independent of the observed depth. Proper set up and adjustment of digital sounding equipment using internal checks and echo simulators will often eliminate instrument error entirely. However, to ensure the proper operation of echosounders, "confidence checks" shall be conducted periodically.

For single beam echosounders, a comparison should be made at least once per week with depths from bar checks, lead lines, or other single beam echosounders.

For multibeam echosounders, comparisons should be made at least once per week between the nadir (vertical) beam of the multibeam and a single beam system or lead line. On surveys where multiple vessels collect data that overlaps with each other to allow comparison of depths, the frequency of formal confidence checks can be reduced to once per survey. In addition, frequent checks should be made between the overlap of mainscheme and crosslines collected on different days. These comparisons should be made frequently during data collection to find errors promptly, and not saved until final data processing after the field party has left the working grounds.

Comparisons should be conducted during calm sea conditions, preferably in areas with a relatively flat sandy bottom. Any differences should be investigated, and if, after analysis, a corrector is necessary, it should be applied with an explanation of the cause of the difference explained in the Descriptive Report (DR) section B.2, Quality Control.

### 5.4.2. Draft Corrections

The corrections for draft account for the depth of the transducer reference point below the surface of the water. Draft corrections comprise a value for the draft of the vessel at rest, sometimes known as static draft, and settlement and squat corrections which compensate for the variation in draft that occurs when the vessel is making way. The sum of the static draft and the settlement and squat correctors is known as the dynamic draft. Draft is transducer-specific. When more than one transducer is fixed to a vessel, the hydrographer must exercise care to apply the proper draft correction for each transducer. In addition to the draft values, to complete the vessels' error model, the hydrographer must determine the uncertainty associated with all draft values.

*Static Draft*
The static draft, as an echo-sounding correction, refers to the depth of the transducer reference point below surface of the water when the vessel is not making way through the water. The required frequency of static draft measurements depends upon the range of variation in the vessel draft and the depths of water to be surveyed. For depths of 30 m or less, the static draft shall be observed and recorded to at least the nearest 0.1 m. Measurements are required with sufficient frequency to meet this criterion. When sounding in waters deeper than 30 m, the static draft shall be observed and recorded to at least the nearest 0.2 m.

Draft values for small vessels such as survey launches should be determined for the range of loading conditions anticipated during survey operations (maximum and minimum). Draft values for larger vessels must be observed and entered into the record before departing from and upon returning to port. In both cases, the draft should be determined by averaging the max/min or beginning/ending values if the differences do not exceed ±0.2 m. Otherwise, the applicable draft should be determined in at least 0.1 m increments. If significant changes to a vessel's draft (greater than ±0.1 m) occur, draft values shall be modified and applied accordingly.

Loading and static draft uncertainties typically represent a small percentage of the total error budget. However, the accuracy of the error model and the results of BAG surface processing are dependent on knowledge of all the uncertainty values that compose the model.

*Settlement and Squat (Dynamic Draft)*
Transducers are generally displaced vertically, relative to their positions at rest, when a vessel is making way. Depth measurements are correspondingly affected by these vertical displacements. The displacements may be of sufficient magnitude to warrant compensation, especially when sounding at moderate to high speeds in shoal water. The factors accountable for this vertical displacement are called settlement and squat.

*Settlement* is the general difference between the elevations of a vessel when at rest and when making way. For lower speed, non-planing vessels, settlement is caused by a local depression of the water surface. Settlement is not an increase in the vessel displacement and, therefore, cannot be determined by reference to the water surface in the immediate vicinity. Vessels surveying at higher speeds may experience a negative settlement, or lift, when planing.

*Squat* refers to changes in trim of the vessel when making way and is generally manifested by a lowering of the stern and rise of the bow. Occasionally, the bow lowers on smaller vessels. Major factors that influence settlement and squat are hull shape, speed, and depth of water beneath the vessel. Squat does not appreciably affect transducer depth on transducers mounted near amidships. Settlement, on the other hand, is almost always significant at normal sounding speeds, regardless of transducer location.

Combined effects of settlement and squat at the full range of sounding speeds must be determined to at least 0.05 meter precision, by the hydrographer at least once a year for each vessel, including launches and skiffs used for hydrographic surveying in shoal or moderate depths. Follow up measurements should be made if there are any major changes to the loading or change to the vessel power plant. When the measurements are made, each vessel should carry an average load and have an average trim. Sounding vessel speeds (or RPM) must be entered in the hydrographic records during survey operations to permit accurate corrections for settlement and squat. If a Heave-Roll-Pitch (HRP) sensor is used to determine changes in squat, care must be taken to ensure that squat is not corrected for twice.

The uncertainty value for Dynamic Draft will be dependent on the method that Dynamic Draft was calculated. Typically, several runs at various speeds will be used to calculate the Dynamic Draft. The uncertainty value could then be the standard deviation calculated for each speed measurement.

### 5.4.3. Speed of Sound Corrections

*Special note: Previous versions of the Specs referred to "Velocity of Sound Corrections". This was technically incorrect, since velocity implies a vector or direction. The new version of the Specs has attempted to change the term to the more correct "Sound Speed" or "Speed of Sound". Other publications and equipment literature may still refer to the concept as "velocity".*

*General*

To ensure that the overall depth measurement accuracy criteria specified in Section 5.2 are met, speed of sound observations should be taken with sufficient frequency, density, and accuracy. The accuracy with which the speed of sound correction can be determined is a complex function of the accuracy with which salinity, temperature, and depth, or alternately, sound speed and depth, can be measured.

The speed of sound through water shall be determined using instrumentation capable of producing sound speed profiles with errors no greater than 2 meters per second. The sound speed profile must reach the deepest depths of the survey but the physical measurement of sound speed need only extend to:

> 95 percent of the anticipated water depth in 30 m or less of water. For example, if the maximum depth to be surveyed is 25 m, then the speed profile should continue to a depth of at least 23.8 m.
> 90 percent of the anticipated water depth in depths from 30 m to 100 m.
> 85 percent of the anticipated water depth in greater than 100 m of water.

Sound speed correctors must be determined accurately and often enough to ensure that the depth accuracy requirements in Section 5.2 are met. If changes in the temperature or salinity in the water column dictate that updated correctors are needed, additional sound speed profiles shall be acquired. Additionally, the hydrographer should establish a means of monitoring changes in the water column between subsequent speed casts.

Regardless of the sound speed determination system employed, an independent sound speed measurement system must be used to establish a confidence check. Confidence checks shall be conducted at least once per week. Include confidence check results in Separate II, Sound Speed Profile Data (see Section 8.1.4.).

A geographic distribution of profiles may be necessary to correct for spatial and diurnal variability. Speed corrections shall be based on the data obtained from the profile, and not based on an averaged sound speed reading for the water column. Survey specific sound speed information shall be included in Separate II, Sound Speed Profile Data (see Section 8.1.4. Descriptive Report Supplemental Records).

The hydrographer shall calibrate sound speed profiler(s) no earlier than six months prior to the commencement of survey operations. Calibration correctors shall be applied to all profiler data. These instrument(s) shall be re-calibrated at intervals no greater than twelve months until survey completion. In addition, the instrument(s) must be re-calibrated when the survey is complete if the completion date is later than six months from the date of last re-calibration. Copies of calibration data shall be included in Separate II, Sound Speed Profile Data (see Section 8.1.4. Descriptive Report Supplemental Records), separates to be included with the survey data.

*Sound Speed Corrections for Single Beam Surveys*
For each individual area identified, a minimum of at least one cast each week, taken in the waters surveyed that week, is required. The variation of physical conditions throughout a survey area or any portion thereof may dictate that this minimum may not be sufficient. Where casts taken early in a project indicate that physical characteristics are extremely variable, observations of speed may be required more frequently.

*Sound Speed Corrections for Multibeam Surveys*
The sound speed profile must be known accurately in multibeam swath sounding for two reasons. First, as in all echo-sounding, the depth is computed from the product of the speed and the

elapsed time between transmission of a sound pulse and reception of its echo. Second, since sound pulses travel at oblique angles through the water column, variations in the speed profile will affect the path of sound through water. The sound path from the transducer to the bottom and back will affect not only the observed depth of water, but the apparent position of the observed sounding.

Even though sampling equipment and computer systems are capable of dividing the water column into intervals so small as to allow close approximation of the integral expression for harmonic mean speed, practical limitations may require the hydrographer to use a small number of discrete points on the speed profile for the purpose of correcting echo soundings. If the hydrographer chooses the inflection points of the smooth speed profile as the discrete points for layer boundaries, the speed curve between the points can reasonably be approximated by a straight line. Integration of all the segments using the trapezoidal rule to approximate the area under each layer will yield very accurate results.

For multibeam operations, the following specifications apply to sound speed profile frequency and application:

> One sound speed profile shall be acquired immediately before the beginning of the data acquisition period. During the course of survey operations, changes in the water column should be monitored at a sufficient frequency such that the general requirements specified earlier in this section are met.
>
> Sound speed profiles shall be acquired in the immediate area where subsequent data acquisition will occur.
>
> When using an undulating velocimeter, the real time sound speed profiles shall extend to at least 80% of the anticipated water depth. At a minimum, one cast per 24-hour period shall extend to 95% of the anticipated water depth (30 m or less water depth).

The uncertainty value of the sound speed measurements must be part of the vessel's error model. One method used by NOAA, is to use the manufacturers uncertainty values for the measured components of conductivity, temperature and pressure. These values must then be used to compute a total uncertainty for the profile by computing how each components uncertainty is propagated through the sound speed computations.

A probe that measures speed of sound directly, could use the manufacturers advertised uncertainty value.

Ideally, sound speed uncertainty should be computed based on both the unit's accuracy and the spatial and temporal error associated with sound speed variation over the entire survey area. However, such advanced error analysis is not currently available in NOAA's processing pipeline. Therefore, NOAA field units and contractors may use the uncertainty associated with measuring the speed of sound at a specific location.

### 5.4.4. Heave, Roll, Pitch, Heading, and Navigation Timing Error Corrections

Heave, roll, pitch, heading, and navigation timing error corrections shall be recorded in the data files and applied to all multibeam soundings and cross- track distances as applicable. For single-beam surveys, only heave shall apply.

*Heave, roll, and pitch.* Heave shall be observed in no coarser than 0.05 m increments. Roll and pitch shall be observed in no coarser than 0.1 degree increments.

*Heading* shall be observed in no coarser than 0.5 degree increments.

*Navigation timing error* shall be observed in no coarser than 0.01 second increments.

The uncertainty value for heave, roll and pitch will typically be the manufacturer's values, assuming that the equipment is properly installed and maintained. The hydrographer must explain any variance from the manufacturer's values.

### 5.4.5 Error Budget Analysis for Depths

The hydrographer shall discuss (in Section B2 of the Descriptive Report) the methods used to minimize the errors associated with the determination of depth (corrections to echo soundings). Error estimate ranges for Six of these errors (measurement error, transducer draft error, settlement and squat error, sound speed error, heave error and tide/water level error) are presented below. These errors are inherent to hydrographic surveying and all have practical minimums that are usually achievable only under ideal circumstances or with highly specialized equipment. In addition, some errors may be dependent on depth (e.g. sound speed). Maximum allowable errors are specified to ensure that all errors sources are properly managed. It should be noted that if the maximum value for each error source is used in an error budget (i.e. root-sum-squared), the result will exceed the prescribed accuracy standard. The minimum and maximum values discussed below are at the 95% confidence level (i.e. 2 sigma).

The hydrographer shall also discuss (in Section B2 of the Descriptive Report) the methods used to quantify the survey systems error model. Uncertainty estimates for all components of the sounding measurement should be provided.

*Measurement error:* This includes the instrument error for the sounding system, the effects of imperfectly measured roll/pitch and errors in detection of the sea floor due to varying density of the bottom material. Multibeam systems are particularly susceptible to this error due to the off-nadir nature of outer beams. The minimum achievable value is expected to be 0.20 meter at 10 meters depth. The maximum allowable error is 0.30 meter plus 0.5% of the depth.

*Transducer draft error:* This error is controlled by variability in vessel loading, and the techniques used to measure/monitor transducer draft. This error is depth independent with an expected minimum of 0.05 meter and an allowable maximum 0.15 meter.

*Settlement and squat error:* Conventional methods of determining settlement and squat are limited by sea surface roughness and proximity of a suitable location to the survey area. Careful application of modern methods (Real Time Kinematic GPS) will minimize this error. This error is also depth independent although the effect of settlement and squat is greater in shallow water. The practical expected minimum is 0.05 meter and the allowable maximum is 0.20 meter.

*Sound speed error:* The factors associated with this error include (1) the ability to accurately measure sound speed or calculate sound speed from temperature, conductivity and pressure, (2) the spatial and temporal changes of sound speed throughout the survey area and (3) how the sound speed profile is used to convert measured time to depth. In addition, this error encompasses depth errors associated with refraction for multibeam systems. The expected minimum is 0.20 meter and the allowable maximum is 0.30 meter plus 0.5% of the depth.

*Heave error:* This error is directly dependent on the sea state and the sensitivity of the heave sensor but is not dependent on depth. The expected minimum is 0.05 meter and the allowable maximum is 0.20 meter.

*Tide/water level error:* This error has been discussed in detail in Section 4. The practical minimum is 0.20 meter and the allowable maximum is 0.45 meter.

## 5.5. Quality Control

### 5.5.1. Multibeam Sonar Calibration

Prior to commencing survey operations, the hydrographer shall conduct a system accuracy test to quantify the accuracy, precision, and alignment of the multibeam system. Testing shall include determination of residual biases in roll, pitch, heading, and navigation timing error and the uncertainty of these values. These values will be used to correct the initial alignment, calibrate the multibeam system and used in the computation of the Total Propagated Error (TPE) for each sounding. System accuracy testing should be conducted in an area similar in bottom profile and composition to the survey area, and during relatively calm seas to limit excessive motions and ensure suitable bottom detection. In addition, system accuracy tests should be conducted in depths equivalent to the deepest depths in the survey area. Static transducer draft, settlement and squat corrections, sound speed corrections, and tide corrections shall be determined and applied to the data prior to bias determination.

The order in which these biases are determined may affect the accurate calibration of the multibeam system. The hydrographer should determine the biases in the following order: navigation timing error, pitch, roll, heading. Variations from this order, simultaneous determination of all values, are other methods of determining the biases must be explained and justified.

Pitch and navigation timing error biases should be determined from two or more pairs of reciprocal lines 500–1,000 m long, over a 10–20 degree smooth slope, perpendicular to the depth curves. The lines should be run at different speeds, varied by up to 5 knots, for the purpose of delineating the along track profiles when assessing time delay. Navigation timing error bias could also be determined from running lines over a distinct feature (i.e., shoal) on the bottom, as long as the feature is pinged by the vertical (nadir) beam.

Roll bias should be determined from one or more pair of reciprocal lines 500–1000 m in length over a flat bottom. Lines should be run at a speed which will ensure significant forward overlap. Heading bias should be determined from two or more adjacent pairs of reciprocal survey lines, made on each side of a submerged object or feature (i.e., shoal), in relatively shallow water. Features with sharp edges should be avoided. Adjacent swaths should overlap by 10–20 percent while covering the shoal. Lines should be run at a speed which will ensure significant forward overlap.

Once calibration data have been processed and final system biases determined, the new corrections shall be used in a performance check to ensure that the new system biases are adequate. The hydrographer shall discuss procedures and results in the Data Reduction section of the project Data Acquisition and Processing Report. Copies of all system alignment, accuracy, calibration reports, and performance checks shall be included in the Data Acquisition and Processing Report.

System accuracy testing shall be repeated whenever changes (e.g., sensor failure, replacement, re-installations, re-configurations, or upgrade; software changes which could potentially affect data quality) are made to the system's baseline configuration, or whenever assessment of the data indicates that system accuracies do not meet the requirements in Section 5.2.

### 5.5.2. Positioning System Confidence Checks

Confidence checks of the primary positioning system shall be conducted and recorded in the survey records at least once every week. A successful confidence check shall compare positions from the primary system to simultaneously observed check positions from a separate, independent system with a positional accuracy better than 10 meters. The inverse distance shall not exceed 10 meters. If correctors for the primary positioning system are obtained from a non-USCG differential system, then the check system must use correctors from a reference station different from the primary system's. If correctors are obtained from a USCG differential station, the check system may use the same correctors as the primary system. The confidence checks shall be an integral part of the daily survey data record. A summary report of positioning system confidence checks shall be included in Separate I of "Separates to be Included with the Survey Data" (see 8.1.3).

### 5.5.3. Crosslines

*General*
The regular system of sounding lines shall be supplemented by a series of crosslines for verifying and evaluating the accuracy and reliability of surveyed depths and plotted locations. Crosslines shall be run across all planned sounding lines at angles of 45 to 90 degrees. The preferred area in which to run crosslines is in an area of gently sloping bottom.

*Single beam*
The lineal nautical miles of crosslines for single-beam surveys shall be at least 8 percent of the lineal nautical miles of all planned sounding lines.

The hydrographer shall make a general evaluation of the single beam crossline to mainscheme agreement, and discuss the results in Section B of the Descriptive Report. If the magnitude of the discrepancy varies widely over the survey, the hydrographer shall make a quantitative evaluation of the disagreements area by area.

*Multibeam or lidar*
The lineal nautical miles of crosslines for multibeam or lidar surveys shall be at least 5 percent of the lineal nautical miles of all planned sounding lines. This figure may be overly burdensome for some lidar projects. In such cases, a deviation from this requirement shall be requested from the COTR and explained in the DR.

An independent analysis of the crossline and mainscheme data shall be conducted. Although any crossline/mainscheme disagreements should be obvious in the attributes of the combined surface, an independent analysis is still required to ensure that the surface implementation is correct and to help find any hidden problems.

Two possible methods of conducting the independent analysis is a beam by beam statistical analysis or by a surface difference. Other methods may be used if approved in advance by the COTR or Processing Branch.

If a beam by beam statistical analysis is conducted, comparisons shall be made between mainscheme lines and crosslines at 25 crossings distributed throughout the data both spatially and temporally. At these crossings the nadir or near-nadir depths of mainscheme lines shall be compared to each of the nearest unsmoothed soundings obtained from the crosslines. The hydrographer shall perform a separate statistical analysis as a function of beam number for each of the mainscheme/crossline intersections used for comparison. Include a statement about the results in Section B of the Descriptive Report, and include a summary plot or table of each crossing analyzed in Separate IV, Checkpoint Summary and Crossline Comparisons.

A surface difference can be conducted by creating a surface using only mainscheme data and comparing to a surface created from only crossline data. The surfaces used to compute the difference should have at least the resolution defined in section 5.3.1. Include a statement about the results in Section B of the Descriptive Report. The difference surface shall also be included in the final deliverables.

### 5.5.4 Multibeam or Lidar Sun-Illuminated Digital Terrain Model (DTM) Images

Regardless of the multibeam or lidar coverage technique used (see Section 5.3. Coverage), the hydrographer shall create two sun-illuminated DTM images.

One image shall be created from the elevation grid in the final set of CARIS BASE surfaces or BAGs of the entire survey area. The set of grids used to create the DTM shall have all designated soundings applied and has been reviewed by the hydrographer and signed off as the final accurate portrayal of the seafloor.

The second image shall be created from the uncertainty grid in the final set of CARIS BASE Surfaces or BAGs of the entire survey area. The uncertainty layer shall be the greater of the standard deviation or a priori uncertainty for each grid node. The uncertainty values shall be color coded, with warm colors (red) showing areas of high uncertainty and cool colors (blue) showing areas of low uncertainty. The uncertainty color map shall be drapped over the elevation DTM. A legend shall be included showing how the color range reflects uncertainty values.

The hydrographer can use their own discretion on the best method of combining the set of grids into a single DTM image. The grids can be combined into a single lowest common denominator grid to create the DTM. Or individual grids can be used to create individual DTM images that are then tiled together into a single image. Other methods may also be acceptable.

The submitted digital image files shall be in a standard geo-referenced image format.

# 6. Towed Side Scan Sonar

During hydrographic surveys, the use of side scan sonar may be required for supplementing echo-sounding by searching the region between regular sounding lines for additional indications of dangers and bathymetric irregularities. Any requirement for side scan sonar coverage in conjunction with a hydrographic survey will be specified in the Hydrographic Survey Letter Instructions or Statement of Work.

## 6.1. Coverage

Scanning coverage is the concept used to describe the extent to which the bottom has been covered by side scan sonar swaths, that is, the band of sea bottom which is ensonified and recorded along a single vessel track line. For hydrographic purposes, scanning coverage of an area is expressed in multiples of 100 percent, and is cumulative. One hundred percent coverage results in an area ensonified once, and two hundred percent coverage results in an area ensonified twice. Advisory note: Side scan coverage may not be achieved as planned due to varying water conditions, such as thermoclines, limiting such coverage.

The scanning coverage requirements will be stated in the Hydrographic Survey Letter Instructions or Statement of Work. Approved 200-percent coverage techniques are as follows:

*Technique 1.* Conduct a single survey wherein the vessel track lines are separated by one-half the distance required for 100-percent coverage.

*Technique 2.* Conduct two separate 100-percent coverages wherein the vessel track lines during the second coverage split the difference between the track lines of the first coverage. Final track spacing is essentially the same as technique 1.

*Technique 3.* Conduct two separate 100-percent coverages in orthogonal directions. This technique may be advantageous when searching for small man-made objects on the bottom as the bottom is ensonified in different aspects. However, basic line spacing requirements for single-beam echosounders may not be met when using this technique

## 6.2. Side Scan Acquisition Parameters and Requirements

### 6.2.1. Accuracy

The side scan sonar system shall be operated in such a manner that it is capable of detecting an object on the sea floor that measures 1 m x 1 m x 1 m from shadow length measurements.

### 6.2.2. Speed

The hydrographer shall tow the side scan sonar at a speed such that an object 1 m on a side on the sea floor would be independently ensonified a minimum of three times per pass.

The number of pulses per unit time, or pulse repetition rate, determines the speed at which the transducer (i.e. the vessel) can move along the track and still maintain the required coverage of the bottom. Longer operating ranges have slower pulse repetition rates, which requires the vessel speed to be slower if the entire bottom is to be ensonified.

The maximum vessel speed for three ensonifications can be calculated if the pulse repetition rate (prr) or the pulse period (pp) is known. The rate is the reciprocal of the period. This rate and/or period is usually published in the operating manual for the side scan sonar system. The calculation is as follows: Maximum vessel speed (meters/second) = target size (meters) X prr/3 ($sec^{-1}$).

### 6.2.3. Towfish Height

The hydrographer shall operate the side scan sonar system with a towfish height above the bottom of 8 percent to 20 percent of the range scale in use. For any towfish height below 8 percent of the range scale in use, the effective scanning range is defined to equal 12.5 times the towfish height, provided adequate echoes have been received.

### 6.2.4. Horizontal Range

The achievable horizontal range of a side scan sonar is a function of several parameters. Among these are sonar conditions, sea bed composition, the range scale in use, side scan sonar system characteristics, and towfish height. Actual conditions in the survey area will determine the effective range of a particular side scan sonar system. The maximum allowable range scale for any towed side scan sonar is 100 m.

If the effective range scale of the side scan sonar is reduced due to external factors, then the representation of the swath coverage should be reduced accordingly. For example, changes in the water column or inclement weather may distort the outer half of the 100 m range scale. In this case, only 50 m of effective range could be claimed.

## 6.3. Quality Control

### 6.3.1. Confidence Checks

Confidence checks of the side scan sonar system shall be conducted at least once daily. These checks should be accomplished at the outer limits of the range scales being used based on a target near or on the bottom. Each sonar channel (i.e., port and starboard channels) shall be checked to verify proper system tuning and operation. Confidence checks can be made on any discrete object, offshore structure, or bottom feature which is convenient or incidental to the survey area. Targets can include wrecks, offshore structures, navigation buoy moorings, distinct trawl scours, or sand ripples.

Confidence checks can be made during the course of survey operations by noting the check feature on the sonargram. If a convenient or incidental target is not available, a known target may be placed on or near the bottom and used for confidence checks. Confidence checks shall be an integral part of the daily side scan sonar operation and shall be annotated in the side scan sonar data records.

### 6.3.2. Significant Contacts

In depths of water less than or equal to 20 m, contacts with computed target heights (based on side scan sonar shadow lengths) of at least 1 m should be considered "significant." In depths of water greater than 20 m, contacts with computed target heights rising above the bottom at least 10 percent of the depth should be considered "significant". Other contacts without shadows may also be considered "significant" if the sonargram signature (e.g., size, shape, or pattern qualities) is notable. In addition, contacts with less than 1 m target heights should be considered "significant" if they are found near the critical navigation depths of the local area. For example, if a 0.5 m contact is discovered in 10 m of water at the seaward approach to a dredged channel with a controlling depth of 10 m, then the contact should be considered significant.

### 6.3.3. Contact Correlation

The hydrographer shall examine and correlate targets between successive side scan sonar coverages (i.e., compare the first 100 percent with the second 100 percent sonar coverage). If applicable, the hydrographer shall examine the multibeam data and correlate anomalous features or soundings with the side scan sonar data. Anomalous features or targets which appear consistently and correlate in each type of data record provide increased confidence that acquisition systems are working correctly and help to confirm the existence of these features or targets. The hydrographer shall cross reference and remark on each target correlation in the *Remarks* column (column 7) of the Side Scan Sonar Contact List (see Section 8.4.2.).

### 6.3.4. Identification of Potential Field Examinations

The hydrographer shall use the sonar contact list, in conjunction with an analysis of echosounder least depths and BAG attributes (standard deviation, uncertainty, etc), to identify hydrographic features which may require further examination.

# 7. Other Data

## 7.1. Bottom Characteristics

When required in the Hydrographic Survey Letter Instructions or Statement of Work, the hydrographer shall obtain samples of the bottom sediment. In general, the distance between bottom samples should not exceed 1200 meters in charted anchorage areas, and the distance between samples in all other areas should not exceed 2000 meters. Bottom samples will not be required in depths greater than 100 meters. NOAA field units should refer to section 2.5.3.6.1 of the Field Procedures Manual.

When sampling is required, the hydrographer shall record position and depth data for each sample obtained. In addition, each sample shall be described and completely attributed in the S-57 feature file. A table listing the position and description of the bottom sample obtained shall also be included in Appendix V of the Descriptive Report.

## 7.2. Aids to Navigation

The hydrographer shall investigate all U.S. Coast Guard (USCG) and privately maintained fixed and floating aids to navigation located within the survey limits. Upon inspection of the most recent edition of the largest scale chart of the survey area and the latest edition of the USCG Light List, the hydrographer shall confirm the aid's characteristics and determine whether the aid adequately serves the intended purpose for which it was established.

If the hydrographer determines that an aid to navigation is located off station, is damaged to the extent that it does not serve its intended purpose or its characteristics are incorrectly charted, the facts should be reported immediately in the form of a danger to navigation letter (see Section 8.1.2 Danger to Navigation Report).

If an uncharted fixed or floating aid to navigation is discovered within the survey area, the hydrographer shall obtain a differential GPS position on the aid and report the new aid to navigation promptly to the nearest USCG district and submit a Danger to Navigation Report. Include geographic position, characteristics, apparent purpose, and by whom the aid is maintained (if known).

Other fixed and floating aids to navigation and landmarks within the survey area may require specific positioning methods. Positioning specifications and requirements will be provided in the Hydrographic Survey Letter Instructions or Statement of Work.

# 8. Deliverables

## 8.1. Field Reports

### 8.1.1. Progress Sketch and Survey Outline

The hydrographer shall submit a Monthly Progress Sketch digitally via email, to the addresses specified in the Hydrographic Survey Letter Instructions or Statement of Work no later than 5 calendar days from the end of the reported month. Progress sketches will typically be constructed using a desktop Geographic Information System. NOAA field units submit their progress sketches in MapInfo format, in accordance with section 5.2.3.2.1 of the OCS Field Procedures Manual.

Contractors shall submit their progress sketches in MapInfo format or as an Adobe Acrobat .pdf file. The Progress Sketch is a page-size graphic that portrays survey accomplishments. All portions of the sketch must be neat and legible for reproduction. Every Progress Sketch shall be overlayed onto the largest scale chart of the survey area (do not include the raster chart file in email attachment, only reference chart used, if submitting in MapInfo format) and depict the following information, if applicable:

Title block
Statistics block
Latitude and longitude tick marks
Sheet limits
Survey area limits
Sheet letters and registry numbers

The title block consists of the title “Progress Sketch”, project number, locality, type of survey, inclusive dates of survey, and name of survey party (vessel or contractor name).

The statistics block contains monthly columns showing, in rows, the following items, if applicable:

Lineal nautical miles of sounding lines (list side scan sonar, multibeam and/or single beam separately)

Square nautical miles of each survey sheet completely surveyed (the sum of all the monthly progress sketches for the survey should approximately equal the final total area surveyed at the end of the project).

Number of sound speed casts

Number of bottom samples collected

Number of items from the Automated Wreck and Obstruction Information System (AWOIS) completed

Number of tide gauges installed

Number of days of down time due to weather

Number of days of down time due to equipment

Number of days field unit was on site working on project (for instance, the field unit may have departed on the 15th, meaning the monthly progress sketch only reflects 15 days of work)

Distinctive hatching or a percentage complete value should be used to differentiate the sheet areas surveyed each calendar month. Additional symbols may be used on the Progress Sketch as necessary, but should be explained in the legend.

Survey Outlines:
After completion of all field work for a survey, the hydrographer shall provide a survey outline region in MapInfo compatible format, Latitude/Longitude coordinate system, NAD 83, that shows the extent of hydrography completed for the registered survey. Contractors shall forward the outline via email to the COTR. NOAA field units shall forward the outline directly to 'survey.outlines@noaa.gov' (see OCS Field Procedures Manual, section 5.2.3.3.3). The outline should be submitted as soon as practical after completion of field work.

If the outline has not been submitted within 30 days of completion of field work, the hydrographer shall contact HSD Operations Branch or the COTR to explain the delay and provide an estimate for delivery. Any large differences (+/- 10%) between the total square miles reported via the progress sketches for the survey and the area defined by the survey outline should be explained in the cover e-mail.

### 8.1.2. Danger to Navigation Report

As soon as practicable after discovery, the hydrographer shall submit a Danger to Navigation Report. Timeliness is a critical issue in reporting dangers to navigation. The hydrographer should ensure that the discovery of a potential danger to navigation is reported immediately to the appropriate authority. Further, should additional dangers be discovered during the processing of the survey, a danger report shall be immediately forwarded.

A danger to navigation is considered to be any natural feature (e.g., shoal, boulder, reef, rock outcropping) as well as any cultural feature (e.g., wreck , obstruction, pile, wellhead) which, during the course of survey operations was found by the hydrographer to be inadequately charted as described below. Potential dangers shall be evaluated in the context of the largest scale nautical chart of the area. Unless specified otherwise in the Hydrographic Survey Letter Instructions or Statement of Work, all submerged features with depths of 11 fathoms (66 feet) or less in navigable waters should be considered potential dangers to navigation and subject to reporting. During the course of reviewing survey data for potential dangers to navigation, the hydrographer should be aware of the types of vessels transiting the area along with usual and seasonal vessel routes throughout the survey area.

Danger to Navigation Reports are required for:

Significant uncharted rocks, shoals, wrecks, and obstructions

Depths from the present survey which are found to be significantly shoaler than charted depths or features, and are navigationally significant (typically depths of 11 fathoms (66 feet) or less)

Uncharted or inadequately charted clearances for bridges and overhead cables or pipelines

A fixed or floating aid to navigation found to be off station to an extent that the aid does not serve its purpose adequately

A fixed or floating aid showing significantly different characteristics than those charted or described in the Light List

Other submerged or visible features, or conditions considered dangerous to navigation

Once all dangers to navigation (DTON) are identified by using the criteria above, they must be reviewed in context with the largest scale chart covering the survey area. DTONs submitted should not cause undue clutter in relation to other soundings or features on the chart. When multiple distinct features are located within 3mm of each other, as depicted on the largest scale chart of the area, then the most significant DTON located within the 3mm radius shall be submitted as a single danger to navigation.

In cases where dangers are too complex to be adequately identified as discrete features, they should be appropriately depicted on a chartlet that accompanies the danger letter. For example, widespread shoaling would be represented as a series of depths with appropriate depth curves instead of listing individual soundings and geographic positions.

NOAA field units shall use Pydro and submit all Danger to Navigation Reports via e-mail directly to Marine Chart Division's (MCD) Nautical Data Branch at e-mail address 'mcd.dton@noaa.gov', with courtesy copies to Chief, Operations Branch and to the chief of the appropriate Processing Branch, in accordance with section 4.4.3.2 of the OCS Field Procedures Manual.

Contractors shall submit all Danger to Navigation Reports via e-mail to the COTR.
The contractor reports will be submitted as follows;
1) Letter in the format shown in Appendix 9,
2) an ascii text file of the format; 'latitude, longitude, depth, feature'.
The COTR will forward the DTON to the appropriate Processing Branch. The Processing Branch will review the DTON, import the ascii file into Pydro, and create the .xml file. A letter and .xml file will then be forwarded to the Nautical Data Branch at 'mcd.dton@noaa.gov'.

MCD will process the Danger to Navigation Reports and send the information to the USCG for inclusion in the Local Notice to Mariners. MCD will notify the submitting party of any changes made to the Dangers to Navigation Report by return e-mail. The Processing Branches will submit any dangers to navigation detected during office processing to MCD as stated above. If the Processing Branch is submitting a DTON that changes an earlier DTON submitted by a field unit, please explain the change in the cover letter.

A copy of the Danger to Navigation Report shall be included in Appendix I of the Descriptive Report.

### 8.1.2.1. Charted Feature Removal Request

Charted features, particularly "Position Approximate" wrecks and obstructions that are located in major shipping corridors should be expeditiously removed from the chart if adequately disproved. The Charted Feature Removal Request is similar to a Danger to Navigation Report, except it is used to remove a charted feature that represents a hazard, which does not exist, rather than add a newly found hazard. This process should be used sparingly, usually by responding to a request from local pilots or other authorities that a charted feature is a hindrance to operations. If removal of a feature is not time critical, utilize the descriptive report to recommend removal from the chart rather than the Charted Feature Removal Request.

The Operations Branch, within the Hydrographic Surveys Division, is responsible for defining the search criteria for all AWOIS items. If local authorities request the hydrographer to investigate a feature that has not been assigned, contact Operations Branch for a determination of the search criteria. Once the hydrographer meets the search criteria and determines the feature does not exist, they should expeditiously prepare the Charted Feature Removal Request and forward it to the appropriate Processing Branch for verification. The format for the request is the same as a

Danger to Navigation Report. The Processing Branch will review the request and, if the verifier concurs with the hydrographer's recommendation, will forward the request to the Marine Chart Division. See Appendix 9 for an example of a Charted Feature Removal Request.

### 8.1.3. Descriptive Report (DR)

A Descriptive Report is required for each hydrographic survey completed, unless specified otherwise in the Letter Instructions or Statement of Work.

The primary purposes of a Descriptive Report are to: 1) help cartographers process and evaluate the survey; 2) assist the compilers producing or revising charts; 3) document various specifications and attributes related to the survey and its by-products; and 4) provide a legal description of the survey standards, methods, and results. The cartographers will have no knowledge of the particulars of a survey, other than what is documented in the Hydrographic Survey Letter Instructions or Statement of Work, digital survey data, Descriptive Report, and supplemental reports referenced in the Descriptive Report. The Descriptive Report is archived as a historical and legal record for the survey.

The Descriptive Report supplements the survey data with information that cannot be depicted or described in the digital data. The Descriptive Report describes the conditions under which the survey was performed, discusses important factors affecting the survey's adequacy and accuracy, and focuses upon the results of the survey. It contains required information on certain standard subjects in concise form, and serves to index all other applicable records and reports.

General statements and detailed tabulations of graphically evident data, such as inshore rocks, shoals, or coral heads already shown in the S-57 feature file or compiled in Pydro, should normally not be included in the Descriptive Report. Hydrographic characteristics of the survey area such as nearshore features, shoreline, currents, water levels, and changes to the chart that are otherwise not clearly defined by the digital products should be completely described in the Descriptive Report.

The following information is required in each Descriptive Report in the order listed below:
*COVER SHEET* (NOAA Form 76-35A, see Appendix 3) Appropriate entries are made to identify the survey. For each survey, the Registry Number, Sublocality, General Locality, and State will be provided in the Hydrographic Survey Letter Instructions or Statement of Work.

*TITLE SHEET* (NOAA Form 77-28, see Appendix 4). The "Hydrographic Title Sheet" is often referred to for information pertaining to the survey. The "State", "General locality", and "Locality" entries are to be identical to those on the Cover Sheet. The "Date of survey" entries are the inclusive dates of the fieldwork.

For "Vessel", enter the name and hull number of the surveying vessel. The name(s) listed after "Surveyed by" are the personnel who supervised sounding operations and/or data processing. The "Remarks" section should contain any additional information, including the purpose of the survey and survey area information that will identify the project or clarify the entries above. Other Descriptive Reports or special reports containing information or data pertinent to the survey that are not listed in Section E of the Descriptive Report text should be referenced here. Note the time zone used during data acquisition (e.g., All times are recorded in UTC). If applicable, list the name and address of the contractor and any major subcontractors. If applicable, include the UTM zone number.

*DESCRIPTIVE REPORT TEXT*. A hard copy of the Descriptive Report (DR) need not be submitted. A digital copy of the DR shall be provided in Microsoft Word format. The main body of the DR (sections A through E) shall be contained in a single file. Text shall be Times New Roman, with a font size of 12. Include all information required for complete understanding of the field records. When referring to a hydrographic feature in the S-57 feature file, give the latitude and longitude of the feature. Discussions and explanations should be written in a clear and concise manner. Avoid using geographic names in the text of the Descriptive Report that do not appear on the nautical chart. Avoid verbosity.

On each page of the DR body, include registry number and field unit as a header. Pages shall be numbered consecutively from the first page of text, continuing through the page preceding the Approval Sheet (page numbers as a footer, centered on page). Include a Table of Contents with page numbers.

To provide uniformity of reports for future reference, arrange the text under the following lettered headings in the order appearing here.

A. AREA SURVEYED

Include a coverage graphic inclusive of the survey area. The information related to the present survey should be clearly shown and highlighted in some way to draw attention to its location within the project area. A second small scale graphic may be appropriate to provide additional geographic context of where the survey is located.

As described in Hydrographic Survey Technical Directive (HSTD) 2006-1, the following statistics shall be provided.

List for each vessel (ship and/or launch number(s)) and the combined total of all vessels, the following information:

- Lineal nautical miles of single beam only sounding lines (mainscheme only)
- Lineal nautical miles of multibeam only sounding lines (mainscheme only)
- Lineal nautical miles of lidar sounding lines (mainscheme only)
- Lineal nautical miles of side scan sonar only lines (mainscheme only)
- Lineal nautical miles of any combination of the above techniques (specify methods)
- Lineal nautical miles of crosslines from single beam and multibeam combined
- Lineal nautical miles of lidar crosslines
- Lineal nautical miles of developments other than mainscheme lines
- Lineal nautical miles of shoreline/nearshore investigation (total length of the inshore buffer line)

NOTE: Any lineal nautical miles that are deleted for any reason should not be included in the above statistics.

- Number of bottom samples collected
- Number of items investigated that required additional time/effort in the field beyond the above survey operations (these can be either from dive operations or obtaining a detached position but should not include items developed by sonar only or items deconflicted by “observations” only)
- Total number of square nautical miles

- Specific dates of data acquisition (e.g. June 5-9,16-19,22,24, 2005)

B. DATA ACQUISITION AND PROCESSING

B1. Equipment

In this section of the Descriptive Report list by manufacturer and model number only the major systems used to acquire survey data or control survey operations (e.g., single beam sonar, multibeam sonar, side scan sonar, lidar system, vessel attitude system, positioning system, sound speed system). Include a brief description of the vessel (e.g., length overall and draft). A detailed description of the systems used to acquire survey data or control operations shall be included in the project-wide Data Acquisition and Processing Report. See Section 8.1.4 for additional information.

Include in a narrative description, with figures when useful, of any deviations from the vessel or equipment configurations described in the Data Acquisition and Processing Report.

B2. Quality Control

Discuss the internal consistency and integrity of the survey data. State the percentage of crossline miles as compared to main scheme miles. Evaluate their general agreement. If the magnitude of the discrepancy varies widely over the sheet, make a quantitative evaluation of the disagreements by area. Explain the methods used to reconcile significant differences at crossings, and give possible reasons for crossline discrepancies that could not be reconciled. See section 5.5.3 for additional information.

Discuss the uncertainty values of the submitted CARIS BASE surface(s) and/or BAG(s). Explain and/or justify any areas that have an uncertainty greater than the IHO levels allowed as described in section 5.3.1.

Evaluate survey junctions in this section. Junctions are made between adjoining contemporary surveys to ensure completeness and relative agreement of depths. List, by registry number, scale, date, and relative location, each survey with which junctions were made. Include a summary of each junction analysis. Explain methods used to reconcile significant differences at junctions, and give possible reasons for junction discrepancies that could not be reconciled. Include recommendations for adjustments to soundings, features, and depth curves, if applicable.

Discuss sonar system quality control checks.

Discuss any unusual conditions encountered during the present survey which would downgrade or otherwise affect the equipment operational effectiveness. Discuss any deficiencies that would affect the accuracy or quality of sounding data. Document these conditions; including how and when they were resolved.

Describe any other factors that affected corrections to soundings, such as sea state effects, the effect of sea grass or kelp, and unusual turbidity, salinity, or thermal layering in the water column.

Discuss the specific equipment and survey methods used to meet the requirements for object detection and coverage for different areas of the survey.

B3. Corrections to Echo Soundings

Discuss any deviations from those described in the Correction to Echo Soundings section of the Data Acquisition and Processing Report.

Discuss the results of any sounding system calibration (e.g. patch test) conducted after the initial system calibration that affect the survey data and were not included in the Data Acquisition and Processing Report. Comment on the reason a new calibration was conducted.

B4. Data Processing

Discuss details of the submitted CARIS BASE surface(s) and/or BAG(s). For instance, how many grids cover the survey area, what grid resolutions were used, why were the different grid resolutions selected, how do the resolutions change over the depth range of the survey, etc.

C. VERTICAL AND HORIZONTAL CONTROL

Include in this section of the Descriptive Report a summary of the methods used to determine, evaluate, and apply tide or water level corrections to echo soundings on this survey.

Describe how the preliminary zoning was determined to be accurate and/or describe any changes made to the preliminary zoning scheme.

State the horizontal datum and projection used for this survey. Briefly discuss the control stations used during this specific survey. If USCG DGPS stations are used, only list the station name in this section. Explain in detail any difficulties that may have degraded the expected position accuracy.

See Section 8.1.4 for additional information to be provided in the project Horizontal and Vertical Control Report.

D. RESULTS AND RECOMMENDATIONS

D.1 Chart Comparison

Compare the survey with the ENC, if available, otherwise use all raster charts listed in the Hydrographic Survey Letter Instructions or Statement of Work. Identify the chart by number, scale, edition number, and edition date. In addition, Notices to Mariners affecting the survey area which were issued subsequent to the date of the Hydrographic Survey Letter Instructions or Statement of Work and before the end of the survey must be specifically addressed. Identify the last Weekly and Local Notices to Mariners compared to during the survey by notice number and date. Any Notice that prompts a chart comparison item must be identified by its Notice to Mariners number and date.

Discuss the methods used for chart comparison and what the results were. Comment on the degree of general agreement with charted soundings. Discuss general trends, such as shoaling or deepening occurring in the survey area. List significant charted depths that have been disproved. Discussion should demonstrate that the chart comparison was accomplished adequately.

Make a comparison between the survey data and all charted shoals and potentially hazardous features. Describe the methods of investigation and include least depths for significant changes. List charted features not found during the present survey. NOAA units should reference the Pydro generated "For Descriptive Report" feature report as necessary for this requirement (see section 5.2.3.3.2 of the OCS Field Procedures Manual).

List and discuss comparisons of survey depths with controlling depths, tabulated depths, and reported depths of all maintained channels. Also discuss soundings in designated anchorages, precautionary areas, safety fairways, traffic separation schemes, pilot boarding areas and along channel lines and range lines.

Briefly describe assigned Automated Wreck and Obstruction Information System (AWOIS) items investigated by singlebeam or multibeam echosounder, side scan sonar, divers, and/or other methods in this section. Include an analysis of any differences between past and present survey findings and make a specific charting recommendation. Also, include any official salvage documentation that would expunge the feature from the chart without having to further investigate with a survey platform.

Any charted features that contain the label PA, ED, PD, or Rep (see Chart No. 1 for definitions.), not specifically assigned as an AWOIS item and investigated in this survey, should be documented and discussed in this section. The source of the charted feature should be listed if known. Also, discuss features such as wrecks and obstructions from miscellaneous sources. Describe the condition and distinguishing characteristics of all items mentioned. NOAA units should reference the Pydro generated "For Descriptive Report" feature report as necessary for this requirement (see section 5.2.3.3.2 of the OCS Field Procedures Manual).

Refer to any Danger to Navigation Reports submitted for this survey. A negative statement is required if no Danger to Navigation Reports were submitted.

D.2 Additional Results

If specified in the Hydrographic Survey Letter Instructions or Statement of Work, describe and discuss the shoreline investigation results.

If applicable, briefly discuss prior survey comparisons conducted by the hydrographer. In general, prior survey comparisons are not required by field personnel, but may be used at the discretion of the hydrographer for quality control purposes. Prior survey comparisons can be very helpful to the hydrographer both in the field and during final data processing. Prior surveys may be obtained by contacting the appropriate Processing Branch or by contacting the COTR (if not already provided on the project CD).

Discuss aids to navigation which do not serve their intended purpose, are damaged, or whose characteristics do not match the chart or Light List (see Section 7.2). A statement shall be made in this section of the Descriptive Report if all aids serve their intended purpose. NOAA units should refer to section 3.4.4 of the OCS Field Procedures Manual and Hydrographic Survey Letter Instructions for specific guidance on positioning aids to navigation.

List all bridges, overhead cables, and overhead pipelines. State the status or condition of each feature. Provide applicable clearances determined by the survey party or by an authoritative source (e.g., the U.S. Coast Guard or U.S. Army Corps of Engineers). Include the geographic coordinates directly below the minimum clearance point. All such charted overhead features that no longer exist must also be listed. Include written documentation, if available, and photographs with the survey records. Invalid or uncharted overhead clearance information, or ongoing construction of bridges or overhead cables and pipelines, constituting a potential danger to navigation, should be reported to the U.S. Coast Guard and the U.S. Army Corps of Engineers. Mention any submarine cables and pipelines and any associated crossing signs on the shoreline. Include coordinates for signage or the water entry point of the feature. Note ferry routes and list position of each ferry terminal, if not shown on the chart or contemporary NOS remote sensing maps.

For each drilling structure, production platform, and well head within the survey area (excluding temporary jack up rigs), make a comparison between the new survey position and the largest scale chart on which the feature is shown and discuss any differences.

Provide information of significant scientific or practical value resulting from the survey. Unusual submarine features such as abnormally large sand waves, shifting or migrating shoals, mounds, valleys, and escarpments should be described. Discuss anomalous tidal conditions encountered, such as the presence of swift currents not previously reported. Discuss any environmental conditions encountered, which have a direct bearing on the quality and accuracy of the hydrographic data. If special reports have been submitted on such subjects, refer to them by title, author, and date of preparation or publication.

Mention present or planned construction or dredging in the survey area that may affect the survey results or nautical charts. Recommend new surveys for any adjacent areas that need them. As appropriate, include recommendations for further investigations of unusual features or sea conditions of interest that go beyond routine charting requirements. Recommend insets to be shown on the published chart of the area, if requested by chart users or needed for clarity.

E. APPROVAL SHEET

The approval sheet with a digital signature shall be part of the digital DR file. The approval sheet shall contain the following:

Approval of the deliverable files, Descriptive Report, digital data, and all accompanying records. This approval constitutes the assumption of responsibility for the stated accuracy and completeness of the hydrographic survey.

A statement as to whether the survey is complete and adequate for its intended purpose or if additional work is required.

The amount and degree of personal supervision of the work.

Additional information or references helpful for verifying and evaluating the survey.

List all reports and data not included with the survey records or Descriptive Report that have been submitted to the processing office or to another office (e.g., Data Acquisition and Processing Report, Vertical and Horizontal Report, Tides and Water Levels Package, Coast Pilot Report). Include date of the report or date of submission.

If appropriate, other personnel responsible for overseeing or directing operations on this survey sheet may also sign the Approval Sheet.

## DESCRIPTIVE REPORT APPENDICES

The Appendices may be submitted either digitally or in hard copy. If submitted digitally, the Appendices should not be included as part of the digital file that contains the main body of the DR. They shall be separate file(s) and be in an Adobe Acrobat format. The use of all digital deliverables, including digital processing logs, digital data acquisition logs, etc., over traditional hard-copy records is strongly encouraged. NOAA units should refer to section 5.1.2.2 of the OCS Field Procedures Manual for additional guidance on the content of DR Appendices.

### I. DANGER TO NAVIGATION REPORTS

Include copies of Danger to Navigation Reports and correspondence. List each document by some type of unique identifier, such as date for a letter or e-mail.

### II. SURVEY FEATURE REPORT

Include a copy of all AWOIS item investigation reports and associated graphic correlation output. Include any official salvage documentation that supports an AWOIS charting recommendation. NOAA units shall meet this requirement by submitting the “For Descriptive Report” feature report generated in Pydro as Appendix II.

### III. FINAL PROGRESS SKETCH AND SURVEY OUTLINE

Include a copy of the final Progress Sketch and final survey outline that were submitted as per the requirements in Section 8.1.1.

### IV. TIDES AND WATER LEVELS

Include the following (if applicable):

- Field Tide Note
- Final Tide Note
- Abstract of Times of Hydrography (lists every day during which hydrography was conducted and the start and end times hydrography was conducted each day)
- A copy of the “Request for Approved Tides/Water Levels” letter
- Any other correspondence directly relating to tides and/or water levels

### V. SUPPLEMENTAL SURVEY RECORDS AND CORRESPONDENCE

Include any additional survey records not previously addressed in the Descriptive Report, Appendices or Separates (e.g., MapInfo tables) and a summary table of bottom samples obtained (if applicable). Any letter or email correspondence relating to the present survey should also be included.

## SEPARATES TO BE INCLUDED WITH THE SURVEY DATA

The following “SEPARATES TO BE INCLUDED WITH THE SURVEY DATA” supplementing the Descriptive Report shall be submitted with each survey. The Separates may be submitted in either hard copy and/or digitally. If submitted as hard copies, they shall be bound, organized and clearly labeled. The SEPARATES should not be included in the digital DR file, but may be submitted digitally as separate files, if available. As noted for the Appendices, all digital submissions are strongly encouraged. NOAA units should refer to section 5.1.2.2 of the OCS Field Procedures Manual for additional guidance on the content of DR Separates.

I. ACQUISITION AND PROCESSING LOGS

Include all acquisition and processing logs from the present survey. Include positioning confidence checks and sounding system comparison checks.

II. SOUND SPEED DATA

Include a table, which identifies the specific sound speed profiles used during the present survey. List the positions and dates of all casts used; the maximum cast depth; and the dates/times for which the profiles were applied. Refer to the location where the digital sound speed files are located, and include a directory listing of the files. If appropriate, describe how the survey area was zoned to account for sound speed variations from differing water masses. Printouts of individual sound speed profiles are not required. NOAA units should be certain to insert "Velocwin SV cast GPs" into their final Pydro data to meet this requirement.

A vessel with a Moving Vessel Profiler (MVP) may use thousands of profiles for a single survey. In such cases, a table of each individual cast is not required. Instead, replace the table with a brief discussion on how the MVP was used (frequency, which areas of the survey, vessels and/or lines it was used, etc.) If individual casts were conducted as well, those casts should be included in a table.

Include confidence check results. Include copies of sound speed profiler calibration report(s), if calibration occurred after submission of the Data Acquisitions and Processing Report (DAPR).

III. HYDROGRAPHIC SURVEY LETTER INSTRUCTIONS/STATEMENT OF WORK

Include copies of the Hydrographic Survey Letter Instructions or Statement of Work. Include all changes/modifications which apply to the survey being submitted.

IV. CROSSLINE COMPARISONS

Include the summary plot analysis as a function of beam number for the mainscheme/crossline intersections as required in Section 5.5.3, if applicable. Include any other crossline quality reports required by the Hydrographic Survey Letter Instructions or Statement of Work.

V. SIDE SCAN CONTACT LISTING AND IMAGES OF SIGNIFICANT CONTACTS

Include the side scan contact listing, along with images of all significant contacts. Side scan contacts are included as part of a normal Pydro data submission, which fulfils this requirement. Non-Pydro users must submit significant contact images in a manner which allows the Processing Branch to easily review and correlate specific contacts with other supporting data sets.

### 8.1.4. Descriptive Report Supplemental Reports

#### 8.1.4.1. Data Acquisition and Processing Report

The Data Acquisition and Processing Report (DAPR) is a project-wide report that shall be submitted before, or not later than, the submission of the first survey of the project. For contract surveys, the Data Acquisition and Processing Report shall be sent to the COTR and appropriate Processing Branch specified in the Statement of Work. For NOAA field units, the DAPR shall be sent to the Chief, Hydrographic Systems and Technology Program (HSTP) and the appropriate Processing Branch specified in the Hydrographic Survey Letter Instructions. This report is separated into three sections: Equipment, Quality Control, and Corrections to Echo Soundings. These sections shall contain a detailed discussion on the project specific information addressed below.

A digital copy of the main text of the DAPR shall be provided in Adobe Acrobat format.

Include a cover sheet and title sheet which contain the following general information:
*Cover Sheet.* Include the type of survey(s), state, general locality and year. (see Appendix 10)
*Title Sheet.* This contains additional descriptive information relative to the project. Include project number, date of Hydrographic Survey Letter Instructions/Statement of Work, vessel(s), field unit/contractor, subcontractors, and Chief of Party/Lead Hydrographer.

A. Equipment

Describe the major operational systems used to acquire survey data or control survey operations. Include the manufacturer, firmware version and model number, operational settings and how the equipment was used. Include a description of the vessel(s) used.

Specifically discuss singlebeam, multibeam, lidar and side scan sonar systems and operations in this section. Include range scales, number of beams, resolution, alongtrack coverage, and quality assurance tools used during data acquisition. Include discussion of other depth determination systems, such as, diver depth gages, lead line, sounding poles, etc. If applicable, explain the calibration or determination of correctors, the dates of most recent calibrations, state whether or not checks were made on their accuracy and describe any nonstandard procedures used. Discuss the computer hardware and software used for all data acquisition and processing. Describe acquisition and processing methods, procedures, and parameters used. Provide a complete list of all software versions and dates.

Include a description of equipment used to conduct shoreline verification. Briefly describe the method of conducting shoreline verification, including the processing of detached positions and depiction of shoreline features in the S-57 feature file.

B. Quality Control

Provide a description of the data processing routines for converting raw sounding data to the final smooth sounding values. Include a description of the methodology used to maintain data integrity, from raw sounding data to final soundings. Processing flow diagrams are helpful. Any methods used to derive final depths such as cleaning filters, sounding suppression/data decimation parameters, gridding parameters, and surface computation algorithms shall be fully documented and described in this section.

Discuss the methods used to minimize the errors associated with depth determination and provide details of how the error models and Total Propagated Error (TPE) for each sounding is computed (see Section 5.4.5).

Methods and standards used to examine side scan sonar records should be noted and a brief description of processing procedures should be provided. Include the methods for establishing proof of swath coverage and the criteria for selecting contacts.

C. Corrections to Echo Soundings

This section addresses the methods used for the determination of all corrections to echo soundings that apply to the entire project. Describe the methods used to determine, evaluate, and apply the following corrections to echo soundings, including the uncertainties for each item:

Instrument corrections.

All vessel configuration parameters, offsets, layback, etc include diagrams, pictures, or figures of the equipment as installed onboard

Static and dynamic draft measurements

Heave, roll, pitch biases, and navigation timing errors. State the manufacturer, model, accuracy, and resolution of heave, roll, and pitch sensor(s). Discuss accuracy and alignment test procedures and results. Include copies of system alignment, accuracy, and calibration reports.

Discuss the source of tide or water level correctors used for data processing and final sounding reduction

D. Approval Sheet

The Chief of Party or Lead Hydrographer shall furnish, on a separate sheet, a signed statement of approval for all information contained within the Data Acquisition and Processing Report.

If appropriate, other personnel responsible for overseeing or directing operations on this project report may also sign the Approval Sheet.

### 8.1.4.2. Horizontal and Vertical Control Report

The Horizontal and Vertical Control Report is a project-wide report which shall be submitted before, or not later than, the submission of the last survey in project area.

A digital copy of the main text of the Horizontal and Vertical Control Report shall be provided in Adobe Acrobat format.

Include a cover sheet and title sheet which contain the following general information:

*Cover Sheet.* Include the type of survey(s), state, general locality and year.

*Title Sheet.* This contains additional descriptive information relative to the project. Include project number, survey registry numbers to which this report applies (with associated dates of survey and locality), date of Hydrographic Survey Letter Instructions/Statement of Work, vessel(s), field unit/contractor, sub-contractors, and Chief of Party/Lead Hydrographer.

A. Vertical Control

The Vertical Control section of the project Horizontal and Vertical Control Report shall document all Tide and Water Level activities that took place as part of this project. Specific information pertaining to an individual survey sheet and the Request for Approved Tides letter shall be documented in the Descriptive Report for the individual survey. This section shall contain a discussion of:

All stations established by the field unit (include gauge model/type). Give station number, latitude/longitude, and the dates/times of operation.
The method by which correctors for the field data were obtained and applied.
The time meridian used to annotate the tide records.
A list of any unusual tidal, water level, or current conditions.
The height and time corrections, and zoning if different from that specified in the Hydrographic Survey Letter Instructions or Statement of Work.
Ellipsoidal benchmark positioning techniques and procedures

B. Horizontal Control

The Horizontal Control section of the project Horizontal and Vertical Control Report shall document Hydrographic Position Control activities that took place as part of this project. Specific information pertaining to an individual survey sheet shall be documented in the Descriptive Report for the individual survey.

For horizontal control stations established by the field unit, describe the survey methods used to establish the station, and state the standards of accuracy used. Include position accuracy plots (see Section 3.2.2). For all horizontal control stations established by the field unit, list:

• The latitude to at least the nearest 1/100th of a second.
• The longitude to at least the nearest 1/100th of a second.
• The station elevation (ellipsoidal height).
• The geodetic station name and year it was established.

Briefly, describe the methods and adequacy of positioning system confidence checks.

C. Approval Sheet

The Chief of Party or Lead Hydrographer shall furnish, on a separate sheet, a signed statement of approval for all information contained within the Horizontal and Vertical Control Report.

If appropriate, other personnel responsible for overseeing or directing operations on this project report may also sign the Approval Sheet.

## 8.2. S-57 Feature File

Smooth sheets will no longer be required of Contractors or NOAA field units. The traditional preliminary smooth sheet plotted on mylar is being replaced by an S-57 feature file. The Processing Branches will use the S-57 feature file in conjunction with the BAG and other survey deliverables to compile the survey data into navigational products.

The deliverables for a survey shall be:

1. Features contained in a single S-57 (,000) base cell file.
2. A collection of Bathymetric Attributed Grids (BAG).
3. Metadata contained in the DR and associated reports.

The BAG should be in the NAD83 datum. The BAG should be UTM projected. The metadata for the BAG shall include the NAD83 datum and UTM projection with the proper zone and resolution of the grid. The S-57 feature file shall be in the WGS84 datum and unprojected.

The S-57 feature file contains all the attributed information on specific objects that cannot be portrayed in a simple depth grid. Features to include in the S-57 feature file include; wrecks, obstructions, shoreline, rocks, islets, oil platforms, nature of seabed (bottom samples) and all other objects that may need to be compiled to a navigational product and require additional information that cannot be included in the BAG.

U.S. Coast Guard maintained aids to navigation shall NOT be included in the S-57 feature file. The hydrographer shall investigate all aids to navigation and report results as required in section 7.2 and 8.1.3. Privately maintained aids and/or mooring buoys should be included in the S-57 feature file, unless they are transitory.

The S-57 feature file shall include shoreline data only if the hydrographer conducted shoreline verification. New features and changes to the source shoreline shall be portrayed in the S-57 feature file and be fully attributed.

General soundings, contours and depth areas will NOT be included in the S-57 feature file since these objects will be derived from the final BAGs during chart compilation. In rare cases, an isolated sounding may be part of the S-57 feature file if it needs a danger circle and/or additional attributions.

### 8.2.1. S-57 Attribution

These Specifications and Deliverables will not attempt to include all possible objects and attributions that may be required for a hydrographic survey. For a full reference the hydrographer should refer to the resources described in section 1.2.

A list of the more common objects and attributions that may be used during a typical hydrographic survey are listed below. If the hydrographer has any questions on the appropriate attribution for an object, they should contact the COTR and/or the appropriate Processing Branch for clarification.

All S-57 mandatory attributes for an object shall be completed. The Hydrographer shall attempt to provide as much additional information as possible on an object to facilitate the Branches in final chart compilation of the survey. Whenever possible, additional information should be associated with the object itself. The attributes, INFORM, TXTDSC and PICREP can be used to provide additional information. If it is not practical to communicate additional information using an attribute associated with the object, then the Hydrographer can provide the information using the DR, Item Investigation Report, Detached Position log (with photo), or other means.

All objects in the S-57 feature file must be properly attributed. S-57 feature file attributions can be divided into three broad categories; depths, features, meta-objects. The most common items for each category and the related mandatory attributes are described below.

ALL objects (depths, features and meta-objects), unless otherwise noted, will have the attributes SORDAT and SORIND populated.

SORIND (Source indication)

Format: 'Country code, Authority code, Source, ID Code'. Example, "US,US,graph,H11393", if data came from a survey. Country (US), Authority (US for OCS), Source (graphic), ID code (registry number). If feature is from RSD provided GC, the ID code becomes the GC number, if the feature is carried forward from a chart or ENC the ID code is the chart number (i.e. 'chart 16707').

SORDAT (Source date)

Is the date associated with the SORIND above. For a hydrographic survey, it is the last day of field operations. For a GC shoreline, the date the survey was flown. From a rater chart, the chart date. From the ENC, it is the date that the ENC has for the SORIND.

**DEPTHS**

Depth information is stored in three different forms, points (SOUNDG), lines (DEPCNT) and Areas (DEPARE). The S-57 feature file will have all depth units in meters.

SOUNDG (Sounding)

A measured water depth or spot which has been reduced to a vertical datum (may be a drying height). Soundings are bundled together by survey and share most attributes. The number of soundings included is appropriate for the scale of the survey as defined in the Statement of Work.

*Mandatory Attributes*

QUASOU (Quality of Sounding Measurement) - Generally set to '1', for depth known.

TECSOU (Technique of sounding measurement) - Typically '1' if found by echo-sounder, '3' if found by multi-beam, '7' if found by laser, '4' if found by diver.

**FEATURES**

All features should be attributed as fully as possible, with a few exceptions. Several common features are listed below, followed by the mandatory attributes required for them.

WRECKS (Wreck)

The ruined remains of a stranded or sunken vessel which has been rendered useless. (IHO Dictionary, S-32, 5th Edition, 6027)

CATWRK (Category of Wreck) – For instance '1' for non-dangerous wreck, '2' for dangerous wreck, '3' for distributed remains of wreck, etc.

UWTROC (Underwater/awash rock)

A concreted mass of stony material or coral which dries, is awash or is below the water surface.

OBSTRN (Obstruction)

In marine navigation, anything that hinders or prevents movement, particularly anything that endangers or prevents passage of a vessel. The term is usually used to refer to an isolated danger to navigation... (IHO Dictionary, S-32, 5th Edition, 3503)

*Mandatory Attributes for all features*

TECSOU (Technique of sounding measurement) - Typically ‘1’ if found by echo-sounder, ‘3’ if found by multi-beam, ‘4’ if found by diver, ‘7’ if found by laser.

QUASOU (Quality of Sounding Measurement) - Generally set to ‘1’, for depth known.

VALSOU (Value of Sounding) – Least depth of the wreck.

WATLEV (Water Level Effect) – For instance, ‘1’ for partly submerged at high water, ‘2’ for always dry, ‘3’ for always under water/submerged, ‘4’ for covers and uncovers, etc.

SBDARE (Seabed area)

The nature of bottom includes the material of which it is composed and its physical characteristics. Also called character (or characteristics) of the bottom, or quality of the bottom. (IHO Dictionary, S-32, 5t h Edition, 515). Bottom characteristic objects will have one or the other of the following attributes (usually NATSUR).

NATSUR (Nature of surface) – Refer to S-57 library for codes, for instance, ‘1’ is mud, ‘2’ is clay, ‘3’ is silt, ‘4’ is sand, etc.

NATQUA (Nature of surface - qualifying terms) – Refer to S-57 library for codes, for instance, ‘1’ is fine, ‘2’ is medium, ‘3’ is coarse, etc.

**META-OBJECTS**

Meta-Objects provide metadata and additional information for large areas of the survey, or to attribute the entire survey area. The required meta-objects with their mandatory attributes are listed below;

M_QUAL (Quality of Data)

This should be separated for different classes of survey. Singlebeam, multibeam (Complete) and multibeam (Object Detection), and Lidar should be separate.

*Mandatory Attributes*

CATZOC (Category of zone of confidence in data) - U for “Unassessed”.

POSACC (Positional Accuracy, in meters) – For USCG beacons or other modern Differential GPS systems, will typically be 10 meters.

SURSTA (Start date of survey) - When compiling from a hydrographic survey, enter the start date of the field operations in format, CCYYMMDD.

SUREND (End date of survey) - When compiling from a hydrographic survey, enter the end date of the field operations in format, CCYYMMDD.

INFORM (Information) - Contains the Following String: Registry Number, Project Number, and Contractor Name (H10934, OPR-D904-00, World Surveys Inc.)

M_COVR (Coverage)

A geographical area that describes the coverage and extent of spatial objects. The area that comprises the compiled data or extents of survey.

*Mandatory Attributes*

CATCOV (Category of coverage) – ‘1’ for coverage available: continuous coverage of spatial objects is available within this area. ‘2’ for no coverage available: an area containing no spatial objects (i.e. an area within the survey limits, not addressed by the hydrographer.)

## 8.2.2. Cartographic Specifications and Conventions

In general, during data acquisition and processing, full precision of the survey data should be maintained in metric. The data shall be maintained with at least millimeter precision, and standard rounding will be performed.

Generalization of Features

There will be no generalization of features in the S-57 feature file. All point features that were surveyed will be included in the file. If possible, these features will not be generalized into foul areas. If the hydrographer determines an area unsafe, a foul area can be shown, but all point features collected as part of that determination should be included. All available survey data that exists for any and all feature objects will be included in the S-57 feature file.

If applicable, the S-57 feature file should have the following parameters set;

Producing Agency = US Office of Coast Survey,
Navigational Purpose = 1 thru 5 according to chart compilation scale,
Individual Cell Code = H number of survey, H12345 becomes '12345',
Horizontal Datum = WGS84 (datum of S-57 file),
Vertical Datum (for heights) = MHW,
Sounding Datum = MLLW,
Units = metric
Compilation Scale = survey scale,
Coordinate Multiplication Factor = 10,000,000,
Sounding Multiplication Factor = 1,000.

## 8.3. Multibeam and Lidar Sonar Coverage

The hydrographer shall produce two swath coverage graphics for all multibeam and lidar surveys; one of the sun illuminated depth and a second of the uncertainty layer for the entire survey area (see section 5.5.4).

Digital images shall be in an image format with associated geographic registration information.

## 8.4. Side Scan Sonar

### 8.4.1 Side Scan Sonar Mosaic

A separate side scan mosaic for each 100 percent coverage shall be used as a graphic means for demonstrating bottom coverage. Pixel resolution of the side scan mosaics should be 1 m by 1 m or less, dependent upon the equipment and speed of towing. The hydrographer shall submit a digital file of each 100% coverage (see Section 8.5.4).

If possible, the mosaics should be generated in one complete image file. If the survey area is too large and/or creates a large image file that is unmanageable due to file size, then the Hydrographer shall subdivide the area into smaller more manageable subsections. Contact the COTR and/or appropriate Processing Branch to discuss file size limitations for each survey. However, do not create mosaics for individual side scan line files.

### 8.4.2. Side Scan Sonar Contact List

Contact List
A Sonar Contact List is required and must include the specific elements of information which the hydrographer needs to prepare the preliminary Sonar Contact Plot. Suggested column entries are described below, along with a brief discussion of how each is to be derived. Specific entries may vary by hydrographer. The format should be reviewed by the COTR and/or Processing Branch before data collection is conducted.

A digital copy of the contact list, ideally in spreadsheet format, shall be submitted with the survey deliverables.

Column 1: Search Track Number—identifies the particular search track from which the contact was observed.

Column 2: Contact Number—uniquely identifies the contact. An example of a contact number is a number based on the date/time the contact was observed, followed by a letter indicating the port or starboard (P or S) channel. For example, if a port-side contact is observed on day 181 at 150125, the contact number will be 181/150125P. Using signed (+ or -) contact range in column 4 eliminates the need for the P or S indicator.

Column 3: Towfish Layback—the approximate distance in meters from the positioning system antenna to the towfish. Unless computed by an automated system, the towfish may be assumed to be directly astern of the towing vessel and on the search track.

Column 4: Contact Range—the horizontal distance from the towfish track to the contact, expressed in meters.

Column 5: Contact Position—the preliminary position as determined by reconstruction of the vessel position, towfish layback, towfish position, port or starboard channel, and contact range at the time the contact was observed. The Contact Position shall be stated as a latitude/longitude (decimal degress) or X/Y (easting, northing) values.

Clumn 6: Estimate of contact height computed from range and shadow length.

Column 7: Remarks—used to denote first impressions of the contact's identity (e.g., wreck, rock, etc.), or to make any comments deemed appropriate. If, after examining the records and correlating targets from overlapping coverage, the hydrographer determines that a contact does not warrant further investigation, it shall be noted as such. A brief statement of the reasons must be made. Any abbreviations should be defined on the list.

Column 8: Comparison with shallow water multibeam data—used to note the corresponding shallow water multibeam data (day/time, line number, etc.), the results of comparing the side scan sonar data with the multibeam data (e.g., contact did not appear in the multibeam data, swmb least depth = x.x—sss least depth = y.y).

Column 9: Contact is depicted in the S-57 feature file—answered in one of three ways: (1) yes, obstr, (2) yes, sounding only or (3) no.

Once added to the list, a contact should never be removed. If, after further processing, a contact is deemed not significant by the hydrographer, it shall be labeled as such in column 7.
The contact list, and any subsequent field examination lists and records developed from the contact list, shall be included with the data submission in digital form.

Contact Plot
In the past, a contact plot showed the position of all significant contacts entered on the Sonar Contact List. Only significant (Section 6.3.2.) contacts, along with the views from adjacent lines, would be plotted on the Sonar Contact Plot. A Contact Plot is no longer required. The contact list can be imported into a GIS so that office verifiers can analyze the distribution of contacts. However, if the hydrographer creates any image files showing the distribution of contacts and/or

other products to assist with processing and analysis of the data, they may be included with the survey deliverables.

In some areas, significant contacts may be clustered (e.g., debris, boulder field). Such an area may lend itself to being depicted as a single feature within the S-57 feature file: a danger curve depicting the limit with accurately positioned least depth(s). If the hydrographer has any questions to how the feature should be portrayed and attributed within the S-57 feature file, they should contact the appropriate Processing Branch.

Contact Images
For each significant contact in the contact list, the hydrographer shall provide an image of the contact. Digital images shall be in a standard image format (e.g., tif, gif, jpg). Copies of the images shall be included in the Separates, Section II. Digital file names and hard copy labels (if provided) shall coincide with the contact name as depicted on the contact list.

### 8.4.3. Data Acquisition and Processing Abstracts

All sonargrams and data acquisition/processing comments shall be submitted digitally. Time references shall be made in Coordinated Universal Time (UTC).

The Hydrographer shall have a system to clearly indicate the status of the side scan acquisition system. Historically, this was accomplished by annotating the paper sonargram as the data was being collected. Further annotations could be made during field and/or office review of the sonargrams. Modern survey systems acquire the data digitally, therefore, separate data acquisition/processing logs may be used to record the needed information.

The following comments (or annotations) shall be made in a manner that they can be correlated by time or other method back to the digital side scan sonar record.

System-Status Annotations
System-status annotations are required to describe the recorder settings and the towing situation. System-status annotations shall include:

- Mode of tuning (manual or auto).
- Range-scale setting.
- Operator's name or initials.
- Length of tow-cable deployed (tow point to towfish)
- Depressor in use (yes or no).
- Weather and sea conditions

System-status annotations shall be made:

- Prior to obtaining the first position of the day.
- While on-line, approximately every hour, regardless of any changes made.

First Position/Last Position Annotations
The following annotations shall be made at the first position on each survey line:

- Line begins (LB) or line resumes (LR).
- Tow-vessel heading (degrees true or magnetic).
- Towing speed (engine rpm, and pitch if applicable).
- Index number and time (at event mark).

The following annotations shall be made at the last position on each survey line:

Line turns (LTRA, LTLA), line breaks (LBKS), or line ends (LE) index number and time (at event mark).

Special Annotations
The occurrence of any of the following events shall also be annotated:

Change in operator (new name or initials).
Change in range-scale setting.
Confidence checks.
Individual changes to recorder channel settings.
Change in tow-cable length (tow point to towfish).
Change in towing speed (engine rpm and pitch) or vessel heading.
Change in tow point.
Significant contact observed.
Surface phenomenon observed (wakes, passing vessels, etc.).
Passes by buoys or other known features within sonar range (identify object).
Interference (state source if known).
Time corresponding to the index marker.

The hydrographer shall make any other annotations necessary to note any occurrence which may later serve to reconstruct the operation. Too much information is always better than not enough.

Annotation Methods
Header and system-status annotations may be made using any of the following methods:

By use of an automatic annotator, if available.
Typed entries in the data acquisition system.
Typed entries in a separate annotation file.

The method is left to the hydrographer's discretion, but should be used consistently throughout the operation.

## 8.5. Digital Data Files

The survey data will be supplied in a digital format. Hard copy plots and hard copy printouts of reports are no longer required. In some cases, survey data may be collected in an analog format (hand written data acquisition logs, etc.). The intent of the Specifications is to submit as much data as possible in a digital format, however, it is not the intention that hydrographers should spend resources scanning analog data records required for the DR Appendices and Separates.

This section is provided as a summary for the major digital deliverables that may be required for a typical hydrographic survey. Not all sections will apply to all surveys. NOAA units should refer to Chapter 5 of the OCS Field Procedures Manual for specific format and other guidance pertaining to survey deliverables.

### 8.5.1. Media

Digital data shall be submitted on USB hard drives. Each registered survey shall be submitted on a separate USB drive unless prior agreement is obtained from the COTR or Processing Branch. The hydrographer shall include a directory listing of each drive, or other method to enable the Processing Branch to determine where specific data sets are located. Other formats may be allowed if agreed upon in advance with the appropriate Processing Branch. The hydrographer shall work with NOAA to ensure no compatibility problems exist after data submission.

Network Attached Storage Units, specifically MaxAttach or equivalent may also be used to submit data. The hydrographer should contact the appropriate Processing Branch ahead of time to determine proper shipping methods, directory structure and reach agreement on when (or if) the Processing Branch will return the device.

### 8.5.2. Single-beam Data

The single-beam data format will be specified in the Hydrographic Survey Letter Instructions or Statement of Work. Typically, the data will be submitted in a CARIS HIPS compatible format.

### 8.5.3. Shallow-Water Multibeam and Lidar Data

The hydrographer's multibeam data format shall provide complete traceability for all positions, soundings, and correctors including sensor offsets, biases, dynamic attitude, sound speed, position, sensor position, date and time, vertical datum reducers, and sounding data from acquisition through postprocessing. Data quality and edit flags must be traceable.

Full Resolution Multibeam Data
The hydrographer shall submit full resolution multibeam data in a format readable by CARIS HIPS (Version 6.0, by CARIS). Full resolution multibeam data shall be delivered fully corrected for tides, sound speed, vessel offsets, draft and settlement and squat. These corrections may be made within CARIS, with data submitted as a complete CARIS project (including HDCS files, sound speed files, Vessel Configuration, CARIS tide files, etc.). Or the data may be submitted fully corrected, such that it will be read in CARIS HIPS using a 'zeroed' Vessel Configuration file (.vcf or .hvf) and a 'zero' tide file (.tid), etc. Full resolution data are defined as all data acquired and logged during normal survey operations. Information and specifications on CARIS HIPS and data formats may be obtained from CARIS at 506-458-8533.

Full Resolution Lidar Data
The contractor shall submit the full resolution lidar data in CARIS compatible format (Version 6.0, by CARIS). The submission will include the appropriate CARIS converter, lidar data before conversion, and all necessary CARIS files so that NOAA can reconvert all files, if desired.

CARIS BASE Surface and/or BAG
The final depth information from the survey will be composed of a collection of grids. This collection of grids must reflect the state of the seafloor at the time of the survey. The finalized uncertainty of the grids shall be the greater of the standard deviation and a priori uncertainty. The hydrographer must take steps to ensure that all data has been correctly processed and that appropriate designated soundings have been selected (see section 5.2.3). The collection of grids representing the final reviewed results of the hydrographic survey shall be submitted as CARIS BASE or BAG surfaces.

The grids shall have a sequential naming convention, such as H12345_1_of_5.BAG, H12345_2_of_5.BAG, H12345_3_of_5.BAG, etc.

Multibeam and Lidar Images

The hydrographer shall produce two swath coverage images for all multibeam and lidar surveys; one of the sun illuminated depth and a second of the uncertainty layers (greater of standard deviation and a priori uncertainty) covering the entire survey area (see section 5.5.4).

Specific Multibeam Data
The hydrographer shall submit data used for determining navigation time latency, pitch, roll, and yaw biases in a separate directory on the submitted drive. The data format shall be such that CARIS HIPS can convert the data, thus making it compatible as described earlier in this Section.

### 8.5.4. Side Scan Sonar Data

The hydrographer shall submit digital side scan data in a format readable by CARIS SIPS (version 6.0, by CARIS, phone: (506) 458–8533). Digital side scan sonar **shall be geocoded using the towfish position (towfish position corrected).** Information and specifications on CARIS SIPS and data formats may be obtained from CARIS.

Side Scan Contact Images
The hydrographer shall submit digital images of all significant side scan contacts within the contact list (see Section 8.4.2). Digital images shall be in a standard image format (e.g., .tif, .gif, .jpg). The file name shall coincide with the contact name as depicted on the contact list.

Side Scan Mosaics
The hydrographer shall submit a digital image file for each 100 percent coverage. The digital image file shall be in a standard geo-referenced image format (section 8.4.1).

### 8.5.5. Other Data

Tide and Sound Speed Data
The hydrographer shall submit tide data and sound speed data applied to all multibeam depths on the project data drives. The hydrographer shall identify the data format and all data element descriptions (e.g., ASCII text file or Excel spreadsheet file; date/time referenced to UTC, tide relative to MLLW datum to the nearest centimeter). All tide data required by Chapter 4, shall be sent directly to the appropriate CO-OPS office.

Vessel Configuration File
The hydrographer shall submit a CARIS HIPS compatible HIPS Vessel File (HVF) for each vessel used during survey operations. CARIS-compatible HVF shall contain those static and dynamic correctors, offsets and uncertainties which are to be applied to the "Full Resolution Multibeam Data" set submitted as referenced in Section 8.5.3. If the data is submitted fully corrected with uncertainties already associated with each sounding, then the CARIS HVF may be "all zeros". In such a case, the hydrographer must provide details on what values were derived for all the static and dynamic correctors, offset and uncertainties and other information that is usually contained within a HVF in the DR and/or DAPR. Information and specifications on the HVF format may be obtained from CARIS.

Metadata
The following reports shall be included on the submitted data drive in a clearly labeled directory;
The main body of the Descriptive Report in Microsoft Word format. The Appendices and Separates to the DR in Adobe Acrobat .PDF format.
The Data Acquisition and Processing Report in Adobe Acrobat .PDF format.

The Horizontal and Vertical Control Report in Adobe Acrobat .PDF format.

S-57 Feature File
The S-57 feature file shall be included on the submitted drive in a clearly labeled directory.

Supporting Data
Any associated text or image files to support S-57 feature file objects.
Other interim data products that may help the Processing Branch verify the survey and understand the pipeline from acquisition to final product.

# Appendix 1

NOAA Form 77-12 Tide Station Report

And

N/OMA121 Form 91-01 Next Generation Water Level Measurement System Site Report

NOAA FORM 77-12
(5-80)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMIN.

**TIDE STATION REPORT**

STATION NAME | STATION NUMBER

*INSTRUCTIONS: This form is to be fully completed and submitted on station installation and at annual inspection/maintenance. (All information will be verified correct and measurements retaken.) At other station visits and on removal, only changes need be recorded in the appropriate blocks.*

LATITUDE | LONGITUDE | TIME MER.

TYPE OF STATION: ☐ PRIMARY ☐ TERTIARY ☐ SECONDARY | REC'D BY NOS HQ

**WHARF**
- NAME
- OWNER'S NAME AND LOCAL CONTACT
- BUSINESS ADDRESS/TELEPHONE NUMBER

PROJECT: ☐ CONTROL ☐ BOUNDARY ☐ CIRCULATORY ☐ HYDROGRAPHIC ☐ OTHER

☐ TEMPERATURE & DENSITY MEASUREMENTS AT THIS STATION
☐ ESTABLISHED ☐ INSPECTED ☐ REMOVED
BY: | DATE
APPROVED BY | DATE

**TIDE OBSERVER**
- NAME
- TELEPHONE NUMBER *(Include Area Code.)* HOME ( ) BUSINESS ( )
- NEW ☐ YES ☐ NO
- HOME ADDRESS | DATE HIRED *(If new)* | PAY/MO.

**TIDE HOUSE & PLATFORM**
SIZE AND BRIEF DESCRIPTION OF INSTALLATION INCLUDING PLATFORM, ACCESS INFO *(Combination, contact, hours...)*
☐ *Continued on reverse.*

**TIDE STAFF/ETG**
- ☐ PORTABLE ☐ ELECTRIC ☐ FIXED | ☐ FIBERGLASS ☐ OTHER ☐ VITRIFIED | HINGED ☐ YES ☐ NO | STAFF/ETG CHANGED ☐ YES ☐ NO | DATE OF INSTALLATION
- LIMITS OF GRADUATIONS | TOTAL MEASURED LENGTH BETWEEN THE LIMITS OF GRADUATIONS FT. | GRADUATION CORRESPONDING TO RODSTOP/ETG WEIGHT FT. | INITIALS
- PRECISE LOCATION, METHOD OF SECURING STAFF, TYPE AND CONDITION OF ROD STOP, AND ADDITIONAL REMARKS

☐ *Continued on reverse.*

**GAGES**

PRIMARY
- TYPE AND MANUFACTURER | SERIAL NUMBER | GAGE CHANGED ☐ YES ☐ NO | DATE OF INSTALLATION
- POWER SOURCE ☐ COMMERCIAL ☐ BATTERY ☐ SOLAR ☐ OTHER ____ | FLOAT/ORIFICE DIAMETER INS. | RANGE/SCALE | ☐ NEGATOR SPRING ☐ COUNTERWEIGHT

BACK-UP
- TYPE AND MANUFACTURER | SERIAL NUMBER | GAGE CHANGED ☐ YES ☐ NO | DATE OF INSTALLATION
- POWER SOURCE ☐ COMMERCIAL ☐ BATTERY ☐ SOLAR ☐ OTHER ____ | FLOAT/ORIFICE DIAMETER INS. | RANGE/SCALE | ☐ NEGATOR SPRING ☐ COUNTERWEIGHT

☐ ADDITIONAL GAGE(S) *(Give details on reverse.)*

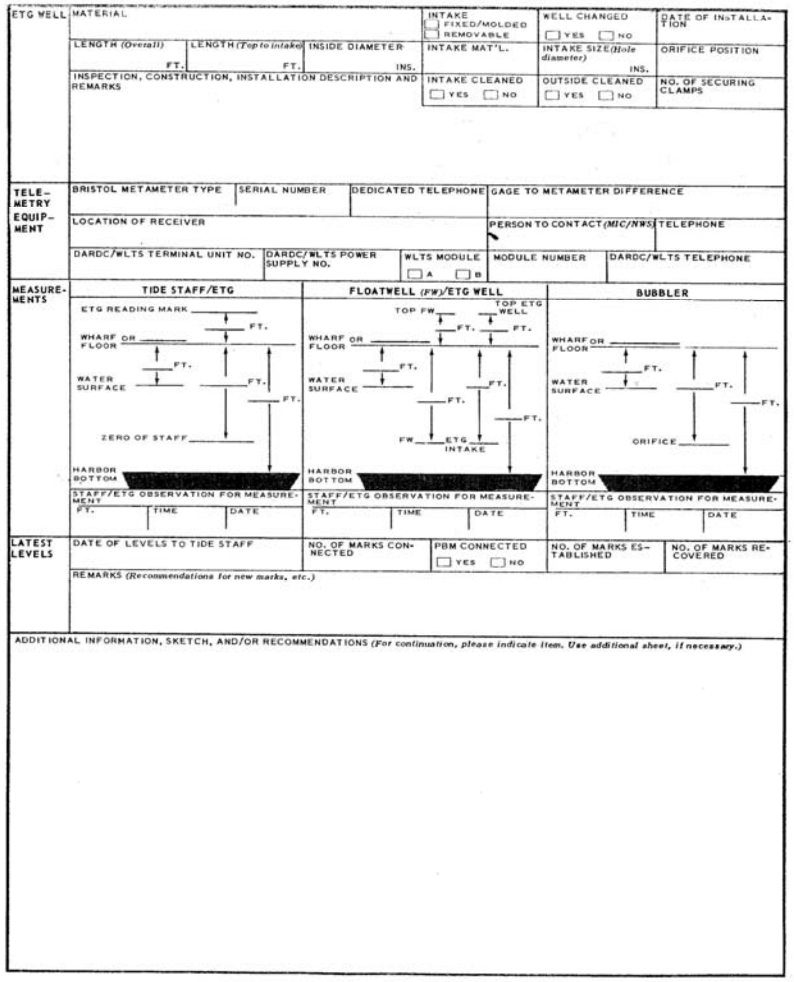
REMARKS

☐ *Continued on reverse.*

**FLOAT WELL**
- MATERIAL | INTAKE ☐ FIXED/MOLDED ☐ REMOVABLE | WELL CHANGED ☐ YES ☐ NO | DATE OF INSTALLATION
- LENGTH *(Overall)* FT. | LENGTH *(Top to intake)* FT. | INSIDE DIAMETER INS. | INTAKE MAT'L. | INTAKE SIZE *(Hole diameter)* INS. | ORIFICE POSITION
- INSPECTION, CONSTRUCTION, INSTALLATION DESCRIPTION AND REMARKS | INTAKE CLEANED ☐ YES ☐ NO | OUTSIDE CLEANED ☐ YES ☐ NO | NO. OF SECURING CLAMPS

☐ *Continued on reverse.*

SUPERSEDES PREVIOUS EDITION. EXISTING STOCK MAY BE DESTROYED UPON RECEIPT OF REVISION.



ETG WELL
MATERIAL
INTAKE
☐ FIXED/MOLDED
☐ REMOVABLE
WELL CHANGED ☐ YES ☐ NO
DATE OF INSTALLATION
LENGTH *(Overall)* FT.
LENGTH *(Top to intake)* FT.
INSIDE DIAMETER INS.
INTAKE MAT'L.
INTAKE SIZE *(Hole diameter)* INS.
ORIFICE POSITION
INSPECTION, CONSTRUCTION, INSTALLATION DESCRIPTION AND REMARKS
INTAKE CLEANED ☐ YES ☐ NO
OUTSIDE CLEANED ☐ YES ☐ NO
NO. OF SECURING CLAMPS

TELEMETRY EQUIPMENT
BRISTOL METAMETER TYPE
SERIAL NUMBER
DEDICATED TELEPHONE
GAGE TO METAMETER DIFFERENCE
LOCATION OF RECEIVER
PERSON TO CONTACT *(MIC/NWS)*
TELEPHONE
DARDC/WLTS TERMINAL UNIT NO.
DARDC/WLTS POWER SUPPLY NO.
WLTS MODULE ☐ A ☐ B
MODULE NUMBER
DARDC/WLTS TELEPHONE

MEASUREMENTS
TIDE STAFF/ETG
ETG READING MARK
FT.
WHARF OR FLOOR
FT.
WATER SURFACE
FT.
FT.
ZERO OF STAFF
HARBOR BOTTOM
STAFF/ETG OBSERVATION FOR MEASUREMENT
FT. TIME DATE

FLOATWELL *(FW)*/ETG WELL
TOP FW
TOP ETG WELL
FT.
FT.
WHARF OR FLOOR
FT.
WATER SURFACE
FT.
FT.
FT.
FW
ETG INTAKE
HARBOR BOTTOM
STAFF/ETG OBSERVATION FOR MEASUREMENT
FT. TIME DATE

BUBBLER
WHARF OR FLOOR
FT.
WATER SURFACE
FT.
FT.
ORIFICE
HARBOR BOTTOM
STAFF/ETG OBSERVATION FOR MEASUREMENT
FT. TIME DATE

LATEST LEVELS
DATE OF LEVELS TO TIDE STAFF
NO. OF MARKS CONNECTED
PBM CONNECTED ☐ YES ☐ NO
NO. OF MARKS ESTABLISHED
NO. OF MARKS RECOVERED
REMARKS *(Recommendations for new marks, etc.)*

ADDITIONAL INFORMATION, SKETCH, AND/OR RECOMMENDATIONS *(For continuation, please indicate item. Use additional sheet, if necessary.)*

*U.S. GPO: 1988-554-006/81003

N/OMA121 FORM 91-01 NOAA/NATIONAL OCEAN SERVICE

**NEXT GENERATION**
**WATER LEVEL MEASUREMENT SYSTEM (NGWLMS)**
**SITE REPORT**

| SITE NAME | | | SITE ID NUMBER | |
|---|---|---|---|---|
| LATITUDE (N/S) | LONGITUDE (E/W) | | TIME MER. (E/W) | |

INSTRUCTIONS: This form is to be fully completed (all information shall be verified correct and measurements relation) and submitted on site installation and inspection. At other site visits (repair/modifications) and on removal, only changes need be recorded. This form shall be accompanied by the NGWLMS Well/Sounding Tube Worksheet or equivalent sketch.

FACILITY

☐ ESTABLISHED ☐ INSPECTED ☐ REPAIRED ☐ REMOVED

| | |
|---|---|
| BY: | DATE |
| APPROVED BY: | DATE |
| RECEIVED (NOS HQ) BY: | DATE |

OWNER'S NAME (And Local Representative)

ADDRESS/TELEPHONE #

**LOCAL CONTACT**

| NAME | HOME TELEPHONE # | BUSINESS TELEPHONE # | |
|---|---|---|---|
| HOME ADDRESS | DATE HIRED | NEW? ☐ YES ☐ NO | PAY/MONTH |

**SHELTER & PLATFORM**

DESCRIPTION, REMARKS (Size, construction, access, utilities, etc)

☐ Continued on reverse

**9000 RTU**

| RTU S/N | DATE RTU INSTALLED | RTU TELEPHONE # | | RTU POWER SOURCE ☐ AC ☐ SOLAR | OPERATING SYS VER | SDL PROGRAM VER |
|---|---|---|---|---|---|---|
| RTU BOARDS CHANGED? ☐ YES ☐ NO | PWR SUPPLY BD S/N | SAT/RADIO BD S/N | COMM CNTL BD S/N | GENERAL I/O BD S/N | MEMORY EXP BD S/N | CPU BD S/N |
| RTU DESICCANT CHANGED? ☐ YES ☐ NO | MODEM BD S/N | AQUATRAK BD S/N | BACKPLANE BD S/N | TRANSITION BD S/N | TERMINATION BD S/N | AC PWR STDN BD S/N |

DESCRIPTION, REMARKS (Location, mounting, etc)

☐ Continued on reverse

**PRIMARY WATER LEVEL SENSOR**

| AQUATRAK S/N | MATCHED TUBE S/N | SENSOR OFFSET | AQ. CHANGED? ☐ YES ☐ NO | DATE AQ. INSTALLED | TEMPERATURE SENSORS SEPARATION |
|---|---|---|---|---|---|

DESCRIPTION, REMARKS

| CPVC SOUNDING TUBE LENGTH (Level point to brass tube end) | BRASS TUBE LENGTH | # BAILS |
|---|---|---|

☐ Continued on reverse

**PROTECTIVE WELL**

| MATERIAL (diameter, schedule, color, etc) | PIPE LENGTH (flange to flange) | DATE WELL INSTALLED | INTAKE: DOUBLE CONE ☐ SHROUD ☐ SIDE ☐ | INTAKE/WELL (Cleaned by divers) ☐ YES ☐ NO |
|---|---|---|---|---|
| BRACKETS (number, type, material, etc) | | TOP HAT? ☐ YES ☐ NO | COPPER INSERT? ☐ YES ☐ NO | PARALLEL PLATES? ☐ YES ☐ NO |

DESCRIPTION, REMARKS (Well location, vent hose number/size/elevation, mounting, brackets, components, etc)

MARINE FOULING POTENTIAL: LIGHT ☐ MEDIUM ☐ HEAVY ☐ SEASONAL ☐

☐ Continued on reverse

**GOES TRANSMISSION & SOLAR PANEL**

| ANTENNA S/N | DATE ANTENNA INSTALLED | CABLE LENGTH | LOW LOSS CABLE USED? ☐ YES ☐ NO | GMT OFFSET | AZIMUTH | LOCAL DEV. | ELEVATION |
|---|---|---|---|---|---|---|---|
| PLATFORM ID NUMBER | | CHANNEL | TRANSMIT TIME | SOLAR PANEL MANUFACTURER & S/N | | RATING | ANGLE |

DESCRIPTION, REMARKS (Antenna mounting, etc)

☐ Continued on reverse

| 8200 DATA RECORDER | | | | | | |
|---|---|---|---|---|---|---|
| 8200 S/N | DATE 8200 INSTALLED | PROGRAM VERSION | POWER SOURCE ☐ DC ☐ SOLAR | DESICCANT CHANGED? ☐ YES ☐ NO | CPU S/N | INTERCONNECT S/N |
| DESCRIPTION, REMARKS (Mounting, location, etc) | | | | | AMP GAIN | SENSOR SLOPE |
| | | | | | | ☐ Continued below |

| BACKUP WATER LEVEL SENSOR | | | | |
|---|---|---|---|---|
| SENSOR MANUFACTURER ☐ DRUCK ☐ IMO ☐ PAROSCIENTIFIC ☐ OTHER ____ | SENSOR S/N | DATE SENSOR INSTALLED | SENSOR CONFIGURATION ☐ WATER ☐ BUBBLER | PARALLEL PLATES? ☐ YES ☐ NO |
| DESCRIPTION, REMARKS (Sensor location, installation details, etc) | | | | ☐ Continued below |

| OTHER SENSORS | | | | | |
|---|---|---|---|---|---|
| AIR TEMPERATURE ☐ YES ☐ NO | DATE INSTALLED | BAROMETER S/N | DATE INSTALLED | CONDUCTIVITY S/N | DATE INSTALLED |
| WATER TEMPERATURE ☐ YES ☐ NO | DATE INSTALLED | WIND SENSOR S/N | DATE INSTALLED | MET TOWER TYPE: STEEL ☐ FIBERGLASS ☐ | DATE INSTALLED |
| DESCRIPTION, REMARKS (Sensor/tower location, installation details, etc) | | | | | ☐ Continued below |

| LATEST LEVELS | | | | | |
|---|---|---|---|---|---|
| DATE OF LEVELS | NUMBER OF BENCH MARKS CONNECTED | NUMBER OF BENCH MARKS ESTABLISHED | NUMBER OF BENCH MARKS RECOVERED | PBM CONNECTED? ☐ YES ☐ NO, EXPLAIN | DOWNSHOT LEVELING FIXTURE REQUIRED? ☐ YES ☐ NO |
| REMARKS | | | ☐ Continued below | AQUATRAK COEFFICIENT 2A (PBM above site datum: from HQ)<br>AQUATRAK COEFFICIENT 2B (Leveling point above PBM: from levels) +<br>AQUATRAK COEFFICIENT 2 (2A + 2B = 2) = | |

REMARKS (Continuations, recommendations, etc)

# Appendix 2

NOS Cartographic Codes and Symbols

No longer in use. All data now uses S-57 attribution.

# Appendix 3

NOAA Form 76-35A
Descriptive Report Cover Sheet

**NOAA** FORM 76-35A

**U.S. DEPARTMENT OF COMMERCE**
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

## DESCRIPTIVE REPORT

*Type of Survey*

*Field No.*

*Registry No.*

LOCALITY

*State*

*General Locality*

*Sublocality*

CHIEF OF PARTY

LIBRARY & ARCHIVES

DATE

# Appendix 4

NOAA Form 77-28
Descriptive Report Title Sheet

NOAA FORM 77-28
(11-72)

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

REGISTRY No.

HYDROGRAPHIC TITLE SHEET

**INSTRUCTIONS** – The Hydrographic Sheet should be accompanied by this form, filled in as completely as possible, when the sheet is forwarded to the Office.

FIELD No.

State ______

General Locality ______

Sub-Locality ______

Scale ______ Date of Survey ______

Instructions dated ______ Project No. ______

Vessel ______

Chief of party ______

Surveyed by ______

Soundings by echo sounder, hand lead, pole ______

Graphic record scaled by ______

Graphic record checked by ______ Automated Plot ______

Verification by ______

Soundings in fathoms feet at MLW MLLW ______

REMARKS: ______

NOAA FORM 77-28 SUPERSEDES FORM C&GS-537

U.S GOVERNMENT PRINTING OFFICE: 1976-665-661/1222 REGION NO.6

# Appendix 5

NOAA Form 76-40
Nonfloating AIDS or Landmarks for Charts

No longer in use.

# Appendix 6

Abstract of Times of Hydrography
For Smooth Tides or Water Levels

Project:OPR-P385-KR[1]Registry No.: H-xxxxxx[1]

Contractor Name:Date:

Sheet Letter: [1]

Inclusive Dates: [2]

Field work is complete.

| Day[3] | Time (UTC) Start[4] | End[4] | Year |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

[1] Project Number, Registry Number, and Sheet Letter from SOW or Hydrographic Survey Letter Instructions.

[2] Dates of the first and last days of data acquisition.

[3] Day of the year (e.g. April 30, 1998 = 120).

[4] Start and end times of hydrography for the day.

# Appendix 7

## Example
## Request for Smooth Tides/Water Levels Letter

TO: NOAA, National Ocean Service
Chief, Requirements and Engineering Branch
SSMC4, Station 6515, N/CS41
1305 East-West Highway
Silver Spring, MD 20910-3281

FROM: <Hydrographer>

SUBJECT: Request for Approved Tides/Water Levels

Please provide the following data:

1. Approved Tides/Water Level Note
2. Final Zoning in MapInfo format (or the Hydrographer may request the data in ArcView format)
3. Six Minute Water Level Data posted to CO-OPS web site.

Transmit the data to:
<Insert hydrographer's name and shipping address>

These data are required for the processing of hydrographic survey:

Project: OPR-xxxx-KR
Registry Number: H-xxxxxx
Sheet Letter: A
Locality: xxxxxxxxxxxxxxx

A progress Sketch or chartlet showing the survey area and Abstract of Times of Hydrography are attached.

Tide/water level data are required within 45 days of this receipt. If this schedule cannot be met, please advise HSD Operations at 301-713-2702 x112.

# Appendix 8

Standard Depth Curves

No longer in use.  The S-57 Feature File does not include contours.

# Appendix 9

Example #1
Danger to Navigation Report

REPORT OF DANGERS TO NAVIGATION

Hydrographic Survey Registry Number: H10895

| | | |
|---|---|---|
| Survey Title: | State: | CALIFORNIA |
| | Locality: | SAN FRANCISCO BAY |
| | Sublocality: | 3.5 NM SSE OF YERBA BUENA ISLAND |

Project Number: OPR-L304-KR-99

Survey Date: July 3, 1999 – July 12, 1999

Features are reduced to Mean Lower Low Water using predicted tides and are positioned on NAD 83.

Charts affected: 18649 60 th Edition/Sept.19, 1998, scale 1:40,000, NAD 83
18650 49 th Edition/May 01, 1999, scale 1:20,000, NAD 83

DANGER TO NAVIGATION

Shoaling was found in an area bounded by:

| LATITUDE(N) | LONGITUDE(W) |
|---|---|
| 37/46/28 | 122/20/26 |
| 37/46/23 | 122/20/43 |
| 37/43/42 | 122/19/28 |
| 37/43/40 | 122/19/43 |

As a result, both the 36-foot contour and the 30-foot contour have shifted to the west between .08 nm and .25 nm. Significant soundings defining these contours are as follows:

| DEPTH (FT) | LATITUDE(N) | LONGITUDE(W) |
|---|---|---|
| 36 | 37/45/31 | 122/20/20 |
| 36 | 37/45/14 | 122/20/10 |
| 36 | 37/44/21 | 122/19/43 |
| 36 | 37/43/55 | 122/19/35 |
| 28 | 37/45/32 | 122/20/07 |

Questions concerning this report should be directed to the Chief, Pacific Hydrographic Branch at (206) 526-6836.

(NOTE: This Example should be used with the graphic in Example #2 of this Appendix.)

# Appendix 9

Example #1
Danger to Navigation Report

REPORT OF DANGERS TO NAVIGATION

Hydrographic Survey Registry Number: H10851

| | | |
|---|---|---|
| Survey Title: | State: | TEXAS |
| | Locality: | GULF OF MEXICO |
| | Sublocality: | 15 NM SSE OF GALVESTON |

Project Number: OPR-L304-KR-99
Survey Date: July 10, 1999 - July 29, 1999

Features are reduced to Mean Lower Low Water using verified tides and are positioned on NAD83.

Charts affected: 11323 55th Edition/July 5, 1997, scale 1:80,000, NAD 83
11330 11th Edition/September 30, 1999, scale 1:250,000, NAD 83

DANGERS TO NAVIGATION

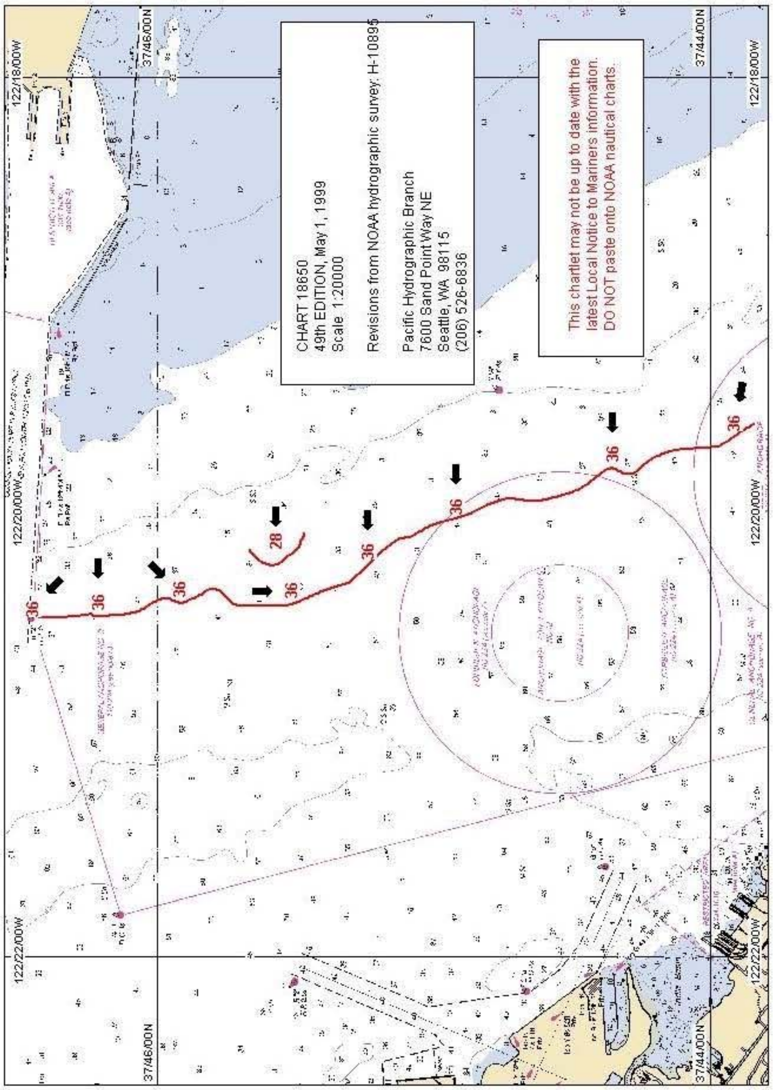
| FEATURE | DEPTH (FT) | LATITUDE(N) | LONGITUDE(W) |
|---|---|---|---|
| Shoal | 25 | 29/45/31 | 094/20/20 |
| Obstruction | 31 | 28/45/14 | 094/20/10 |
| Wreck | 39 | 29/44/21 | 094/19/43 |

Buoy R “2" which is charted at 29/30/15N, 094/23/35W, was not found at its charted location. The current position of buoy R “2" is 29/28/35N, 094/21/10W. The purpose of buoy R “2" is to mark the northeast entrance into the Galveston Ship Channel.

Questions concerning this report should be directed to the Chief, Atlantic Hydrographic Branch at (757) 441-6746.

## Appendix 9
## Example #2 (Con't)

## Chartlet to Accompany Danger to Navigation Report



# Appendix 10

## Data Acquisition and Processing Report

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE

**Data Acquisition & Processing Report**

*Type of Survey* Hydrographic

*Project No.* OPR-O327-RA

*Time frame* March - April 2000

**LOCALITY**

*State* Alaska

*General Locality* Northern Clarence Strait

**2000**

**CHIEF OF PARTY**
CDR Daniel R. Herlihy

**LIBRARY & ARCHIVES**

DATE