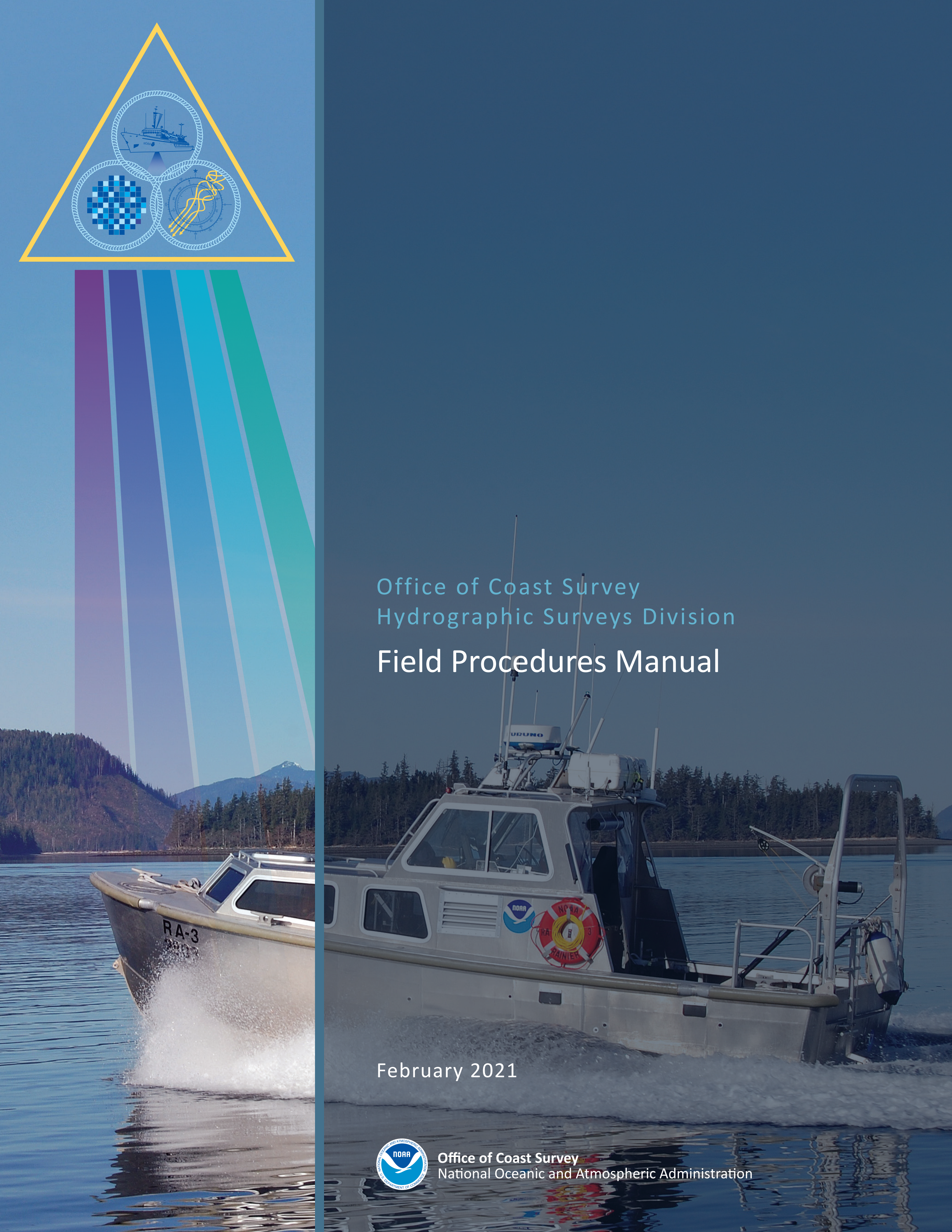

Office of Coast Survey
Hydrographic Surveys Division

Field Procedures Manual

February 2021

Office of Coast Survey
National Oceanic and Atmospheric Administration

FOREWARD:

The frequency with which a chart changes depends on the weather, tides, and the physical population of an area. The field of hydrography is similar in evolution with changes driven by environmental challenges and its physical inhabitants. Fortunately, hydrographers who staff and support National Oceanic Atmospheric Administration (NOAA) Field Units are the physical populations who drive change. They are led by questions, a desire to learn more about a method, and wanting to better identify how to optimize a process or capitalize on new technology.

Hydrographic change is driven by our coworkers and colleagues as they continue to reevaluate the standards we use to collect, analyze, and apply data. Our data are being used in more ways than imaginable by our predecessors as the quest continues to learn as much about the seafloor as we possibly can. Without standards of data collection, we have nothing to deviate from.

The goal of the Field Procedures Manual (FPM) is to provide NOAA field units with a set of standardized guidelines and best practices for conducting, processing, and generating final deliverables. This FPM has received a major revision from the one released in 2014 and will be adopting a new collaborative format before the 2021 field season to keep up with further changes. NOAA field units drive the changes to better enhance our products. Modernizations do not start with silence, and we are inviting the field units to contribute to future editions and continual development.

Future FPMs will require more than periodic maintenance. To ease this change, the document will be released on a digital interactive page. This will allow users to navigate between topics with a simple click. Additionally, a digital version will allow our field units to better contribute, edit, and share methods to the data collections standards outlined in this manual.

The benefits of hydrography can be seen daily in its contribution to the nation's economy, maritime defense, marine and environmental science, tourism, and recreational activities. This list has grown since explorers started charting the coastline, and I imagine hydrography will continue to deserve greater attention than it has previously. Together, we can continue to develop the best practices to serve and contribute to national and worldwide needs.

Any mention of a commercial company or product within this manual does not constitute an endorsement by NOAA. The use for publicity or advertising purposes of information concerning proprietary products or software or the tests of such products is not authorized. Any new procedures put into effect will be implemented via a Hydrographic Surveys Technical Directive.

Respectfully,

Richard T Brennan

Captain Richard T. Brennan
Chief, Hydrographic Surveys Division

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1 Chapter 1: Systems Preparation & Maintenance

NOAA uses a wide array of systems, tools, and procedures to perform modern hydrographic surveys. Because of the variety of equipment and highly technological nature of operations, a consistent, well-documented program of systems' preparation and quality assurance is essential to ensure that NOAA's hydrographic field units are capable of producing data to meet Office of Coast Survey (OCS) specifications. These procedures can be broken down into two categories: the Hydrographic Systems Readiness Review (HSRR) and the Periodic Quality Assurance.

1.1 Hydrographic Systems Readiness Review

Hydrographic Systems Readiness Review (HSRR) is an annual series of calibration, maintenance, and verification procedures conducted by the field unit prior to a field season. Each field unit should schedule an adequate period for HSRR; typically, it is done during winter import for ships. During this time, survey systems will undergo annual calibration, maintenance, and verification procedures. These procedures should also be performed following any significant period of inactivity and after major changes or upgrades to a field unit's hydrographic systems.

HSRR should be conducted and documented by field unit personnel; however, at a field unit's request, a representative from Hydrographic Surveys Division (HSD) or Hydrographic System Technology Branch (HSTB) may be sent to provide technical support.

The primary purpose HSRR is to officially document and inform OCS senior-level management of a field unit's level of readiness to perform hydrographic surveys that will meet OCS specifications. This process also allows field units to identify any deficiencies that will prevent optimal performance and production throughout the field season. These deficiencies may include such items as damaged or unreliable equipment, unmet training needs, and personnel shortages. Formally documenting field unit requirements in the HSRR memo will better prepare OCS to provide support and meet the needs of NOAA's hydrographic fleet.

1.1.1 HSRR Memo

NOAA field units should submit the results of their HSRR in the form of a memo within 10 working days after competition of HSRR. This memo should outline the status of all hydrographic systems and list any identified deficiencies. Additionally, a plan to address each problem and any modifications or restrictions in operations that will be necessary in the interim must also be identified. Each deficiency should be identified in three categories.

Category One identifies deficiencies that indicate the failure or absence of mission essential equipment and skills required for upcoming projects. This includes any systems that the NOAA field unit was not able to operate as part of HSRR because of time, equipment, or personnel limitations. Items addressed here are essential to the acquisition and/or processing of hydrographic data for each survey platform unit from the ship, hydrograph survey launch, and unmanned systems. Some examples can range from complete system crashes to the failure of a cable. A list of tests performed on critical systems should be included in this section. A test not performed on a platform or a system should be indicated with red text.

Category Two should identify areas of non-compliance with established policies, directives, instructions, or accepted hydrographic practice not serious enough to be addressed in category one. Deficiencies provided in these categories, if not addressed, could cause the field unit to cease or to severely limit its hydrographic survey operations. Items in this category should be corrected at the earliest opportunity as funding, time, training, and professional assistance allow.

Category Three identifies observations that came up during HSRR that require corrective action. Items included in this section serve to identify specifics in need of review or further discussion to improve operational efficiency. This is to call attention to acquiring specific resources for the field unit. The items included in this section are needed to sustain the efficient operation, upkeep, and repair of the field unit's hydrographic systems.

NOAA field units should submit a zipped submission folder to the HSTB archive within 10 working days after competition of HSRR. Included in the compressed folder should be:

- The various Vessel HIPS Vessel Files (HVFs) for MBES & SSS systems

- Zipped export of Hypack configuration settings per platform

- Excel Offset report, generated by Pydro Explorer's Charlene: Offset Report Tool

- Version number of hydrographic systems (as applicable)
  - Applanix POSView, POSPac
  - Hypack
  - CARIS: HIPS and SIPS, Notebook, Base Editor
  - Pydro Explorer
  - FMGT
  - SonarPro
  - Kongsberg SIS
  - Castaway

- Patch Test files:
  - Planned line files
  - Bathymetric surface (.bag) from data

- Reference Surface file:
  - Bathymetric Surface (.bag)
  - POS M/V (*.000)
  - Individual sonar file (*.all, .r2s, .HSX)

- A complete Built-In Self-Test (BIST) while the vessel is not moving through the water.

A digitally signed HSRR memo should be sent to ocs.hsrr@noaa.gov. Files should be named using the following format <UNITNAME_HSRR_MMDDYYYY.pdf>. For additional HSRR memos, add Addendum or Amendment <UNITNAME_HSRR_Adendum1_MMDDYYYY.pdf>.

The HSRR memo should also be sent to the following people:

A. Chief and Deputy Chief, Hydrographic Surveys Division (HSD)
B. Chief and Deputy Chief, Navigation Services Division (NSD)
C. Chief, Atlantic Hydrographic Branch (AHB)
D. Chief, Pacific Hydrographic Branch (PHB)
E. Chief, Navigation Response Branch (NRB)
F. Chief, Hydrographic Systems Technology Branch (HSTB)
G. Field Support Liaison - East/West Coast, HSTB
H. Technical Advisor, Hydrographic Surveys Division (HSD)
I. Technical Director, Office of Coast Survey (OCS)
J. Chief, Coastal Survey Development Lab (CSDL)

1.1.1.1 Hydrographic Systems Readiness Acknowledgment

Within 10 working days of receiving the Hydrographic Systems Readiness Review Memo, the Chief of HSD or Chief of NSD should formally acknowledge receipt via digital memorandum to the field unit's Chief-of-Party with a copy sent to here. This memorandum of acknowledgment should also state OCS acceptance, qualified acceptance, or rejection of the field unit's hydrographic systems readiness. If systems readiness is partially accepted or rejected, the memorandum should list any specific actions required by OCS for the field unit to meet data quality standards.

1.2 Periodic Quality Assurance

Periodic quality assurance refers to any additional procedures required by OCS to maintain or verify continued data quality between annual Hydrographic Systems Reviews. These procedures vary by equipment type and are generally performed on a scheduled basis throughout a unit's field season. Specific requirements are organized by system type and defined in this chapter.

1.3 Hydrographic Systems Inventory

The Hydrographic Systems Inventory is a critical element of systems' documentation for both HSRR and changes occurring throughout a unit's field season. Preparation and maintenance requirements will vary, typically by survey system category and type. Field units are encouraged to assess their systems to determine areas for improvement. Any new procedures or products to collect or develop efficient hydrographic data should be used in consultation with HSD and HSTB.

A system inventory should be completed with each Hydrographic Systems Readiness Review. Field units are to maintain and keep an up to date inventory of the vessels, hardware, and software systems used to collect hydrographic data. The inventory should capture changes that occur throughout the field season such as major software, firmware, vessel, and system updates. Each field unit may use a digital inventory that works best.

1.3.1 Basic Methods and Documentation

Each field unit should complete and maintain a digital Hydrographic Systems Inventory addressing the three systems categories recorded in the format described below:

- Vessels: Include all vessels to be used for hydrographic data acquisition. For new vessels or platform types not commonly used in OCS hydrography, additional descriptive information with diagrams and/or pictures should be included.

- Hardware Systems: Include all hardware systems such as sonar, horizontal and vertical control, sound speed, laser, computer stations, and so on to be used to acquire hydrographic survey data.

- Software Systems: Include all software and versions to be used to acquire or manipulate hydrographic survey data.

As this inventory will typically change throughout the field season or surveying period, the Hydrographic Systems Inventory should be updated as changes occur and submitted as part of the Data Acquisition and Processing Report (DAPR) for each project. The DAPR is a cohesive document created (or updated) during the HSRR by the field units. It details all the systems, vessels, processes, and equipment used by the field unit during data collection and processing. Before the field unit's first survey project, the DAPR should be sent to the Chief of HSTB. More direction on the information that should be included in the DAPR can be found in the HSSD.

1.3.1.1 HiBase (Hydrographic Inventory Database)

OCS has further established a standardized hydrographic system database, HiBase, which may be used for recording this inventory. HiBase is intended to serve as a centralized database that retains and archives all vessels and hydrographic hardware and software used fleet-wide. HiBase can also be used to track the history of a piece of equipment, including when and if it were sent back to the manufacturer, sent to another field unit, or swapped to another vessel within the field unit. Field units are free to use any method they see fit to meet this requirement; however, HiBase is a purpose-made utility for this objective. Field personnel may register for a HiBase user account here.

1.4 Vessel

Vessels are the most fundamental systems in hydrography. Accurate measurement of the dimensions and dynamic parameters of these platforms is essential to obtain high-quality survey data. Vessel "calibration" consists of measuring and estimating uncertainty for static parameters such as the physical positions of instruments and equipment on a vessel as well as dynamic parameters such as waterline and dynamic draft. Information on measurement, verification, and documentation of static and dynamic parameters will be addressed throughout this section.

1.4.1 Vessel Static Offsets

Static offsets of a vessel and its instrumentation are measured to establish a local reference frame to which all soundings and positions will be tied. Thus, errors in these measurements will directly translate to errors in the survey data acquired by that vessel.

Although the choice of a survey reference frame is arbitrary, it is generally convenient to establish a reference frame aligned with the vessel. For small boats where a full three-dimensional model may not be created, the vessel surveying process is much simpler if the vessel is removed from the water and leveled with respect to the desired reference system (e.g., if the Inertial Motion Unit [IMU] will define the reference system, level the boat with respect to the IMU). This alignment of the vessel frame with gravity will allow methods such as plumb bobs, levels, and other gravity-sensing tools to be used to measure offsets. The orientation may be defined by the face of an IMU or an independent set of axes defined using bench marks. For larger vessels, there is typically an independent reference location, commonly a granite block with inscribed axes, used to define the origin and orientation of the surveyed reference frame. When a professional survey is conducted, reported coordinates and orientations of relevant equipment should also be requested in equivalent reference frames defined by the sonar system and IMU origins. Different hardware and software vendors utilize different reference frames, and do not use the same x, y, z conventions. For assistance translating and rotating field surveyed reference frames, contact the regional HSTB Field Support Liaison.

The following items should be positioned as part of any static offset survey conducted for an NOAA hydrographic survey platform:

- Permanent Bench Marks: Bench marks should be sufficient in number and position to maintain the vessel reference frame if instrumentation is altered.

- Sonar Transducers: All single beam echo sounders, multi-beam echo sounders, and hull-mounted side-scan sonar that may be used to acquire hydrographic survey data should be positioned. Transducers mounted on poles, levers, or other movable mounts should be surveyed in their fully deployed position. Offsets should be measured to a central point on the transducer face (software later adjusts this to the phase center) to the phase center or the origin of the sonar's local reference frame. OCS recommends also documenting measurements to a nearby permanent mounting point for reference if the sonar head must be removed or replaced. Consult the corresponding manufacturer's documentation for further guidance on the location of transducer phase centers.

- Global Navigation Satellite System (GNSS) Antennae: All survey system GNSS antennas should be positioned. This includes any GNSS antennas integrated with differential beacon receivers and typically used only for differential corrections, although they could be used to acquire complete survey position data. Antennas only capable of receiving differential correctors do not need to be surveyed. Offsets should be measured to a reference point on either the antenna or its base (preferably a punch mark on the base) and corrected to the phase center of each antenna. Consult the corresponding manufacturer's documentation to determine the phase center location of a specific antenna type. OCS recommends also documenting measurements to the permanent mounting post for reference if the antenna must be removed or replaced.

- Inertial Measurement Unit (IMU): For all vessels equipped with a POS MV system, measurements should be made to the origin of the POS MV IMU's local reference frame. The manufacturer's documentation will define the IMU's local reference frame and identify its origin.

- Reference Point (RP): A RP should be established and positioned for each vessel. This point will define the origin of the local vessel reference frame to which all survey data will be tied. Ultimately, the identification of a reference point should follow manufacturer recommendations. OCS strongly recommends that a vessel's RP be established at the transducer's phase center when possible. On vessels with more than one sonar system, placing the RP at the sonar system's reference point can complicate downstream workflows. Vessels equipped with a POS MV system can place the RP and vessel reference frame coincident with the origin of the IMU's reference mark. In both configurations, by collocating at least two reference frames, the number of physical offset measurements required will be reduced, thus minimizing sources of error in position and attitude data.

- Center of Motion (CM): A CM should be defined and positioned for each vessel. A true “center-of-rotation” does not exist for a vessel in a seaway. However, many motion systems, including the POS MV systems in use in the NOAA fleet, have a field to designate a “center-of-rotation.” This is the point at which the heave-filters are applied, so this point will have a zero-average heave value. The dynamic draft must be defined at this point. For most field units, having the center of rotation coincident with the reference point is the simplest solution.

- Tow Point: If the vessel is equipped to perform towed sonar operations, the tow point should be positioned. The position of the tow point is defined as the last point of contact between the tow cable and the vessel, typically the top of a sheave over which the tow cable is led. If the sonar is towed from a movable point (e.g., J-arm, A-frame), it should be in its fully deployed position for this measurement.

- Draft Marks: Or other marks necessary to tie the static waterline to the vessel frame.

1.4.1.1 Full Survey

The goal of a full survey is to establish a completely new three-dimensional local vessel reference frame that is independent of any prior vessel surveys conducted. Information from existing surveys should not be incorporated into any full survey.

A full survey of a hydrographic vessel is required when no prior survey exists or under any circumstances where all previous surveys are determined to be unusable. Circumstances where a full survey could be necessary include the following:

- A vessel is new or will be engaged in hydrography for the first time.

- Significant modifications have been made to the vessel since the last full survey.

- New equipment is installed, or existing equipment is repositioned (especially the IMU), and the items cannot be accurately referenced to bench marks from a prior survey.

- New technology or techniques become available that would significantly increase the accuracy of offset measurements or error estimates for the vessel.

- Complete documentation of the previous survey, including offset values, error estimates, and procedure descriptions, is not available.

- Blunders or unexplained discrepancies are discovered when verifying the results of a previous offset survey.

- The vessel is involved in an incident such as a grounding that has altered the positions of bench marks and instrumentation affecting the validity of the previous survey.

Full vessel surveys should be conducted by the National Geodetic Survey (NGS) personnel or an appropriately qualified professional surveyor. Full vessel surveys can be both time consuming and expensive; thus, proper documentation is important to preserve the value of this work.

The following items should be considered when conducting a full survey:

- Accuracy Requirements: OCS has not defined specific numerical values for required offset measurement accuracy. However, uncertainties introduced in the offset measurement process will be combined with errors from other sources to produce a final Total Propagated Uncertainty (TPU) for each sounding. Measurement errors must be accurately estimated and small enough for vessel data to meet OCS survey specifications. Some integrated position and attitude sensors in use on NOAA platforms, such as the Applanix POS MV, do have specific accuracy requirements for offset measurements between system components during installation. Hydrographers should review the manufacturer's documentation for any system-specific requirements. They should also reference the Multibeam Advisory Committee's "Recommendations for Reporting Vessel Geometry and Multibeam Echosounder System Offsets," available here.

- Bench Marks: Bench marks are permanent, known positions on the vessel used to identify the established local reference frame. They may be existing points, such as antenna posts or well-defined features of the vessel, or monuments specifically created or installed for the survey. Examples of monuments are punch marks, scribe marks, and survey disks. Hydrographers should avoid establishing vessel reference frames consisting of bench marks of impermanent features. The following two factors should be considered when selecting or installing bench marks:
    1. Permanence: Bench marks should be permanent features affixed to the vessel's hull or superstructure. Instruments are typically not appropriate bench marks because of their potential to be moved. If points such as sensors, antennae, or transducers are used as bench marks, the reference frame may be invalidated if the equipment is removed, replaced, or relocated.
    2. Accessibility and Location: Bench marks should be established in locations that are protected but can be readily accessed for future surveys. OCS strongly recommends establishing bench marks near hydrographic instruments such as transducers and antennae to allow sensors to be accurately reintegrated into the network if they are moved. Because these bench marks are used to hold a three-dimensional reference frame on the vessel, three bench marks should be readily accessible from each instrument location to accurately position sensors regardless of vessel attitude.

- Selection of a Reference Point: Every bench mark network must have a defined origin (i.e., a reference point) for the local reference frame. OCS recommends locating this point at the transducer head or a centrally located, durable, and permanent mark.

- Error Estimation: Accurate error estimates for a vessel survey are as important as the offset measurements themselves. While specific sources of error are inherent to each method of survey, the following common factors affect the accuracy of all vessel offset surveys.

- Setups: This refers to the number of individual measurements required to compute the relative position of two bench marks and the actual number of times the surveyor's instruments must be set up to complete the measurement. Multiple setup measurements use intermediate points as temporary bench marks between the two desired points. Physically positioning the measurement instrument on or over a bench mark or another reference point is a possible source of error, so multiple setups can increase the measurement error between two points. Hydrographers should attempt to minimize the number of setups required between bench marks and record the number of setups for each leg of the survey.

- Redundancy: If possible, the hydrographer should arrange the survey such that no bench mark is tied to the rest of the network by only one measurement. Ideally, each bench mark should be tied directly to multiple other bench marks. In cases where vessel layout makes this impractical, multiple measurements along the same leg may be useful. These additional data can be used to improve the accuracy of positions generated by the survey. While redundant positions can simply be averaged, a more accurate method of determining a final value is to combine measurements using a least-squares algorithm.

- Total Error: When estimating the total error for one leg of a vessel offset survey, individual measurement errors are combined using a root sum squared method rather than simple addition. For example, in the case of a two-setup measurement, the final error estimate for the leg would be computed as follows:

$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2}$$

  Where σ is the standard deviation of the total measurement, and σ_1 is the standard deviation of the measurement from the first bench mark to the temporary bench mark, and σ_2 is the standard deviation of the measurement from the temporary benchmark to the second benchmark.

1.4.1.2 Partial Survey

A partial vessel survey should be conducted if minor changes have been made to the vessel configuration, but the most recent full survey has not been rendered obsolete. Partial surveys are typically appropriate when equipment is removed and replaced or repositioned on a vessel without disturbing the network of permanent bench marks. In such cases, the new position of the instrument can be determined by surveying its position relative to the undisturbed marks. The original survey should then be updated and thus remain valid. Partial surveys are significantly less time-consuming than full surveys but are only valid if bench marks installed as part of the original survey remain undisturbed. When in doubt as to whether a new full survey is necessary or a partial survey is sufficient, field units should complete a full survey of the vessel.

Partial surveys are identical to full surveys but on a much smaller scale. The same rules and considerations described for full surveys apply to partial surveys. Because measurements are typically made over short distances and require few setups (assuming bench marks have been installed near instrumentation as recommended), high accuracy can often be achieved with traditional survey methods. However, advanced methods may provide a more accurate estimate for measurement error.

1.4.1.3 Verification Survey

Verification surveys are conducted to check the validity of pre-existing full (or combination of full and partial) surveys when no changes to the vessel's configuration have occurred. This is the minimum survey required as part of HSRR and so should be conducted at least annually. The purposes of a verification survey are to review the offsets, error estimates, and documentation of the prior survey, and to check for measurement blunders, vector algebra mistakes, sign errors, and so on.

Verification surveys can be viewed as a "sanity check" of the existing survey data and may be conducted using basic methods. Typical procedures consist of pulling steel tape between bench marks to verify the offset values and rechecking the vector algebra to confirm established values. Error estimates in the original documentation should be reviewed for consistency and suitability for the vessel's current mission. Any discrepancies discovered during a verification survey may trigger a partial survey or a new full survey of the vessel.

Verification surveys are typically completed using traditional survey methods described in the following section. While these methods can produce very exact measurements, particularly on small vessels such as launches, this technique relies on the assumption that the vessel is level and true. With this method, the surveyor uses the existing planes and axes of the vessel's construction, such as the deck, doorframes, and keel lines, to establish the local reference frame. Not only can significant error be introduced if the vessel is not level and true, but it can also be more difficult to estimate error using basic methods. OCS recommends using advanced survey methods if equipment and expertise are available.

1.4.2 Methods

Basic Methods: These methods refer to conducting a vessel offset survey using tools such as steel measuring tapes, T-squares, plumb bobs, and lasers, and carpenter's levels. While these instruments can yield very exact measurements, particularly on small vessels such as launches, this technique relies on the assumption that the vessel is level and true. With this method, the surveyor uses the existing planes and axes of the vessel's construction, such as the deck, door frames, and keel lines to establish the local reference frame. Not only can significant error be introduced if the vessel is not level and true, but it can also be more difficult to estimate error using basic methods. OCS recommends using advanced survey methods if equipment and expertise are available.

Advanced Methods: These methods employ precision survey equipment such as theodolites, laser range finders, total stations, and optical levels. One advantage of using these optical techniques is that measurements are independent of the vessel's attitude and alignment. Because the surveying instrument can be positioned anywhere convenient, measurements between bench marks can often be accomplished with a single setup, thereby minimizing error. Detailed procedures for conducting vessel surveys using advanced methods have not been established by OCS. Field units desiring a full vessel survey using advanced methods should consult the regional HSTB Field Support Liaison before proceeding. Assistance using these techniques may also be available through the National Geodetic Survey (NGS) Geodetic Services Division.

1.4.3 Documentation and Reporting Requirements

The documentation required for vessel static offset surveys varies with the extent of the survey conducted. Documentation, as defined below, for static offset surveys should be maintained by the field unit and available for review during the Hydrographic Systems Reviews and at the request of OCS. Copies of documentation for all full and partial surveys should be transmitted to HSTB. The dates, basic methodology used, and responsible professional survey agency (if applicable) for vessel static offset surveys should be entered in the Hydrographic Systems Inventory. Any interim survey performed as a quality assurance check should be described in the DAPR for all associated projects.

Documentation for full or partial vessel offset surveys should include the following:

- A full description of the equipment and technique employed, including diagrams showing the positions of setups and any pertinent technical data available for the instruments used for the survey; the survey location and description of how the vessel was leveled and immobilized, if applicable, should also be provided;

- Pictures and/or diagrams showing the general arrangement of the surveyed vessel and identifying the positions of bench marks and instruments;

- An error analysis describing how the error values for each measurement were determined;

- Raw measurement data and a table of final results (including error estimates); a reviewer should be able to easily reconstruct the steps of data reduction from the information provided; and

- A copy of Vessel Reports, generated in CARIS HIPS and SIPS Vessel Editor for each resulting CARIS HIPS Vessel File (HVF).

Documentation for a verification vessel offset survey should include the following:

- A simple description of the equipment and techniques used for measurements;

- A reference to the full survey or combination of full and partial surveys that were verified;

- A copy of Vessel Reports, generated in CARIS HIPS and SIPS Vessel Editor, for each HVF that will remain in effect; and

- Notation of any discrepancies discovered in the prior survey(s) and how these items were resolved.

1.4.4 Vessel Dynamic Offsets

Dynamic offsets are those parameters of a vessel that are expected to change over relatively short periods. The primary dynamic offset is the vessel draft. A hydrographic survey vessel's draft is affected by many factors, including the vessel's loading, weight distribution, and speed through the water. These factors impact the vertical position of the sonar transducer within the water column. The loading effects are captured in the measurement of the static draft. The effect of speed on vertical motion is captured in the dynamic draft.

The static draft is the draft of the vessel at rest, fully loaded, and outfitted for surveying. This value can be affected by the amount of equipment, fuel, personnel, and other gear loaded on the vessel and is a function of the density of the water in which the vessel is operating.

"Settlement" is the purely vertical component of this vessel characteristic and is measured at the vessel's approximate center of motion.

Draft, both static and dynamic, is a critical component of traditional, water-level based datum reduction methods. A survey that relies on GNSS vertical positioning for reduction to datum will, if properly executed, be largely insensitive to draft. Some consideration of transducer draft relative to sound-speed profile may be important, so even in a GNSS controlled survey, notions of draft cannot be completely discounted.

"Squat" refers to the tendency of a vessel's stern to sink into the water as speed increases while operating in displacement mode (i.e., not on a plane). Squat typically results in a bow-up attitude, although a reverse effect may take place at higher speeds for some hull designs. Because motion sensors' echo sounders are generally not mounted directly at a vessel's center of motion, squat acts on a lever arm from the center of motion to the instrument, causing a vertical displacement of the measurement.

The effects of settlement and squat are combined into a speed-referenced table of vertical offsets known as dynamic draft. This correction will depend on the point where it is defined. The dynamic draft of a measurement made in the bow of a boat will generally be different from a measurement in the stern. The choice of a dynamic draft measurement point is largely arbitrary though it *must* correspond to the location where the heave filter is effectively applied (e.g., the “center-of-rotation” in a POS MV). For vessels without heave or trim sensors, the dynamic draft should be measured at the transducer itself.

1.4.4.1 Static Draft

As part of HSRR, a static draft should be measured across the anticipated range of loading and buoyancy conditions. At a minimum, field units should track changes in the static draft for a sufficient period to develop a statistically significant sample of values from which an error estimate can be produced. Depending on these results and the requirements of the survey, the frequency of draft measurements and updates of the HVF necessary during survey operations will vary. On some vessels, it may be necessary to measure the static drafts as often as twice a day, whereas annual measurements may be sufficient for others.
Factors influencing the frequency of the static draft measurement include the following:

- Survey Accuracy Required: If the error associated with static draft measurement is determined to be acceptable for meeting survey accuracy requirements, a single static draft value may be sufficient. This value should be the mean of multiple observations taken over a wide range of loading and buoyancy conditions for the vessel. In the unlikely need for survey accuracy requirements to increase, more frequent static draft measurements may be necessary.

- Loading Conditions: Vessels with a wide range of loading configurations will require more frequent static draft measurements than vessels with minimal loading changes. For example, many NOAA ships conduct survey operations with various loading conditions such as fuel, black/grey water, and ballast levels, which can create a difference in the vessel draft. Likewise, a hydrographic survey launch's static draft may vary noticeably with the amount of fuel loaded and the number of personnel embarked.

- Buoyancy: A vessel's static draft will vary with the density of the water in which it floats. If the vessel will be operating in waters with a wide range of densities (most strongly influenced by salinity), more frequent observation of static draft may be necessary. Additionally, water density may change significantly with the project area, making static draft determined at one location inappropriate for survey operations in another area.

1.4.4.1.1 STATIC DRAFT MEASUREMENT TECHNIQUES

The technique chosen to measure static draft may be influenced by the anticipated frequency of measurement required. For survey offsets, the draft of the reference point is needed. Examples of measurement techniques include the following.

Draft Marks on Hull: During the static offset measurement survey, the vessel's hull can be marked with vertical elevation differences from the vessel reference point. If this method is used, the hull should be marked on both the port and starboard sides in the athwart ship plane of the vessel reference point. The static draft is then determined by averaging the port and starboard readings.

Sight Tube: A more precise method for measuring the static draft is a clear plastic or glass sight tube installed in the interior of the vessel.

This method can be particularly useful in hydrographic survey launches. The lower end of the tube is connected to a through-hull fitting below the waterline (with a valve at the hull), and the top is either connected to a through-hull above the waterline or extends sufficiently high enough above the waterline to prevent flooding. The clear portion of the sight tube, where measurements will be read, should be installed directly over (or as close as possible to) the vessel’s RP and graduated for direct measurement of the waterline offset from the reference point. The static draft information is to be placed in the “waterline” entry in the CARIS HVF with apply “no” only if the waterline value is entered elsewhere such as the sonar acquisition software.

Static draft should be re-measured at whatever frequency determined necessary to meet survey specifications. However, at a minimum, the static draft should be checked against previous survey values at the start of a new project and whenever a vessel will be conducting survey operations with an atypical loading configuration. This is mainly required to account for sound speed sensor depth rather than any effect on dynamic draft.

1.4.4.2 Dynamic Draft

Dynamic draft is critical in determining how the sonar changes position as the vessel moves through the water at varying speeds. The draft of a vessel can be affected by many factors, including the number of personnel aboard, shifting equipment and weight distribution, and speed through the water. Once the vessel is outfitted for surveying, a variety of measurements at different speeds is collected to account for the settlement and squat of the vessel. "Settlement" refers to the vertical displacement and "squat" is the vessel's stern tendency to sink into the water as speed increases

Dynamic draft is a function of both hull shape and weight distribution; the influence of weight distribution is typically negligible. Thus, dynamic draft can be measured annually with the vessel in an average loading configuration. The results are combined with a range of static draft measurements for a final dynamic draft determination (Figure 1-1). The dynamic draft should be recorded with any major vessel modifications that would result in a change of weight distribution and vessel displacement.

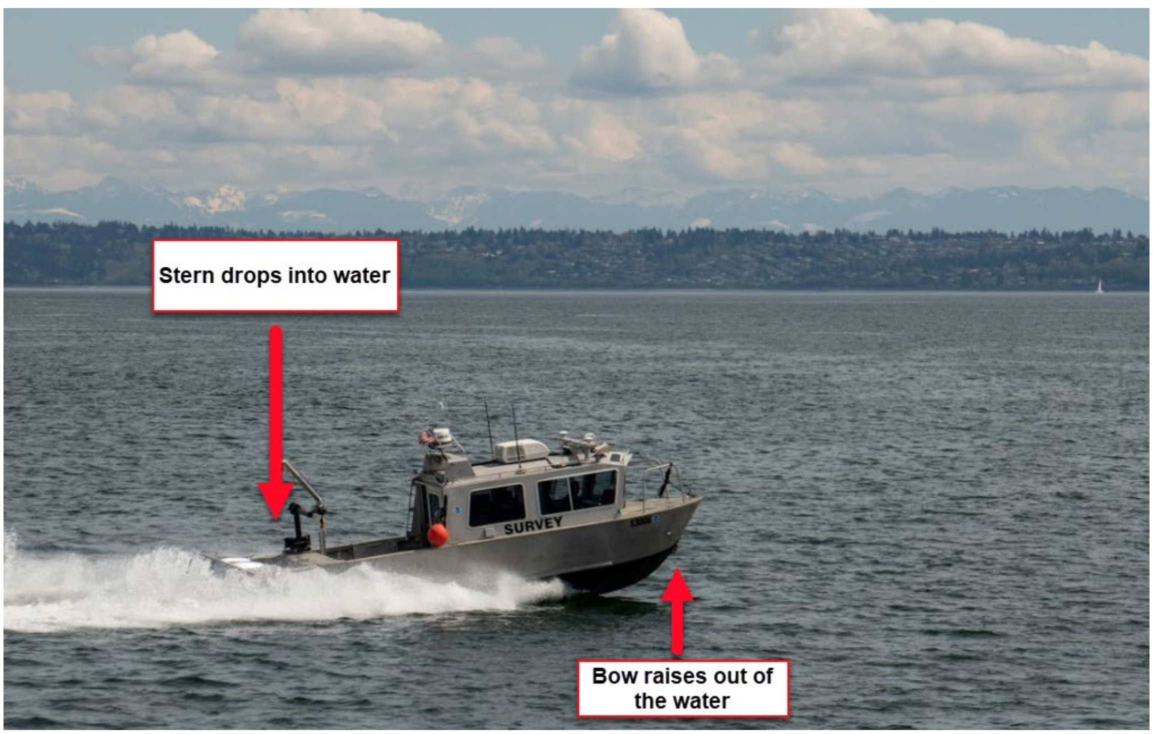


FIGURE 1-1 SQUAT AND SETTLEMENT AFFECT THE SONAR'S VERTICAL LOCATION. AS THE VESSEL INCREASES SPEED, THE SONAR'S VERTICAL POSITION LOWERS IN THE WATER.

1.4.4.2.1 DYNAMIC DRAFT MEASUREMENT TECHNIQUES

Settlement and squat are two separate parameters but can be measured together. This measurement should be performed in a body of water at least seven times the vessel draft where water level, current effects, and wave conditions will be minimal for the period of the calibration. The most common method is described below.
It is strongly recommended that field units maintain a historical log of each year's dynamic draft measurements for analysis and statistical comparison.

1.4.4.2.1.1 *POST-PROCESSED KINEMATIC (PPK) GNSS*

This technique uses the vessel's POS MV system and POSPac data acquisition and processing to measure vessel ellipsoid heights at speeds relevant to survey operations. A polynomial regression of the changes in height is used to formulate a dynamic draft table with associated uncertainties. SBET AutoQC will create a dynamic draft table during the SBET creation process by reading the SBET elevation data, adjusting for tidal water levels, and outputting graphs and tables per a 3rd- or 4th-order polynomial regression. The basic procedures are as follows:

If the dynamic draft calibration test is performed in a tidally active area, plan to perform the data analysis using a VDatum Separation model, or appropriate water level corrector (TCARI or zoned tides). It is best to avoid areas with a high slope in the ellipsoid to datum separation. Inspection of the separation model may help highlight areas to be avoided (e.g. continental shelf breaks). A spreadsheet analysis may be used, particularly in areas with negligible tides, or during a time when water level changes due to tide will be negligible.

For Best Results

- Wave conditions need to be minimal as with all dynamic draft measurements.
- Assume that the ellipsoid is relatively parallel to the water level over the area of this test. Periods of static vessel heights at the end of each line will help to confirm this assumption. If there is evidence to the contrary once data have been acquired, another area may need to be selected or another technique may need to be used for dynamic draft measurements.
- Body of water is at least 7x vessel draft.
- Vessel has a straight space to maneuver for 2-5 minutes at speed; ~2-5 nautical miles.
- POS file is logged for 5 minutes before testing.
- Run from bare steerage speed to 12 knots at intervals of 2 knots.
    - Have 1–2 minute-rest period between speed changes.
    - At end of the "line," complete testing again in an opposing direction.
    - Do *not* stop logging POS file.
- Log POS for 5 minutes post-testing.
- Provide complete written record of dynamic draft calibration fieldwork.

For data analysis, a time-series of both speed and ellipsoid heights, as well as a plot of speed versus ellipsoid heights, should be examined to ensure data quality and to look for offsets. A polynomial least squares fit regression on speed versus ellipsoid height is completed with user-preferred software, typically Pydro's POSPac AutoQC. A minimum of a third-order regression should be used. A comparison between the regression and the plotted data should be completed both through a raw plot with a regression curve and through the ellipsoid height minus regression residuals. Changes in the ellipsoid height not captured by the curve should be noted, and changes to the regression process may be needed. Take special care to note the zero speed crossing because it can result in vertical offsets in the dynamic draft table. A quantitative comparison to the previous dynamic draft values may be considered.

Once a satisfactory curve is obtained, a dynamic draft table can be created between regular speed increments and the corresponding height from the regression equation subtracting the zero speed ellipsoid height constant. Dynamic draft values should be added to the vessel's CARIS HIPS and SIPS HVF under "Draft." Uncertainty in the dynamic draft table is obtained by calculating two standard deviations of the residual data to the regression difference. If uncertainty for each speed is desired, the residuals can be binned by speed and the standard deviation calculated for each bin. Care should be taken that sufficient data exist in each bin.

Signs of the dynamic draft values placed in the Draft sensor entry in the CARIS HVF are important. CARIS expects the change in Z to be a positive down, so a sinking of the transducer creates a more shallow depth than the "true depth," and the dynamic draft value will be positive. If the vessel rises in the water, the measured depth will be deeper than the "true depth," and the dynamic draft value will be negative. Depth = Observed depth - Waterline + change in depth.

1.4.4.2.1.2 *DOCUMENTATION AND REPORTING REQUIREMENTS*

Draft offset measurement documentation is broken into two separate sections, one for static draft and one for dynamic draft measurements. All information listed below should be documented. This documentation should be maintained by the field unit and available for review during the Hydrographic Systems Readiness Review and at the request of OCS. The dates and basic methodology used to determine dynamic offset measurements should be reported in the DAPR for each applicable project. The actual frequency of static draft measurements, any significant changes to the static draft, and any subsequent changes to dynamic draft should also be included with this documentation.

Static draft measurement documentation should include the following:

- A complete description of the procedure used to determine draft;
- Location information such as vessel status (e.g., in water, on a trailer);
- Where measurements were made;
- Number of observations used;
- Final averaged static draft value and potential errors; and
- Location where the final static draft value is applied.

Dynamic draft measurement documentation should include the following:

- A description of the procedure used to determine dynamic draft;
- Chart identifying the geographical area test;
- Raw data file information;
- Final dynamic draft values, to be applied in the CARIS HVF; and
- Comparison with previous dynamic draft results if available.

1.5 Hardware Systems

Hardware systems used by NOAA field units for hydrographic survey operations consist of a variety of echo sounders and attitude sensors, and each instrument must be properly maintained and calibrated to provide quality data.

Calibration, maintenance, documentation, and reporting requirements are established by OCS for common hardware systems used by NOAA hydrographic field units. New sensors and instruments unique to only one or two field units may not be addressed in this manual. Likewise, as NOAA’s organizational expertise with existing systems continues to grow, new and improved procedures that supersede those documented here will be developed. In such cases, this section of the FPM should be used as a guide for the development, implementation, and documentation of new procedures. If a new procedure is used, it must be approved by HSTB and documented with sufficient detail for the process to be recreated.

1.5.1 Wiring Diagram

All field units should maintain up-to-date wiring diagrams for each of their survey vessels (Figure 1-2). These documents are to be submitted as an appendix within a project’s DAPR. These wiring diagrams should be reviewed and updated during the Hydrographic Systems Readiness Review process.
Typical information found in a wiring diagram may include:

- Hardware components
- IP address
- Cabling
- Ethernet switches

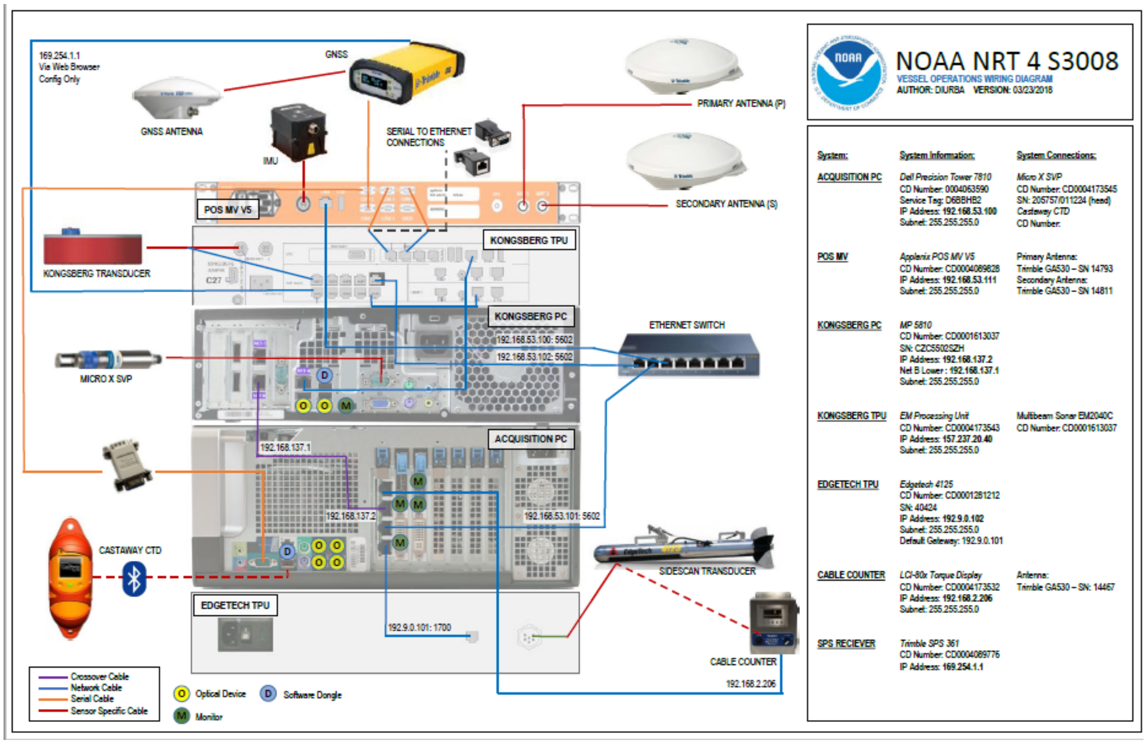


FIGURE 1-2 EXAMPLE OF A TYPICAL WIRING DIAGRAM AND ITS COMPONENTS

1.5.2 Position, Attitude, and Heading Sensors

For OCS hydrographic surveys, vessel position is typically determined using a variety of GNSS-based positioning methods, as described in the Hydrographic Survey Specifications and Deliverables (HSSD). Attitude sensors are often employed to measure a vessel's roll and pitch about its RP and any purely vertical heave action affecting the vessel. The vessel's orientation about its vertical axis (i.e., yaw) is generally determined with a heading sensor or gyroscopic compass. Attitude and heading values measured by these sensors are typically applied to sounding data during post-processing. Each of the aforementioned sensors may be stand-alone systems, or they may be integrated into a navigation system that will collectively determine vessel position, attitude, and heading.

Not all NOAA hydrographic field units may be outfitted with an attitude sensor. However, this equipment will be included on any NOAA vessel used to acquire multibeam echo sounder data. Vessel attitude must be measured and applied to multibeam data to produce accurate soundings. Single beam echo sounders (SBES) are incentive to attitude of small motions; therefore, attitude corrections are less critical for this type of data. However, CARIS HIPS is capable of applying attitude data to SBES when available.

The Applanix POS MV (Position and Orientation System/Marine Vessel), a GNSS-aided inertial navigation system, is the most common system used by NOAA hydrographic field units to measure vessel position, attitude, and heading. As such, the POS MV calibration and reporting requirements are specifically addressed in this manual. Field units equipped with alternate position, attitude, or heading sensors should contact the regional HSTB Field Support Liaison to develop approved calibration and maintenance requirements.

1.5.2.1 Applanix POS MV

The POS MV navigation system will calculate survey-quality vessel position, heading, and attitude data. Primary system components consist of a processing unit, two GNSS antennas, and an inertial measurement unit (IMU), which is typically installed at the vessel's RP for NOAA configurations.

1.5.2.1.1 CALIBRATION REQUIREMENTS AND METHODS

At a minimum, NOAA hydrographic field units should calibrate the POS MV heading during HSRR. This calibration is performed with a GNSS Azimuth Measurement System (GAMS), which blends GNSS data with angular rate and acceleration data from the IMU to produce a robust and accurate full 6-degrees-of-freedom position and orientation solution. Additionally, the POS MV should be recalibrated after any IMU or antenna installations, movements, and/or modifications. The appropriate POS MV Installation and Operation Guide will contain comprehensive guidance on system operation and calibration.

If a field unit has been equipped with a Version 4 or higher POS MV system, one can perform an additional lever-arm calibration. However, this calibration should not be attempted without appropriate Real-Time Kinematic (RTK) support. Field units should contact the regional HSTB Field Support Liaison for RTK support before conducting a lever-arm calibration.

1.5.2.1.2 OFFSETS & REFERENCE FRAME CONVENTIONS

Before calibration, POS MV lever-arm distances should be entered, as necessary, and/or verified in the POS/MV controller software. Be very careful not to enter values for offsets that will be applied to data during post-processing via the HVF. If the IMU is co-located with the vessel's RP and Center of Motion (CM), the distance from the IMU to the primary GNSS antenna and the distance between GNSS antennas may be the only offsets that need to be entered in the POS MV controller software. Measured antenna separation distance must be accurate to within 5 mm per the manufacturer's specifications. Refer to the POS MV Installation and Operation Guide for additional measurement accuracy requirements and coordinate system conventions. Be certain that offsets entered in the POS MV controller software correspond to the local POS MV coordinate system, which may differ from the vessel reference frame coordinate system.

1.5.2.1.3 PERFORMING THE CALIBRATION

If the IMU is co-located with the vessel's RP and CM, the distance from the IMU to the primary GNSS antenna and the distance between GNSS antennas may be the only offsets that need to be entered in the POS MV controller software. Measured antenna separation distance must be accurate to within 5 mm per the manufacturer's specifications.

Detailed instructions for performing a POS MV calibration should be reviewed in the POS MV Installation and Operation Guide. For a successful calibration, the POS MV must have data available from 7 or more satellites and a Positional Dilution of Precision (PDOP) equal to or less than 3.0. The calibration should be performed at a time when satellite geometry is good. GNSS mission planning software can be used to identify an optimal calibration time during which the PDOP will be at a minimum.

The POS MV calibration should be conducted per Applanix instructions and SOP available from the regional HSTB Field Support Liaison.

Once a high-quality POS MV calibration has been performed, it should remain valid until system components are moved or altered. The POS MV should operate reliably provided adequate satellite coverage and differential correctors are available. If the POS MV becomes problematic, recalibration may be conducted at the discretion of the field unit. If a recalibration is desired, the same process used for the annual calibration should be repeated.

If any individual part of the POS MV is replaced or moved, a new patch test should be performed for any associated multibeam echo sounder systems.

For each calibration conducted, system settings, procedures, and results achieved should be recorded in a POS MV Calibration Report. This documentation should be maintained by the field unit and available for review during HSRR and at the request of OCS. The dates of current POS MV calibrations should be reported in the

Hydrographic Systems Inventory. All POS MV calibrations conducted should be described in the DAPR for each applicable project.

1.5.3 Sound Speed Measurement Instruments

Accurate measurements of sound speed (often referred to as “sound velocity”) both through the water column and at the water’s surface are critical to hydrography. Two basic types of sound speed instruments are currently used by NOAA hydrographic field units, those that directly measure sound speed (commonly referred to as “velocimeters”) and those that measure conductivity, temperature, and depth and then calculate sound speed (commonly referred to as “CTDs”).

All field units performing OCS surveys should proactively monitor the accuracy of sound speed-measuring instruments and conduct preventative maintenance as described below.

1.5.3.1 Calibration Requirements and Methods

All sound speed-measuring instruments employed by NOAA hydrographic field units should be calibrated per the manufacturer recommendation. OMAO field units should coordinate the calibration of instruments with their shipboard Electronics Technicians (ET). NRB field units should coordinate their calibrations with the NRB Technical Advisor, as needed.

1.5.3.2 Documentation and Reporting Requirements

Results from annual sound speed instrument calibrations (i.e., manufacturer’s documentation and the corresponding digital calibration coefficient file) should be maintained by the field unit and available for review during HSRR. The dates of annual calibrations and any instrument problems or non-routine maintenance performed should be reported in the Hydrographic Systems Inventory.

Documentation for all calibrations or maintenance conducted should be included in the DAPR for each applicable project.

1.5.3.3 Data Quality Assurance Checks

Periodic quality assurance checks should be performed for all sound speed-measuring instruments. NOAA hydrographic platforms should conduct these quality assurance checks on a daily or weekly basis, as described below. Field units with sound speed-measurement instruments not addressed in this manual should contact the regional HSTB Field Support Liaison to develop a comparable quality assurance plan.

If the vessel is equipped with a surface sound speed-measuring instrument (typically installed at the head of a multibeam sonar), compare a measurement from this instrument to the results of a full sound speed profile acquired. This comparison can be performed in Sound Speed Manager, using the “Surface Sound Speed DQA” function. All discrepancies greater than 1 m/s should be noted and tracked to determine whether the instrument requires repairs or recalibration. If the vessel has a “towing a moving vessel” profiler, this comparison can be done in real-time; however, it should be noted that in areas of dynamic water chemistry change, a false positive may result from relying solely on this comparison. Should a divergence of greater than 1 m/s be noted, the field unit should conduct a static cast to determine whether instrument drift or water chemistry changes are causing the divergence.

A full water column profile from each sound speed-profiling instrument should be compared to an independent source as needed. This comparison should be accomplished by conducting a simultaneous cast with two profiling instruments and comparing the results using Sound Speed Manager. Comparison casts should be conducted in water at least as deep as typical depths for the current project. If there appears to be a sound velocity problem with your processed data, it is important to check the physical sound velocity sensor for error sources.

1.5.4 Manual Depth Measurement Equipment

Although no longer used as a primary means of survey, lead lines are invaluable for some operations. These tools can be used to take soundings in areas too shallow for echo sounders and to verify the least depths over dangers to navigation or shoals. However, like all measuring devices, these tools have their own calibration requirements. Both lead line and sounding pole requirements are addressed in this section.

1.5.4.1 Calibration Requirements and Methods

All field units engaged in hydrographic surveys where general depths are less than 40 meters should carry one or more marked and calibrated lead line. Depending on the depths in which they will be used and the size of the vessel, OCS recommends that lead lines are 30–60 meters long. Each lead line should be marked with a numerical identifier to be retained throughout the life of the lead line or until re-marking is necessary.

Traditional lead line material is mahogany-colored tiller rope with a phosphor-bronze wire center. Because line and tape materials have evolved significantly and lead lines are now used in special circumstances rather than for entire surveys, it may be appropriate for alternate materials to be used when constructing a lead line. When choosing a lead line material, key properties to be considered are strength and elasticity. The line or tape must not part if deployed from a vessel underway and must not stretch significantly under tension or when wet.

All lead lines used for OCS hydrographic surveys should be graduated to at least the decimeter level. Any convenient system of marking that will minimize reading errors may be used, provided each whole meter of line is marked and identified with a clearly written numerical depth value.

Lead lines should be calibrated by comparison with a known standard during a Hydrographic Readiness Review and before each day's use if constructed with a nontraditional material. The testing standard should be a survey quality metal tape, premeasured graduation marks on deck or ashore, or similar items. If the mean correction exceeds 0.1 meter, the lead line should be re-marked, or a correction table should be referenced.

1.5.4.2 Documentation and Reporting Requirements

A Lead Line and Sounding Pole Calibration Report should be completed each time a lead line or sounding pole calibration is made or compared to a standard. Reports for calibrations conducted during HSRR should be maintained by the field unit and available for review during HSRR and at the request of OCS. The dates of current calibrations should be reported in the Hydrographic Systems Inventory. Documentation for calibrations should be included in the DAPR for each applicable project.

In addition to the abovementioned requirements, a full sounding system comparison should be completed each year as a part of HSRR, following a calibration of all sounding systems. A lead line should be used to manually acquire a standard for comparison to calculated depths from each of the field unit's single beam echo sounders, multibeam echo sounders, and diver least depth gauges. This process should be documented and included in the DAPR for each applicable project.

1.5.4.3 Periodic Quality Assurance Checks

Because of the static nature and infrequent use of manual depth measurement equipment, there are no requirements for accuracy checks other than annual calibrations. As previously stated, lead lines constructed with a non-traditional material should be calibrated before each day's use, and sounding poles created on the fly for special circumstances encountered should be calibrated before use on any OCS hydrographic survey.

1.5.5 Single Beam Systems

Single beam echo sounders (SBES), formerly known as Vertical Beam Echo sounders (VBES), can be used for water depth measurement and/or to confirm depths measured by other systems, such as multibeam echo sounders. The consistency and accuracy of single beam soundings are directly related to the care with which these instruments are calibrated, maintained, and operated. It is critical that field units both ensure these systems are properly calibrated, and operators are educated about the effects of manually adjusting the transceiver controls such as power, gain, and sensitivity.

Single beam echo sounders are typically either dual frequency or single frequency. Users should operate each echo sounder following its manufacturer's documentation. When used for OCS hydrographic surveys, SBES systems should be set with an assumed speed of sound through water of 1500 m/s. Recorded sounding data should be corrected for actual sound speed, determined with a sound speed-profiling instrument during data post-processing.

1.5.5.1 Calibration Requirements and Methods

During HSRR, the field unit should verify that SBES sounding data are accurate and that each system is in proper working order. Single-beam data should be compared to either a multibeam beam measurement or lead line as part of the HSRR. If the SBES unit is found to be out of calibration, its return to the manufacturer should be coordinated with either EEB or the NRB Technical Liaison.

1.5.5.1.1 LATENCY TEST

This test is used to solve for the delay in time between the GNSS "time tag" and the HYPACK PC time stamp. Select a well-defined slope for the test, and run at least three reciprocal lines (that is, three in each direction) across the slope while logging SBES data. Follow instructions found in the Hypack user manual for a calibration in Hypack or use CARIS HIPS & SIPS's calibration tools to determine the timing offset. Once the user has determined the final latency value, it can be entered in the offsets menu on the HYPACK device parameters, or it can be added to the navigation timing lever arm correction in the CARIS HVF file. Ensure the latency value is only entered in the HVF once.

1.5.5.1.2 BAR CHECK

A bar check is a test of SBES by placing an acoustically reflective surface at a known distance directly beneath the transducer, thereby allowing one to identify any small biases in the system and correct them accordingly (Figure 1-3).

In the case of small Autonomous Surface Vessels (ASVs) using SBES, one should do a bar check at the time of the system's acceptance and once annually. The methodology for conducting the bar check using the manufacturer-specific software can be found in their manual; however, the hardware for it will likely have to be custom-built. The image below has a general arrangement of a system that has been used in the past successfully. Contact the regional HSTB representative for more information.

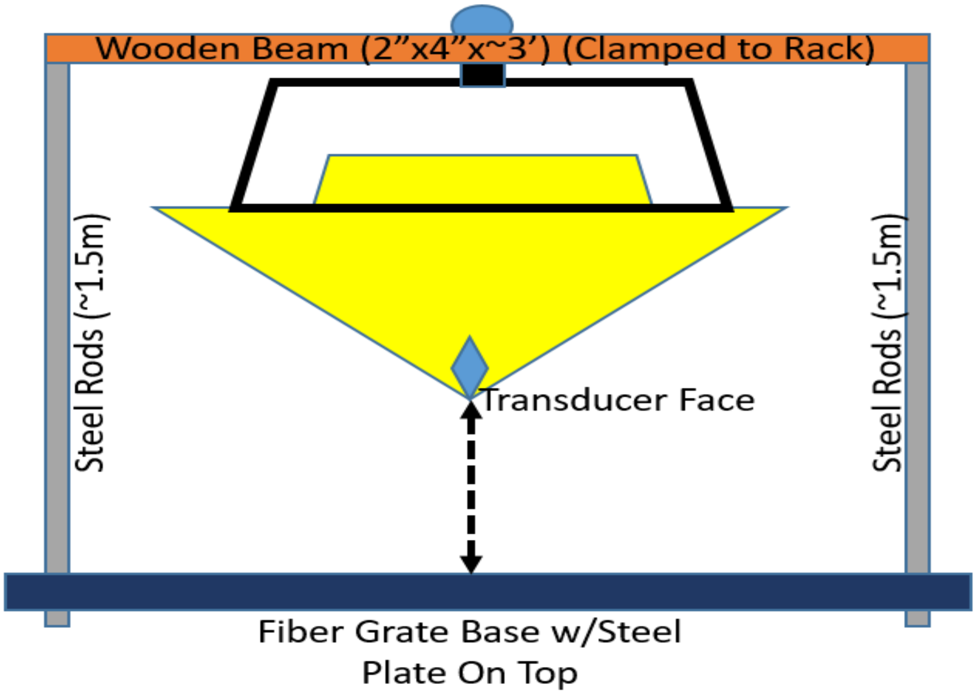


FIGURE 1-3 A GENERAL ARRANGEMENT EXAMPLE FOR AN ASV BAR CHECK ASSEMBLY

1.5.5.1.3 DOCUMENTATION AND REPORTING REQUIREMENTS

Results of SBES calibrations and confidence checks should be recorded in a Sounding System Comparison Log to be maintained by the field unit. Calibration records for each SBES used for hydrographic surveying should be available for review during HSRR and at the request of OCS. Sounding System Comparison Logs should be included in the DAPR for all applicable surveys.

1.5.5.1.4 PERIODIC QUALITY ASSURANCE CHECKS

For modern digital SBES systems, instrument errors are generally small, fixed in magnitude, and independent of observed depths. However, to ensure that echo sounders continue to operate properly, periodic confidence checks should be conducted. As when performing a calibration, routine comparisons should be conducted in an area with a relatively flat and hard bottom with calm sea conditions.

Any discrepancies identified between sounding systems that are greater than the allowable depth error for the corresponding survey must be investigated to determine if the equipment needs repair.

1.5.6 Multibeam Echo Sounder (MBES) Systems

NOAA's hydrographic survey units use MBES systems to acquire full- and partial-bathymetric coverage throughout a survey area and to determine the least depths over critical items such as wrecks, obstructions, and dangers- to-navigation and for general object detection.

Proper calibration of MBES systems is critical for maintaining a high level of accuracy and meeting OCS hydrographic survey specifications. Various models of swath-type multibeam sonars are used for NOAA hydrographic survey operations. In this document, these MBES systems will be treated as equivalent units unless otherwise specified.

1.5.6.1 Offset Measurement and Verification

Offsets for MBES systems need to be measured and verified as part of the vessel static offsets survey. NOAA surveys can be completed on hull, pole, or lever mounted MBES systems. Attention must be paid to the alignment of the sonar head.

Pole- and lever-mounted systems introduce potential sources for positioning error. Because these systems are deployed and then retrieved after each use, care must be taken to ensure that the sonar is both stabilized during use (e.g., via pins, guy wires) and that its deployed position does not vary. Stabilizing mechanisms should be inspected regularly for wear, stretching, or general deterioration that could affect the sonar offsets or stability.

In a lever-mounted system, the field unit should mark indexing points on the deployment lever at the time of calibration. During each deployment and recovery of the system, the operator should observe the indexing points to assess drift. If an observed drift occurs, the system should be recalibrated.

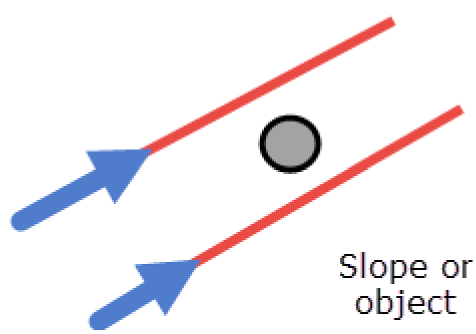
1.5.6.2 MBES Calibration

As part of the HSRR, field fields should conduct a system calibration to quantify the roll, pitch, heading, and attitude timing error for each MBES system. This procedure, commonly referred to as a "patch test," is performed by acquiring data that will highlight only one bias parameter at a time. Patch tests must also be conducted any time equipment is installed or disturbed in any way (e.g., new or swapped hardware, vessel grounding).

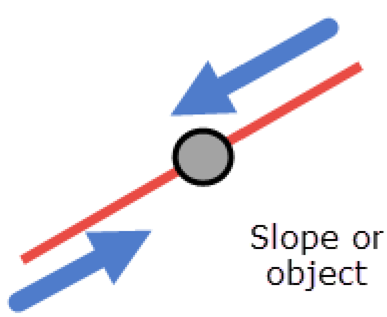
Any defined feature can be used for a patch test; a well-defined slope at approximately 10 to 20%, or more, grade will provide the best results. Wrecks can be used; however, it is strongly recommended that the wreck be well-defined to remove any possible ambiguity when processing the calibration data. Features that lie in debris fields or other cluttered areas should be avoided because of likely ambiguity.

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 motion and ensure suitable bottom detection.

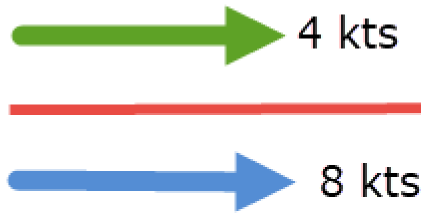
The procedure for each line set is as follows:



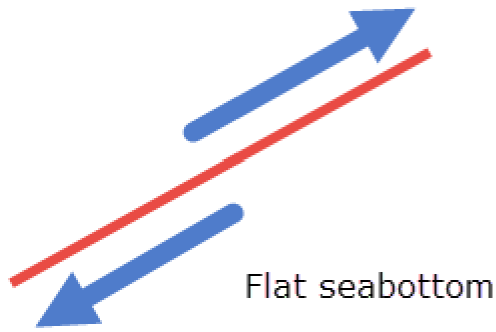
Heading/ Yaw: Run two offset lines in the same direction and speed over a steep, well-defined slope, with the outer ⅓ of the two swaths overlapping. Compare the along-track profile midway between the two lines.



Pitch: Run one line twice in opposite directions at the same speed over a steep, well-defined slope. Compare *the nadir profiles of the swaths.*



Timing: ***This test is best for finding gross timing errors, and is NOT RECOMMENDED OR NEEDED for annual HSRR or standard patch testing.*** *Timing is often referred to as latency. Run one line twice in the same direction at different speeds (one run will ideally be half the speed of the other) over a steep, well-defined slope. Compare the nadir profiles of the swaths.*



Roll: Run the same line twice in opposite directions at the same speed over a flat seafloor area. Compare the across-track profiles of the swaths.

The hydrographer should determine the biases in the following order: pitch, roll, and heading (yaw).

Processing and acquisition of bias corrector values may be done through HIPS and SIPS, Kongsberg SIS, Hypack, and other means. It is strongly recommended that the field unit use more than one means to develop its bias corrector values. There are several methods of achieving corrector values. One method is utilizing software that determines the values automatically. Another method is having three to five observers generate individual sets of values, eliminating outliers, and using quantitative methods to develop a mean value for each corrector. Additionally, one knowledgeable individual determining values and having another individual check those values. This will provide a quantifiable, verifiable patch test result that minimizes the potential for human or systematic error. Some software will automatically generate bias values, whereas other methods enable human interpretation.

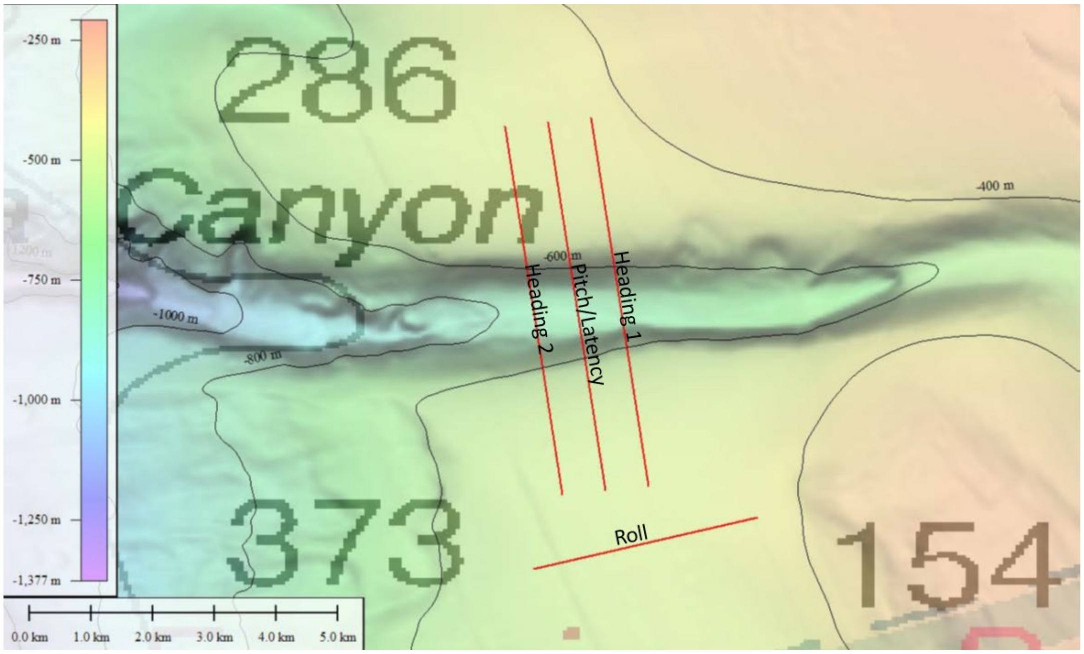


FIGURE 1-4 *A SAMPLE PATCH TEST LINE PLAN. NOTE DEFINITION OF SLOPE FOR ALL BIASES EXCEPT ROLL, WHICH IS ON A FLAT AREA. IMAGE SOURCE: PAUL JOHNSON, NSF MULTIBEAM ADVISORY GROUP*

Depending on the platform and system setup, values derived from the patch test should be entered into the CARIS HVF, POS MV, Kongsberg, Hypack, or used acquisition and processing suite. Special consideration of sign values should be taken to software specific reference frames (Figure 1-5).

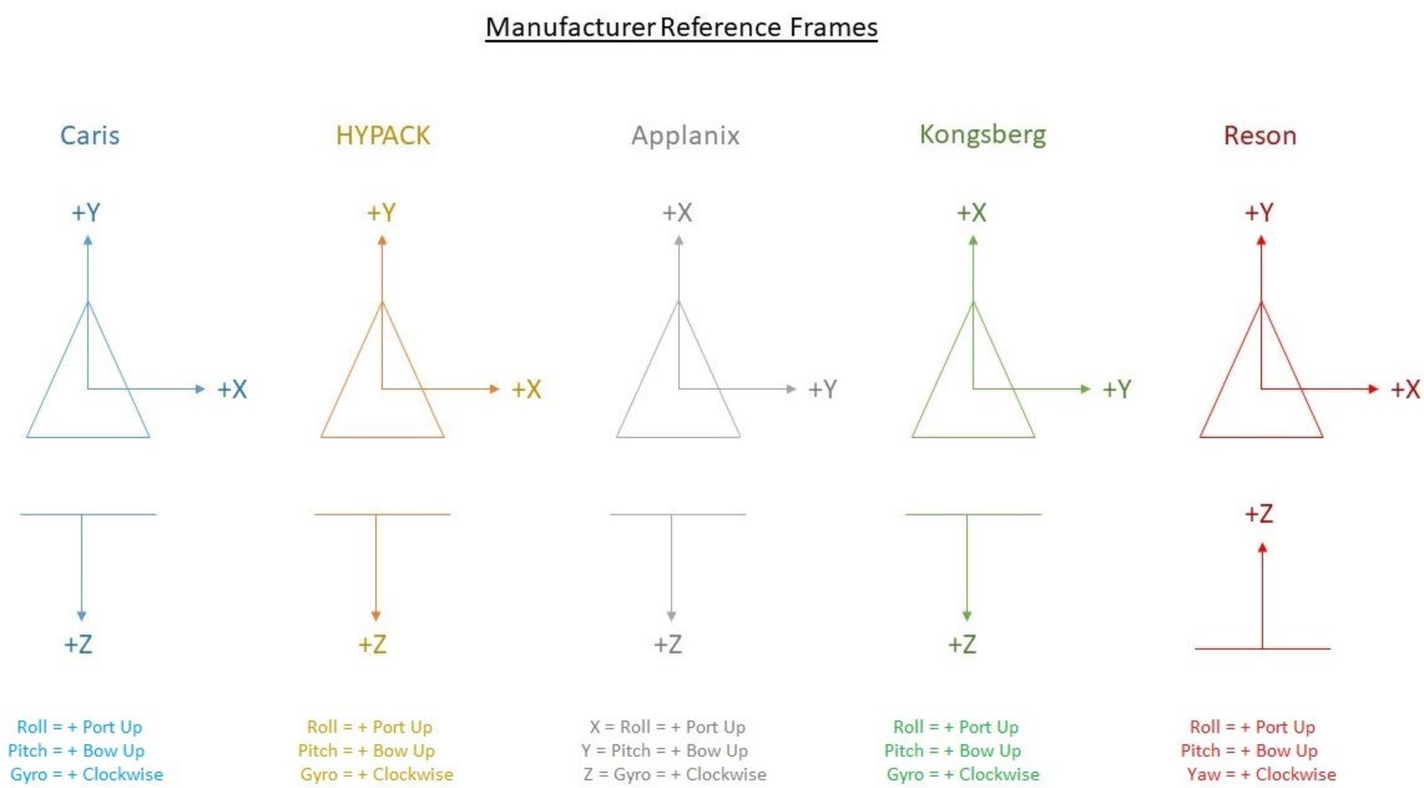


FIGURE 1-5 *COMMON MANUFACTURER REFERENCE FRAMES. SOURCE: ERIC YOUNKIN, NOAA*

1.5.6.2.1 DOCUMENTATION AND REPORTING REQUIREMENTS

Each patch test conducted should be documented in an MBES Calibration Table. In addition, a chartlet showing the test area and line plan, with line numbers and headings clearly identified, should be created for each system tested. The exact image of the chartlet is left to the discretion of the hydrographer. Calibration information should be maintained by the field unit and available for review during HSRR. Copies of patch test documentation should be submitted with the DAPR for each applicable project.

1.5.6.3 Reference Surface

A reference surface is critical to find errors from hydrographic platform to hydrographic platform. Additionally, data may be compared to historical survey data. The reference surface is completed after all sonar and ancillary instrument calibrations are completed. Field units can assess the combined effects of vessel offsets, patch test biases, and sonar bottom detection for each platform and system setup. Data and grids are collected and compared against each other for agreement. This is a capstone of the system preparation process as it combines the data from all constituent systems for an assessment of the final result.

In the event there is only one vessel and sensor, a comparison should be made with another field unit or data from previous years if possible. If there is no previous coverage readily available, a self-comparison of the reference surfaces should be conducted. Self-comparisons cannot be used to check for overall vertical biases but are useful for checking for other data anomalies.

Field units are encouraged to collaborate in establishing and using reference surfaces. Ideally, these would be located in an area to which field units could return annually or as needed with all datasets centrally archived for future comparison.

1.5.6.3.1 REFERENCE SURFACE ACQUISITION AND PROCESSING

A grid pattern should be acquired with each sonar-vessel combination for a robust comparison (Figure 1-6). Some aspects of a reference surface are:

- The grid should be planned over a relatively flat area of depth appropriate for the sonar under evaluation. (It may be helpful if the test area includes a few discrete features such as wrecks or rocks, but this is not required.)

- Survey lines should be planned for at least 100% coverage in each direction, leading to ~200% coverage over the entire grid.

- Sonars and vessels should be operated (speed, system settings) as they would ordinarily be for standard survey operations in the area.

- Settings should be the same for the comparative systems but may differ for different frequencies of the same sonar.

- All necessary data correctors such as delayed heave, sound speed, and TPU should be acquired and applied to the data.

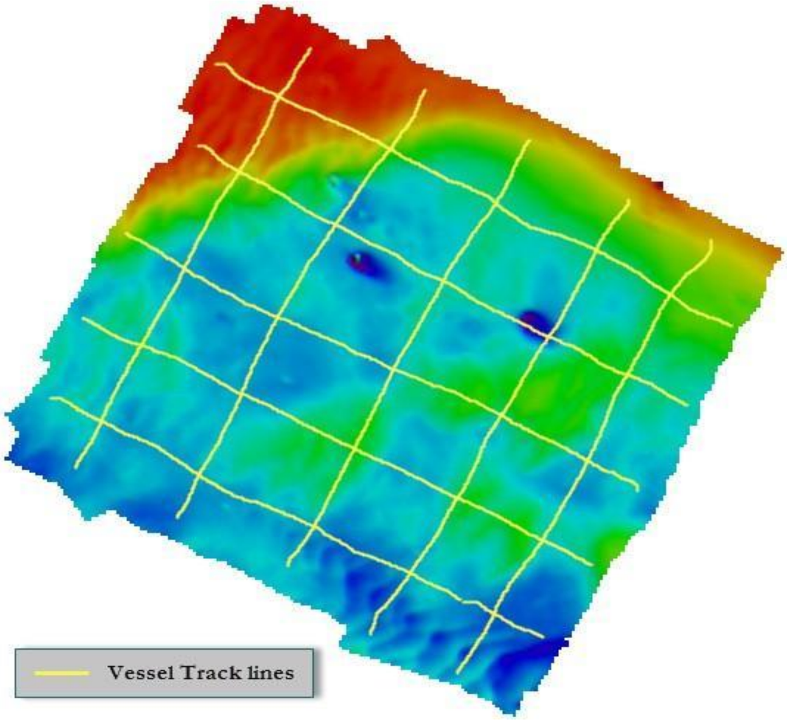


FIGURE 1-6 ***SAMPLE REFERENCE SURFACE ACQUISITION PLAN. A 200% COVERAGE SCHEME WAS EMPLOYED OVER A SITE THAT DISPLAYED A MIXTURE OF FLAT BOTTOM, SAND WAVES, AND TARGETS (BUOY BLOCKS).***

Following processing of the reference surface data, create a CUBE surface at the appropriate resolution for water depth for the reference area; complete the following steps:

- Visually check each surface for any data artifacts, especially those associated with offset issues, poor patch test values, timing errors, or incorrect motion stabilization application.
- Assess the computed total propagated uncertainty (TPU) and standard deviation of each reference surface, comparing these uncertainty estimates to IHO thresholds.
- Compute difference surfaces to compare the different vessel/sonar combinations acquired at roughly the same time (Consider performing these differences with data referenced to both tidal and ellipsoidal reference frames). Compare the difference between the estimated uncertainty for each of the comparison grids and the IHO thresholds. (This tests inter-system agreement).
- Compute difference surfaces to compare each vessel/sonar combination with previous year(s) results from the same vessel/sonar combination. (Again, consider performing these differences with data referenced to both tidal and ellipsoidal reference frames). Compare the difference between the estimated uncertainty for each of the comparison grids and the IHO thresholds.

1.5.6.3.2 REPORTING REQUIREMENTS

As the reference surface test is a capstone of the HSRR, any results which indicate concerns in the overall health of the sonar-vessel system(s) should be discussed in the HSRR Memo.

A full description of the reference surface process and results should be included in the DAPR as an attachment. The text should include the following:

- A description of the reference surface area in sufficient detail to allow other units to use the same location;

- A brief description of data acquisition and processing, including discussion of any problems encountered or non-standard procedures followed; and

- Results and a discussion of the comparison tests performed.

1.5.6.4 Backscatter Calibration

While bathymetric data between sonar instruments are typically consistent, backscatter outputs can vary significantly. The resulting mosaics of the same surveyed area will change based on sonar equipment, survey parameters, and post-processing methods. To help bring mosaics generated by multiple MBES sonars into alignment, a field backscatter normalization is performed. This provides a relative offset between mosaics generated from different platforms.

A relative backscatter normalization accounts for differences between vessels and sonars. Therefore, all other parameters must be the same to obtain the best results. This includes sonar frequency, pulse length, location and bottom type, and environmental conditions. When considering a location for a backscatter calibration, it is important to ensure that enough time is available to collect data across all survey platforms in the same location. If a sonar within the field unit cannot be normalized over the same reference area, a single separate normalization cannot be done. All sonar data must be re-collected for a single area. An ideal location is a flat, sandy to medium gravel area in about 20–40 meters of water; large sand waves, scour marks, and flora can have impacts on backscatter quality. Rocky and uneven surfaces are not suitable for backscatter normalization analysis.

A single line of approximately 300 meters should be collected on reciprocal headings at all the frequencies used in surveying. For example, for Kongsberg EM 2040 sonar, this would occur at 200 kHz, 300 kHz, and 400 kHz. For each frequency, reciprocal lines should be collected at a short pulse (SP), long pulse (LP), and frequency modulated (FM) pulse lengths (note: there is no FM pulse for 400 kHz in Kongsberg systems). For Kongsberg EM 2040 sonar, this would result in 16 lines: 2 lines (reciprocal headings) for SP, LP, and FM lines at 200 and 300 kHz, and 2 lines for SP and LP and 400 kHz. Next create a mosaic for each of these survey lines. Conduct a cross-correlation analysis of all the lines of the same heading; studies have found that heading changes may also impact the resulting backscatter mosaic. This will give a relative offset, or normalization value, for each survey frequency and pulse length setting. Please consult HSTB for further details or assistance in this process.

1.5.7 Side Scan Sonar (SSS) Systems

NOAA hydrographic survey units use side scan sonar systems for both object detection and object recognition. Side scan sonar is typically used in conjunction with an SBES or MBES system to meet object detection coverage specifications outlined in the Hydrographic Specifications and Deliverables. Any SSS system used for OCS hydrography should be capable of detecting an object on the sea floor with minimum dimensions of 1 m x 1 m x 1 m from shadow length measurements.

NOAA field units use both hull-mounted and towed SSS system configurations. Horizontal accuracy for SSS operations will depend on the system configuration, investigation technique, water depth, and target density. However, the position of targets identified with side scan imagery must be sufficiently accurate to relocate the item for the least depth and survey position usually determined via an MBES system. In general, concurrent multibeam is needed to position objects found in the side scan imagery. NOAA field units use various models of side scan sonar for hydrographic survey operations. In this document, these systems will be treated as equivalent unless otherwise specified.

1.5.7.1 Offset Measurement and Verification

Side scan system offsets must be measured and/or verified before performing a calibration. Depending upon whether the sonar configuration is hull-mounted or towed, requirements for offset measurements will vary. Offset requirements for each type of configuration are described below.

1.5.7.1.1 HULL-MOUNTED SSS CONFIGURATION

For hull-mounted configurations, the phase center of the side scan should be positioned during the vessel static offsets survey. The phase center of the towfish is considered to be at the fore and aft midpoint of the transducer and on the centerline in the athwart ship and vertical axes (Figure 1-7).

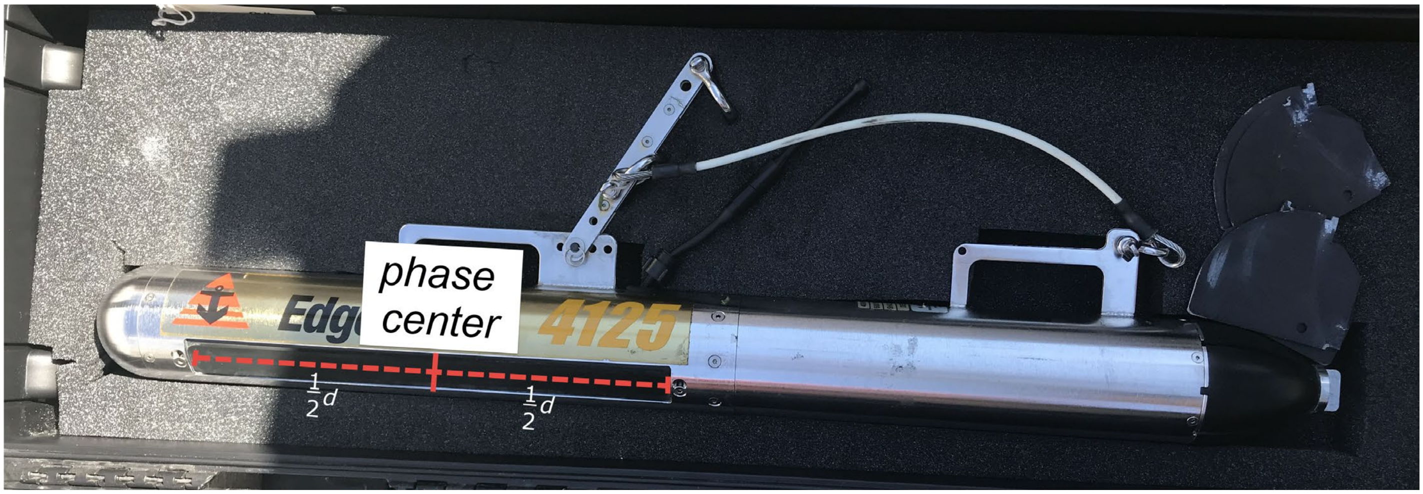


FIGURE 1-7 DETERMINING THE PHASE CENTER ON A SIDE SCAN SONAR

When hull-mounting an SSS, particular attention must be paid to the alignment of the towfish with respect to the keel of the survey vessel as a very small alignment error can introduce significant positioning errors in the data. For example, a heading alignment error of only 1° will add 1.75 m horizontal positioning error at the edge of the swath on a 100-m range scale. In extreme cases, it may be necessary to measure alignment error with a yaw patch test and enter a correction in the HVF. The field unit should contact the regional HSTB Field Support Liaison for assistance with this test if needed.

1.5.7.1.2 TOWED SSS CONFIGURATION

For towed SSS operations, static vessel offsets should be measured to the tow point. The actual towfish position is typically calculated using towfish depth and cable out measurements (Figure 1-8). Towfish depth may be determined by a depth sensor installed in the towfish or calculated by subtracting the towfish height (determined by a separate echo sounder installed in the towfish or the first return of each sonar ping) from the depth of water (determined from a vessel echo sounder). If an SSS is equipped with a pressure sensor, its accuracy should be tested annually and whenever the horizontal positioning accuracy of side scan targets is in doubt. Cable out can be estimated visually from calibrated markings on the cable or measured with an electronic cable counter. When measuring cable out, the cable zero mark is not at its connection to the towfish but at the phase center of the sonar. Each configuration is described below.

- Marked Cable: Marked tow cables should be measured using a survey-grade metal tape and clearly marked. Cable markings should be in meters and enable visual interpolation to a 10th of a meter. Because a cable jacket can stretch and slide over the conductors during use, cable measurement markings should be verified annually and whenever the hydrographer believes they may be in error. It is highly advisable to add marks using retroreflective or otherwise highly visible tape to aid in nighttime cable checks.

- Cable Counter: Electronic cable counters should be configured according to the manufacturer's instructions. The hydrographer should verify the accuracy of the cable counter by comparing manual and electronic cable measurements at a range of cable lengths. This check should be conducted annually, whenever the counter, cable, or sheave configuration is changed, and whenever the hydrographer believes there may be a cable measurement error. For some cable counters, the serial data output being logged may be in different units than what is shown on the cable counter display. In such cases, the hydrographer may need to perform a conversion on raw cable out data either before logging or during post-processing.

FIGURE 1-8 EXAMPLE OF LAUNCHING A TOWED SIDE SCAN SONAR ON NOAA SHIP *THOMAS JEFFERSON*

1.5.7.1.3 POLE-MOUNTED SYSTEMS

Pole-mounted systems provide the benefit of adjustable and repeatable survey operations. They are often quick to set up (~1 day) and can provide a safe and quick release of the sensor during a collision or snag with a submerged hazard. For pole-mounted SSS systems, it is important to measure and confirm offsets annually.

Measuring pole-mounted offsets can be completed through an NGS survey or through basic methods by the field unit. The bench mark closest to the pole mount should be used as a reference point. The X, Y, and Z should be measured from the vessel's RP. The distance from the RP should be entered as the tow point in the CARIS HVF. The date should be entered with the associated tow-point value.

Some pole-mounted systems do not require traditional offset measurements because of their "plug and play" ability. In these setups, the antennas, IMU, and sonar are all integrated into the single boat set up, making the measurements of the vessel negligible (Figure 1-9).

FIGURE 1-9 EXAMPLE OF A POLE-MOUNTED SIDE SCAN SYSTEM

1.5.7.2 SSS Calibration

As part of the HSRR, the field unit should demonstrate that all side scan sonar systems to be used for OCS hydrographic surveys are capable of meeting object detection standards outlined in the HSSD. An operational SSS calibration test should be conducted to demonstrate the system's ability to detect and accurately position seafloor targets across the system's range on both sonar channels. Test information can be recorded in an SSS Calibration Table.

The SSS calibration test should consist of a minimum of 10 side scan passes on a target approximately 1 m x 1 m x 1 m. The target should be imaged from a variety of ranges and directions with survey speed, water depth, and weather representative of typical survey conditions. Dedicated test targets can be created and used for this check; also targets of opportunity, such as buoy blocks, lobster pots, and appropriately sized rocks, may be sufficient. The hydrographer should use an alternate system (e.g., MBES) to determine a high-accuracy absolute position of the target for comparison with SSS detected positions. This test should be conducted across all range scales intended to be used for data acquisition.

Line plans are recommended for conducting an SSS calibration test (Figure 1-10). This line plan balances ensonifications on the port and starboard channels, across the range scale, from different target aspects, and from different directions. This approach assists the hydrographer in differentiating systematic and random errors in detection and positioning.

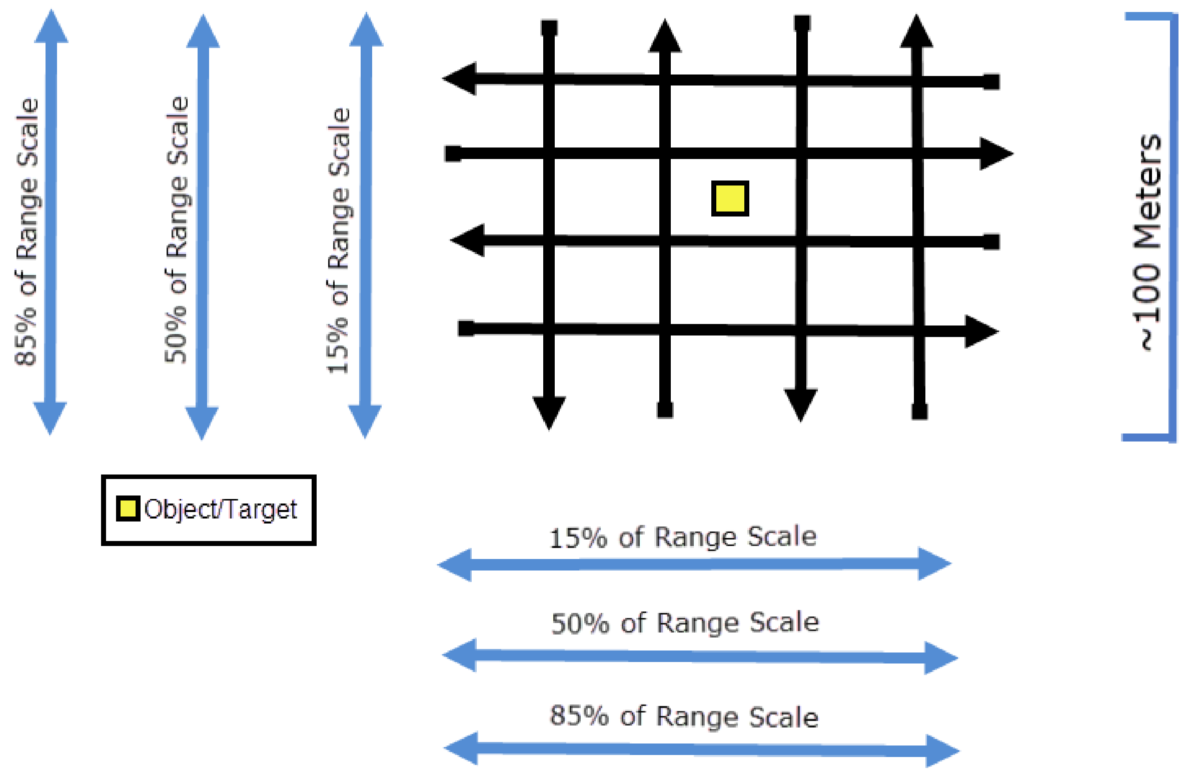


FIGURE 1-10 *RECOMMENDED LINE PLAN FOR SSS CALIBRATION TESTING*

Test data should be processed according to the field units' standard survey procedures and evaluated to identify any systematic problems with the sonar or vessel offsets. If the contact is not detected in more than one of the 10 passes, the SSS towfish should be carefully inspected for damage, and the system retested. If detection remains problematic, the field unit should contact EEB and the regional HSTB Field Support Liaison for guidance.

Successful object detections should be used to compare the mean detected position with the absolute target position and to compute the approximate 95% confidence radius for the system. This radius should not exceed 5 meters for hull-mounted systems and 10 meters for towed systems. Several methods can be used to estimate the 95% confidence radius.

A simple option is to export the detected target positions to ArcMap/ArcPro and use the "Compute Statistics" function in the attribute table to compute the sample standard deviation of the x and y components of the detection positions (computing statistics of the Eastings and Northings yields values in meters). Assuming a normal distribution, 95% of the samples will fall within 1.96 standard deviations of the mean. If the distribution of detections is similar in x and y, the 95% confidence radius is roughly 1.96 times the square root of the sum of the squares of the standard deviation of detected positions in x and y. If the distributions in x and y are not similar, a systematic bias likely exists that was not canceled by ensonifying the target from multiple ranges and directions.

Similar results can be obtained by measuring the error for each detection (the distance from the absolute target position to the detected position) and computing the sample mean and standard deviation of the errors. The approximate 95% confidence radius is then the sample mean plus 1.96 times the standard deviation.

1.5.7.2.1 DOCUMENTATION & REPORTING REQUIREMENTS

In addition to an SSS Calibration Table, a chartlet showing the test area, actual target position, test line plan, positions of successful detections, and the approximate 95% confidence radius for the target location should be created for each system tested. The exact format of the chartlet is left to the discretion of the hydrographer. This information should be maintained by the field unit and available for review during HSRR and at the request of OCS. Documentation for SSS calibration tests conducted should be included with the DAPR for each associated project.

1.5.7.2.2 PERIODIC QUALITY ASSURANCE CHECKS

At least one confidence check of an SSS system should be conducted each day the system is used for data acquisition. These checks should follow the HSSD and consist of detecting a discrete object at the outer range scale limits for both sonar channels (i.e., port and starboard). Confidence checks should be annotated in the daily data acquisition records. If these confidence checks repeatedly show discrepancies with expected performance, a new system calibration may need to be performed.

Before surveying with an SSS system that has been either reconfigured or in storage, a rub test should be performed, which is a simple procedure wherein a hydrographer observes the SSS trace while an assistant physically rubs one transducer on the towfish and then the other while the system is pinging. As the assistant rubs the transducer, the hydrographer should see a return on the corresponding channel of the imagery. A rub test failure can indicate system errors such as incorrect gain or power settings, a faulty cable, or damaged transducers. This test should be conducted while the towfish is out of the water and dry, to avoid the possibility of electric shock.

For Klein SSS systems, rub test failures can be caused by problems in the tow fish's .INI file, mainly in the Preemphasis and LBOGain fields. These numbers can be increased or decreased as needed to ensure a successful test. Follow manufacturer specifications for the length of cable used as a first step; increase or decrease as needed from these specs.

Caution: Do not leave an SSS towfish turned on for more than 5 minutes while out of the water. These are water-cooled systems and can easily be damaged by excessive heat buildup if left on when not deployed.

1.5.8 Leveling Equipment

Geodetic leveling equipment is used to measure elevation differences between bench mark locations and to extend vertical control from established bench marks to water level measuring equipment or a water level staff. For hydrographic survey operations, this equipment consists of a compensator leveling instrument and level rod. The quality of the vertical datum measured partially depends on the quality of the leveling performed between bench marks and the water level staff or equipment. It is important to properly maintain leveling instruments and rods to ensure that they are within calibration tolerances.

Follow the standards and procedures established by CO-OPS for calibrating and operating leveling equipment used to survey water level stations. These requirements are described in the User Guide to Vertical Control and Geodetic Leveling for CO-OPS Observing Systems (May 2018), published by CO-OPS. These requirements are summarized here, but the hydrographer should refer to the User's Guide for specific information on leveling operations.

1.5.8.1 Calibration Requirements & Methods

For OCS hydrographic survey operations, level surveys should be conducted to at least third-order accuracy standards. The minimum scale calibration standard for level rods being used for third-order surveys is the manufacturer's standard. Level rods do not have a recommended time between scale calibrations. If an error is suspected in a rod scale, the rod may be calibrated and certified by an approved laboratory.

No leveling instrument is perfectly aligned. The angle from which the line of sight departs from the actual level surface when the instrument is leveled is referred to as collimation error. If errors are found during HSRR and adjustments are necessary, service shall be performed by a qualified manufacturer-approved technician. To minimize collimation error, the leveling instrument should be serviced and adjusted whenever a collimation error cannot be reduced to acceptable tolerances in the field.

The hydrographer should verify the collimation of leveling instruments after annual calibration. Collimation should be checked according to either of the two approved methods described in Section 3 of the User Guide to Vertical Control and Geodetic Leveling for CO-OPS Observing Systems. The collimation error should be no greater than ± 0.05 mm/m. If it exceeds this tolerance, the level instrument must be adjusted, and another check performed. Collimation checks should be processed and documented on NOAA Form 75-29 (or an equivalent) according to the procedure and example in Section 3 of the User's Guide.

1.5.8.2 Documentation and Reporting Requirements

Collimation check and calibration records for leveling equipment used for OCS hydrographic surveys should be maintained by the field unit and available for review during HSRR and at the request of OCS. Leveling equipment and dates of calibration should be reported in the Hydrographic Systems Inventory. Documentation for any subsequent collimation checks and/or calibrations conducted should be included in the DAPR for each applicable project.

1.5.8.3 Periodic Quality Assurance Checks

Collimation and general performance of leveling equipment should be verified before each leveling survey by repeating the collimation check. If the collimation error exceeds ± 0.05 mm/m, the level instrument must be adjusted and another check made until the error can be successfully reduced below this threshold.

1.5.9 Horizontal & Vertical Control Equipment

No standard calibration requirements have been implemented at this time for GNSS horizontal and vertical control equipment. This equipment's calibration requirements and quality assurance checks should be maintained per the manufacturer's recommendations.

The field unit should conduct an annual occupation of a known high-quality (vertical stability B or better) bench mark with each base station intended to be deployed in the field. This will help to ensure that the base station is recording accurate positions. Should the position not match within the stated positional uncertainty of the occupation and the mark description, the station should be taken out of service and returned for repairs.

1.5.9.1 Documentation & Reporting Requirements

Calibration and quality assurance documentation for horizontal and vertical control equipment used for hydrographic surveying should be maintained by the field unit and available for review during HSRRs and at the request of OCS. Horizontal and vertical control equipment and dates of calibration should be reported in the Hydrographic Systems Inventory. Documentation for any subsequent calibrations or quality assurance checks conducted should be included in the DAPR for each applicable project.

1.6 Software Systems

Computer software plays an essential role in NOAA's hydrographic surveying operations and must be managed with care and attention to detail. Each field unit must ensure during the HSRR that their systems are up-to-date with the most current approved versions of survey related software by consulting HSTB. HSTB is the first point of contact for most commercial hydrographic software packages in use by NOAA hydrographic field units and is directly responsible for writing and maintaining many of the in-house programs used for OCS surveys. Before installing software upgrades, it should be ascertained that the new version or update has been tested and approved for use. The field unit's regional HSTB Field Support Liaison should be able to answer questions about software availability and testing.

OCS has established basic guidelines for maintaining, updating, and testing software. All field units should incorporate adequate computer and software maintenance periods into their annual schedules. This should be planned to coincide with a period of relatively low operational activity. Field units should use this opportunity to install and configure software on new computer systems and conduct comprehensive rebuilds of systems to be retained. Any mid-season software changes should be carefully documented so that the field unit can revert to a prior software version if problems arise.

Hydrographers should coordinate all software requests and changes with the embarked Electronics Technician, HSTB, or NRB-Technical liaison. Hydrographers are expected to exercise common sense in these cases. All software issues should be documented in written format and communicated to HSTB, ET, and/or NRB Technical Liaison.

1.6.1 Types of Software Systems

Reference to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement, recommendation, or favoring by the US government. The views and opinions of authors do not necessarily state or reflect those of the US government and should not be used for advertising or product endorsement purposes.

1.6.1.1 Data Acquisition Software

Data acquisition software updates should be performed during HSRR. Field units wishing to install updates during normal operational periods should contact the regional HSTB Field Support Liaison to determine if the new version has been successfully tested in a controlled environment. The following is neither exhaustive nor inclusive of all possible approved collection software. (Table 1-1).

TABLE 1-1 COMMON OCS DATA ACQUISITION SOFTWARE PACKAGES.

Software Packages	Manufacturer	Common NOAA Uses
Hypack/HYSWEEP	HYPACK	SBES and MBES acquisition; survey line navigation
SonarPro	Klein	SSS acquisition
SIS	Kongsberg	MBES acquisition
POSVIEW	Trimble/Applanix	POS MV settings, lever-arms, and logging (POSPAC) control
Discover I	EdgeTech	SSS acquisition
Sound Speed Manager	HydrOffice	Download and process sound speed information
MVP Controller	AML	Interface to control MVP operations
Castaway	SonTek	Used to download sound speed information from CastAway CTD

1.6.1.2 Data Processing Software

Data processing software are those programs used to manipulate and analyze survey data. There are several common hydrographic data processing software packages used by NOAA field units (Table 1-2). The following list is neither exhaustive nor inclusive of all possible approved collection software.

Table 1-2 Common OCS Data Processing Software Packages

Software Package	Manufacturer	Common OCS Uses
HIPS / SIPS	CARIS	Bathymetry and imagery data processing
Notebook	CARIS	Survey planning and processing
ArcMap	Esri	Survey planning; survey product creation
Fledermaus	QPS	3D survey data visualization
Pydro Explorer	NOAA	Survey data analysis; QC/QA; report creation; TCARI tide application, DtoN reporting, separation model creation, Charlene
Sound Speed Manager	NOAA	Sound velocity profile processing; variability wedge analysis, est. sound speed uncertainty
POSPac	Trimble/Applanix	Derive IAPPK or 5P solution to hydrographic data
OPUS	NGS	High accuracy positioning
VDatum	NOAA	Conversion from different horizontal/vertical references into a common system
Qimera	QPS	Troubleshooting bathymetry
FMGT	QPS	Backscatter processing

1.6.2 Documentation & Reporting Requirements

A record of system settings for hydrographic data acquisition software should be created and updated throughout the field season. If a software system has the capability to output a file identifying all configuration settings, a copy of this file will meet system settings reporting requirements. Otherwise, the field unit will need to manually generate a digital record (e.g., a spreadsheet). Software documentation should be maintained by the field unit and available for review during HSRR and at the request of OCS. A copy of the Software Inventory and system settings records in effect during operations should be included in the DAPR for each respective project.

1.7 Personnel Rosters

People are the most essential component of any hydrographic survey system, and training hydrographic personnel is a critical element of survey preparation for any field unit. NOAA field units are to report on the status of their personnel roster in their HSRR memo. Guidelines for training and qualification of hydrographic personnel are described below.

For this manual, “hydrographic personnel” are defined as those members of a field unit’s complement (permanent or temporary duty) whose normal duties include responsibility for any activities that directly affect survey planning, data acquisition, or data processing. In addition to Physical Scientists, Survey Technicians, Commissioned Officers, and others in immediate control of survey operations, this includes Launch Coxswains and Officers of the Deck (OODs) responsible for operating vessels during surveying, visitors who participate in data acquisition and processing without direct supervision, and the unit's command.

1.7.1 Personnel Qualifications & Training

There are a variety of training and qualifications available to hydrographers. The following is a list of some of the opportunities:

- OCS Basic HydroSchool
- OCS Advanced HydroSchool
- Hydrographer in Charge (HIC) qualification
- Multibeam Training Course
- Smart Start
- University of New Hampshire (UNH) Center for Coastal and Ocean Mapping/Joint Hydrographic Center
- University of Southern Mississippi (USM) USV course
- FAA Drone Certification
- Hardware & Software specific training
- University of New Hampshire (UNH) & University of Southern Mississippi (USM) offer Cat- A or Cat- B certification
- Python Training (Training modules offered in Pydro Explorer)
- National Society of Professional Surveyors Hydrographer Certification
- 5-minute modules

1.7.2 Reporting Requirements

Although the Hydrographic Systems Inventory includes only a basic roster of hydrographic personnel, deficiencies in either numbers or qualification of personnel should be noted in the Hydrographic Systems Readiness Memo.

Additionally, OCS recommends that each field unit maintain a record of personnel training and qualifications. Formally documenting personnel training and qualifications will assist Chiefs-of-Party in assessing the readiness of their personnel. This record can also help identify hydrographic training needs, enabling units to request and allocate resources accordingly. Copies of curriculum and/or requirements for any internally crafted qualification or training should be maintained by the field unit for reference purposes.

2 Chapter 2 Pre-Survey Planning

Pre-survey planning is essential for any field unit to effectively and efficiently conduct hydrographic survey operations. When planning operations, the hydrographer must keep in mind the assigned survey specifications and approved methods for meeting those criteria. This chapter describes the information that will be provided to a field unit when a hydrographic survey is assigned and provides project preparation and survey planning guidance.

2.1 Crew & Vessel Safety

Above all, every member of the field party should understand that the safety of the crew and vessel is the number one priority. Safety should be the foremost consideration in all aspects of OCS hydrographic surveys from the planning stages through data submission. It is the responsibility of the Chief-of-Party, as well as the vessel crew, to be aware of safety hazards and take steps necessary to ensure undue risks are avoided even if it means ceasing operations.

Good planning and information can minimize risks associated with hydrographic surveying. Recommended practices to increase safety include, but are not limited to the following:

- Use historical weather information to prepare for seasonal patterns and monitor weather forecasts for specific local conditions before survey operations.
- Review the survey region for exposed areas, constricted areas, shallow areas, surf, heavily trafficked areas, and so on. Plan on surveying challenging areas when weather, tides, and currents are optimal.
- Review lidar data (if available) to determine general depths and identify potentially dangerous features in an area.
- Review prior survey Descriptive Reports (DR), when available, for uncharted hazards. Often, the DR will describe deficiencies, hazards, and challenges from prior surveys and field experience.
- Review current charts to determine the quality of currently reported data.
- Create thoughtful survey progression plans (e.g., polygons, boat crew experience) while remaining aware and alert to the location of safe and hazardous waters.
- When surveying near restricted water, ensure all permissions are obtained and be familiar with local traffic practices.
- Use daily survey information progressively in the field to minimize hazards. Communicate survey and safety information to all personnel involved in operations.
- Understand the limitations of vintage data and approach features conservatively during the initial operations.

2.2 The Project Instructions

When a hydrographic survey is assigned, the Hydrographic Surveys Division's (HSD) Operations Branch (OPS) or the Navigation Services Division's (NSD) Navigation Response Branch (NRB) will electronically deliver relevant project information within a Final Project Package. This information will include Hydrographic Survey Project Instructions, as well as supporting information and data files to be used during field operations and subsequent survey processing.

The field unit will receive draft project instructions 60 days prior to the planned start of the project for review and comment. The Final Project Package will be disseminated to the appropriate field at a minimum of 30 days before the start of the project. The file structure is standard for typical Final Project Package (Figure 2-1). If a folder is intentionally left empty, the project planner will create a readme.txt file indicating such.

Prior Survey or Junction Survey information will not be delivered to the field unit within the Final Project Package unless it is available in Bathymetric Attributed Grid (BAG) format.

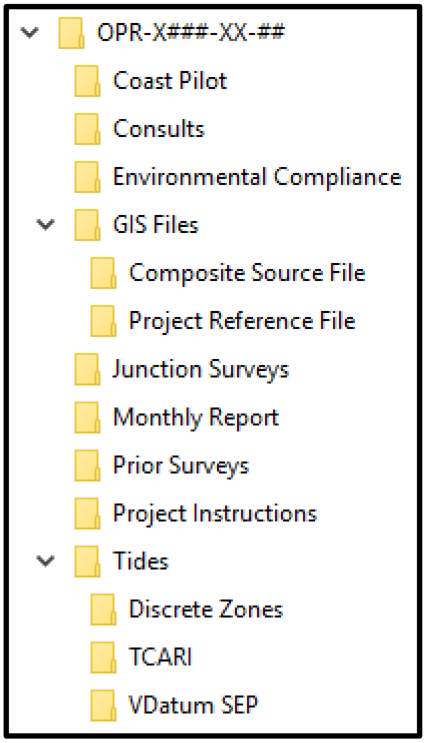


FIGURE 2-1 ***EXAMPLE OF A FINAL PROJECT PACKAGE***

The Hydrographic Survey Project Instructions, commonly referred to as Project Instructions, within the Final Project Package will identify specific requirements for a survey project. Field units should acknowledge receipt of Project Instructions via email to the assigned OPS Project Manager or NSD Project Manager. Field units should review the Final Project Package and contact the Project Manager with any questions or concerns.

2.2.1 Consults

HSD and NSD are responsible for conducting the entire consultation process and documentation relating to correspondence with the various stakeholders. OCS may consult with other NOAA offices or governmental agencies, depending on the jurisdiction.

These communications will be included in the “Consults” folder provided to the field units. Consultation and correspondence may pertain to environmental compliance and regulations, local information or guidance from Navigation Managers and stakeholders, lobster fisheries guidance, and indigenous/tribal organizational information. Additional correspondence may be required as prescribed in the final project instructions. Some examples of external partners are:

1. US Geological Survey (USGS)
2. National Historic Preservation Act (NHPA)
    a. State Historic Preservation Officer (SHPO)
3. Integrated Ocean and Coastal Mapping (IOCM)
4. Various Environment Groups:
    a. US Environmental Protection Agency (EPA)
    b. US Fish and Wildlife Service (US FWS)
    c. Washington State Department of Ecology
    d. Oregon Department of Environmental Quality (DEQ)
    e. Mississippi Department of Environmental Quality (MDEQ)
    f. Florida Department of Environmental Protection (FLDEP)
5. Tribal Organizations

2.2.2 GIS Files

A Composite Source File (CSF) and Project Reference File (PRF) should be provided with the Project Instructions. If no PRF/CSF is provided, contact the HSD/NSD Project Manager for advice on how to proceed with feature verification. The CSF is an S-57 attributed data set compiled from applicable sources (ENCs, preliminary ENCs, and geographic cells), providing the field unit with the largest scale and most up to date shoreline data. The CSF is compiled of the S-57 data format that is the foundation for the Final Feature File (FFF) deliverable.

The PRF contains extended attribute information such as survey limits, junctions, recommended bottom sample locations, and features for investigation.

Features requiring verification should have the NOAA extended attribute "Assignment flag" (asgnmt) populated with "Assigned." The CSF will also include "Unassigned " and "For Info Only" features that do not require verification but are included in the CSF for the hydrographer's awareness. All field units should conduct a feature search and least depth development for all survey types, regardless of if a CSF was provided to the field unit. Any features that are found by the field unit and not included in the CSF should be added, attributed, and included in the submission of the FFF.

Aids to Navigation (ATON) may also be included with the CSF and assigned for verification. The most recent edition of the largest scale chart of the survey area and the latest edition of the U.S.C.G. Light List should be inspected before ATON verification to then determine whether the aid adequately serves the intended purpose for which it was established.

2.2.3 Junction Surveys

Project Instructions will state whether junction surveys are assigned. Junction surveys are defined as where two survey areas adjoin and overlap. A junction comparison evaluates the current survey data to other contemporary and previously collected data.

Field units are required to ensure continuity in the survey coverage and depth by evaluating junctioning or overlapping surveys. The survey coverage should be planned such that there is adequate overlap to perform a junction comparison. The junction between prior survey data and current coverage should be approximately one bathymetric swath width at the nominal depth of junction. Junction data should be reviewed by the field unit prior to departing the area to ensure there is significant overlap between surveys and to allow for significant time to correct acquisition issues.

The Project Instructions will indicate if a junctioning survey requires a data conversion or re-projection due to being in a projection and datum other than UTM NAD83.

2.2.3.1 Junctioning with Light Detection and Ranging (lidar) Surveys

Lidar junction surveys may be assigned to NOAA field units to obtain required coverage to the lidar extent line or the Navigation Area Limit Line (NALL). Lidar junction data may be provided in a gridded or S-57 (*.000 or .HOB) format. Instructions for any required comparison or specific feature investigation will be provided in the HSD/NSD project instructions.

Features found by the lidar survey will be added to the Composite Source File (CSF) as an existing feature. Lidar features requiring further investigation will be added to the Project Reference File (PRF). The standard practice for coverage overlap between lidar and MB surveys is to overlap one swath width inshore of the Lidar Good Line (LGL), a line showing the area of most confidence in lidar coverage. Verify or disprove all lidar investigation items seaward of the NALL.

2.2.4 Prior Surveys and Request Information

NOAA field units can locate information available from prior surveys from NOAA's National Centers for Environmental Information (NCEI), Bathymetric Data Viewer, and Lidar Data Viewer. Some information that is available and downloadable from prior surveys are the descriptive report, features, surfaces, and sounding layers.

HSD or NRB will include in the Project Instructions, if available, copies of documents from the maritime community, research groups, or other entities requesting the survey project.

2.2.5 Orthoimagery

Orthoimagery is a high-resolution aerial image that is geometrically corrected. The hydrographer may request orthoimagery for a project if considered necessary to support pre-survey planning and post-processing. Available imagery can be found from the Remote Sensing Division (RSD) Data Access Viewer or on NOAA's Coastal Data Viewer.

Examples may include (but are not limited to) areas with drastic differences from the shoreline features in the CSF to the real-world features. In these cases, the hydrographer should contact the project manager from HSD or NRB that is listed in the project instructions to request approved orthoimagery. The project planner will work with the HSD OPS Team Lead and Remote Sensing Division (RSD) to acquire the approved orthoimagery if available. Orthoimagery should be used for reference only.

2.3 Additional Resources

Some additional Planning Resources:

1. Software and hardware manuals
2. Coast Pilot
3. Internal Hydrographic Organization (IHO) S-57 FAQ's
4. Chart 1
5. Hydroforum
    a. Maintained by Hydrographic Systems and Technology Branch (HSTB); message board for asking NOAA specific survey questions

2.4 Project Preparation

Once a field unit has received the Final Project Package, survey personnel should begin preparatory tasks such as reviewing project information, creating a data management structure, contacting constituents, and planning horizontal and vertical control if necessary. These tasks are typically performed on a project-wide basis before individual survey planning.

2.4.1 Project Information and Instructions

As soon as practicable, the field unit should inventory files provided in the Final Project Package to verify that all necessary information has been included. Once it has been confirmed that all files are present, project information should be copied to the field unit's network following the unit's standard data management practices. The OPS Project Manager or the NRB Project Manager will deliver draft Project Instructions approximately two months (~60 days) from the start of a project. All applicable departments and personnel should review the draft Project Instructions.

Questions and concerns should be brought up with HSD OPS or NRB. Once the final Project Instructions are delivered one month before the start of a project, all appropriate hydrographers should review the Project Instructions and Project Data Package files to become familiar with the project.

2.4.2 Data Management

2.4.2.1 Digital Data Directory Structure

Data directory structures used during acquisition and processing may vary among field units. However, a standard should be in place within each field unit. It is important to adhere to any field unit directory standards because some software configurations must reference specific directories. Refer to HSSD for an example of a field unit directory structure.

In HSTB's developed processing system, Charlene, all directory structure creation is fully automated, and each subsequent acquisition day is added to the final structure until the user is left with a ready-to-submit project.

2.4.2.2 Digital File Naming Conventions

It is important to follow file naming standards within the field unit. Maintaining these conventions greatly assists AHB and PHB in identifying data records. Do not create data files with non-standard names that are unrelated to the file content and will confuse others who must access that data. Reference the HSSD or Hydrographic Technical Directives (HTDs) to identify the naming conventions which must be adhered to by all field units. Additionally, any preliminary, temporary, or extraneous files created by the field unit should not be included with data submitted to AHB or PHB.

Working file names are okay for processing or field organization. Survey files should not be submitted with working names (e.g., "_SIGNED_CO", "_DRAFT", or "_To_Delete").

2.4.3 Horizontal and Vertical Control

Horizontal Control (HorCon) generally refers to the terrestrial network of geodetic marks that support two-dimensional hydrographic positioning as well as how NOAA field units position survey data in relation to a datum.

In remote survey locations or confined areas such as a fjord, U.S.C.G. differential correctors or other positional correction services may be unavailable or severely limited. For these areas, the field unit should establish at least one horizontal control point where a portable base station can be installed. A review of the survey area should be combined with local knowledge to determine a feasible location. Security measures may include locking instruments, affixing owner identification to equipment, and choosing a discrete station location.

HorCon techniques may also be used to determine high accuracy positions for ATONs. If an ATON is required to be positioned using high accuracy HorCon methods, specifications will be noted in the ATON information provided on the Final Project Package. Typically, higher-order ATON positions will be required for range lights.

"Vertical control" refers to a network of geodetic marks that support three-dimensional hydrographic positioning. Vertical control activities are typically conducted to support water level gauge installations, water level measurements, and ERS. Personnel from CO-OPS are responsible for all planning of tide and water level requirements for OCS hydrographic surveys. CO-OPS will analyze historical data and tidal characteristics for each project area, specify operational NOS control stations, specify general locations for subordinate water level stations to be installed, and provide the tidal zoning (both preliminary and final) to be used during survey operations.

Installation, operation, and maintenance of controlling water level stations are typically the responsibility of the CO-OPS Field Operations Division (FOD). However, the hydrographic field unit may be required to install, monitor, repair, and/or uninstall a control water level station under the instructions of the CO-OPS FOD. The Project Instructions will state if installation, operation, and/or removal of subordinate water level stations are required for a project. In such cases, FOD will work in collaboration with the field unit to complete these tasks. FOD can be emailed at nos.coops.fod@noaa.gov.

A location is typically coordinated with the Project Manager prior to surveying or arriving to the survey area so that permission to access the property and install horizontal or vertical control equipment can be granted. If it is necessary to drill into rock during the installation, permits should be obtained for this purpose.

2.4.3.1 General Data and Reference Datum Requirements

The present NOAA Nautical Chart Reference Datum for tidal waters is MLLW for hydrographic surveys and mean High Water (MHW) for shoreline mapping surveys 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 should be referenced to this datum. The final determination of an appropriate control station for the subordinate station datum computation must result from a direct comparison of the collected subordinate station observations with all nearby potential control stations. The station best matching in tidal characteristics and ranges will be used as the final control for datum computation.

In non-tidal coastal areas, soundings will be reduced to Low Water Datum (LWD), which is 0.5 feet below Mean 20 Sea Level (MSL). In the Great Lakes, all soundings will be reduced to Great Lakes Low Water Datum as referenced to the current International Great Lakes Datum 1985 (IGLD85). In areas that are charted to "special vertical datum" such as Columbia River Datum (CRD), Hudson River Datum (HRD), and Mississippi River Low Water Reference Plane (LWRP), the soundings will be reduced to the specific special datum.

If a subordinate station has a currently published datum set the station datum for the new installation to the historic station datum via re-occupation. This will ensure that all newly collected observations are on the same zero reference as the currently accepted datum. If the length of the new series of observations is shorter than that of the accepted datum time series, the newly submitted datum may be validated as acceptable for survey use but may not supersede the longer already published data.

2.4.4 Constituent Contact

The Project Instructions will list constituents who must be contacted at or near the beginning and end of field operations to discuss survey objectives and accomplishments. It is mandatory that the field unit contact the appropriate NOAA Regional Navigation Manager as identified in the Project Instructions to discuss local survey requests or charting concerns that are not addressed in the current project.

The Project Instructions will also list various local contacts for reference. These resources should not be overlooked and can often provide local knowledge regarding shoaling, marine activities, traffic patterns, and other areas of concern. Local information sources include port authorities, pilot associations, local ferry companies, fishermen, towing companies, US Coast Guard (USCG), US Army Corps of Engineers (USACE), and local and state government agencies.

2.4.4.1 Local Notice to Mariners Announcement

Before commencing survey operations for a project, the field unit should submit an announcement to be included in the USCG Local Notice to Mariners (LNM). The announcement should be submitted two weeks before commencing operations and include information about the project work area, the type of work being conducted, the field unit characteristics (e.g., size, color, markings of ship and launches), means of contacting the field unit, and the start and end dates of the survey. These announcements can be submitted via email to the appropriate USCG District email addresses, which are listed in the LNM for each district.

2.4.4.2 Cultural or Historic Submerged Features

The HSD Operations Branch will contact the State Historic Preservation Officer (SHPO), historical/archaeological contact at NOAA's Office of National Marine Sanctuaries (ONMS), or other relevant governmental agency during the preparation of Project Instructions to request information on any historically significant man-made features on the seabed within the survey area. Information provided by these Historic Preservation Points of Contact (HPPOCs) will be included in the Project Instructions. While the Project Instructions will also include contact information, field units are generally not required to consult with the HPPOCs. Instead, the Hydrographic Processing Branches are responsible for contacting the HPPOCs in the event of the discovery of a potentially historically-significant man-made feature.

Field units *should* not comment on potentially historically significant features in official reports (DR or feature reports) or post images or comments of potentially historical wrecks on social media.

2.4.4.3 Potential for Lost or Damaged Fishing Gear

In many areas, particularly the Northeast United States, field units may encounter significant densities of fixed or floating fishing gear such as lobster pots, crab pots, fishing pots, long lines, and gill nets. NOAA field units should always attempt to minimize the impact of hydrographic survey operations on the commercial fishing industry. There is an expectation that Coast Survey and all field units will make every effort to prevent damage or interaction with fishing gear. If damage does occur, state agencies may not detain or prosecute a federal employee for violation of state law.

When operating in areas with high densities of fishing gear, field units should consider modifying survey operations to reduce the possibility of damaging fishing gear and survey equipment. Some steps that may be taken in areas of dense fishing gear include:

- Limiting survey operation to daylight hours.
- Using survey launches instead of the ship to conduct operations.
- Using hull-mounted sonar systems instead of towed survey gear.
- Limiting the use of towed-sensors such as Moving Vessel Profilers

During project planning, the HSD Operations Branch project manager will contact the Regional Navigation Manager to inquire whether there may be areas of concern for lobster or other fishing gear in the project area. If there are, the Regional Navigation Manager will contact the local fishing and lobster associations and organizations to inform them of where an NOAA survey vessel will be working and the approximate time frame.

The field unit should contact their Regional Navigation Manager for confirmation. This notification will be completed via an official letter to the association president or other point of contact. The Regional Navigation Manager should CC the field unit on communications with the associations.

A mandatory point of contact will be listed in the Project Instructions for projects which have the potential to significantly interfere with the work of local fishermen/lobstermen. In those cases, the field unit must use that point of contact to solicit input and coordinate with the local fishermen/lobstermen in an effort to reduce the possibility of fishing gear interaction and better plan survey operations.

These announcements should also be provided directly to the fishing or lobstermen association for distribution to their members and inclusion in their newsletters. Notices should not only be sent to associations operating in the region the survey operations are being conducted but also adjacent associations as they will likely have some overlap.

Even when field units make every effort not to cause damage or otherwise interfere with fishing gear, some entanglements and other damage may occur. In instances where fishing gear has been damaged, local fishermen or lobstermen may make a claim regarding lost or damaged fishing gear and request compensation. The claims process for damaged fishing gear that may have been damaged by an NOAA hydrographic survey field unit is listed below:

1. Initial claims of gear interaction may be received from the fishermen by the field unit, the U.S.C.G., or the State Marine Patrol. Claimants will typically be referred to the State Marine Patrol as the best point of entry into the process. Note that NOAA hydrographic survey field units are not authorized to collect sworn statements so whenever possible claimants should be referred to a law enforcement agency.

2. State Marine Patrol and NMFS Office of Law Enforcement special agents will collaborate to collect sworn statements from affected fishermen, depending on whether the alleged loss occurred in state or federal waters. At a minimum, claims need to give the location of gear lost, an estimate of when it was lost, what was lost, and the fair market value.

3. All completed claims will be routed from NMFS OLE special agents to the regional NOAA Navigation Manager.

4. The Navigation Manager will request route data from the field unit, and compare the positions and times of the alleged loss with the unit's activities. The Navigation Manager may request assistance from the local NOAA Fisheries lab to determine if the fair market value claimed for lost gear is reasonable.

5. The Navigation Manager will forward substantiated claims to NOAA Office of General Counsel for final certification and payment for reimbursement. Unsubstantiated claims will be referred back to the State Marine Patrol and NMFS OLE with supporting documentation.

6. OCS and OMAO leadership will determine how the costs of any claims will be shared.

2.5 Survey Planning

OCS recommends that systematic data acquisition plans be prepared before vessel operations. These plans may consist of lines used directly for vessel navigation, polygons used to designate survey areas if the acquisition software provides a real-time coverage map, or target files used to mark predetermined data acquisition points.

When creating data acquisition plans, many factors must be considered including the scope of the survey, object detection criteria, sheet layout related to surrounding features, available data acquisition systems, number of features to be addressed, traffic patterns, local currents, tide stages, and prevailing weather and sea conditions. Input from other survey personnel, particularly those who have previously operated in the area, can be invaluable when creating data acquisition plans. Proposed plans should be reviewed by the Operations Officer, Chief Survey Technician, surveys departments, and/or Chief-of-Party before vessel operations.

2.5.1 Survey Scope

The scope of an OCS hydrographic survey will be categorized as a basic hydrographic, navigable area, field examination, or special project. Survey requirements will vary according to this classification. The type of survey to be conducted and any special requirements will be identified in the Project Instructions.

Hydrographic survey projects are created from an evaluation of requirements and priorities. Survey limits are based on these requirements and priorities as well as quantitative and qualitative measures of shipping and boating in an area, the adequacy of existing survey information in the area, the rate of change of the bathymetry, safety precautions, and an assessment/weighting of benefit versus efficiency.

2.5.1.1 Basic Hydrographic and Navigable Area Surveys

A basic hydrographic survey must be able to stand alone without supplementation by any other survey. The basic survey must be adequate to supersede all prior surveys for charting purposes and meet all applicable survey requirements specified in HSSD.

All assigned surveys are navigable area surveys unless otherwise specified in the Project Instructions. Navigable area surveys are basic hydrographic surveys with a constrained inshore limit.

The Project Instructions will also describe the project purpose, coverage (e.g. object detection, complete, etc.) and other survey requirements.

More details will be provided in the Project Instructions for the following surveys:

1. Field Examination: Item investigations or surveys that cover small areas of specific interest (i.e., disprove a reported obstruction).
2. Special Projects:
    a. Habitat Mapping: Mission where data were collected for habitat mapping and can be used for charting
    b. Homeland Security: Surveys assigned at the request of US Naval Oceanographic Office (NAVOCEANO) for hydrography to support Homeland Security in the nation's coastal waterways. These projects are typically 200% side scan sonar surveys
    c. ENC Verification: Surveys used to assist in the transition from Raster charting to ENC
    d. Maritime EEZ Mapping: Mapping to support the US Exclusive Economic Zone (EEZ)
    e. Technological Development: Data collected during technology testing that can be used for charts or publication
    f. Natural Disaster Response: Survey assigned to aid in the recovery of an area impacted by a natural disaster to aid recovery
    g. Debris Mapping: Survey completed in response to a new hazard or debris that may impact waterway traffic
    h. Safety Fairways: Lanes or corridors typically at the entrance to major harbors; safety fairways surveys ensure safe navigation of the area and that there are no artificial islands or fix structures, such as oil platforms, within the designated fairway
    i. Reconnaissance: Completed in response to an event or action that has been reported to OCS
    j. Support Partner Missions: Data collected to support NOAA's partners USGC, USN, BOEM, IOCM, and so on

2.5.2 Survey Line Planning

Before creating a line plan, the Project Instructions should be reviewed for any required methodology, line spacing, or coverage requirements. Besides Project Instruction requirements, factors such as general bathymetry, traffic patterns, shoreline features, currents, prevailing weather, and sea states, and distance from GNSS base stations should also be considered during line plan creation. New features discovered during operations may warrant additional adjustments to line plans as the survey progresses. It should be noted that survey limits are subject to revision based upon command decisions and/or requirements for safe vessel operation. Any significant survey limit adjustments should be coordinated through the project manager.

Line plans used for data acquisition can be classified into the following categories. Safety should never be compromised for the sole purpose of following a line plan:

- Mainscheme (MBES, SSS, or SBES)
- Holidays (MBES, SSS or SBES)
- Crosslines (MBES or SBES)
- Developments (MBES or SBES)
- Bathymetric Splits
- Target Files
- Special Circumstances

Acquisition requirements vary depending upon the data category and the type of equipment used. OCS recommends that field units standardize survey line numbering such that data classification can be determined based upon line number. For example, use the 100 number series for the first 100% of side scan sonar lines; the 200 number series for 200% side scan numbers; the 300 number series for side scan holidays lines; the 400–500 number series for mainscheme, multibeam lines; the 600 - 800 number series for development data; and the 900 number series for crosslines. Standardization within each field unit is strongly recommended.

Line plan guidelines for each data category are discussed in the following sections. Keep in mind that these guidelines are provided to help the field unit maximize survey efficiency, but they should not be followed at the expense of personnel and vessel safety.

2.5.2.1 Mainscheme

"Mainscheme" refers to primary survey data acquired during a project. The survey line and operational plan should be based on the coverage required prescribed in the Project Instructions. When planning mainscheme lines, special consideration should be given to junction areas. For surveys that are part of the same current project and from the same year, data overlap in junction areas should be sufficient to ensure continuous coverage. To adjoin with a non-contemporary survey from a different year and possibly conducted by a different vessel, a 100–200 meter overlap of mainscheme data is required unless the Project Instructions and provided project limits indicate otherwise.

2.5.2.1.1 MULTIBEAM ECHO SOUNDER (MBES)

When planning mainscheme MBES lines, the hydrographer must consider survey detection requirements and how the effective swath width will be impacted. Line Planning for MBES mainscheme is typically done for set line spacing surveys as assigned in the project instructions. During set line spacing surveys, lines should be planned in such a way that depth contours can be easily identified.

MBES line planning is also executed when operating autonomous systems. The method of autonomous platform used dictates the level of line planning required and the method to do so. Line planning requirements for autonomous vessels vary from system to system. Because of the diversity of systems, many of the techniques are still in development, and up to the field unit's discretion. Some conditions to consider are efficiency limitations, communication abilities, and the ability for the system's path planning system.

2.5.2.1.1 SIDE SCAN SONAR (SSS)

Side scan sonar data quality will inherently degrade both at nadir and at outer ranges. Because of this characteristic, line plans for the second 100% should be either offset or oriented differently than the first 100%. Alternatively, offsetting 200% lines by ½ of the line spacing for the first 100% lines achieves object detection quality.

The line spacing necessary to obtain 100% SSS coverage is dependent upon the effective range scale, achievable positional accuracy, and any positioning errors inherent to a towed system. Range scale refers to the athwartships distance ensonified on each side of the towfish. Thus, range scale equals one half of the total swath ensonified. A good rule of thumb to obtain complete coverage is to plan survey line spacing at 1.6 x Range Scale, allowing for an overlap of 40% of the range scale (20% of the total swath) between adjacent swaths.

Generally, the SSS range scale is chosen for maximum survey efficiency. The sonar should be maintained at an altitude of 8–20% of the range scale during acquisition; thus, water depth will determine an upper range scale limit of a particular survey area. However, the hydrographer should also consider the system configuration (towed, hull or pole mounted) and if a minimum sonar depth will be necessary to avoid water column disturbances such as propeller wash. Based on the chosen range scale's corresponding ping rate, vessel speed should be adjusted to ensure that data are sufficient to meet coverage requirements as indicated in the project instructions.

Multibeam backscatter imagery is not considered equivalent to or a replacement for side scan sonar imagery. Side scan sonar provides low grazing-angle imagery that enables identification of features not visible in lower resolution, higher grazing-angle MBES backscatter imagery.

2.5.2.1.2 SINGLE BEAM ECHO SOUNDER (SBES)

Since complete coverage cannot be efficiently completed using SBES alone, this will rarely be assigned as the sole method for acquiring mainscheme survey data. Typically, SBES systems will be used to provide correlating sounding data for SSS operations, define an inshore contour, or develop shoal or foul areas where there is a high probability of damaging either an MBES or SSS system.

If SBES has been assigned as a stand-alone mainscheme data acquisition method, the required line spacing will be noted in the Project Instructions. If possible, SBES mainscheme data should be acquired by running lines perpendicular to depth contours. This practice assists the hydrographer in accurately defining the contour. If extensive discrepancies are found between SBES sounding data and charted depths, the project manager should be contacted to determine if a more extensive survey is warranted.

2.5.2.2 Holidays

Holidays are described in the HSSD and are defined as gaps in mainscheme data or areas where accuracy requirements have not been met. Holidays may be caused by various events such as vessel maneuvering, survey equipment problems, unexpected shoals, or rejection of poor quality data during post-processing.

Holiday line plans are typically developed to address these data gaps as mainscheme acquisition progresses rather than at the end of mainscheme operations. This practice will minimize the transit time required to revisit each area of the survey with a holiday and the time required to acquire, process, and manage additional sound speed profiles. If the field unit uses a real-time coverage map during mainscheme data acquisition, most holidays should be identified and collected before ceasing operations that day, thus increasing survey efficiency.

When estimating time to complete a survey, additional time should be allocated to ensure data coverage is adequate for the required coverage. A general rule of thumb for survey planning is holiday collection will use about 1% of the total time to complete the survey.

2.5.2.3 Crosslines

Crossline data are used to identify any systematic data problems by comparing the crosslines to mainscheme data (Figure 2-2). As much as possible, crosslines should be independent of the main-scheme lines of which they check. Different systems, vessels, times, and days should be used for crossline data acquisition to help identify any vessel-to-vessel system errors.

Crossline comparisons can call attention to a variety of vessel, tidal, and positional errors. Collecting crossline data before mainscheme data collection allows the hydrographer to determine data issues early. It also offers a reconnaissance of the survey area at the start of acquisition. Collecting crossline data after mainscheme data ensures that the crosslines do run perpendicular to mainscheme coverage. Regardless of when crosslines are collected, the hydrographer should ensure that the proper amount of required crossline coverage is collected.

Crossline data may not agree well with mainscheme soundings if acquired in areas of irregular submarine relief and/or if SBES systems are used. In rocky areas, large depth differences may occur over small horizontal distances, making a small positioning error appear to be a large depth error. This effect is often noted when using SBES systems due to the large beam footprint.

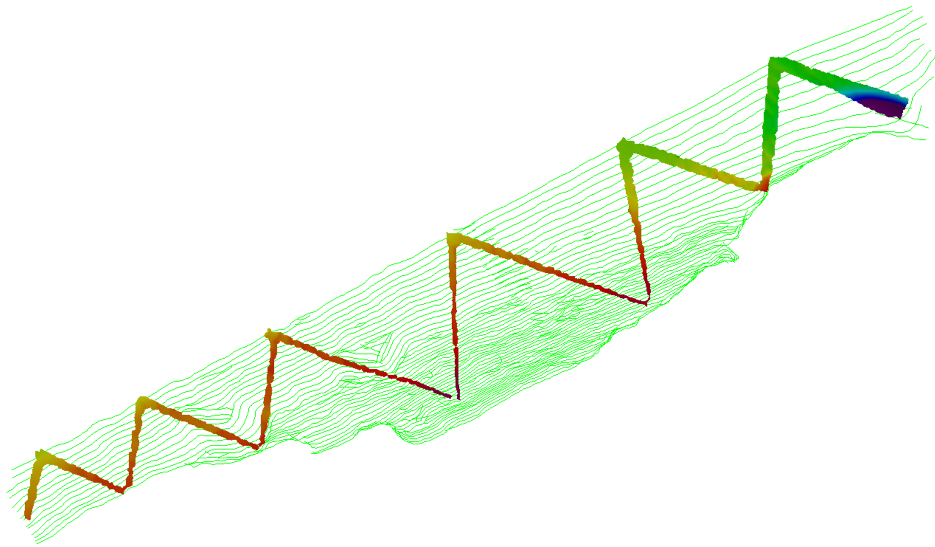


FIGURE 2-2 EXAMPLE OF SURVEY CROSSLINES

2.5.2.4 Developments

A development is performed to either obtain a least depth over a known point feature or further define an area-based feature such as a shoal. Typically, dense MBES data are acquired for developments although multiple SBES lines can be appropriate. If an SBES system is used to determine the least depth on a point feature, several parallel lines should be run over the feature until the hydrographer is confident that the least depth is recorded, or it is not safe to survey further (Figure 2-3).

Conducting developments during high stages of tide will improve MBES efficiency and may also provide increased vessel safety by maximizing under-keel clearance. If development lines are created to be run during a specific tide range, the hydrographer must be certain to convey this information to the vessel crew that will be acquiring the data.

When developing point features, least depths should be acquired using the center region of the MBES swath, typically 45° or less off the nadir. This section of the MBES swath will have fewer errors because of refraction or side lobe interference than the outer beams. It is recommended that, during development acquisition, a confidence swath be run in an orthogonal direction to the primary development lines. A common MBES development line plan may appear to be an assortment of “H” or “+” patterns over numerous features.

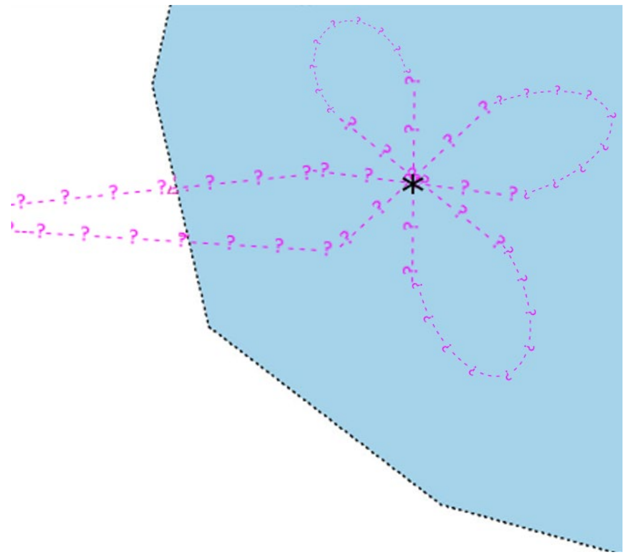


FIGURE 2-3 EXAMPLE OF SBES INVESTIGATION PATTERN

2.5.3 Survey Polygon Planning

As an alternative to line planning, polygon planning defines areas to be covered. While the entire area could be covered with a continuous line, polygons provide the hydrographer with discrete sections to be covered. This assists in better plans for survey timing, vessel efficiency, and ease of communications. Most of the guidance that applies to line plans also applies to polygon planning.

- The data should be acquired with the boat traveling parallel to the contours.
- Polygons should be planned so the boat will be running offshore to nearshore. Creating separate offshore and nearshore polygons (those that can be run at any time vs. those that need a specific tide window) is also helpful.
- Make polygons longer in the dimension the boat should run, providing a clear indication to the coxswain and surveyor of the polygon's directionality. For example, if running N to S will be most efficient with the contours, make your polygon longer in the N to S dimension.
- Do not plan polygons inshore of the 2.5-meter curve unless there is a specific reason to do so.
- In a channel consider having two polygons such that there is a straight edge in the middle of the channel. This provides the vessel with a straight baseline and encourages running from offshore to nearshore.
- Set polygons up so that that turns are minimized and lines are of a manageable length for processing.
- Traffic lanes and directions should be considered when creating polygons.
- Be aware of any possible sources of freshwater, or other factors that will affect the water column.

2.5.4 Bottom Samples

Samples of bottom sediment throughout the survey area should be obtained and analyzed in accordance with the HSSD if required by the Project Instructions. A bottom sample plan is compiled by the Project Manager and delivered to the field unit in the Project Reference File (PRF) using the S- 57 Object Class, "SPRING." The field unit should review the prescribed bottom samples to the survey data acquired to determine if the bottom sample locations are appropriate. The survey data will often better differentiate varying bottom characteristics within the survey compared to the assigned bottom samples. The sheet manager should coordinate with the CST and OPS to determine the best vessel day to collect bottom samples.

If different locations are collected, the change should be referenced in the descriptive report.

2.5.5 Special Circumstances

2.5.5.1 Search Patterns

In emergency or accident situations, NOAA field units may be involved with wreck, obstruction, or debris searches. Search operations should be conducted with the best survey method available for the circumstance. Several different types of search patterns can be used such as the star pattern, "H" pattern, creeping line, parallel, expanding square, and sector searches. Factors that can determine the spacing in a search pattern are:

1. Type of object being searched
2. Meteorological visibility
3. Time of day
4. Sea condition- prevailing currents and tides

2.5.5.2 Special Wreck Investigations

If a hydrographic field unit discovers a potentially significant historic wreck site or conducts a special wreck investigation through a request from NOAA, the field unit should make an effort to ensonify the wreck site and associated debris field with each type of sonar system that is readily available.

When planning side scan sonar operations, run parallel tracks on either side of the wreck, so that both sides are imaged, as well as two additional tracks orthogonal to the site. Acquiring multiple MBES lines over the wreck from offset or perpendicular directions at slow speeds will increase the data density of soundings on the wreck. Water column data may be beneficial for wreck development. The field unit should plan appropriately for water column data storage requirements.

The imagery and bathymetry data will provide clues to the wreck's status and identity, identify any obstructions, and provide researchers with an adequate baseline assessment with which to compare future surveys.

2.5.6 Survey Plan Finalization

Proposed survey acquisition plans should be reviewed by the Operations Officer, CST, and/or Chief-of-Party and any necessary adjustments made. Once reviewed, the plan should be disseminated out onto the survey platform(s). It is recommended to put the plans on all survey platforms even if the POD (plan of the day) does not call for other platforms to be used. This is in case the planned platform has mechanical/electrical issues and can't survey, another platform can begin work without delay.

2.5.7 Time to Completion Estimation

There are numerous ways to estimate survey sheet time completion that vary from field unit and branch operations. There are tools available in programs such as Pydro (Beets – Batts/Bathy Effort Estimation ToolS) or Hypack to assist with estimations while many spreadsheets are used as well. Typically, acquisition plans (polygons and lines) will be designed within CARIS, Hypack, or ArcGIS. Number and mileage statistics of any line plan should be recorded and used to estimate the amount of time required to complete the survey. When using these tools or others be sure to account for swath overlap, the time occupied by turning, anticipated speeds, and traffic interference. These estimations are critical to overall project planning.

2.5.8 Preparing the Survey Crew

The Sheet Manager will provide a boat sheet to the survey crew(s) at the beginning of each day. Some recommended information to include is a plot depicting line plans, polygons, bottom samples, coast pilot information, and/or shoreline files overlaid on the largest scale chart. The boat sheet should clearly depict a NOAA chart with uncharted hazards, tide information, charted and reported features, contacts, holidays, and/or developments before each survey day.

Templates for these boat sheets vary between NOAA field units. Boat sheets should be completed with adequate time for the boat crew to prepare, discuss, and gather equipment for the day's intended operations. The boat crew will discuss, determine, and calculate a Green, Amber, Red (GAR) score, outlined from the Small Boat Program based on their intended operations.

3 Chapter 3 Data Acquisition

3.1 Sensor Risk Management

NOAA field units deploy valuable oceanographic sensors in the water when conducting hydrographic surveys. The sensors are typically deployed in a variety of ways including being mounted directly on the hull of the survey vessel, suspended in the water by mounting them to a rigid retractable pole, and towed via a cable.

3.1.1 Best Practices for Preventing Loss of Equipment

The utmost care should be taken to prevent the loss of a hydrographic sensor before its deployment. This is accomplished through regular inspection of all key components of survey systems, proper preventative maintenance, safe operating procedures, and adequate precautionary measures to aid in recovery if a loss does occur.

All mounting hardware should be inspected regularly for defects or potential loosening. Weekly inspections are recommended. Components that are susceptible to degradation in marine environments such as rubber isolation mounts or metal fasteners prone to oxidation should be checked regularly for the material's condition. Routine inspection of mounting hardware and components for any sensor system should have an established inspection schedule that is determined by the likelihood of system loss.

Safety devices designed to prevent the loss of a sensor (e.g., safety cable attachment) or aid in the recovery of a sensor (i.e., pinging locator beacon) should be used at all times. These devices and associated components should be checked regularly for material defect, damage, or disengagement of fastening components. Weekly inspections are recommended. For systems deployed but not statically mounted (i.e., AUVs), the safety system should be checked before every deployment. Fixed mounted sensor's safety systems should be checked regularly in the same manner as the mounting hardware.

The sensors should be stowed for transit (e.g., SSS towfish secured on deck, swing arm multibeam in the retracted position) when not in use.

When publicly mooring the vessel, the crew should take care to secure equipment and property. Such as hatches are battened, doors are locked, and on-deck equipment is stored below. If applicable, securing mechanisms such as hitch locks should be used if being left unattended for an extended period of time. Vessel rounds should be completed at the field unit's discretion.

Care should be taken to stage this equipment in secured areas (whenever possible) to prevent vandalism or theft. If the base station is installed in a remote location, the user should be aware of natural conditions (such as wildlife) that may disturb the installation and take action to prevent damage or loss. Dual-frequency GNSS base stations may be installed for up to 30 days in a variety of locations. Once installed it is important to ensure that the antennae are not disturbed or moved for the duration of the deployment. Antennae should be secured in such a way that wind and rain or snow events will not move the antennae. GNSS receivers as well as batteries and radio electronics should be enclosed in a weatherproof, locking case.

3.1.2 Best Practices for Recovery of Lost Equipment

With the frequency of operations, sensor loss can occur even when adhering to best practices. The first concern should always be for the safety of the crew and vessel. This section discusses scenarios where sensor loss does not create safety concerns (for those scenarios follow established emergency procedures). If a thru-hull sensor is lost, the crew should take action to stabilize the vessel then worry about the sensor.

Every sensor loss situation is unique. Chances of recovery can be maximized by: (1) rapidly notifying others of the potential loss, (2) determining if the sensor might still be connected, (3) determining an accurate location where the loss occurred, and (4) using all available search and recovery means to locate the sensor as soon as possible. Details for each item are:

(1) Once a loss is suspected, the operator should notify the vessel crew, evaluate vessel safety, and make note of their position. Notify the appropriate chain of command for additional guidance and correspondence.
(2) The vessel should be maneuvered with care as the sensor may still be attached. Use any means possible to determine if the sensor is still attached. If a determination as to the sensor status cannot be made or is not safe, then the vessel should transit as slowly as possible back to the ship or harbor for further inspection.
(3) A successful recovery of the sensor is dependent on having an accurate location to begin the search. Marking this location on Hypack, ECDIS, or ECS, even if approximate, at the time of the loss will greatly increase the chances of locating the sensor subsequently.
(4) Once a position for the loss is determined, the search and recovery operation for the sensor should begin. It is imperative to begin the search operation as soon as possible after the loss to increase the probability of locating the sensor. All available resources should be considered to locate missing equipment.

3.2 Bathymetry Acquisition

While physical means of measurement (i.e., lead lines) are still part of NOAA's surveying capabilities, NOAA hydrographic field units primarily use two types of echo sounders to acquire bathymetry data: multibeam echo sounders (MBES) and single beam echo sounders (SBES). This section briefly describes lead line data acquisition but is primarily is dedicated to operating echo sounder systems and recording sonar data using common software packages.

3.2.1 Lead Line Data

A lead line can be used to measure depths in areas too shallow for echo sounders and to verify the least depths over dangers to navigation or shoals. Additionally, lead lines can be used to calibrate echo sounders. Lead lines are a powerful tool for troubleshooting electronic systems. Lead line soundings should be acquired at slack current, if possible, to ensure that readings are true vertical measurements of depth. All lead line soundings should be clearly identified as such in the survey records.

The lead line calibration table determined during HSRR should be used during any lead line collection. The hydrographer should also, at a minimum, record the lead line number, geographic position, and time of measurement for each sounding. Lead line-derived sounds were traditionally tidal corrected; however, this workflow is no longer recommended. All submitted soundings should be vertically corrected to the ellipsoid. Vertical datum correctors must be applied to lead line data during post-processing.

3.2.2 Single Beam Echo Sounder (SBES) Data

Single-beam echo sounder systems may vary among NOAA hydrographic field units. Most NOAA systems are dual-frequency, using both a high and a low frequency with beam widths between 3 and 8 degrees for high frequency and larger for low frequency (20–30 degrees). Provided the magnitude of vessel roll and pitch is less than the sonar beam width and heave is less than 0.5 meters, these attitude characteristics will have little effect on sounding accuracy. If the system is not equipped with an attitude sensor to correct for vessel motion, SBES should not be used in sea states where vessel roll and pitch angles exceed sonar beam width or heave exceeds 0.5 meters.

Most SBES systems output calculated depth values rather than the two-way travel time of each sonar ping. To facilitate these calculations, the systems must be configured with a value for the speed of sound through the water column. Hydrographic field units should configure SBES systems using a standard estimate for their given operating area (e.g., 1,500 m/s for the speed of sound in seawater). SBES data should then be corrected using full sound speed profiles acquired during the survey in post-processing.

The HYPACK software package, produced by HYPACK Inc., is commonly used by NOAA hydrographic field units to acquire SBES data. It is compatible with most SBES systems and can also be used for MBES acquisition. Users should consult with HYPACK or applicable reference materials/manuals for more information regarding the software and contact the regional HSTB Field Support Liaison for current configuration guidance.

3.2.3 Multibeam Echo Sounder (MBES) Data

NOAA hydrographic field units typically use swath systems, which produce multiple acoustic beams from a single transducer and measure both the angle and two-way travel time of the acoustic signals. The frequency of the signal varies from system to system and typically ranges between 12 and 455 kHz. During each sonar ping, a projector beam transmits a swath of acoustic energy into the water, and reflected energy returns to the transducer where it is detected by the receiver (a hydrophone). These swath MBES systems generally operate in one of two different scanning modes: Frequency Modulated (FM) and Continuous Wave (CW), equidistant and equiangular.

The equidistant mode electronically forms the MBES beams such that each beam footprint has a uniform width along the seafloor across the entire swath width (Figure 3-1). These beams are adjusting to maintain this equal footprint as depth changes across the survey area. This even sampling across the swath width reduces the amount of overlapping coverage and intensity of returns in the inner half of the swath, providing a more uniform coverage across the entire swath. This scanning mode is the one most commonly used by NOAA field units.

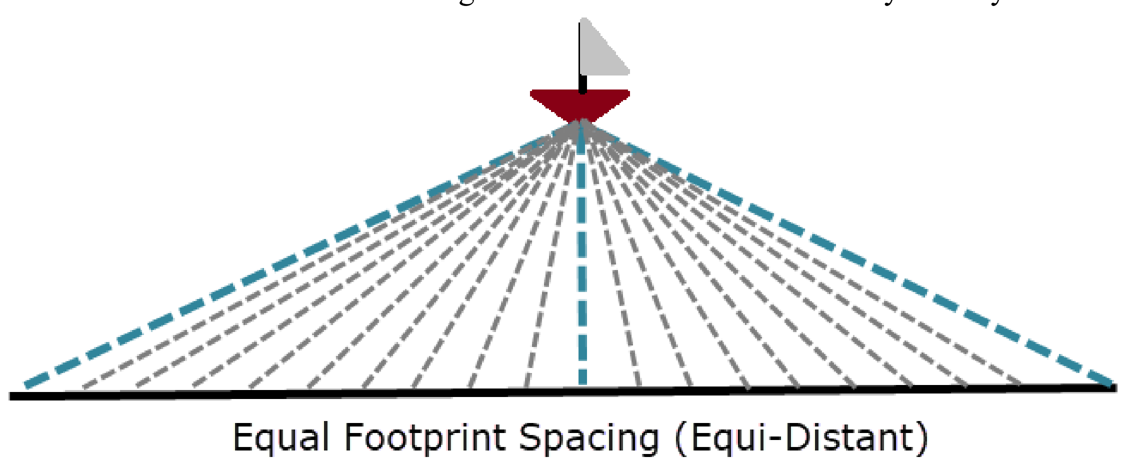


FIGURE 3-1 EQUI-DISTANT BEAM SPACING.

The equiangular mode electronically forms the MBES beams in equal angles across the swath (Figure 3-2). The beam overlap is constant with an equi-angular system, due to the angular beam widths is more or less constant across the swath. This means that while inner beams have a very small beam footprint that overlaps with adjacent beams, the outer beams have a much wider beam footprint with minimal to no overlapping coverage from adjacent beams. The advantage of this mode is the high-resolution overlapping coverage of the inner half of the swath and is excellent for hazard investigation surveys where precise measurements of small targets are necessary.

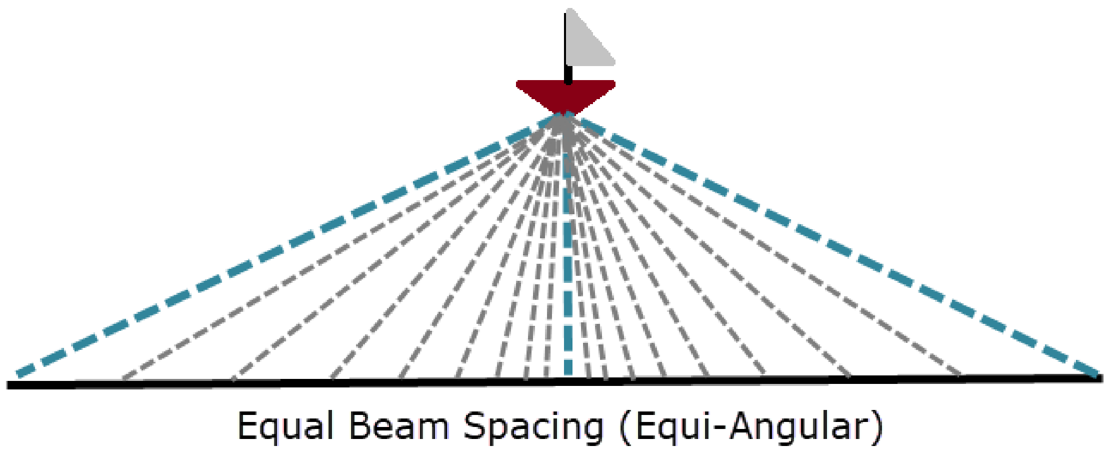


FIGURE 3-2 EQUIANGULAR BEAM SPACING.

NOAA hydrographic field units with mounted MBES systems can have either hull-mounts or pole-mounts. Each type of sonar mount has inherent benefits and potential problems that should be considered during data acquisition.

A hull-mounted system is generally very stable, producing data with minimal noise from vibration. A hull-mounted configuration can be accomplished by notching the vessel keel and installing the sonar head along the keel line, attaching a mounting plate for the sonar head to the vessel hull, or cutting a box into the hull and creating a retractable mount for the sonar head. The flow of water along a vessel hull can create air bubbles, which may cause noise in a hull-mounted system. This problem should be considered when designing a hull-mount system. Benefits and drawbacks associated with each type of configuration should be considered when designing and installing such a system.

A pole-mounted system is often the quickest and least intrusive mounting configuration. Pole-mounted systems are used often during navigation response, using OCS's Mobile Integrated Survey Team (MIST) kits and a vessel of opportunity. The MIST kit includes all equipment required to conduct a high-quality MBES survey, including a universal pole mount in about six pelican cases. The sonar head is mounted to a large pole that can be pivoted into the water during data acquisition. At the completion of the acquisition, the pole can be pivoted back out and secured to minimize drag during transits. When using a pole-mounted system, it is critical that the sonar can be both reliably deployed to a repeatable position (with respect to the vessel reference frame) and adequately stabilized during data acquisition. Pins or guy-wires are often used to help with system stabilization. Noise due to vibration of the mounting pole at certain vessel speeds is a common problem with pole-mounted systems.

Auxiliary sensors are necessary for high-quality data from an MBES system. The four most critical measurements are vessel attitude, positioning, timing, and sound speed. Vessel attitude (roll, pitch, yaw, and heave) is recorded via an inertial measurement unit (IMU) such as the Applanix POS MV unit used by most NOAA field units. Positioning data is also logged via the Applanix POS MV unit. Timing is critical to coordinate MBES data with position and attitude data and is often provided by the positioning system. Sound speed data are necessary for beamforming and is managed by a real-time sound speed sensor by at the transducer face.

During acquisition, Conductivity, Temperature, and Depth (CTD) information is also collected at a frequency prescribed by the HSSD. Information collected by the CTD is downloaded, converted on the survey vessel, and applied to determine beam spacing and later to correct depth during post-processing.

HYPACK/HYSWEEP, produced by HYPACK Inc. and Seafloor Information System (SIS), produced by Kongsberg, are the two software systems commonly used by NOAA hydrographic field units to acquire MBES data. Users should consult with the respective vendor or applicable reference materials/manuals for more information regarding the software and contact the regional HSTB Field Support Liaison for current configuration guidance.

3.3 Acoustic Backscatter Acquisition

NOAA hydrographic field units use a variety of sonar systems to acquire acoustic backscatter data. This data may assist with the determination of seabed characteristics and locations for conducting bottom samples. Side scan sonar (SSS) natively acquires backscatter imagery and is preferred for its object detection capabilities. MBES systems can also record seafloor acoustic backscatter data along with bathymetric data.

Multibeam backscatter is intensity data that can be processed to create low-resolution imagery of the reflective intensity or hardness of the ocean floor. Backscatter is co-registered with the bathymetry data and is often used to assist with bathymetric data interpretation and post-processing. To optimize a system for backscatter data quality, refer to the manufacturer's documentation. However, the hydrographer should be cognizant that adjusting an MBES system to enhance backscatter data may affect the quality of acquired bathymetry data.

The acquisition of multibeam echo sounder seafloor backscatter may be required in the project instructions. MBES backscatter may be used to supplement hydrographic data for non-charting purposes. Refer to the HSSD, annual HTDs, or the regional HSTB Field Support Liaison for further guidance.

3.3.1 Side Scan Sonar (SSS) Data

Side scan sonar systems and configurations vary among NOAA hydrographic field units. Traditional SSS operations consist of a sonar body or "towfish," which is towed behind a vessel via a cable and winch system or can be hull-mounted. During operations, transducers located on each side of the towfish emit an acoustic signal that ensonifies a wide swath of seabed. The frequency of the signal varies from system to system, typically ranging between 100 and 500 kHz. Lower frequencies will increase the maximum range scale of an SSS, but image quality and resolution increase with higher frequencies. The amplitude of returning echoes from the seafloor are recorded and georeferenced based on the return time series. The intensity of the SSS return signal will also be affected by the acoustic reflectivity of the seafloor. For example, rock and metal objects are better reflectors than sand or mud.

Given a flat seafloor, the SSS will return consistent values across the entire range scale. However, if an object or scour is present which is elevated from the seafloor, a portion of the return signal will be irregularly spaced in time. This interruption causes an acoustic shadow or a lack of return signal along a portion of the range scale. This basic side scan sonar theory of operation (Figure 3-3).

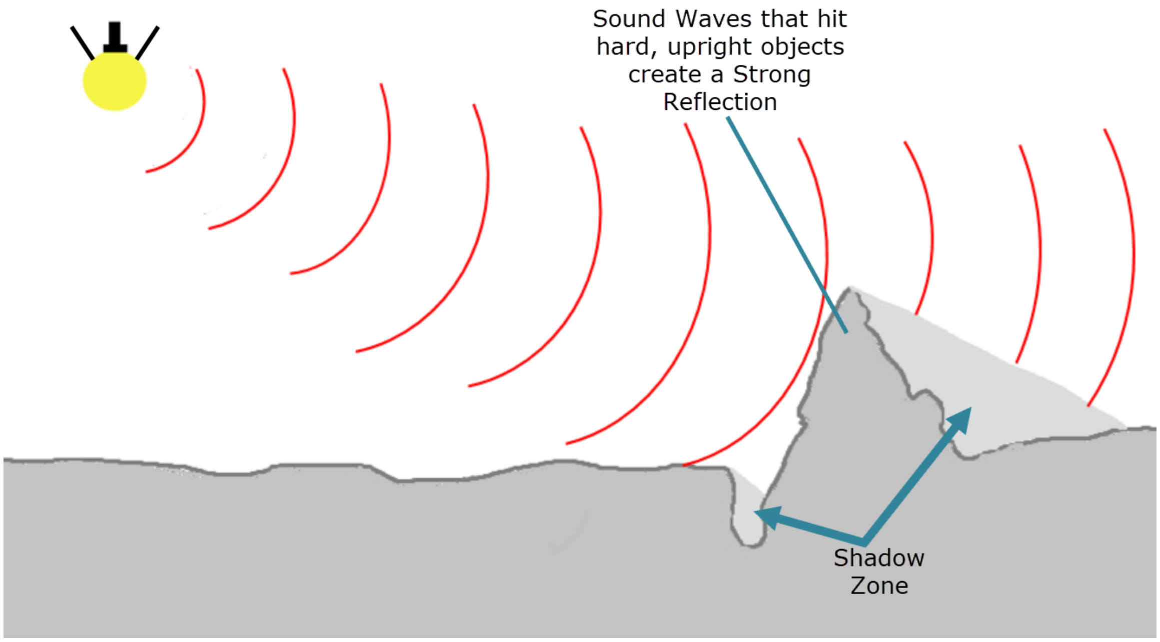


FIGURE 3-3 BASIC SIDE SCAN SONAR THEORY OF OPERATION

Side scan systems are typically towed at depth to increase sonar grazing angles and object detection capability. For optimum object detection, Coast Survey requires maintaining a towfish height of 8–20% of the operating range scale. NOAA's hydrographic field units effectively use both towed and hull-mounted SSS configurations. Each type of configuration has inherent benefits and potential problems that should be considered during data acquisition.

In towed configurations, towfish height is controlled by a combination of vessel speed and cable out. The relationship between cable out and the depth of the towfish at a given speed is known as layback. This allows the operator to maximize object detection abilities in various water depths. The downside of a towed system is the increased positioning uncertainty caused by how the towfish follows the vessel underwater. This may cause issues correlating SSS contacts and MBES developments. In towed systems there is also the increased risk of grounding the towfish if cable out and vessel speed are not carefully monitored. Perhaps counter-intuitively, if towfish grounding appears to be imminent, rapidly increasing vessel speed will cause the towfish to rise in the water column and hopefully avoid grounding.

For hull-mounted configurations, position data are more accurate and operations can be conducted safely and effectively in shallow waters. However, since a hard-mounted system cannot be adjusted within the water column, it may be difficult, if not impossible, to maintain the 8–20% towfish height required for object detection.

SonarPro, produced by Klein, and Discover, produced by EdgeTech, are the two principal software systems commonly used by NOAA hydrographic field units to acquire SSS data. Hypack integration is also possible with certain systems. Users should consult with the respective vendor or applicable reference materials/manuals for more information regarding the software and contact the regional HSTB Field Support Liaison for current configuration guidance.

3.4 Position and Attitude Data

Position and attitude data are critical for acquiring high-quality survey data. These data may come from multiple systems working together or one integrated unit/system. At a minimum, a position and attitude system will contain a GNSS receiver and an inertial measurement unit (IMU). The GNSS receiver (or receivers) acquires the position of the vessel using GNSS satellites (i.e., GPS), and when multiple receivers are used, it can also provide heading information. Additionally, the highly precise GNSS clock signal for positioning is often used as the timing signal for the entire survey system. The IMU measures vessel attitude (i.e., roll, pitch, yaw, and heave) across all axis and rotations. These data in conjunction with the positioning data and sound speed allow data to be corrected to its true position on the seafloor. In integrated systems, the data from the IMU allows the vessel to maintain an accurate position, even in the event of a full loss of GNSS satellites for short durations such as operating under a bridge or other obstructions.

The POS MV, produced by Applanix, is the integrated positioning and attitude system most commonly used by NOAA hydrographic field units. Users should consult with Applanix or applicable reference materials/manuals for more information regarding the system and contact the regional HSTB Field Support Liaison for current configuration guidance.

3.4.1 Wide Area Augmentation System (WAAS)

GNSS positioning accuracy can be improved by using the FAA's Wide Area Augmentation System (WAAS) or commercial services. Both serve to resolve various errors in the GNSS position by broadcasting correctors derived from land-based stations. These processes improve the accuracy of GNSS positioning from the order of ~10 meters to 1 meter. Furthermore, while not strictly required for integrated positioning systems such as the Applanix POS MV, using WAAS allows the system to initialize far more rapidly at the start of the survey day.

3.4.2 Horizontal Control (HORCON) GNSS Reference Stations

If insufficient horizontal (or vertical) correctors are available, a portable GNSS reference station can be established by a field unit to provide additional positional control and accuracy. The example reference station consists of an L1/L2 GNSS antenna and receiver for position, tripods, marine batteries and solar panels for power, and an optional radio modem for communicating with the field unit (Figure 3-4). Data from these stations can be post-processed to determine an exact position for the station and to calculate positioning correctors for survey vessels.

When choosing a site for a GNSS reference station, the hydrographer should set it in a convenient place with a good line of sight to the survey area (for radio communications) and a clear view of GNSS satellites overhead (substantially clear sky all around from above 10 degrees from the horizon). Efforts should be made to find either tidal bench marks or other established bench marks to reoccupy the station as doing so presents a valuable data point for geodesists and allows the hydrographer to start with a known position. If no existing bench marks are available, a new mark may be established. Established bench marks can be found through NGS's National Geodetic Data Explorer.

Data from HORCON stations is processed by NGS's Online Positioning User Service (OPUS). The OPUS solution (position) will be used for post-processing of the HORCON data and is also used to verify the station is stable and has not been impacted by weather or wildlife. Field units should wait 24 hours after an occupation to process a usable OPUS solution to attain the highest quality position possible.

FIGURE 3-4 GNSS REFERENCE STATION SET UP BY NOAA SHIP *RAINIER*

3.4.3 Alternate Positioning Equipment

3.4.3.1 Private Satellite Correction Services

Various private real-time or post-processed correction services are available which provide a highly accurate real time position and minimize the need for post-processing of positioning data. These services include Fugro MarineStar and Trimble RTX, both of which are in use in the NOAA fleet. Identification of what solution may work best for a particular platform or mission should be discussed with HSTB and HSD ahead of the start of a field season.

On some projects, Real-Time Kinematic (RTK) correctors, like Florida Department of Transportation Permanent Reference Network (FDOT FPRM), may be the preferred means of correcting position. RTK applies correctors to positional data in real-time based on inputs from a nearby base station with either set up by the field unit or from an outside source (NGS, state DOTs, private entities). RTK is capable of correcting vertical position within 3cm, making it an excellent option for survey operations. However, it is reliant on a highly stable internet connection to receive its data via the Network Transport of RTCM over Internet Protocol (NTRIP) protocol. This also requires software to decode the signal and send it to the positioning system via RTCM messages. Assistance with configuring this can be obtained from HSTB.

3.4.3.2 Portable GNSS Units

In some situations, such as shoreline verification, it is more efficient for the field unit to position features using a portable GNSS unit. Various models of portable GNSS units are available on the open market. Portable GNSS units should meet the horizontal accuracy requirements as stated in the HSSD.

3.5 Ancillary Data

Two basic types of ancillary data are acquired in conjunction with OCS hydrographic surveys. The first type is used to correct sonar data and includes such measurements as sound speed and water levels as well as horizontal and vertical control data. The second type consists of information that supports survey analyses, such as positions for aids to navigation (ATONs), bottom samples, shoreline features, and Coast Pilot reviews.

3.5.1 Sound Speed Data

Sound speed data are used by NOAA hydrographic field units for multiple purposes. Sound speed profiles are used to correct sounding data from varying speed of sound in the water and refraction. Additionally, flat arrays and to a lesser extent the outer beams in curved arrays (of MBES systems) require a continual real-time input of surface sound speed data at the sonar head for proper beamforming and beam steering.

When acquiring sound speed profiles to correct bathymetry, casts should be taken in the deepest portion of the working survey area. Doing so provides the best representation of the surveyed area for which the profile will be applied. Sound speed profiles can be extended using World Ocean Atlas and historical cast data using Sound Speed Manager software. There are typically three files that are exported from sound speed casts for a variety of post-processing and submission requirements.

1. SVP- used by CARIS to apply sound speed data to depth data
2. NOC- sent to NCEI, submitted with the survey
3. ASVP- sent to Kongsberg via Sound Speed Manager

The required frequency of casts will be dependent on the survey area, but OCS strongly recommends that a cast be performed no less than once every four hours during MBES data acquisition and once per week for SBES data. For areas with high variation in sound speed, casts should be taken more frequently.

The Sea-Bird SEACAT and CastAway conductivity, temperature, and depth profiler (CTD) and Rolls- Royce Moving Vessel Profiler (MVP) are commonly used by NOAA hydrographic field units to acquire sound speed data. Position information will be required by Sound Speed Manager for data processing and the user must be certain to record the most accurate GNSS position possible. Data acquisition is briefly discussed for each of these systems below.

3.5.1.1 Sea-Bird SeaCAT

The SeaCAT is a portable, user-deployed, battery-operated instrument, typically housed in a protective cage (Figure 3-5). The SEACAT records water salinity, temperature, and pressure (i.e., depth) during deployment and retrieval. The sampling rate depends upon the CTD model being used and is typically between 2–4 samples per second. These data are processed using NOAA's Sound Speed Manager software to calculate a sound speed profile for the water column. If the SEACAT voltage is less than the following values listed below, the instrument batteries should be changed:

- SBE 19plus v2: 11 volts
- SBE 19plus: 9.5 volts
- SBE 19: 7 volts

All three cases, the user is told to inspect the battery cut-off value in the status message produced by the Sound Speed Manager. The battery should, at the very least, be one volt greater than the cut-off value.

CTD cast setup orientation in relation to the wind is critical to a successful cast; communicate with the coxswain to orient the vessel so the CTD can be deployed off the windward side. This will prevent the vessel from drifting over it and fouling the props in the line.

When conducting SEACAT casts, using the SBE 19 and SBE 19 plus, the instrument should be lowered and held just below the water's surface for about 2 minutes to flush air out of the salinity cell and allow the sensor to acclimate to the water. After soaking the instrument beneath the surface, the user should lower the instrument through the water column at a rate of 1 meter of depth per second.

It is important to note that when the sensor detects a reverse in the change in pressure, it triggers the SEACAT sampling to stop. As such, it is important to take care to not let the equipment jerk upward during the 2 minute acclimation period or during deployment as this can cause a premature termination of the cast.

FIGURE 3-5. EXAMPLE OF AN SBE 19+ TYPICALLY USED BY NOAA FIELD UNITS

3.5.1.2 CastAway

The CastAway CTD is a handheld castable instrument that provides instantaneous profiles of temperature, salinity, and sound speed (Figure 3-6). These units are designed for coastal profiling and can collect high-resolution CTD measurements for depths up to 100 meters.

The castaway CTD is deployed similarly to the SeaBird units over the side of the vessel. Because of its small size, a weight should be affixed to the bottom of the unit to ensure the collection of the full water column. With its portable nature, this castaway CTD is often deployed and recovered by hand or via a fishing pole. The CastAway unit should soak in the water for 10 seconds before deploying, allowing the sensors to stabilize.

This unit transmits and downloads data via Bluetooth to the acquisition machine, and information can then be processed and exported in the Sound Speed Manager.

FIGURE 3-6. EXAMPLE OF A CASTAWAY UNIT USED BY NOAA FIELD UNITS

3.5.1.3 Rolls-Royce Moving Vessel Profiler (MVP)

The Moving Vessel Profiler (MVP) is an automated winch system that deploys a free fall towfish fitted with a sound speed sensor (Figure 3-7). When not sampling but in the water, the towfish is configured to be in the "docked" position at a specified depth. The docked position is marked by a messenger on the cable such that the towfish flies at or above the transducer depth.

The towfish can either be user-deployed or deployed automatically by the computer at a defined time interval to a user-defined depth or a preset depth off the bottom (typically 10 meters). The towfish is automatically recovered to transducer depth, ready to be deployed again. Even though the MVP software can process casts, it is convenient to batch process the sound velocity profiles using Sound Speed Manager because of the large number of casts that can be recorded by the MVP in a short time frame.

Refer to the MVP Operation and Maintenance Manual and the MVP Controller Software Manual for additional information on this system.

FIGURE 3-7 MVP BEING DEPLOYED FROM FERDINAND HASSLER

3.5.1.1 Surface Sound Speed Sensors

The Reson SVP 70, SVP 71 and AML Micro X SV are portable sound velocity probes. These all connect to a topside computer and feed sound speed data to the sonar and acquisition software. Surface sound speed is used for real time beam steering for flat faced transducers, and is essential for high quality data from these sonars. These sensors directly measure sound speed by transmitting a sound pulse and detecting it's time to travel a well-defined path length. The transmitted signal is generated using waveform techniques that yield optimal conditions for timing the arrival of the returning signal, which is digitized at high frequency and high resolution. The timing is established using a high-stability clock oscillator.

Surface sound speed sensors should be mounted near the head of a flat face MBES transducer to ensure that valid sound speed data are being used during the beamforming process. The hydrographer should monitor that the sound speed sensor is receiving a continuous readout.

The SVP 70 and SVP 71 are both 6.5-inch probes sampling up to 20 times per second (Figure 3-8).

FIGURE 3-8 SVP 70 ONBOARD RAINIER

The AML Micro X SV is a 3.4 inch sound velocity probe that provides real-time surface sound velocity with a response time of 20 ms (Figure 3-9). The sensor instrumentation can be easily removed for calibration and inspection while the housing body of the sensor remains installed. The body of the sensor can remain installed, and the sensor can be unscrewed and mailed in for calibration.

FIGURE 3-9 AML MICRO SV ATTACHED TO THE SENSOR BODY, MICRO X

3.5.2 Vertical Datum Transformation Data

The majority of hydrographic surveys are now Ellipsoid Referenced Surveys (ERS). ERS is utilized to improve the efficiency, accuracy, and flexibility of survey operations. Bathymetry referenced to the ellipsoid can be easily transferred to any of the many ellipsoidal, orthometric, or tidal datums supported by NOAA's VDatum tool.

Typically, VDatum is used to transform survey data to MLLW for chart compilation. The information collected in the POS file is used during vertical datum transformation in post-processing using various models such as VDatum and ERTDM (Ellipsoidally Referenced Tidal Datum Model).

For data acquisition, it is critical the hydrographer recognizes potential satellites and clock errors. These variables comprise and explain the components of orbital perturbations. Orbital perturbations can alter satellite trajectories from their predicted path. This "ephemeris error" is the difference between the expected and actual orbital path. These deviations are corrected in post-processing using rapid or precise ephemerides.

3.5.3 Tidal Data Collection

The field party should obtain all required permits and permissions for the installation of the water level sensor(s), DCP(s), bench marks, and utilities, as required. The field party is responsible for security and/or protective measures, as required, for all components in the manner prescribed by the manufacturer or the installation manuals. The field party should provide CO-OPS the geographic position of all gauges installed before the coastal shoreline mapping survey begins, including those that were not specified in the Project Instructions, as appropriate. The horizontal geographic positions of bench marks, sensors, and DCPs installed or recovered should be obtained and reported in latitude and longitude in the format of degrees, minutes, seconds, and tenth of a second.

The water level station and its various components (e.g., tide house, DCP, all sensors, bench marks, and pertinent access facilities such as railings, steps), when designed or installed by contractors, should be installed and maintained as prescribed by the manufacturers, installation manuals, appropriate local building codes, and/or as specified by the COR, where applicable. The water level station and all installed components should be structurally sound for its intended application, secure, and safe to use for NOS, local partners, contractors, and public, as appropriate.

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

3.5.3.1 Tide Station Installation

Complete water level measurement station installation should consist of the following:

1. The installation of the water level measurement system (water level sensor, DCP, and satellite transmitter), its supporting structure, and a tide staff, if required.
2. The recovery and/or installation of a minimum number of bench marks and a level connection between all bench marks and the water level sensor(s), and the tide staff, as appropriate. For all installations, a minimum of five bench marks with stability code A or B are required.
3. The documentation of the horizontal geographic positions of the sensors, station, DCP, and bench marks installed or recovered. The positions should be obtained using a hand-held GPS receiver in latitude and longitude and reported in degrees, minutes, seconds, and tenth of a second (e.g., bench mark position as latitude 37 degrees 45 minutes 34.1 seconds and longitude as 75 degrees 25 minutes 32.5 seconds).
4. The collection and submission of GPS observations at one or more bench marks in the network and the preparation and submission of the station installation documentation.

3.5.3.2 Tide Station Operation and Maintenance

The field party should monitor the near-real-time water level data daily for indications of sensor malfunction or failure and other causes of degraded or invalid data such as marine fouling.

When GOES telemetry and the NOS satellite message format are use and CO-OPS is monitoring the gauges for NOS in-house projects, the data can be viewed by accessing the CO-OPS Diagnostic Tool (DiagTool). The raw data are typically available within 18 to 30 minutes after collection for 6-minute data, or between 48 minutes to

1.5 hours depending upon the frequency of the transmissions. For NOS contract projects, contractors are responsible for monitoring the gauges and for taking the proper corrective actions, as necessary.

All repairs, adjustments, replacements, cleaning, or other actions potentially affecting sensor output or collection of data should be documented in an eSite report or the appropriate maintenance forms as identified in contract documents and retained as part of the water level data record. This documentation should include but not be limited to the following information: date/time of start and completion of the maintenance activity, date/time of adjustments in sensor/DCP, datum offset/sensor offset/orifice offset changes and date/time of the change, personnel conducting the work, parts/components replaced, component serial numbers before and after the maintenance, acceptance tests results, purpose of the trip, and recommended actions that could not be completed and the reason for the incompletion, and so on.

3.5.3.3 Removal of Tide Station

Complete removal of the water level measurement station should consist of the following:

1. Closing levels: a level connection between all bench marks and the water level sensor(s) and tide staff as appropriate.
2. Removal of the water level measurement system and restoration of the premises with reasonable wear and tear accepted.
3. Disposal of expendable or unusable components in an environmentally friendly manner.
4. Termination of any utilities.
5. Closeout or termination of a license agreement.
6. The preparation and submission of the station removal documentation.

The field party should obtain all required permits and permissions for installation of the water level sensor(s), DCPs, bench marks, and utilities, as required.

3.5.4 Tide Staffs

The field party should 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 bench marks (e.g., the orifice is laid on the seafloor). Even directly leveled pressure gauge(s) may require staff readings for assessment of the variations in gauge performance because of density variations in the water column over time. The tide staff should be mounted on a separate piling other than the piling on which the water level sensor is installed so independent stability of the staff and sensor is maintained. The staff should be plumb. When two or more staff scales are joined to form a long staff, the field party should take extra care to ensure the accuracy of the staff throughout its length. The distance between staff zero and the staff stop should be measured before the staff is installed and after it is removed, and the staff stop above staff zero height should be reported on the appropriate site report.

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."

3.5.4.1 Staff Observations

When using the vented pressure sensor, a series of gauge/staff comparisons through a significant portion of a tidal cycle (minimum 3 hours) should be required:

1. At the start of water level data collection
2. At frequent intervals during deployment
3. At the end of a deployment before gauge has been removed.

The staff observations at the installation and removal of the water level gauge should consist of a minimum of 3 hours of observations at 6-minute intervals. Frequent gauge/staff comparisons during the deployment should be required to assist in assuring measurement stability and minimizing processing errors. The staff-to-gauge observations at the start and end of deployment should each be at least 3 hours long, and the periodic observations during the deployment should be at least 1 hour long. The staff-to-gauge observations should be performed three times per week, during each week of the project with at least 1 hour of observations at six-minute intervals.

The observations should be recorded at the same time the gauge is collecting data at the six-minute interval starting with 0 minutes (e.g., 0, 6, 12, 18, 24, 30, 36, 42, 48, and 54 minutes after the hour). Where staff-to-gauge observations cannot be performed three times a week as required, then an explanation is required, and CO-OPS ED will grant a waiver, or alternate staff-to-gauge observations will be performed:

1. Minimum eight times spread out over each month (e.g., two times per week) and at each time at least 1 hour of observations at 6-minute intervals.
2. Minimum of four times spread out over each month (e.g., one time per week) and at each time at least 2 hours of observations at 6-minute intervals.

The performed staff observations along with the time-stamped gauge data should be forwarded to CO-OPS ED and the HSD/NSD Project Manager within 15 business days or sooner, if practicable. The staff-to-gauge differences should remain constant throughout the set of observations and show no increasing or decreasing trends. After the water level data have been collected, the averaged staff-to-gauge should 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 reference number 32 for an example pressure tide gauge record (see Section 4.6). If the staff is found destroyed during the deployment, a new staff should be installed for the remainder of the deployment, and a new staff-to-gauge constant should be derived by staff-to-gauge observations. When a staff or an orifice is replaced or re-established, check levels should be run for a minimum of three bench marks including the Primary Bench Mark (PBM).

When reoccupying historic water level stations, NOS CO-OPS will provide the station datum (SD) information for the station. This information is generally given about the PBM above the historic SD. In that case, for pressure sensors that require staff-to-gauge observations, all the water level data should be placed on the station datum (Figure 3-10). By using the following equation:

$$
\begin{aligned}
&Water\ level\ data\ on\ the\ SD \\
&= (Premimniary\ pressure\ water\ level\ data\ on\ an\ arbitrary\ datum\ as\ collected\ by\ the\ gauge) \\
&+\ (PBM\ above\ SD) - (Staff\ zero\ below\ PBM) - (weighted\ staff\ to\ gauge\ constant) \\
&Staff\ zero\ below\ PBM = (Staff\ stop\ below\ PBM)\ + (Staff\ zero\ below\ Staff\ Stop)
\end{aligned}
$$

The staff-to-gauge constant should be derived as a weighted average of all the staff-to-gauge readings done for the project per deployment.

The staff zero below PBM is obtained generally by:

a. Leveling from PBM to staff stop
b. Measuring the staff stop to staff zero elevation with a steel tape
c. Then combining the two (a and b) elevation values.

The staff zero below PBM is obtained by averaging the elevations differences during the opening (installation) and closing (removal) leveling runs for short-term occupations. At most locations requiring BMPG deployments, a "virtual tide staff" procedure may be required. This procedure requires repeated geodetic leveling from a bench mark or temporary bench mark (backsight) to a level rod held at the water's edge (foresight staff shots). The water level should be read off the level rod scale, taking into account wave action (a small stilling tube attached to the rod helps with this reading). Foresight water level readings should be made every 6-minute for a 3-hour period after initial deployment of the pressure sensors and just before retrieval of the sensors. Backsight closures to the bench mark should be made at the beginning and end of the 3-hour periods with the leveling instrument setup remaining undisturbed

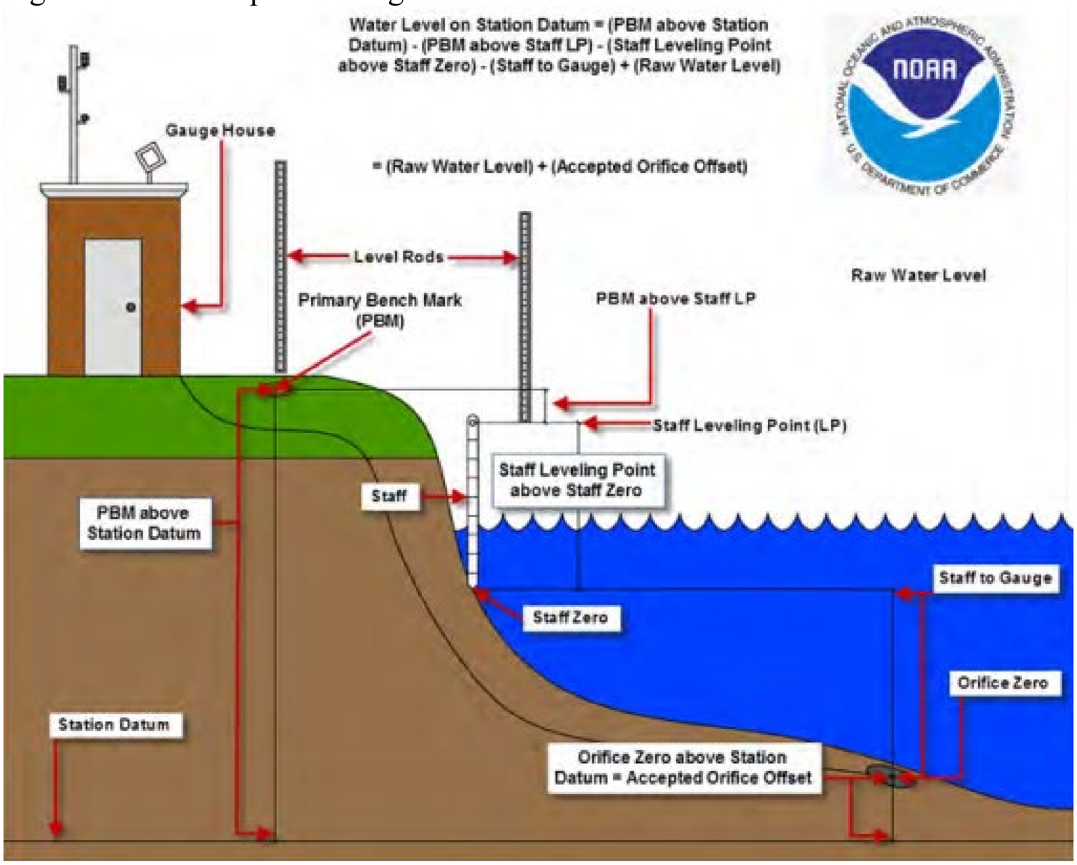


FIGURE 3-10 RELATIONSHIP OF STATION DATUM, ORIFICE, AND STAFF

3.5.5 Bench Marks

According to the National Geodetic Survey (NGS) geodetic glossary, a bench mark is a relatively permanent, natural or artificial, material object bearing a marked point whose elevation above or below an adopted surface (datum) is known. A bench mark is set to monitor stability and used as a reference to the vertical and/or horizontal datums. Bench marks in the vicinity of a water level station are used as the reference for the local tidal datums derived from the water level data. The relationship between the bench marks, the water level sensor, and tide staff should be established by differential leveling. Please note that if a direct measurement between the water level sensor and the bench marks cannot be made, then staff-to-gauge measurements and comparison is required.

Before installing a new mark, perform a 1.6 kilometer (1 mile) radial search from the tide station (DCP) location at NGS web site, or the NGS Online Positioning User Service (OPUS) database to check if any NAVD 88 marks are available that are not part of the local leveling network. Inclusion in the local leveling network of an existing mark(s) that has a NAVD88 elevation located within a 1.6 km (1 mile) leveling distance of the station location is desirable and should be preferred over installing a new mark.

Bench mark descriptions should be written according to the User's Guide for Writing Bench Mark Descriptions. Descriptions should be checked by verifying distances with tape measurements in metric units, verifying cited landmarks, verifying the location using a hand-held GPS, and using a compass to confirm directions. The handheld GPS coordinates of each mark should be entered in the description file for electronic levels, or noted on the published bench mark sheet or equivalent for optical levels. The latitude and longitude fields of the bench mark should be reported in the following format: degrees/minutes/seconds and tenths of seconds for example, 40 degrees, 45 minutes, 35.2 seconds.

All bench marks must be identified on the bench mark diagram using the CO-OPS' standard bench mark diagram title block. If a digital diagram is used, submit the digital file in JPEG format with the leveling files and photos. Submission of updated bench mark diagrams are required only when necessary to document newly established marks, marks removed from the network, and/ or physical changes in the area. Refer to reference number 32 for the bench mark diagram template.

If a bench mark is discovered disturbed or mutilated during the visit to a station, include it in the level run to determine if it is holding its elevation relative to the PBM and report it to CO-OPS ED and the supporting FOD field office. If the disturbed or mutilated bench mark is the PBM and/or it is not holding its elevation, contact CO-OPS ED for assistance in selecting another PBM and determining its elevation above Station Datum.

3.5.5.1 Types of Bench Marks

The number and type of bench marks required depends on the duration of the water level measurements. The User's Guide to Vertical Control and Geodetic Leveling for CO-OPS Observing Systems dated May 2018, specifies the installation and documentation requirements for the bench marks. Generally, for hydrographic surveys, a minimum of five bench marks are required at each station. The required minimum separation between each bench mark is 200 feet (61.0 m).

Each water level station will have one bench mark designated as the PBM, which should be leveled on every run. The PBM is typically the most stable mark near to the water level station. The surveyor should select a PBM at sites where the PBM has not already been designated. For historic water level station reoccupations, CO-OPS' COET will furnish the designation/stamping of the PBM and PBM elevation above station datum, if available.

If the PBM is determined to be unstable, another mark must be designated as PBM. Contact CO-OPS ED for assistance in selecting another PBM and determining its elevation above Station Datum, the date of the change, and the elevation difference between the old and new PBM should be documented.

For GPS observations, the most desirable bench mark will have 360 degrees of horizontal clearance around the mark at 10 degrees and greater above the horizon and a stability code of A or B. Refer to the User's Guide for GPS Observations At Tide and Water Level Station Bench Marks. An obstruction diagram must be submitted with the initial GPS Observation documentation included in the installation deliverables.

3.5.5.2 Digital Photographs of the Station and Bench Marks

Digital photographs of water level station components (station, DCP, sensors, well, supporting structure, equipment, and bench marks) should be taken and submitted. The station and bench mark photographs should be updated whenever any changes are noticed such as damaged bench mark disk, or changes to settings, and so on, or as requested in the station-specific requirements. GPS photos should be taken according to the User's Guide for GPS Observations at Tide and Water Level Station Bench Marks.

A minimum of four photos for each bench mark should be taken: close-up of the disk face, chest or waist level view of disk and setting and horizontal views of the location of the bench mark from two different (perpendicular) cardinal directions. Photos should also be taken of station components such as protective wells, staff, houses, shelters, met towers (if applicable), DCPs, sensors, and so on. One general location photo should be taken showing the water level station in relationship to its supporting structure and the local body of water. All digital photographs should be submitted in JPEG format. All digital station photo files should be named such that the name of the file will indicate the station number and the type of photo taken. For example, the acoustic sensor photo for DCP1 at Los Angeles should be named as 94106601 sensor A1.jpg.

All digital station bench mark photo files should be named such that the name of the file will indicate the station number, dash, Permanent Identifier (PID) number (if available), dash, stamping or designation, dash, photo type, dash, date, dot.jpg. For a new mark, the PID is not applicable as it is unavailable. A close-up photo vertically taken of the bench mark is photo type 1, chest or waist level photo vertically taken of the bench mark is photo type 2, and the horizontal view taken of the bench mark is photo type 3. For photo type 3, include the cardinal direction (e.g., N, NE, S, SE) that the camera is pointing. If there is more than one type of photo taken, then rename them as 1A, 1B, 2A, 2B, 3A, 3B, and so on. If a PID is available, then use designation instead of stamping for the naming of the file. Use a maximum of 30 alphanumeric characters to the left of the dot. So, if you are exceeding 30 alphanumeric characters in the name, then truncate the stamping or designation so that the maximum characters in the name is 30. For example, the bench mark E close-up photo for the Seattle water level station should be named as 9447130- 7130E1990-1-20090101.jpg

TABLE 3-1 SAMPLE STATION AND BENCH MARK FILE NAMES

Bench mark Situation	Image Naming Convention
New bench mark without a PID and disk face photo	9414290-4290A2008-1-20090101.jpg
Existing bench mark with a PID and eye level view photo	9410660-DY2512-BM N-2-20090101.jpg
Existing bench mark without a PID and north direction photo	9447130-7130E1990-3N-20090101.jpg

3.5.5.3 Obtaining and Recording Using a Handheld GPS Receiver

Latitude and longitude of the station, DCP, all sensors, and bench marks should be recorded using a hand-held GPS receiver and recorded as degrees, minutes, seconds, and tenth of seconds (e.g., 45 degrees, 34 minutes, 32.6 seconds). The positions of the primary and backup DCP (if applicable) and all sensors that are installed in a tide 34 house (gauge house) should be recorded as that of a station. This position will be obtained in front of the tide house (gauge house) at the center of the front door/front wall of the tide house (gauge house). The front portion of the roof of the tide house (gauge house) may also be used as applicable if the GPS satellites are blocked from the structure.

For standalone DCP or met sensors that are 3 m (10 ft.) or greater from the station, obtain positions and report appropriately on the site report. For Aquatrak sensors, MWWL sensors, or Paroscientific sensors that are installed 3 m (10 ft.) or greater from the station location, obtain the positions of the sensors at the center of the sensor. If the Aquatrak sensor or Paroscientific sensor is installed inside a tide house (gauge house), then report the latitude and longitude as that of the station.

For bench marks, obtain positions using the hand-held GPS receiver and placing the receiver on the (horizontal) bench mark. For bench marks that are installed vertically, obtain the position as close to the mark as satellite coverage will allow

3.5.6 Hydro Hot List

CO-OPS maintains a list of water level stations that are currently providing data for OCS hydrographic surveys. This list is referred to as the "Hydro Hot List."

If a water level station is on the Hydro Hot List, it is monitored by CO-OPS' Continuously Operating Real-Time Monitoring System (CORMS), and its data are given priority over other gauge data for office processing. Field units should notify CO-OPS by emailing: nos.coops.hpt@noaa.gov and nos.coops.oetteam@noaa.gov. Field units will receive an email twice a day reviewing the status and quality of the data produced from water level stations that are relative to active survey projects.

3.5.7 Nearshore Hydrography and Shoreline

Working near shore is inherently dangerous, and all field units are reminded that safety should always be the primary consideration when conducting operations. Shoreline verification should not be attempted unless conditions are favorable. Even though an initial assessment is made by the Chief-of-Party, conditions at the actual survey area may be different or degrade as the day progresses. In such cases, the launch or skiff personnel should not perform shoreline operations until conditions are favorable.

Given acceptable weather conditions, shoreline acquisition should be conducted during a period of negative tide. This will expose normally submerged features, and allow an adequate definition of partially exposed features.

3.5.7.1 Source Shoreline Data

Unless otherwise specified in the project instructions, HSD and NRB should compile and provide a Composite Source File (CSF) and a Project Reference File (PRF) for all projects.

The Composite Source File is an S-57 attributed dataset in *.000 file format, compiled from one or a combination of the following sources: largest scale ENCs, preliminary ENCs, GCs and/or lidar junction surveys. During planning, the project planner reviews the sources listed above to ensure the CSF encompasses the most recent data for the project area.

The source of each feature is indicated in the SORDAT and SORIND attribute fields.

The Project Reference File (PRF) is an NOAA attributed data set containing reference layers such as survey limits, junction or recommended bottom sample positions, and other investigation features such as Maritime Boundary Points or unresolved lidar features.

TABLE 3-2 FEATURES CONTAINED IN THE PROJECT REFERENCE FILE FROM OPERATIONS BRANCH

Reference Features	**S-57 Object**	**Description**
Investigation Items	CRANES	Lidar, Maritime Boundary investigation items
Survey Sheets	TESARE	Outline of the survey sheet*
Junction Surveys	TWRTPT	Outline if junction survey
Bottom Samples	SPRING	Recommended bottom samples locations

3.5.7.2 Types of Shoreline Verification

Hydrographic Survey Project Instructions will specify which shoreline source documents are to be verified as well as the type of verification required, either "traditional" or "limited." Traditional shoreline verification is rarely assigned with modern project instructions. Shoreline source(s), chart scale(s), and local vessel traffic patterns are among the factors used in determining which method is appropriate for the survey area.

3.5.7.2.1 TRADITIONAL VERIFICATION

Traditional shoreline verification is the most thorough and complete method, requiring a full examination of all shoreline details and features seaward of MHW. This technique is very rarely required and is only necessary if the Project Instructions explicitly calls for it. The hydrographer should examine all nearshore details and features seaward of the shoreline (MHW line) originating from composite source documents, NGS-verified remote sensing shoreline data, prior hydrographic surveys, and nautical charts. All features should be verified, changed, or disproved if the operations can be conducted safely. Features located near the shoreline or some accurately plotted reference point may be verified by visual inspection.

3.5.7.2.2 LIMITED VERIFICATION

Typically, a limited verification will be assigned for OCS hydrographic surveys. When conducting limited shoreline verification, the hydrographer should examine all features seaward of the Navigable Area Limit Line (NALL) as defined in the HSSD. If there is no MHW adjacent to features and the area is not safe to survey, then the area is determined to be foul. Features should be examined under the following directions:

- All ENC, RNC, Preliminary ENC's, and contemporary lidar features in the composite source file that are seaward of the NALL should be verified or disproved. If a feature is within two millimeters of the survey scale on the composite source file, all heights and depths of features seaward of the NALL should be determined by the best means available given the sea conditions at the time of the survey (Table 3-3).

TABLE 3-3 COMMON SURVEY SCALE EXAMPLES OF THE CHART INTERVAL 2MM CONVERTED TO GROUND DISTANCE.

Chart Interval (millimeters)	Survey Scale	Ground Distance (meters)
2mm	1:5,000	10m
2mm	1:10,000	20m
2mm	1:20,000	40m
2mm	1:40,000	80m
2mm	1:80,000	160m
2mm	1:100,000	200m

- New features seaward of the NALL should be properly positioned.
- New point features and new area features where the high point may be used for a navigational landmark also require a corresponding height/depth. Composite source features that are correctly charted do not require corresponding height/depth verification.
- Features with any horizontal dimension greater than 1.0mm at the survey scale should be treated as area features and delineated appropriately. Features with lesser horizontal dimensions should be positioned and attributed as point features.
- The hydrographer should check their bathymetry to their assigned features in the CSF. Features found in the bathymetry that are not included, assigned, or included in the CSF should be ensonified, attributed, and included in the FFF.

It may be necessary to position, verify, or disprove some features inshore of the NALL if they are both navigationally significant and safe to approach. Examples of features which might meet this standard include:

- Aids to Navigation:
    - Natural or man-made features sufficiently conspicuous to be an obvious navigational landmark (e.g., piers, pilings, or very large and isolated boulders or outcroppings)

3.5.7.3 Conducting Shoreline Verification

Shoreline verification operations should be scheduled for daylight periods when the tide is less than 0.5m above Mean Lower Low Water (chart datum). To maximize the shoreline "window," it is usually advantageous to plan for shoreline operations during spring tides when the extreme range allows for longer low water periods each day. In some cases, ideal water level conditions may not be available while the field unit is in the project area. Shoreline verification should be performed before the main scheme bathymetric data acquisition in nearshore areas to ensure that submerged hazards have been identified to the fullest extent possible before launches with protruding transducers operate in the area.

Shoreline verification is typically conducted from a small, maneuverable survey vessel such as a skiff or jet-drive survey launch. The vessel should be equipped with survey-grade GNSS and a single beam echo sounder.

The vessel's data acquisition software should be loaded with the composite source file and other applicable files (ENC, RNC, and Project Reference File). Also it is often helpful to print a large scale "boat sheet" of the composite source as it is useful for orientation and quickly recording field observations.

A method for conducting shoreline verification is to run an SBES survey line parallel to the shore, observing exposed features. In the case of Limited Shoreline Verification, this survey line should approximate the NALL, allowing the hydrographers to focus most of their attention offshore of the vessel. This approximate NALL can be used later to assist in planning the inshore extent of the bathymetry. As features are encountered, the survey vessel should break and investigate as required, then return to following the NALL.

When conducting shoreline verification, field units outfitted with a lidar laser scanner can acquire ellipsoidally referenced elevations on exposed features. Ellipsoidally referenced heights can also be obtained using other methods. Operations may vary from field unit to field unit

3.5.7.4 Recording Shoreline Data

Point and line feature extents are recorded using GNSS information by a Trimble backpack, POS file, or other positioning information. Shoreline data can also be recorded using laser scanners and Unmanned Aerial Systems (UAS) at its availability to the field unit. In all cases, it is prudent to take written notes on log sheets and/or the boat sheet and record data digitally (Figure 3-11).

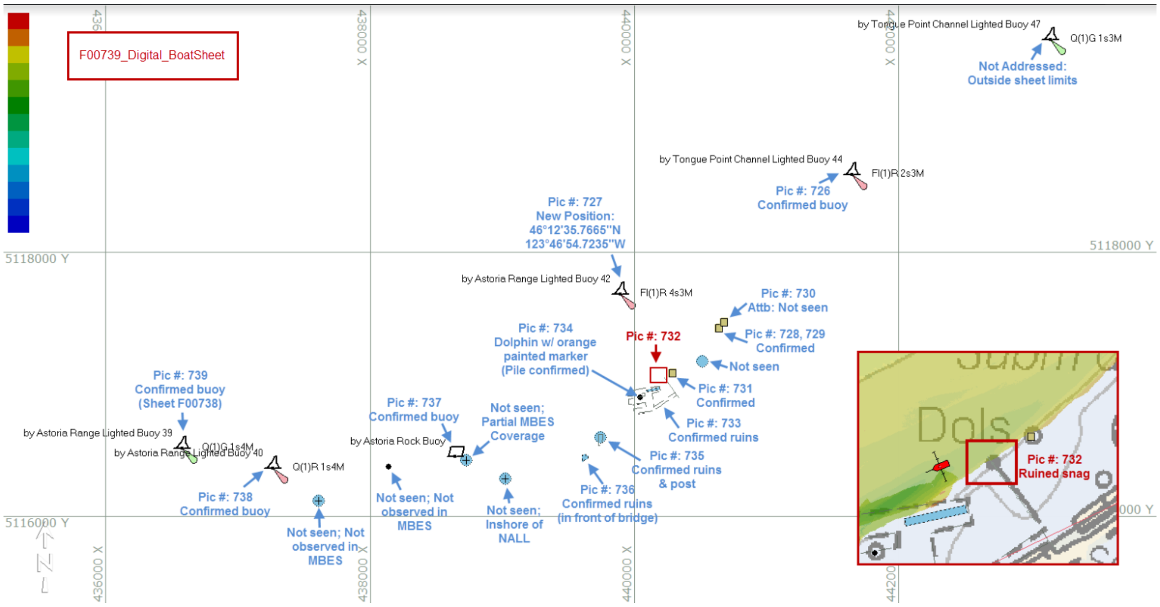


FIGURE 3-11 EXAMPLE OF A DIGITAL BOAT SHEET CREATED BY A FIELD UNIT

Accuracy requirements for point positions depend on the type of feature being located. Accuracy for all points should meet the minimum horizontal position accuracy requirement outlined in the HSSD. The method of positioning a feature to the required accuracy is typically left to the discretion of the hydrographer subject to the guidelines set in the HSSD.

When recording line data, positions are logged at regular intervals small enough to facilitate a "connect the dots" drawing of the area. Line data are a valuable tool for accurately delineating curved or irregular features. OCS recommends that line data used to define such features be acquired with a data collection interval of one second.

All data should be acquired with S-57 and NOAA attribution collected at the times of acquisition. The hydrographer should consult the S-57 catalog for further guidance. All shoreline data should be ellipsoidally referenced upon delivery.

3.5.8 Maritime Boundary Delineation

OCS is responsible for depicting the following delineations on NOAA nautical charts:

1. Three Nautical Mile Line. Territorial Sea at 12 nautical miles
2. Contiguous Zone at 24 nautical miles
3. Exclusive Economic Zone (EEZ) at 200 nautical miles.

These maritime zones, whose limits are measured using principles set forth in the United Nations Convention on the Law of the Sea (UNCLOS), define areas of United States jurisdiction for a variety of regulations. For example, the Three Nautical Mile Line is often used by state and federal enforcement officials to police fisheries and other laws.

Among a host of marine boundaries, the US maritime zones include the territorial sea (0-12nm), contiguous zone (12-24nm), and EEZ (12- 200nm). These maritime zones are marked in red on the RNC. The United States also retains and charts a territorial sea at 3nm, which supports enforcement of the Clean Water and Oil Pollution Acts. All of these zones are measured from the US baseline, which is largely composed of the charted low water line (at MLLW) as well as closing lines across legally-defined bays and rivers (Figure 3-12). Various federal, state, and local governments reference the limits on NOAA nautical charts as well as best practices for defining those limits to enforce their regulations.

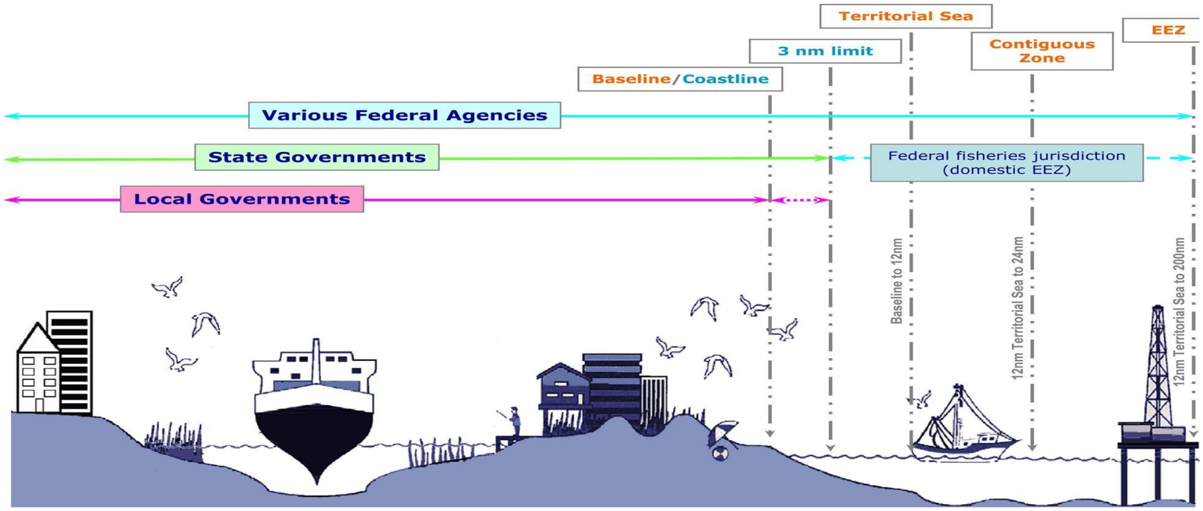


FIGURE 3-12 BREADTH OF OFFSHORE MARITIME AND MARINE BOUNDARIES

Following customary international law and UNCLOS, the US maritime zones are measured from what is referred to as the "normal baseline." Simply stated the normal baseline is composed of features that are dry at mean lower low water (MLLW). This includes naturally-formed offshore rocks awash and harbor structures, such as groins, jetties, and breakwaters (not recreational fishing piers) using this method, only the most seaward features influence the outer limits of the US maritime zones.

Arcs generated from these salient baseline points are blended together to form continuous limit lines at 3, 12, 24, or 200 nautical miles. Finally, the US baseline as well as the maritime zones are reviewed and approved by an inter-agency federal group called the U.S. Baseline Committee, which was established in 1970 and is chaired by the Department of State.

Determining the exact nature of charted low-water features is not always straightforward, and to aid enforcement of the US maritime zones, US policy is to refrain from using uncertain features in the baseline. The most controversial feature is the charted rock awash because many times the compilation of older surveys to the nautical chart did not include height information.

3.5.8.1 Procedures

The maritime boundary verification requests are compiled by HSD OPS and delivered to the field units in the Project Instructions. The point features are included in the Project Reference File (PRF) as the S-57 Object CRANES and are distinguished by the NOAA Extended Attribute "Special Feature Type" (sftype) populated with MARITIME BOUNDARY. The hydrographer is responsible for verifying the existence of the furthest offshore feature that is dry at MLLW recognizing that the furthest offshore feature may not be the feature within close proximity to the Maritime Boundary investigation point.

3.5.9 Special Instructions for Positioning Aids to Navigation (ATONs)

Positions and characteristics for all ATONs within a survey area should be visually observed and compared to both the largest scale chart and current U.S.C.G. Light List information during survey operations.

Any ATON that is not serving its intended purpose, off-station, damaged, otherwise compromised, or uncharted and is determined by the field unit to present a hazard to navigation should be immediately reported to the local U.S.C.G. district, following instructions in HSSD.

Information for assigned ATONs will be provided in the project instructions from HSD or NRB. Additional ATONs may be positioned at the field unit's discretion if determined to be navigationally significant. Unless specific positioning methods or accuracies are assigned in the Project Instructions, ATONs throughout the survey area should be investigated and positioned if necessary under the following guidance:

- Assigned Charted Fixed ATONs: If possible, the field unit should position each fixed ATON assigned by HSD OPS or NRB. Assigned ATONs should be positioned to an accuracy of less than 1 meter, at a 95% confidence level, unless otherwise specified such as range markers, which should be positioned to within 4 cm precision and reported to one-thousandth of a second of latitude (0.001'). When submitting ATON reports, include the methodology of position collection.

- Unassigned Charted Fixed ATONs: If an unassigned fixed aid is observed to be significantly off station based on the largest scale chart, the hydrographer should review the U.S.C.G. Local Notice to Mariners (LNM) for a discrepancy report on the aid. If no discrepancy report has been published, the field unit should complete an ATON Discrepancy Report with the U.S.C.G., and the project and navigation manager must be contacted.

- Uncharted Fixed ATONs: This category of ATON is typically comprised of privately maintained aids. If navigationally significant, a position should be acquired, and the ATON reported as if it were assigned. For private aids reported, the field unit should specify both the apparent purpose and by whom the aid is maintained in the ATON Discrepancy Report.

- Charted Floating ATONs: The field unit should visually verify positions and characteristics of charted floating ATONs during survey operations. If a floating aid is significantly off station with both the scale of the chart and scope of chain considered, the hydrographer should review the LNM for a discrepancy report on the aid. Temporary positions of aids relocated to facilitate dredging, construction, or similar activities are typically not charted. If it remains off station, acquire a detached position (DP) for the ATON and report this item as if it were an assigned aid. Static GNSS observations are not required when positioning floating aids.

- Uncharted Floating ATONs: The field unit should determine if each uncharted floating ATON is navigationally significant (e.g., a mooring buoy or full-size private buoy, typically not a small private float). If navigationally significant, the field unit should acquire a DP for the ATON and report this item as if it were an assigned aid.

3.5.10 Bottom Samples

Bottom samples are typically obtained and analyzed in accordance with the HSSD. If so equipped, a field unit should use the Imaging Grab Sampler or similar unit to collect imagery of both the seafloor at the sample site as well as the sample on deck. Imagery should be processed in accordance with HTD 2018-4 and supporting documentation. While collecting bottom samples, it is imperative to document the bottom sample location and image number (s) for properly attributing the Final Feature File down the line. Bottom sample images can easily be renamed using Pydro Explorer's SHAM, QC Tools' SBDARE Export, or Rename FFF Images.

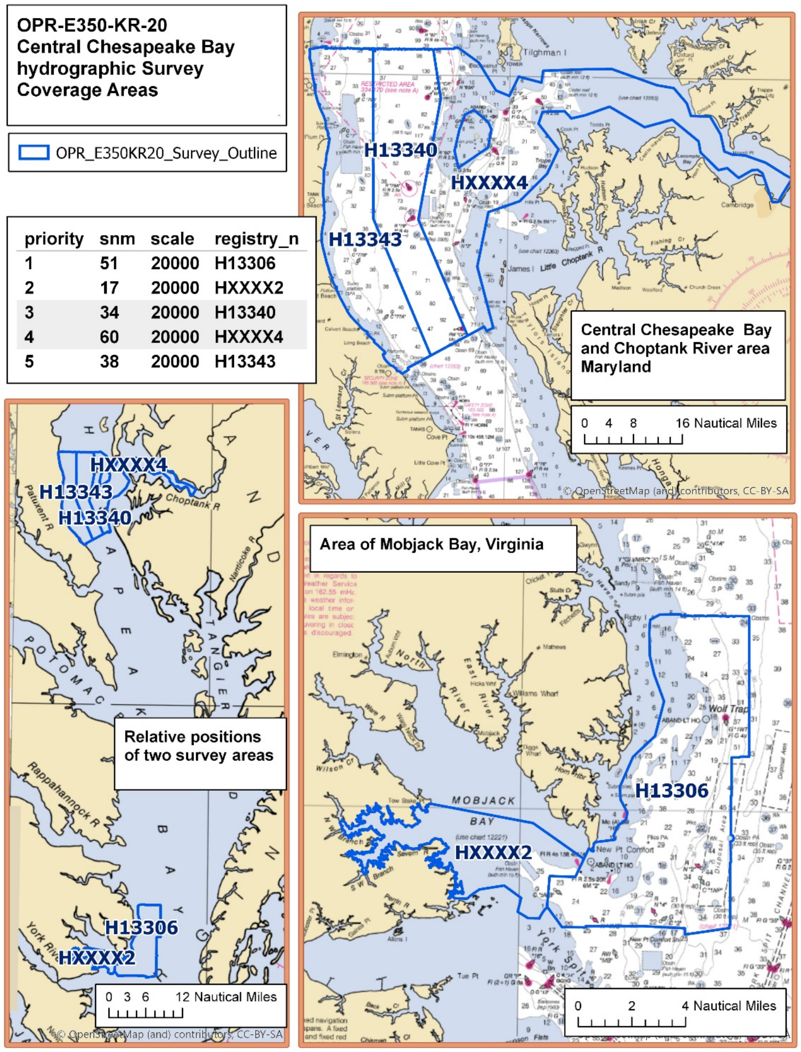
Several sizes of bottom samplers are used in the NOAA hydrographic fleet, and the field unit should use the most appropriately sized bottom sampler for the vessel and conditions. If the bottom sampler is deployed and tripped three times yet no sediment sample is acquired, then imagery alone can be used to determine the bottom type. The HSSD describes the requirements for images needed for bottom sampling. If a project area does not require bottom samples, this will be reflected in the Project Instructions.

3.5.11 Coast Pilot Data

A Coast Pilot Review should be conducted for each assigned survey area. The Nautical Publications Branch (NPB) will provide the field unit with a text file of the most recent section of the Coast Pilot or various particular

Coast Pilot paragraphs with chart sections to be investigated. The field unit reviews this text file in conjunction with the latest largest scale nautical charts of the area being inspected.

The survey coverage area/project outline example below is emailed to NPB from field unit (Figure 3-13). NPB will then email the appropriate CP text back to the field unit to update/review. Please email project outlines to NPB at: coast.pilot@noaa.gov



priority	snm	scale	registry_n
1	51	20000	H13306
2	17	20000	HXXXX2
3	34	20000	H13340
4	60	20000	HXXXX4
5	38	20000	H13343

FIGURE 3-13 SAMPLE COVERAGE AREA

There are several types of Coast Pilot field inspections; they can be anywhere from a single day to 6 months or longer, ranging from short investigations (mostly verifications) to long detailed inspections. The field unit should use whatever tools and methods available to produce accurate and reliable information that meets the standards required for inclusion in the Coast Pilot and nautical chart.

3.5.11.1 PERFORMING A COAST PILOT REVIEW

The Coast Pilot reports are revised using the following format.

Add new information add in **red**
Deleted text, use strikethrough (~~strikethrough~~)
Inspected and confirmed information, change to **green**
Unverified information, leave **black**.

When determining what information is pertinent for the Coast Pilot, the size, type, and number of vessels using each waterway must be taken into account. The requirements of the deep-draft navigator, yachtsman, and fisherman must all be kept in mind. Allowance must also be made for the thoroughness with which the region has been surveyed and charted. If the surveys of the area are incomplete, if the harbor charts are on too small a scale, or if the harbor has grown in importance, more detail will be required in the Coast Pilot. If possible, digital photographs may be submitted for significant Coast Pilot features.

If additional information is necessary to address a Coast Pilot item, a wide variety of locally knowledgeable people can be used. However, information from outside sources should be verified by the reviewer. The source of the report should be given so that the report's value may be weighed against conflicting information that may be received by NOAA's Marine Chart Division: Nautical Data Branch.

The following is a list of the principal organizations and officials who can be interviewed to obtain local information:

1. Coast Guard stations and other aids to navigation units, buoy tenders and other cutters, patrol craft.
2. Marine Safety Offices.
3. Corps of Engineers district offices.
4. Other Federal field offices such as Customs Service Pilot associations, port authorities, harbormasters, and harbor police
5. Other NOAA field parties operating in the area.
6. Operators of repair yards and marine service stations.
7. Captains of towboats, ferries, and coastwise vessels operating in the area.
8. Individuals very familiar with the area such as fishermen and longtime residents.
9. Yacht clubs

The following sections describe categories of information that should be addressed during a Coast Pilot Review.

The majority of this information is best obtained during field operations and is thus considered a part of data acquisition.

3.5.11.1.1 AIDS TO NAVIGATION
Every effort should be made to ensure that aids to navigation referenced in the Coast Pilot are correctly identified and in agreement with both the chart and the Light List. Information regarding significant new aids to navigation (e.g., buoys/lights marking specific dangers to navigation) should be added.

3.5.11.1.2 ANCHORAGES
Attempt to obtain information on both charted and uncharted anchorage areas. The adequacy and accuracy of anchorage information in the Coast Pilot should be checked, and new reliable information should be added when possible. Anchorage information is one of the most difficult types of information to obtain and check since it must come from actual anchoring experience. Good judgment must be exercised by field personnel in obtaining such information. A particular location is not a good anchorage simply because someone has anchored there.

3.5.11.1.3 BRIDGES
Note bridges that are in the process of renovation (to the extent that type of bridge, vertical clearance, horizontal clearance, or other description normally mentioned in the Coast Pilot is affected), bridges that have been newly constructed, and/or bridges that have been removed in whole or in part. Confirm proper names of bridges as included in the Coast Pilot or shown on the charts. Obtain new names as appropriate. Confirm or obtain VHF

radio frequencies/channels monitored, hailing protocols used by local traffic, and telephone contacts related to bridge operations, if applicable.

3.5.11.1.4 CHANNELS

Text referring to privately maintained channels and basins, natural channels, and federally maintained channels within the assigned survey area should be reviewed and updated as necessary.

3.5.11.1.5 DANGERS TO NAVIGATION

Review and update as necessary any Coast Pilot text addressing charted rocks, shoals, reefs, wrecks, piles, snags, and other objects dangerous to navigation within the survey area.

3.5.11.1.6 DEPTHS AND SOUNDING DATA

Once the survey soundings have been processed and compared to charted depths, any Coast Pilot text referencing specific depths within the survey area should be reviewed and updated as necessary. The hydrographer should be certain that final water level correctors have been applied to sounding data before reporting specific depths in the Coast Pilot Review.

If new depth information is received for an area outside of the assigned survey, but cannot be verified by approved NOAA hydrographic survey methods, this information can be included in the Coast Pilot as "reported." Reported information should be avoided unless deemed critical for safe navigation. If reported information is used, it must be qualified as such, giving the date and the source of information. Reported depths are published in the Coast Pilot as shown in the following example: "In June 2020, the channel had a reported controlling depth of 3 feet."

3.5.11.1.7 FERRIES, CABLE FERRIES, AND PONTOON BRIDGES

Report the locations of new ferry terminals and routes and/or the abandonment of old ones. If applicable, include information about VHF radio frequencies monitored, hailing protocol, and telephone contacts. Cable ferries and pontoon bridges pose a potential hazard to mariners. Obtain detailed information on their operations. Information regarding operational peculiarities of any other movable bridges encountered should be included.

3.5.11.1.8 LANDMARKS

Landmarks should be inspected from seaward insofar as practicable. New landmarks considered to be significant for vessel navigation should be positioned. Describe each landmark, including position, height, color, and any other distinctive features that will aid in identification. Give the shape of objects that may not be generally recognized by the name alone.

3.5.11.1.9 LOCKS, CANALS, AND HURRICANE GATES

Operational peculiarities of locks, canals, hurricane gates, and other navigation projects should be noted. Include information about traffic signals, VHF radio frequencies/ channels monitored, hailing protocol, and telephone contacts, if applicable.

3.5.11.1.10 OVERHEAD CABLES

Make note of overhead cables that are not charted and/or not mentioned in the Coast Pilot. Attempt to ascertain the following about the owner of the new cable: name of the company, address, telephone number, and name of a cognizant individual in the company. This information is necessary to obtain copies of the cable permits from the local District Engineer staff of the Corps of Engineers.

3.5.11.1.11 MAJOR DEEP DRAFT PORTS

Coast Pilot information about major ports, shipping terminals, and wharves within the survey area should be reviewed and confirmed to whatever extent practicable via sounding data and reconnaissance during survey operations. Particular attention should be paid to depth information stated in the text.

If at all possible, the local pilot association should be contacted. Pilotage information is one of the most important items in the Coast Pilot. Pilots should be requested to read the pilotage section in the Coast Pilot and point out any errors and/or new information that should be added. Be sure to address where vessels are boarded or anchored for quarantine, and whether inspections are made by any US Government agency.

Additional information may be obtained from a variety of sources such as the local port authority, harbormaster, harbor police, customs, immigration, public health, and agriculture officials at the port. Information on repair facilities can be obtained from shipyards and boatyards. Local towboat companies are often a good source of information not only regarding the size and type of tugs available but also for other information such as local peculiarities of winds and currents, and the routes followed by tugs, barges, and the like.

3.5.11.1.12 SMALL DEEP DRAFT PORTS

Coast Pilot information about smaller deep-draft ports, shipping terminals, and wharves within the survey area should be reviewed and confirmed to whatever extent practicable via sounding data and reconnaissance during survey operations. Particular attention should be paid to depth information stated in the text. Although small deep-draft ports do not typically have large port authority staffs, additional information may be available from the port's general manager.

3.5.11.1.13 SMALL CRAFT HARBORS

Coast Pilot information about small craft harbors within the survey area should be reviewed and confirmed to whatever extent practicable via sounding data and reconnaissance during survey operations. Additional information may be available by contacting either the harbormaster or harbor patrol personnel as well as operators of towboats, boatyards, marinas, and state and federal agencies. Local yachtsmen and fishermen can be consulted when appropriate.

3.5.11.1.14 RADAR AND RADIO INFORMATION

If possible, obtain information on the best radar targets and the approximate maximum range at which they can be positively identified and used. The VHF radio frequencies/ channels used in port areas for different types of communications between various private and public concerns should be ascertained. Where a radio watch is maintained by pilots, harbormasters, bridge tenders, lockmasters, and other parties significant to the mariner, confirm guarding schedules, VHF radio frequencies, hailing protocol, and telephone contacts, if applicable.

3.5.11.1.15 SHORELINE CHANGES

Coast Pilot information about the shoreline within the survey area should be reviewed and confirmed to whatever extent practicable via sounding data and reconnaissance during survey operations. Note condition, additions, and deletions of wharves, piers, and other waterfront structures. If a pier or other shoreline structure has been removed, note whether piles or ruins remain as a navigational hazard. Assume the existence of submerged ruins unless there is contrary evidence. Also report significant shoreline changes whether caused by dredging and/or filling or by natural events.

3.5.11.1.16 WRECKS

Where numerous wrecks exist, the inspector should attempt to ascertain the causes from local sources. Suitable highlighting of the area should appear in the report.

In addition to the above categories of information, any anomalous conditions that may affect safe navigation should be addressed.

3.5.11.2 Digital Photographs

There is an ongoing requirement for sea level photography to supplement the Coast Pilot narrative. Photographs can aid in describing harbor approaches, channel entrances and turns, landfall aspects, major navigational aids, landmarks, and other views that would assist the mariner in location or orientation especially on the first call at a harbor. Sea level photos taken by NOAA vessels or field parties are used to augment oblique aerial photos obtained from various sources.

When possible, digital photographs portraying significant Coast Pilot features should be acquired. Sea level photos should be taken from seaward, from as high a vantage point as possible, and close enough so that principal landmarks can be identified. Photos taken successively from two miles out or less, typically upon entering or departing a harbor, may be useful in identifying the harbor approach or specific landmarks. If a single photo will not adequately cover the view of a harbor with sufficient detail, a panoramic series of photos can be submitted.

To ensure photographs are of sufficient quality for publication, the following criteria should be met:

1. The camera should have a resolution capability of 12 megapixels or better.
2. A digital zoom feature should not be used.
3. A camera with minimum optical zoom capability from wide-angle (35mm) to a mild zoom (out to 105mm) is recommended. (Ideally, the camera would accept lenses of different focal lengths, such as wide-angle, normal, and zoom.)
4. Drones have been used to capture digital photos; however, there could be airspace restrictions in certain areas.

JPEG (*.jpg) format is required for submission. The use of any other format should be cleared by the Nautical Publications Branch.

4 Chapter 4: Data Processing and Analysis

The purpose of this chapter is to provide the information necessary to clean, finalize, and analyze data for hydrographic surveys. The following types of data are addressed separately in this chapter:

- Bathymetry (SBES and MBES data)
- Imagery (SSS data, MBES acoustic backscatter, and MBES "side scan")
- Features (bathymetry and imagery contacts, detached positions, AWOIS items, geographic positions)

4.1 Preparation for Data Processing

There are various processing tools available for use, and this section briefly goes over how these tools are used. Each spring, a Hydrographic Technical Directive (HTD) is released from the Chief of the Hydrographic Surveys Division Data titled "Configuration Management," which provides procedures for the configuration management of hydrographic data acquisition and processing systems aboard NOAA hydrographic field units. This information includes major software, hardware, and firmware changes that would provide a significant change in acquisition and processing procedures, data, and deliverables. The current list of approved systems is maintained by HSTB and is listed in the OCS Approved Configuration List spreadsheet.

Program licensing is managed by personnel at HSTB and NRB. Before the field season, HSTB will distribute licenses for various programs such as CARIS. Network-based licenses such as QPS's Qimera and Applanix POSPac are managed differently depending on the field unit. If the license manager of the program you are looking for is unclear, contact the [Chief of HSTB].

4.1.1 CARIS

Processing for hydrographic surveys is typically performed using CARIS HIPS and SIPS software. Various modules can be enabled in HIPS and SIPS; for most field unit operations, the following modules are used:

1. HIPS Essential- Tools for importing, reviewing and correcting bathymetric sonar sounding data and productive raster and vector products
2. HIPS Professional- Advanced tools for importing, review, and processing full water column, multiple detections in the water column, lidar and bathymetric lidar waveform data and producing variable resolution coverages
3. SIPS- sonar imagery processing tools to create accurate, high resolution images from raw sonar data and to identify contacts within that imagery

4.1.2 CARIS Project Creation

CARIS Projects should be created for each survey including only the survey registry number (e.g., H12345 or F00123). New projects are created using the "New HIPS File" or Pydro's Charlene interface. When adding a new project, the wizard will request the following data:

1. Description: Provide a brief summary of the purpose of the project and any significant survey-specific information. The bulk of the description can be extracted from the Project Instructions. Entering a description is an option because it is one of the few places in HIPS and SIPS for external metadata to be attached to digital data
2. User: The individual who is logged onto the computer the New HIPS file is being created
3. Map Projection: Map Projection establishes the coordinate system to be used for the Project view in HIPS/ SIPS
4. Project Extent: Enter the basic boundaries of the survey area. The project extent is expressed as a regular (i.e., non-rotated) rectangle. Project Extent should completely cover the assigned survey limits.

4.1.3 Pydro Explorer, Charlene- Automated Data Processor

Charlene is an automated processing and data transfer tool developed by NOAA's Office of Coast Survey. Charlene is used in the processing of multibeam, multibeam backscatter, and side scan data. Charlene allows the user to:

1. Perform verification of raw data
2. Build a deliverable directory structure
3. Transfer and verify raw data
4. Process MBES and SSS data with the CARIS Batch Processor
5. Generate SBETs with POSPac Batch
6. Use NOAA tools like AutoQC and QCTools
7. Apply vertical control data to soundings via a VDatum file or ERTDM, TCARI tides, or traditionally observed or predicted tide files.

Charlene includes the tasks between raw data collection and a final daily product that typically occur each day at NOAA field units. The benefits of Charlene are many, but a few of these benefits are:

1. Data Management:
    a. Automated default to submission directory structure
    b. Automated data transfer, freeing up personal time

2. Processes data in:
    a. CARIS HIPS and SIPS
    b. CARIS BDB
    c. Applanix POSPac
3. Data QC:
    a. Automated logs
    b. Bathy surface creation
    c. NOAA tools:
        i. QCTools
        ii. POSPac AutoQC

Charlene works across NOAA's standard software platforms; the program transfers raw data to appropriate submission folders, processes SBETs/RMSs, converts survey lines into a CARIS Project, applies sound velocity profiles, water levels, run in-house QC reports, and generates processing logs.

Charlene uses a tool within CARIS for automated processing called CARIS Batch. Then the commands from CARIS Batch are structured in python to make the Charlene program user-friendly. Similarly, Charlene uses a command-line toolset that allows the user to run files to create SBET and RMS files. SBET and RMS files can be created for Smartbase, Marinestar, RTX, and different coordinate systems (NAD83 and WGS84). Additionally, Charlene can process daily backscatter mosaics using CARIS. Charlene does not interact with QPS products.

4.1.3.1 Setting up a Project Folder and Transfer Drive in Charlene

The launch transfer drive is simply a USB hard drive (or just a folder on a hard drive) with a basic CARIS folder structure set up in a specific way as to be read by Charlene at the end of each survey day. The Create Launch Transfer Drive tool is designed to be run before each survey day so that the appropriate day number folders can be generated. Then at the end of the survey day, the operator will place the day's data in the appropriate day-number folder.

4.1.4 HIPS Vessel Files (HVFs)

The HIPS Vessel File (HVF) establishes, in HIPS and SIPS, the relationship between survey sensors and the vessel reference frame. The HVF must reflect any corrections or compensation of logged sensor data performed during acquisition. Any real-time corrections included in the logged data must be accounted for when creating the HVF. The HVF can contain information essential for estimating sounding measurement errors. Depth and position errors will be introduced if data are processed using an incorrect HVF.

Proper setup of HVFs is critical for accurate survey data, and this process is usually completed under the direction of senior survey personnel. These files are typically created at the beginning of a field season, but they will need to be amended if configurations or boat characteristics change.

4.1.4.1 HIPS and SIPS Vessel Wizard

The Vessel Wizard is used to set the parameters needed to create a new vessel file. The wizard takes the user through the steps to enter vessel information and sensor configuration information based on the type of survey data the field unit will be collecting. Some of the information the user will need to provide are: types of survey operations and number of transducers, TPU parameters, information recorded by the motion sensor (heave, roll, pitch), dynamic draft values, and sound velocity corrections

HVF naming conventions have been standardized throughout the NOAA hydrographic fleet. There are common data types acquired during OCS hydrographic surveys and examples of HVF names for each (Table 4-1). Note that the field season year is not included in the name; rather, timestamp entries within the HVF are used to track application dates. If questions or issues arise about the HVF setup, please contact the HSTB Chief.

TABLE 4-1 EXAMPLES OF HVF NAMING CONVENTIONS FOR NOAA HYDROGRAPHIC VESSELS.

Data Type	HVF Name Examples
Multibeam Echo sounder:	**"FA_2806_EM2040_MB.hvf"** Ship Name_ Vessel number_Sonar Name_Sonar Type **"BHII_S5501_EM2040_MB.hvf"** Ship Name_ Vessel number_Sonar Name_Sonar Type
Vertical Beam Echo sounder:	**"RA_S221_Odom_VB.hvf"** Ship Name_Vessel Number_Sonar Name_Sonar Type **"NRT4_3008_Odom_VB.hvf"** Team Name_ Vessel Number_Sonar Name_Sonar Type
Towed Side Scan Sonar:	**"FA_2807_Klein5000LW_SSS.hvf"** **"FA_2808_Klein5000HW_SSS.hvf"** Ship Name_Launch Vessel number_Sonar Name (If Klein have HW (heavy weight) or LW (light weight) designation)_Sonar Type **"NRT4_3008_Edgetech4125HF_SSS.hvf"** Team Name_Vessel number_ Sonar Name and Frequency (high frequency)_Sonar Type
Hull-mounted Side Scan Sonar: Pole-mounted Side Scan Sonar:	**"TJ_3101_Klein5000HW_Hull_SSS.hvf"** Ship Name_Launch Vessel Number_Sonar Name_Hull-mounted_Sonar Type **"NRT4_3008_Edgetech4125HF_USM_SSS.hvf"** Team Name_Vessel Number_Sonar Name and Frequency (high frequency)_PoleMounted_Sonar Type
Echo sounder Point Observations Depth "Detached Positions" (DPs):	**"NRT2_1210_Echosounder_DP.hvf"** Team Name_Vessel Number_Sonar Name_DPs **"RA_2801_Echosounder_DP.hvf"** Ship Name_Launch Vessel Number_echosounder_DPs
Non-Echo sounder Point Observations: Diver Least Depth DPs Shoreline DPs:	**"RA_2801_ShorelineDP.hvf"** Ship Name_Launch Vessel Number_Shoreline DPs **"TJ_3101_DiverDP.hvf"** Ship Name_Launch Vessel Number_Diver DPs

4.1.4.1.1 CONFIGURATION OPTIONS

The Vessel Wizard configuration options enable the user to enter offset parameters for "sound velocity" corrections. Typically, multibeam bathymetry data will require sound speed (i.e., refraction) correction during post-processing. Imagery data does not require sound speed correction in general practice, and "defining parameters for sound velocity corrections" is unnecessary for HVFs used only to process data that will not be sound speed corrected during post-processing.

Dynamic draft refers to changes in draft induced by the flow effects of a vessel moving through the water. Corrections for this effect can be applied during post-processing via either a Dynamic Draft table of speed-versus-draft values entered in the HVF or from a "delta draft" time series that is loaded during post-processing. NOAA field unit's standard practice is to enter a speed-versus-draft table that is applied in post-processing. Thus, in most cases, the option to "create a dynamic draft table or speed-versus-draft values" should be checked, and values should be manually entered into this table by the hydrographer.

The term "waterline height," refers to the measured vertical difference between the vessel waterline and the established origin of the local vessel reference frame (RP). This value will be positive if the vessel waterline is below the RP and negative if the vessel waterline is above the RP. Variations in static draft of the transducer should be accounted for by adjusting the waterline height in the HVF. If waterline height is included in the sonar system's configuration setup, the waterline should be recorded in the HVF but not applied. This prevents the waterline from being applied twice.

4.1.4.1.2 HIPS AND SIPS VESSEL EDITOR

Once a new HVF has been created, sensor offsets and additional sensors, such as CARIS "TPU values," can be activated using the CARIS HIPS and SIPS Vessel Editor. It should be noted that HVFs use a left-handed coordinate system (Figure 4-1). The user should verify that offset values determined during the vessel survey adhere to the same coordinate system as the HVF. If this is not the case, surveyed offset values will need to be converted so that the vessel configuration is accurately represented in the HVF.

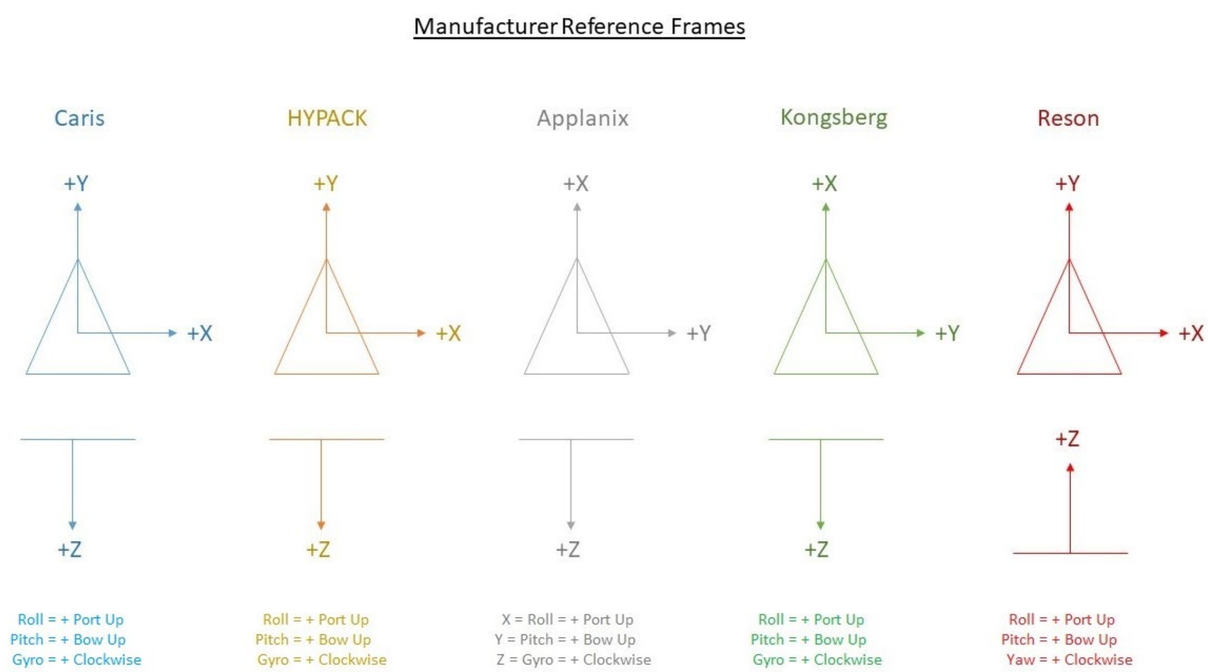


FIGURE 4-1 COMMON COORDINATE SYSTEMS; IMAGE SOURCE: ERIC G. YOUNKIN, NOAA

Coordinate systems vary among NOAA survey systems and software. This information should be verified in the appropriate user's manual before entering offsets into any software or equipment configuration.

The field unit should ensure that the vessel offsets entered in the HVF are fully consistent with those listed in the DAPR as outlined in the HSSD. Any inconsistencies should be identified in the DAPR or DR of the project. If there are any undocumented inconsistencies, the survey will not be accepted by the designated branch.

4.1.4.1.3 CHARLENE- OFFSET REPORT

Pydro Explorer's automated processor, Charlene, has a tool that enables users to create an Offset Report. This tool reads the offsets entered into the HVF, MBES files (*.all or .HSX), and POS MV logged *.000 files and compares the offset values entered to make sure they do not conflict. The result of this tool is an excel spreadsheet with values highlighted in red for those that disagree, yellow for values that need more attention, and green for values that do not conflict.

Offset Report complies with dual sonar systems that produce an *.all file. The Offset Report is not intended for use with Sidescan Sonar logged files.

This report should be submitted with HSRR information to the HSRR Deliverables folder via Google Drive.

4.2 Bathymetry Processing

NOAA hydrographic field units typically acquire bathymetric data using SBES, MBES, or a combination of both. SBES depths are processed using the CARIS HIPS Single Beam Editor tool to review and edit data anomalies.

MBES data may be edited in two different ways: using CARIS HIPS Swath Editor tool to edit data in a time-series mode or using the CARIS HIPS Subset Editor tool to edit data in a spatial mode. CARIS HIPS Subset Editor tool is the most frequently used.

In both instances, Bathymetry Associated with Statistical Error (BASE) methods are used to generate, using one or more different algorithms, a digital seafloor model that contains depth and uncertainty information at each model node. In addition to the basic bathymetric layer, auxiliary information layers such as standard deviation of soundings, sounding density, shoal depth, source identification, hypothesis count, and hypothesis strength will be generated depending upon the algorithm used to construct the BASE surface. These BASE surface layers are used to guide the hydrographer to areas that require further examination and/or editing.

Unlike SBES and MBES data, depth measurements acquired by a lead line, sounding pole, and/or diver least depth gauge are positioned using a type of target file referred to as a detached position (DP), and depth data are entered manually to an S-57 feature.

4.2.1 The BASE Surface Concept

A BASE surface represents bathymetry as a dense grid of statistically derived depth estimates. Various products can be derived from BASE surfaces, including a shoal-biased set of depth estimates for safe vessel navigation. The BASE surface paradigm discussed herein is specifically designed for MBES data, which typically has a high sounding density. Nevertheless, SBES data can also be assimilated into the BASE surface model.

4.2.1.1 Base Surface Methods

There are two different algorithms used by NOAA hydrographic field units for creating BASE surfaces: uncertainty weighted grids and the Combined Uncertainty and Bathymetric Estimator (CUBE) method. The preferred method should be the CUBE method, but uncertainty weighted grids will be allowed. Their use should be documented in the Descriptive Report. Each of these methodologies is described below.

4.2.1.1.1 COMBINED UNCERTAINTY AND BATHYMETRIC ESTIMATOR (CUBE)

CUBE is a gridding algorithm developed at the University of New Hampshire (UNH)/NOAA Center for Coastal and Ocean Mapping Joint Hydrographic Center. The primary aim of the algorithm is to use as much information as possible from the data to determine the true depth at any point in the survey area from the noisy estimates of that depth (i.e., the soundings) and to quantify an uncertainty on the depth estimate. The following information is pulled from the CUBE User's Manual. CUBE works in three stages:

1. Assimilation is the assembling of statistically based nodal depth estimates and depth uncertainties based on the input sounding measurements and their three-dimensional uncertainty estimates. The three steps of this process are establishing a network of nodes over the survey area, maintain sequentially-determined estimates of depth at each node, and compare incoming sounding measurements against existing nodal estimates and depth uncertainty.
2. Intervention is a decision to interrupt the straightforward assimilation process when an incoming sounding measurement is not statistically compatible with any of the existing nodal depth estimates. Intervention results in the creation of an "alternative hypothesis" where CUBE recognizes the possibility that soundings in the same area may be sensing more than one depth trend (e.g., the top of a school of fish as well as the bathymetry beneath them).
3. Disambiguation is the process of deciding which of many hypotheses about the depth at a particular node (i.e., the ambiguity in the nodal depth) is the best estimate of the "true" depth. This is decided by looking at:
    a. Which hypothesis is consistent with the greatest number of incoming soundings at that node?
    b. Which hypothesis is closest to a prediction based on nearest neighbor nodes that have only one hypothesis?
    c. Which hypothesis is closest to an "external" (probably lower resolution) reference surface? This surface could be generated by a median filter through all the soundings being processed or based on an older chart or survey data.

The CARIS HIPS integration of CUBE is well documented in the CARIS HIPS and SIPS User's Manual. When editing a CUBE surface, the user may opt to edit soundings or to edit hypotheses. For NOAA hydrographic survey data, it is critical that only sounding edits be used to correct gridding problems. This is primarily because hypothesis edits exist only in the context of a single grid and will be lost if that grid is recomputed.

CUBE is also implemented in a variety of hydrographic software packages such as Kongsberg Maritime, Triton-Imaging, QPS, HyPack, and Reson.

4.2.1.1.1.1 *CUBE PARAMETERS*

There is a small parameter file called "CUBEParams.xml" that is referenced in the HIPS environment. The values in this file control the behavior of the CUBE gridding and disambiguation processes.

The default CUBE parameters are not authorized for NOAA surveys.

Before each field season, the CARIS representative from HSTB will distribute the CUBE Parameters files to the appropriate representative for distribution to the field unit. The CUBEParams_NOAA_YYYY.xml file is appropriate for the year; each of the following grid resolutions has its own CUBE parameter set: 0.5m, 1m, 2m, 4m, 8m, 16m, 32m. VR Field units should use the parameter set corresponding to the appropriate resolution(s) and depth ranges of their survey data as specified in the HSSD. A description of each parameter and its default value and the allowable range of values can be found in the header of the XML version of the parameter file.

Three parameters have been modified from the CARIS default values: Capture Distance Scale, Capture Distance Minimum, and Horizontal Error Scalar.

The Capture Distance Scale value is a percentage of depth used to limit the radius of influence a sounding may have on the grid. The system default value is 5.0. However, for all grid resolutions in the NOAA parameters file, the value has been set to 0.5. Setting the value this low disables the function and forces the Capture Distance Minimum to be used instead over the range of applicable grid resolutions. This fixes the Capture Distance to the grid resolution. A value of 0.5 was determined to be low enough for all grid resolutions since they grow with depth.

The Horizontal Error Scaler value is used to scale the horizontal error of each sounding when used in the radius of influence computation. It affects the propagated uncertainty of each sounding and how it is combined into each hypothesis. The system default value is 2.95. However, based on discussions with Dr. Calder, the value has been set to 1.96, for all grid resolutions in the NOAA parameters file.

The Capture Distance Minimum value is the minimum distance that the CUBE algorithm will search for soundings to contribute to a node. It is used in conjunction with the Capture Distance Scale to limit the radius or influence of a sounding. The system default value is 0.5. The Capture Distance Minimum is the only parameter that varies between the grid resolutions in the NOAA parameters file.

The minimum capture distance radius is specified in the HSSD and is limited to (0.707*grid resolution), or:

$$minimum\ capture\ distance = \frac{gride\ resolution}{\sqrt{2}}$$

This value defines the capture distance to ensure that the radius of influence touches the outer corners of the grid resolution but not farther. With this capture distance, no sounding is ever "lost" to the algorithm, but there is not an oversampling of data from areas significantly further than the grid resolution. Because all of the soundings are in near to the node, the grid most accurately depicts the seafloor in that area without losing any soundings.

4.2.1.1.1.2 *UNCERTAINTY WEIGHTED GRIDS*

To generate uncertainty-weighted BASE surfaces, TPU must be calculated for each sounding. TPU accounts for either the priori estimate or sensor recorded horizontal and vertical components of uncertainty associated with each sounding measurement. TPU is formulated from the summation of the modeled uncertainties for all sub-systems included in the overall hydrographic survey system (e.g., water levels, tide zoning, attitude sensor error, navigation sensor horizontal position error, sound velocity profile error, sonar bottom detection method). The sources of uncertainty values include (or may be a combination of) manufacturer specifications, theoretical values, and empirical observations from the field. *A priori* estimate values are entered into the HVF while sensor recorded values are applied from the recorded data during the Compute TPU process.

Any deviation from the derived TPU values should be completely described in the applicable Descriptive Reports and DAPR.

In general, soundings (observation points) do not coincide with grid nodes (BASE surface estimation points). To account for this, the vertical component of a sounding's TPU is propagated to a grid node according to a power law that models the increase in uncertainty as a function of three variables: the distance between sounding and node, the sounding's horizontal component of TPU, and grid node resolution. The amount of weight an observation exerts on a given BASE estimation point is inversely proportional to the propagated vertical uncertainty of the observation.

$$\hat{\sigma}\rho = \widehat{\sigma_V}\left[1 + \left[\frac{\|x_i - n_j\| + s_H\widehat{\sigma_H}}{\min(\Delta x, \Delta y)}\right]^{\alpha}\right]$$

FIGURE 4-2 MODEL FOR PROPAGATED UNCERTAINTY IN DEPTH.

V and H are the vertical and horizontal components of TPU (resp.), SH is a scale factor representing the worst-case error that horizontal TPU can contribute; x_i and n_j are the locations of the sounding and estimation node (resp.); x and y are the two-dimensional spacing of grid nodes, and the exponent is a heuristic to control overall growth or propagated uncertainty, P (Figure 4-2). The HIPS BASE surface algorithm uses a value of 1.0 (HIPS has already scaled H by 1.96, for a 95% confidence interval) and a value of 2.0.

Theoretically, every sounding can affect every node in a BASE surface encompassing a survey area (Figure 4-3). For computational efficiency, HIPS limits a sounding's radius of influence on surrounding nodes through the following spreading conditions:

1. At a minimum, each sounding affects all nodes within a radius of 0.707 times the grid resolution of its position (i.e., within half the distance of the diagonal on a regular [square] grid). Hence, a given sounding will affect at least two to four nodes, depending on where it is situated in relation to the nodes.
2. Each sounding will propagate at most a distance determined by a user-specified threshold of propagated vertical uncertainty. The uncertainty threshold is expressed in HIPS according to an IHO sounding error model; that is, an estimate of all constant errors (a) and depth-dependent errors (b times d) are summed in quadrature.

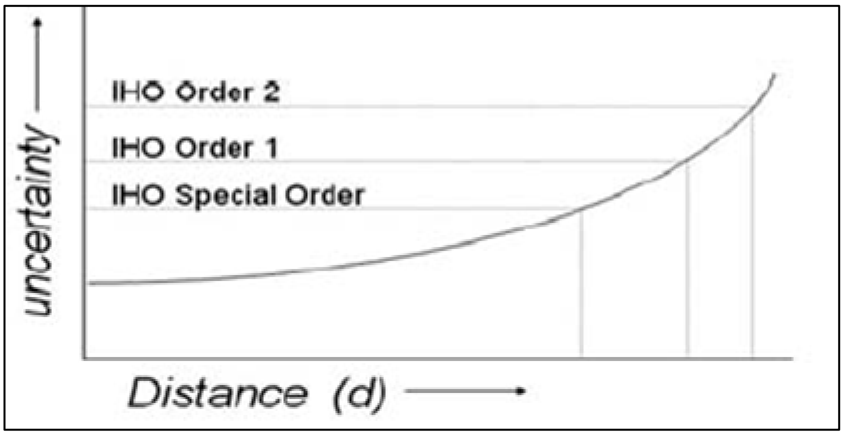


FIGURE 4-3 GENERALIZED UNCERTAINTY GROWTH CURVE WITH RESPECT TO SOUNDING RADIUS INFLUENCE (D).

OCS requirements for the accuracy of measured depths are adapted from IHO S-44, Standards for Hydrographic Surveys and are described in the HSSD. If either an IHO Special Order standard or a user-defined accuracy is required for a survey, the requirements will be stated in the Project Instructions.

CARIS HIPS allows BASE surfaces to be generated using either swath-angle weighting, uncertainty weighting, or CUBE discussed in the previous section. Swath-angle weighted BASE surface nodes do not incorporate TPU, so node "uncertainty" is not available therein. Unless specifically stated to the contrary, the use of the term "BASE surface" in conjunction with OCS hydrographic surveys refers to those surfaces generated using the uncertainty weighting method or CUBE.

4.2.1.1.2 BASE NODE ATTRIBUTES

The depth at a given BASE surface grid node, n, is the mean depth (weighted by propagated depth uncertainty) of the set of N soundings whose domain, Di, contains n. Likewise, the uncertainty at a given node is the mean uncertainty (weighted by propagated depth uncertainty) of all the soundings contained in set N. See Note that the depth at grid node n is the weighted mean of soundings 1, 2, and 3. Sounding 4 is not included because its radius of influence does not encompass grid node n (Figure 4-4)

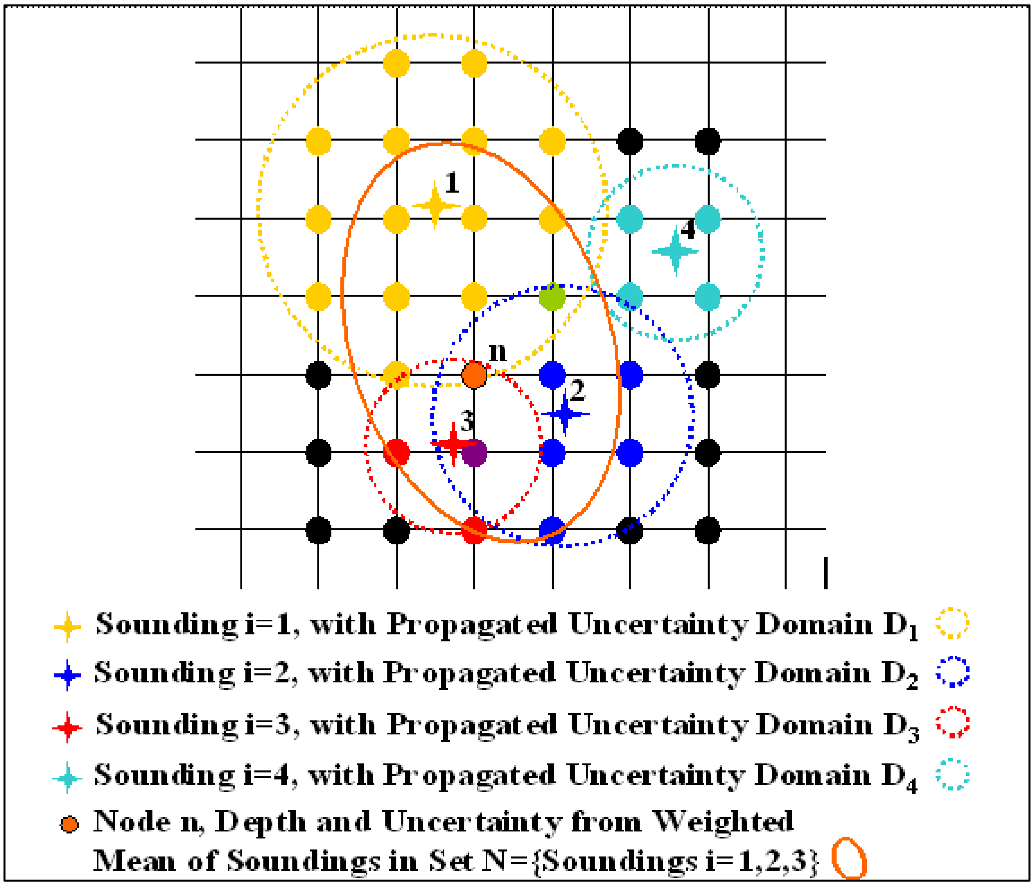


FIGURE 4-4 FORMULATION OF BASE SURFACE NODES FROM SOUNDINGS.

In addition to depth and uncertainty, users can include five additional attributes in the BASE surface nodal data. The definitions of the seven nodal attributes are summarized below. Note that all node statistics are computed from the set of surrounding soundings whose propagated vertical uncertainty passes a user-supplied threshold (IHO Order):

- Depth: weighted-mean depth of soundings that contribute to a node; weighting is inversely proportional to the propagated vertical uncertainty of the soundings.
- Uncertainty: weighted-mean vertical component of TPU of soundings that contribute to a node; weighting is inversely proportional to the propagated vertical uncertainty of the soundings.
- Density: thee number of soundings that contribute to a node.
- Std_Dev: standard deviation of soundings that contributed to the selected hypothesis at the 68%CI.
- Node_Std_Dev: standard deviation of the soundings that contributed to the current grid node at the 68%CI.
- Shoal: the shoalest sounding from the set of soundings that contribute to a node.
- Mean: sample mean of the set of soundings that contribute to a node.
- Deep: deepest sounding from the set of soundings that contribute to a node.

4.2.2 Bathymetry Processing Diagrams

Field units benefit from having processing diagrams available for quick reference and instruction. Below are some processing diagrams for commons processes. These workflows are updated by NOAA users (Figure 4-5, Figure 4-6, and Figure 4-7).

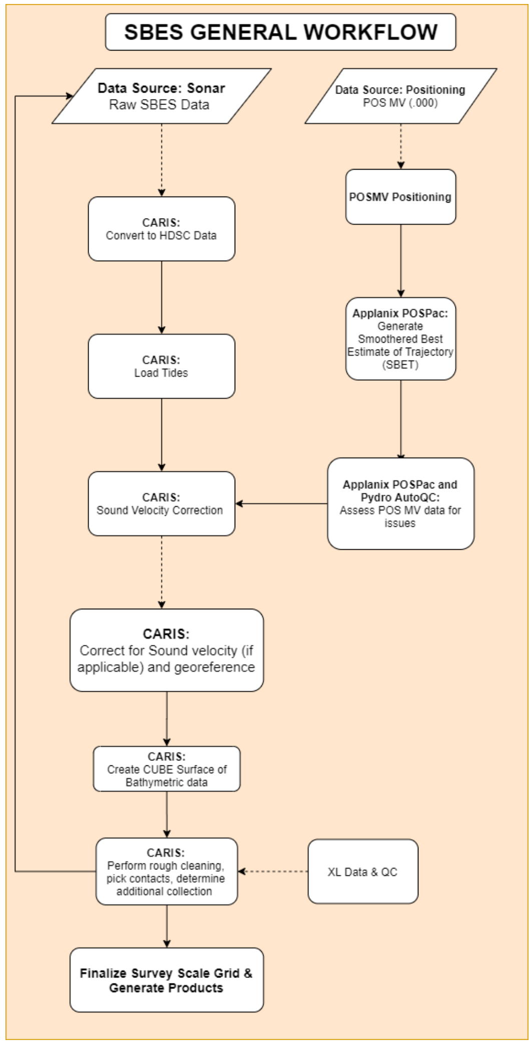


FIGURE 4-5 PROCESSING FLOW DIAGRAM FOR SBES DATA

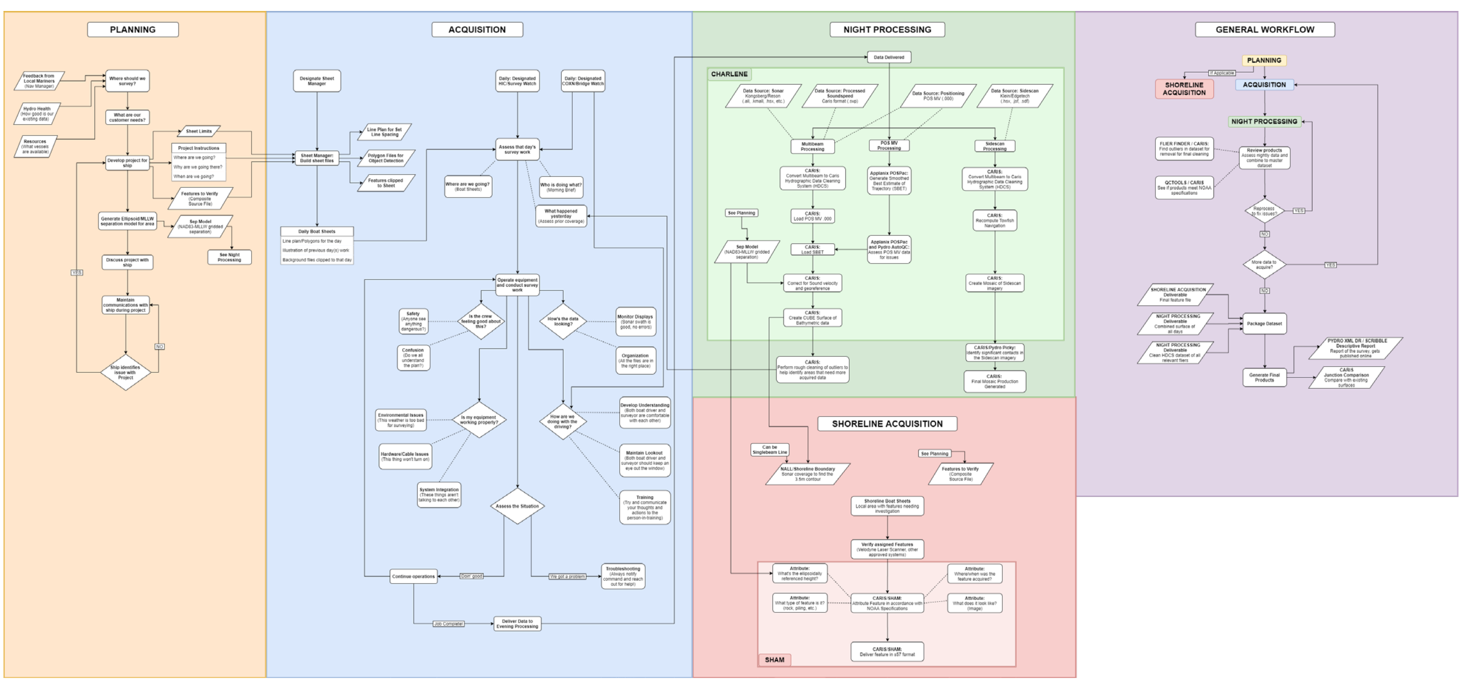


FIGURE 4-6 PROCESSING FLOW DIAGRAM FOR MBES AND SSS DATA.

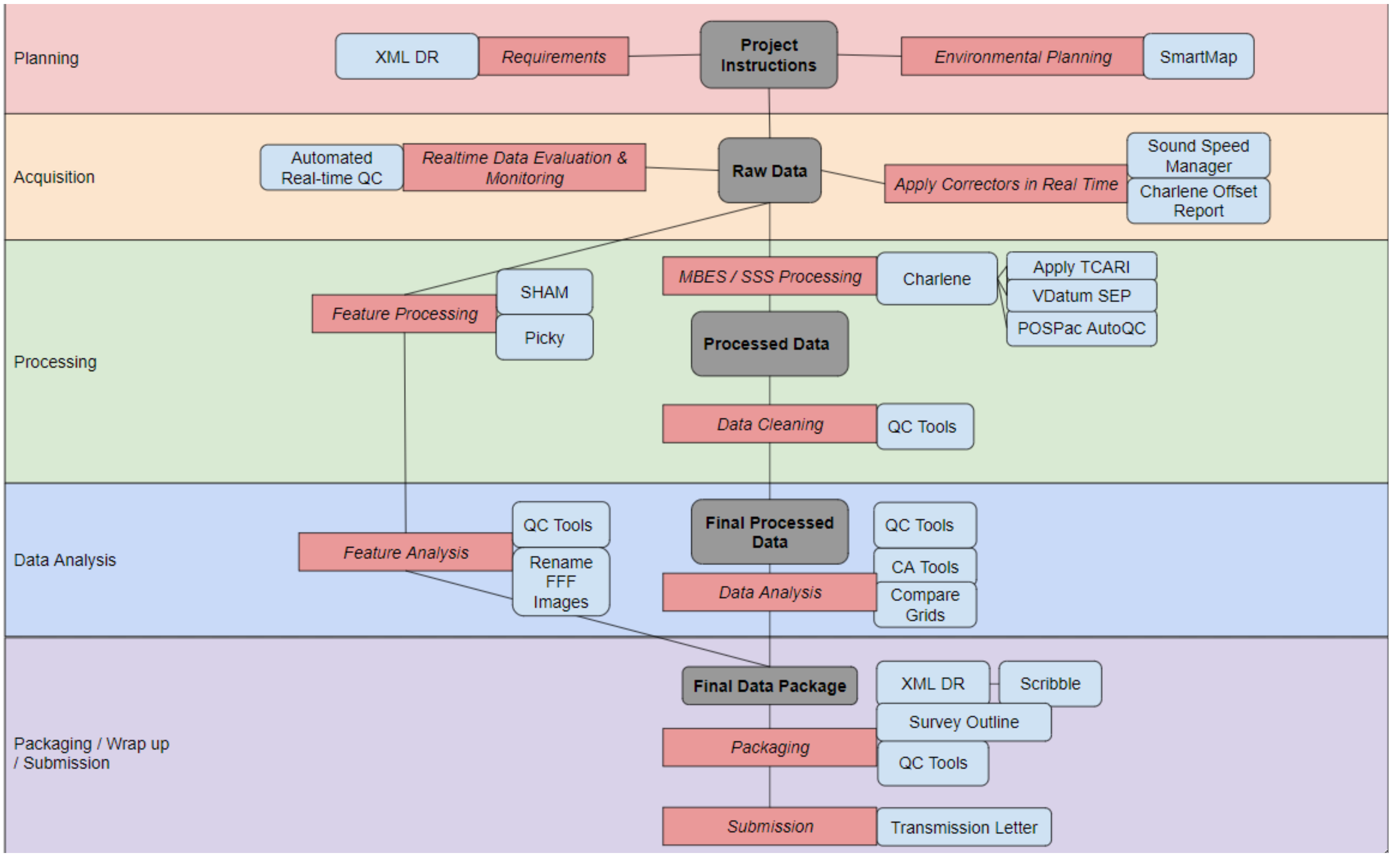


FIGURE 4-7 OVERVIEW OF NOAA FIELD UNIT SURVEY WORKFLOW AND ASSOCIATED PYDRO EXPLORER TOOLS TO ASSIST IN EACH STEP

4.2.3 Daily Batch Processing

During Boat day processing, a single "boat-day's" worth of bathymetric data is being viewed, edited, and flagged for internal consistency, gross errors, and any features that warrant further investigation. Several processing tasks need to be performed on "raw" bathymetry data (i.e., unaltered data in the format recorded by the acquisition software) before any detailed analysis and evaluation can occur. Some of these daily tasks are interdependent, and the specific sequence is critical.

Standard Operating Procedures (SOPs) are developed and maintained by the individual field and branches. These documents will go into detail of what settings, steps, and file paths for processing that may differ from unit to unit.

Most of the tasks can be automated using the Charlene or HIPS Batch Processor tool. Data format dictates how specific batch processing actions should be configured; thus, a separate HIPS Batch Processing File (*.hbp) is needed for each raw data format type.

In general, all of the aforementioned tasks should be completed for any type of echo sounder data. A basic set of batch processing files can be specified for each data type and reused on the appropriate set of survey lines acquired each day. In some circumstances, either creation of custom batch processing files or manual processing of one or more tasks, line-by-line in non-batch mode may be necessary. For example, conversion and filtering options may need to be customized to reflect changes in echo sounder performance as weather conditions varied throughout a survey day.

4.2.4 HYPACK

HYPACK is the standard data format used by NOAA hydrographic field units to log SBES, MBES, and SSS data. HYPACK software is used to store data from a variety of MBES systems via an additional software module called HYSWEEP. Field unit survey data HYPACK SBES files should be recorded using a DOY termed "Julian Date" in the HYPACK software file extension. MBES data, recorded using HYSWEEP, should be logged as ASCII *.HSX (HYSWEEP Survey Extension) files.

Within the raw HYPACK file, data recorded from each sensor in the acquisition system is assigned a "device number." This numbering scheme will vary according to the specific hardware configuration used to record the data. During conversion, device numbers can be specified to correlate each sensor's data string with a specific type of data (e.g., echo sounder, heading, navigation). If no device numbers are specified, the converter will look for sensor data using known NMEA device strings. Specifying device numbers during conversion ensures that HIPS does not incorrectly identify a data string. Device numbers can be verified by reviewing a raw HYPACK line file in a text editor, such as WordPad, in which each device number will be listed adjacent to its respective device name.

4.2.5 SBES & MBES Data

When logging SBES data, HYPACK records depth values directly from the echo sounder, rather than two-way acoustic travel times. For field unit survey data, field units must recalculate SBES depths using an actual measured sound speed profile during post-processing. HIPS assumes an estimated sound speed of 1500 m/s was applied to data during acquisition and uses that value to determine a two-way acoustic travel time for each sounding. HIPS then recalculate SBES depths using a measured sound speed profile.

If dual-frequency SBES data are being converted, high- and low-frequency soundings are stored side-by-side in the HYPACK raw data record. In dual-frequency systems, the low-frequency beam width will be wider than the high-frequency beam width. If the low-frequency return shows a shoaler depth more than the high frequency, it often indicates a feature offset from the vessel trackline. The least depth of such a feature may not have been captured by the low-frequency signal; thus, the hydrographer should note the feature's position and perform a development. During conversion, each sounding will be flagged as either "Primary" or "Secondary" in the order in which it appears in the datagram. For example, if the high frequency depth is listed first in the record and the user chooses "Primary, Secondary" for conversion, the high frequency depth will be flagged Primary and the low frequency depth will be flagged Secondary. Primary soundings are also flagged "Selected" by default in HIPS, and only selected depths will be carried through to final processing. Users may override the Primary/ Secondary flagging assigned during conversion to force a depth into, or remove one from, the set of selected depths.

Converting HYSWEEP MBES data is nearly identical to converting HYPACK SBES data. The primary differences are that the user must select raw *.HSX files for conversion and choose the "Multibeam" option for soundings, rather than Single Frequency or Dual Frequency as would be required for converting SBES data. Device numbers should still be specified as described in the beginning of this section (Table 4-2).

TABLE 4-2 OCS GUIDELINES FOR CONVERTING HYPACK DATA.

Options	OCS Guidelines
Single Frequency	If Single Frequency SBES data are being converted, it will automatically be classified as "Primary."
Dual Frequency	The OCS standard is to read in high frequency as "Primary and low frequency as "Secondary."

Multibeam	For HYSWEEP MBES data, simply choose the multibeam option.
Static Draft Apply during conversion	Typically, static draft should not be applied during conversion. The OCS standard is for sensors to be referenced to a vessel RP and static draft to be accounted for via a "waterline" correction entered in the HVF.
Device Numbers	If the hardware setup in HYPACK is unambiguous, then blank device numbers may work fine; OCS recommends explicitly stating the device numbers during conversion.
Sound Velocity	Data acquired for OCS hydrographic surveys should be corrected for sound speed using actual measured sound speed profiles. For HYPACK data, this process is performed in HIPS.

4.2.6 Georeference

Georeference Bathymetry merges data from time-based sensor data into processed geographically-referenced depth data. Data are imputed from one or more tracklines and outputted as a processed point cloud. Here, raw data from along and across-track depths into latitude, longitude, and depth by combining the ship navigation with the horizontal and vertical offsets from the HIPS vessel file, by geographically referencing the sounding position and depth in the world. Additionally, georeferencing incorporates for sound velocity, TPU, and applying a vertical adjustment using a GPS height or tide.

4.2.6.1 ERS:

NOAA chart datums are typically tidal datums, where hydrographic sounding data must be merged with water level observations relative to the local "chart datum." Mean lower low water (MLLW) is the typical water level observation, but it may vary in lakes and rivers. These water levels observations over extended periods, typically 19 years, and data collected by field units need to be combined with positional datum information collected from the survey information.

ERS requires Smoothed Best Estimate Trajectory (SBET) and Root Mean Square error (RMS) files. These files are created in Applanix POSPac from the POSMV positioning data collected during data acquisition. The SBET and RMS files are assessed for issues. For ERS based projects, SBET & RMS files are loaded using the CARIS/HIPS Load Attitude/Navigation tool. Load Attitude/Navigation will overwrite any previously converted real-time attitude and navigation data. The hydrographer can review/edit the attitude and navigation of time-series data using HIPS editors. The processed error metrics file that accompanies the SBET and RMS file is used in the CARIS HIPS and SIPS georeferencing.

For ERS Projects, data are converted to ellipsoid-to-chart using a VDatum Separation Model (SEP). NOAA VDatum software is developed jointly by offices within the National Ocean Service (NOS), OCS, the National Geodetic Survey (NGS), and CO-OPS. VDatum allows the hydrographer to take data collected in one reference frame and convert it to another. These transformations use a combination of stepwise transformations between geometric (ellipsoidal), orthometric (geoidal), and tidal datum reference frames, leveraging the best available geodetic data, hydrodynamic models, and historical tidal datums at each step. A composite uncertainty value is supplied with each SEP for use in ERS propagated uncertainty calculations. VDatum SEP models are to be applied during the "georeferenced" phase of CARIS HIPS and SIPS processing.

A VDatum SEP is supplied with the field units' project instructions or may be created in Pydro's "VDatum SEP from Shapefile" tool. There are some areas that are not covered by VDatum such as Alaska. For these locations the Ellipsoid Referenced Tidal Datum Model (ERTDM) is used.

4.2.6.2 Ellipsoid Referenced Tidal Datum Model:

There are areas field units may be assigned to survey that do not have enough information to create a VDatum SEP. These surveys are non-ERS surveys in this case, an alternative SEP model is created to enable ERS processing techniques. This is achieved by creating an Ellipsoid Referenced Tidal Datum Model (ERTDM), a localized model that follows the same idea of VDatum. ERTDM pulls information from alternative source data that consists of a composite value per variance sum law of the constituent ellipsoidal and orthotidal components.

Another alternative separation model includes Ellipsoid References Zoned Tides (ERZT) and is an option in areas lacking a published/verified VDatum or ERTDM model. ERZT relies on the survey vessel's GPS height, heave, and dynamic draft. The approved zone water level models to the ellipsoid by adding in situ ERS platform water line (ellipsoid) heights to zoned water level correctors. The zoned water level correctors are pulled from TCARI, direct, or discrete-zoned modeling. The ERZT SEP is formed by combining these observations from all project survey lines that traverse the zoned tidal water mass regions.

If tidal effects throughout a survey area are complex or if multiple water level stations are located nearby, an optional zone definition file (.zdf) can be used to express how the amplitude and phase of the tide within a given area is to available water level station data. This is referred to as discrete tidal zoning, and references the water level station, time corrector, and range corrector will be provided. This technique does not account for the effects of spatially varying harmonic and non-harmonic effects on the water levels. The accuracies achieved by discrete tidal zoning may be inconsistent from one survey area and/or time period to others, and the resulting uncertainties may be difficult to quantify. A tide or water level file must be loaded before georeferencing data in HIPS, but actual water level data may not yet be available. Thus for daily data processing, a zero or predicted tide file will often be used. If survey data were compensated for water level variances during acquisition or if water level measurements are not necessary for the survey area (e.g., some non-tidal rivers or lakes), a "zero tide" file must still be loaded to enable the georeferencing process. Non-tidal areas are still subject to water level variances due to factors such as wind, rain, barometric pressure changes, and freshwater runoff. If preliminary or verified water levels are available, the most accurate of these data should be applied. It is not recommended that the field units use "weighted averaging," while using zone tides. This is because the two-dimensional character of the survey area is not taken into account (i.e., the station-to-vessel distance vector may cut through land).

Tidal Constituent and Residual Interpolation (TCARI) was designed for total water levels relative to Mean Lower Low Water (MLLW) at selected hydrographic survey areas along the coast by the spatial interpolation of tidal data. The model spatially interpolates the harmonic constants (used to predict the astronomical tide), tidal datums, and residual water levels (i.e., the non-tidal component or the difference between the astronomically predicted tide and the observed water level) using the values at a combination of operational and historical stations. The method works best in regions where there is an abundance of high-quality tidal data surrounding the survey area. TCARI methodology has the potential to yield water level correctors with increased accuracy and reduced uncertainty.

Within CARIS HIPS and SIPS, the "georeference" function creates the HDCS GPS Tide file using the SBET converted GPS height and the loaded ellipsoid to chart the datum separation model. Computing GPS Tide with a "zero" separation is used to maintain merged soundings relative to the ellipsoid, and a vertical datum transformation is applied during grid processing.

4.2.7 Load Heave Source

Applanix POS/MV logs True Heave, during data acquisition to improve the performance of real-time heave filters in long period swells. True Heave is an Applanix trade mark and is loaded as delayed heave for post processing.

For post-processing, Delayed Heave is loaded using the CARIS HIPS and SIPS “Import Auxiliary Data.” Delayed Heave gets loaded as Import Auxiliary data that converts data on heave, motion, post-processed positioning, and attitude data (SBET and RMS). The hydrographer can review/edit the heave data using CARIS HIPS and SIPS Attitude Editor. The Attitude Editor displays sensor data related to the movement of a vessel or a towed sensor.

4.2.8 SV Correct

Correcting sonar data for the speed of sound (through water) refers to performing a refraction correction based on a sound speed profile of the water column. Variations in the speed of sound are primarily caused by thermocline (water temperature variations) or halocline (salinity variations), and results in refraction (bending) of the sonar beams. The speed of sound through water will decrease as water temperature lowers, causing a sonar beam to bend downward and creating depth and position errors in any measurement calculated based on travel time and an assumed linear travel path of the sonar beam. The sound wave striking the thermocline at point slows down, while point A on the same sound wave continues at the original speed until it strikes the thermocline at C. As a result, the sonar beam bends downward (Figure 4-8).

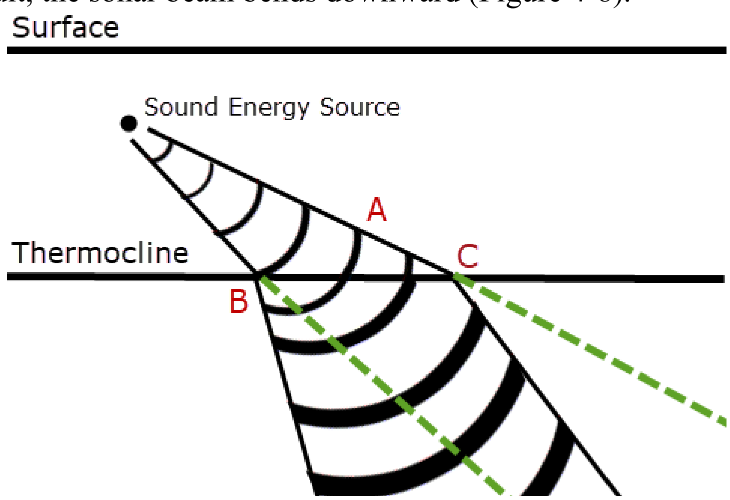


FIGURE 4-8 SONAR REFRACTION DUE TO THERMOCLINE

If sound speed corrections have not been applied in real time during data acquisition, a HIPS Sound Velocity Correction is performed during “georeferenced.” Two stages of sound speed processing are possible in HIPS: (1) An adjustment of sonar beam (reported) launch angle through flat face refraction (FFR), which is not applicable for all MBES systems, and (2) adjustment of the sounding horizontal position and depth through geometric beam ray-tracing. During HIPS SV Correct, survey line “Observed Depths” data (along-track/across-track position, and depth with respect to the vessel RP) are recalculated from “SLRange” data (beam launch angle, one-way travel time) and corrected for acoustic refraction as well as (if indicated in the HVF) waterline, dynamic draft, heave, roll, and pitch.

Beam ray-tracing is performed on all MBES data during HIPS SV Correct regardless of echo sounder type. Starting from the initial launch angle (reported or otherwise FFR-corrected), each sonar beam within a given survey line is processed as a ray refracting through the loaded sound speed profile and tracing a non-linear path. The distance of this path is assumed to be equivalent to the measured one-way travel time for the beam. By calculating a more precise one-way travel time, a more accurate beam position and depth can be determined.

Typically, a concatenated SVP file generated by NOAA’s Sound Speed Manager contains multiple sound speed profiles, complete with metadata to indicate when and where observations took place that will be applied to survey data. In such cases, the user will need to choose a method for selecting how individual sound speed profiles are applied. HIPS SV Correct provides four options: previous in time, nearest in time, nearest in distance, and nearest in distance within time. The method selected should be whichever will most accurately represent the survey area conditions.

4.2.9 Compute TPU (Total Propagated Uncertainty)

Before data processing, vessel offsets and total propagated uncertainty values based on uncertainty estimates for survey equipment should have been entered into the corresponding HVF.

For the most part, uncertainty estimates entered into the HVF file are static over a field season or in the absence of changes to the vessel configuration. Some HVF uncertainty estimate values may need to be adjusted on a case-by-case basis to account for any un-modeled uncertainty in a given component of the sounding.

Most of the uncertainty estimates that are entered into a CARIS HVF are straightforward and are based on direct measurement techniques or manufacturer-provided information. Some TPU entries need to be estimated including MRU alignment. One method to estimate these values is to calculate the standard deviation of a large sample of angular bias values resolved with a patch test. The sample size can be created either by several people resolving the angular biases or a couple of people resolving the values numerous times. Angular bias values resolved in a patch test are a measurement of the angular bias between the transducer reference frame and the Motion Reference Unit (MRU) reference frame.

Therefore, any uncertainty values derived from the patch test angular biases are based on the same relationship. Uncertainty can be assigned to either the MRU alignment or the transducer alignment. The angle between the MRU and the transducer is measured, not the absolute alignments between the MRU and the transducer to a vessel reference frame. CARIS expects the offset value to be entered into the MRU alignment uncertainty field.

All changes made to the HVFs used to process hydrographic survey data should be approved by the field unit's Chief-of-Party and completely described in the Descriptive Report. Once the process has been selected, uncertainty values that change on a survey-by-survey basis, such as tide and sound speed, are entered during the Compute TPU process of georeference.

Certain error values in the HIPS vessel file (HVF) may be overridden with real-time or post-processed error values. Before computing TPU, use HIPS Load Error Data from the Applanix POS PCS raw file (*.000) or the Applanix POSPac post-processed RMS file (smrmsg).
The sound speed component of the total propagated uncertainty is a function of environmental variability with respect to space, time, and instrument uncertainty.

The HSSD states that the measured sound speed uncertainty may range from 0.5 to 4 m/s, which is a conservative estimate. This range depends on the spatial and temporal environmental variability and the frequency at which sound speed casts are taken. Casts taken at a high frequency (i.e., every 15 minutes or less) will capture the spatial variability better and lower the uncertainty values.

The TPU values associated with surface sound speed have a smaller range and magnitude than measured sound speed (0.2 m/s to 2 m/s) because sound speed is continually measured at the transducer. The sound speed uncertainty, therefore, is dictated by the sound speed gradient at the velocimeter's sensor head.

As with any deviation from procedures specified in the HTD's FPM or the HSSD, methods for estimating uncertainty and justification for this deviation should be clearly described in the Descriptive Report as well as the Data Acquisition and Processing Report. The field should be aware; however, if the processing branches disagree with the method used, any corresponding surveys using these uncertainty values may be returned to the vessel. Field units should communicate any deviations from standard practices in the DAPR to their respective branches and their project manager.

4.2.10 Filter

Depending upon data quality, the hydrographer may choose to filter a dataset during post-processing. HIPS provides several filtering tools that can be used to automatically flag data as rejected or accepted. Filtering methods commonly used for processing hydrographic survey data include TPU, sonar quality flags, angle from nadir, and depth threshold. The TPU filtering option can be used to expeditiously reject soundings with uncertainty values that fall outside limits set for either an IHO order survey or some user-defined parameter. However, the hydrographer should keep in mind that it is the grid node depth that must meet survey specifications, not each individual sounding. Thus, the TPU filtering tool may over clean data. MBES data can be filtered based on sonar quality flags and/or the angle from nadir. Both MBES and SBES data may be filtered based on the depth threshold. This method can be used to eliminate anomalous soundings resulting from double-echoes or near-surface reflection such as propeller wash, entrained air, and marine life. Consult the CARIS HIPS and SIPS User's Manual for more information on filtering methods.

4.2.11 Data Processing

"Boat day processing" and "night processing" as described in this chapter refers to that portion of hydrographic data processing that is performed on a single vessel's data that were acquired during a single day of data acquisition. Before commencing boat day processing, all of the daily batch processing tasks should have been performed. For most field units, data processing is typically accomplished during a "night processing" shift. For ERS based projects, boat day processing includes generating POSPac SBETs for all survey vessels.

4.2.11.1 Create Boat day BASE Surface

The first step in boat day processing is to create a CARIS BASE surface of the vessel's daily data using final gridded data specifications as defined in the HSSD. Initially, the boat day BASE surface is used to direct the editing process. Once editing and the appropriate checks are complete, the boat day BASE surface can be re-gridded and added to a survey-wide BASE surface to be finalized and submitted.

4.2.11.1.1 REVIEW BOAT DAY BASE SURFACE

Boat day processing is based on the natural interpretive power of the human eye to evaluate a BASE surface for anomalous bathymetry, directing attention to areas that require review and/or editing by a hydrographer. Once a boat day BASE surface has been created, it should be investigated for features and indications of data problems (artifacts). A bathymetric feature is any object that may be of importance for nautical charting, such as a wreck, shoal, or other items that may need further investigation. Typically, the depth and standard deviation BASE surface layers are most useful for identifying data anomalies

If artifacts are perceived, the hydrographer can measure the vertical distance of the artifact (peak-to-trough) and compare this distance to the allowable vertical error for the survey to determine if the data are acceptable. If major data artifacts or issues are observed, the CST, Operations Officer, or Team Lead should be informed to identify and resolve the issue. In most cases, data anomalies can be easily evaluated and edited using HIPS Subset Editor. However, complex areas may require additional line-by-line evaluation and editing via HIPS Swath Editor.

The hydrographer should systematically inspect a variable resolution surface numerous times.

Problems that may be encountered in an MBES data set can generally be broken down into the following seven categories: refraction, attitude, position, heading, sonar, environmental, and tide (Figure 4-9).

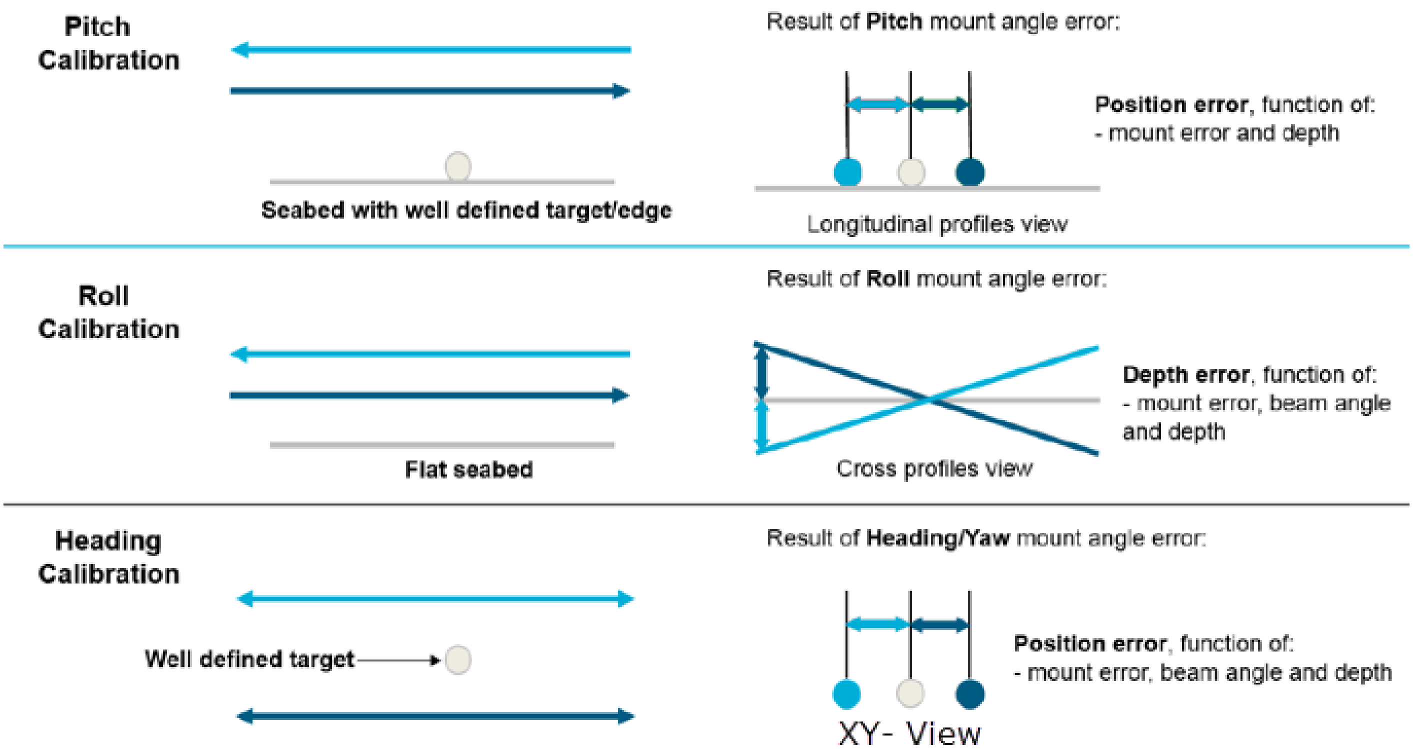


FIGURE 4-9 GENERAL OVERVIEW OF OBSERVED ERROR AND POTENTIAL SOURCES

4.2.11.1.1.1 *REFRACTION*

Acoustic refraction-induced errors are caused when the speed of sound through the water column is not adequately modeled over time or space. When viewing data with refraction errors in the across-track direction, the hydrographer will notice a "smiling" or "frowning" characteristic (Figure 4-10).

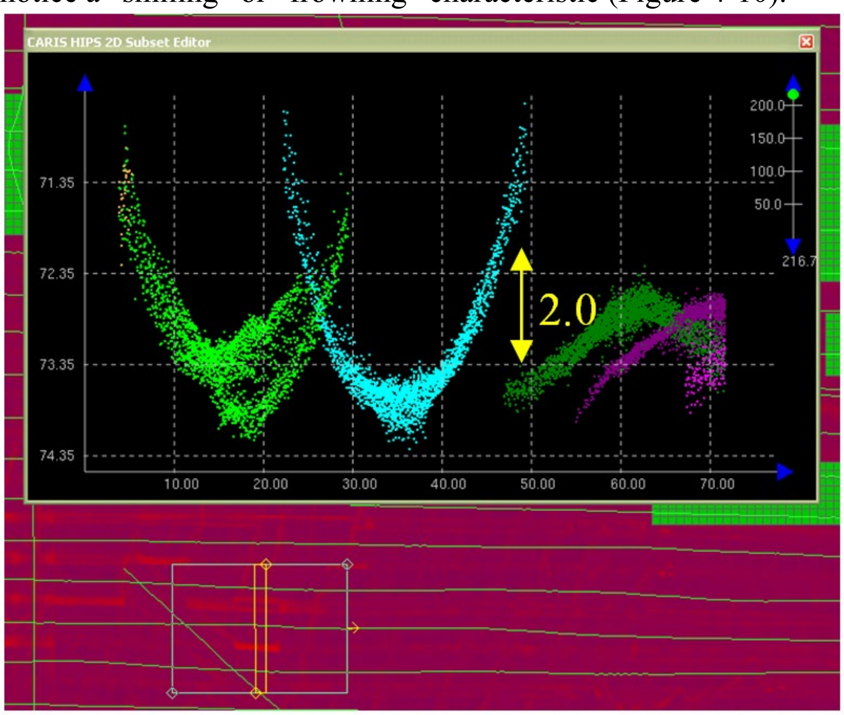


FIGURE 4-10 HIPS SUBSET EDITOR VIEW (TOP) OF ACOUSTIC REFRACTION-INDUCED BATHYMETRY ERRORS, USING BASE SURFACE STANDARD DEVIATION IMAGE FOR REFERENCE.

Depending upon the cause of this artifact, it may indicate a need for additional sound speed profiles each day or more profiles spatially over the survey area. Typically, the amount of time required to obtain additional sound speed profiles is far less than that required to edit or otherwise "fix" data afflicted with acoustic refraction artifacts.

HIPS Refraction Editor, a tool in Swath Editor, may be used to assist with troubleshooting refraction errors. Refraction Editor allows the user to enter a step sound speed correction at a specified water depth. As sound speed corrections are entered, the effect is reflected in the swath edit display by increasing or decreasing the curvature (smiling or frowning) of the swath. This tool should only be utilized as a last resort.

4.2.11.1.1.2 *ATTITUDE*

Vessel motion artifacts may arise due to a failing accelerometer within the heave/pitch/roll sensor, a gap occurring in data transmission or recording, an inaccurate patch test (e.g., conducted in insufficiently deep water for the given survey area), or unaccounted latency within the data acquisition system. A gap is illustrated in the attitude time series (Figure 4-11).

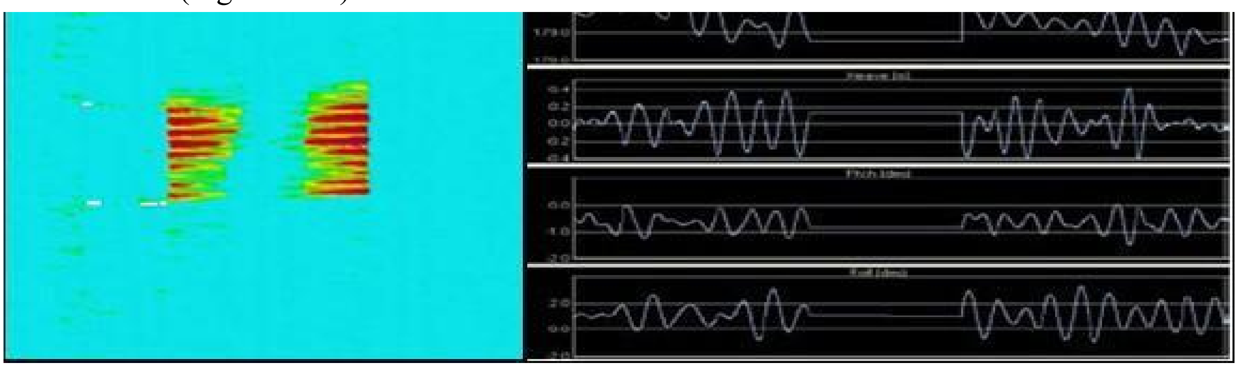


FIGURE 4-11 BASE SURFACE STANDARD DEVIATION LAYER (LEFT) OF A SURVEY LINE WITH DATA IN ATTITUDE TIME SERIES (RIGHT).

If a specific cause of vessel motion artifacts can be determined, it may be possible to repair the data. For example, a new patch test could be run, or data could be reprocessed to account for a known latency. In other cases, data may need to be either smoothed to minimize the artifact or rejected entirely. If systematic errors are found in a vessel's attitude data, the time spent troubleshooting the source of the problem will typically far outweigh the time required to continually edit data.

4.2.11.1.1.3 *POSITION*

Gross horizontal positioning errors are uncommon when using modern surveying equipment. Inertia-aided GNSS navigation equipment, such as the Applanix POS MV, uses Kalman filtering to constrain vessel speed, acceleration, and displacement, eliminating the majority of potential positioning errors. The most common cause of error in an inertia-aided system is when the GNSS portion of the position solution fails.

Because of the horizontal position accuracies required for hydrographic surveys, loss of differential GNSS corrections should also be considered a GNSS failure. The effects of temporarily losing differential corrections can be viewed in HIPS Navigation Editor (Figure 4-12).

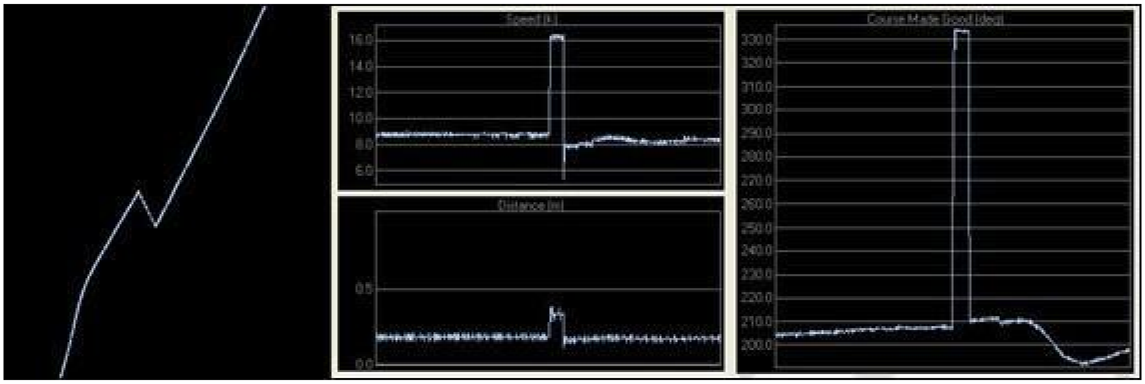


FIGURE 4-12 HIPS NAVIGATION EDITOR TIME-SERIES SHOWING POSITIONING ERROR CAUSED BY TEMPORARY LOSS OF DIFFERENTIAL CORRECTIONS.

During a GNSS failure, inertial navigation systems can dead reckon for approximately 30 seconds before errors accumulate to a level that produces unacceptable positioning. For surveys that reference an ellipsoid, 30-second delays are not acceptable to correct for ellipsoid height.

The hardware/software interface for an inertial navigation system should be configured to alert the user of failure events so that data acquisition can be suspended if the position data become unacceptable.

Positioning "problems" associated with horizontal uncertainty may be seen in areas of extreme slopes. For example, if the horizontal accuracy is approximately 4 meters, the vertical depth error on a slope of 60° would be almost 7 meters. Inconsistencies will be observed from swath to swath in these areas because of the horizontal positioning error.

4.2.11.1.1.4 *HEADING*

Heading errors can be induced by a faulty sensor or an incorrect heading alignment correction entered in the HVF. This problem can be easily identified as a break in the continuity of linear features from one swath to the next.

During data acquisition, heading values are sometimes included in datagrams from sensors other than the primary navigation system. However, the accuracy of the heading data will vary depending upon its source. If heading errors are discovered, it may be possible to re-process the data using heading information from another source. The field unit's FOO/OPS or equivalent should be notified if an alternate heading source (e.g., calculated course-over-ground) is used to process survey data as TPU.

4.2.11.1.1.5 *SONAR*

Sonar-induced data problems are typically caused by inappropriate settings in the sonar system. This may include improper range settings for the water depth. Any of these circumstances could prevent the sonar from accurately representing the seafloor. The best way to minimize sonar-induced errors is by having attentive and well-trained operators during data acquisition.

4.2.11.1.1.6 *ENVIRONMENTAL*

Environmental data problems are those caused by objects or disturbances in the water column, such as marine life, vegetation, entrained air from passing vessels, or weather-induced disturbances from heavy seas or rain (Figure 4-13).

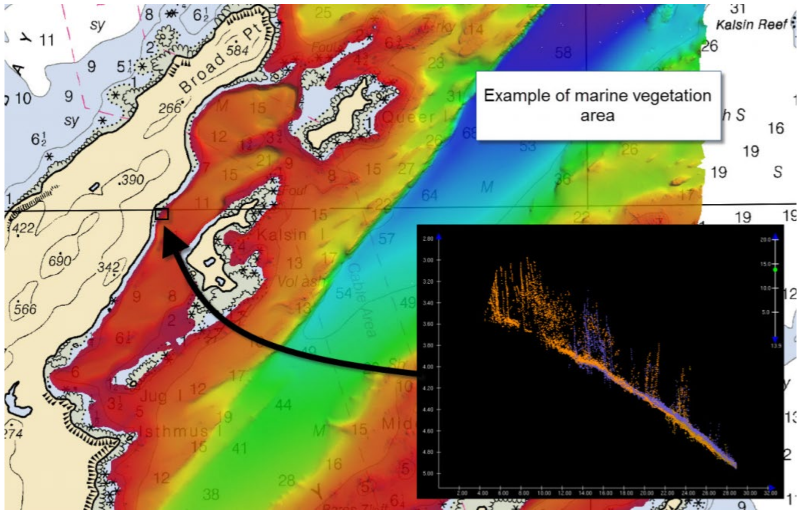


FIGURE 4-13 HIPS SUBSET EDITOR VIEW (RIGHT) AND BASE SURFACE DEPTH LAYER VIEW (LEFT) SHOWING NOISY DATA CAUSED BY MARINE VEGETATION.

As with all data problems, environmental data issues are most effectively addressed during the acquisition stage rather than during processing. Depending upon the severity of the data problems, acquisition may need to be suspended until environmental conditions have improved.

4.2.11.1.1.7 *TIDE*

Tide errors can result from inaccuracies in any of the source data used in the vertical datum transformation algorithm, such as inaccuracies in the water level observations, tide zoning model, or navigation. This type of error is often identified by a measurable vertical offset visible when data are viewed in the across-track direction (Figure 4-14).

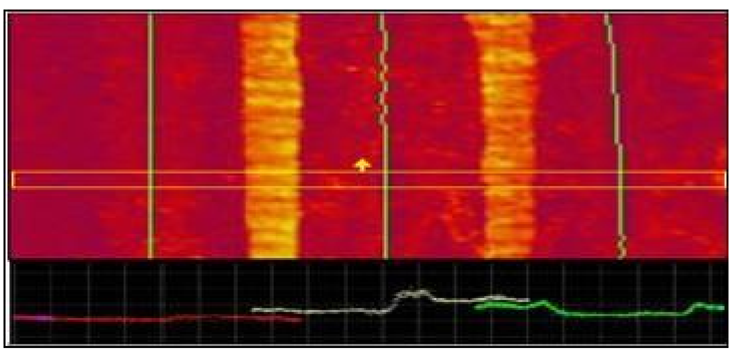


FIGURE 4-14 HIPS SUBSET EDITOR VIEW OF TIDE-INDUCED BATHYMETRY ERRORS (BOTTOM), USING THE SURFACE STANDARD DEVIATION IMAGE FOR REFERENCE (TOP).

If tide errors are identified, the hydrographer should ensure that the correct water level data have been loaded for the suspect dataset. Thus, what appears to be a data problem may correct itself once observed water level data are applied. For example, during ERS it is important to ensure that the Separation model covers the entirety of the area being surveyed. If not, there will be larger variations in depths (Figure 4-15). To ensure this is a Sep model error, a traditional tide method, such as fetch tides, may be used to help determine the issue (Figure 4-16).

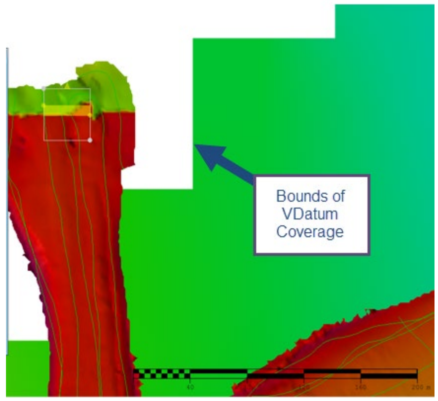


FIGURE 4-15 SHOWS A LARGE CHANGE IN DEPTH (25 METERS TO 100 METERS) CAUSED BY A LACK OF VDATUM COVERAGE.

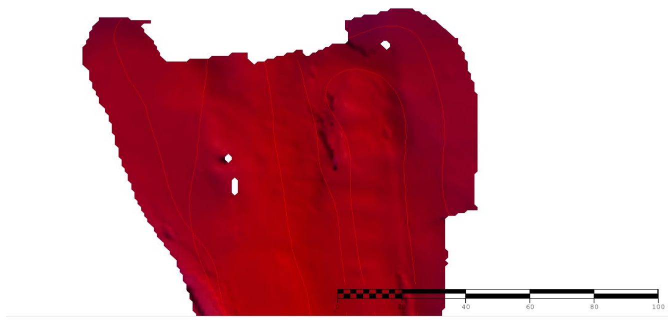


FIGURE 4-16 THE DEPTH ISSUE CAN BE CORRECTED EITHER BY TEMPORARILY USING A TRADITIONAL TIDAL METHOD SUCH AS FETCH TIDES, OR BY CREATING A SEP MODEL AS A DECREASED RESOLUTION (E.G. GOING FROM 100 M TO 250 M).

When using actual tide gauge data rather than predictions, there may be varying accuracies and unquantifiable amounts of uncertainties due to discrete zoning and tide-induced bathymetric errors. This can be an indication that the tide gauge does not adequately reflect the tidal range for the area or that the method of discrete tidal zoning does not account for the tidal effects occurring in the area.

4.2.11.1.1.8 *ERS SBET HEIGHT ERRORS*

This type of error may be identified by a measurable vertical offset visible when data are viewed in the across-track direction, similar to a tide error.

SBET height errors can take two forms: a simple bust or a gradual one. A simple bust consists of an immediate failure and will have a stair-like appearance. Gradual errors are more insidious and will have a ramping effect on the data that changes the recorded depth as one progresses along a track. This can be caused by a degraded corrector service.

The most common height issue with ERS methods is mistakenly exporting the survey SBET to NAD83 when the SEP model is WGS84-MLLW. This will result in changes in ellipsoid height relative to one day and another height the following day (Figure 4-17).

FIGURE 4-17 ERS HEIGHT ERROR

4.2.11.1.1.9 *DIRECT SURFACE EDITING*

Processing is critical to the safety of future boat crew operations for it is needed to provide an updated coverage visualization. Processing and editing the data collected from a single boat day increases the efficiency for the next day's operations. The goal of "Night" processing is to convert, correct, and process the raw data collected to provide an accurate product for the field teams to use the following day. The workflow varies between field units but typically, the workflow consists of converting data from raw format (e.g., **.all, **.000, **.scp) to a combined processed product (e.g., HDCS, *.SBET) and updating the overall status of the survey. This helps identify glaring issues such as holidays, SVP errors, positioning issues, or areas that need to be recollected.

One or more of the HIPS data "editors" can be used to analyze data artifacts and features of interest that are identified on the surface. With the exception of SBES data, depth values cannot be directly edited or changed in HIPS; however, soundings can be flagged with various attributes, including "rejected" which will suppress a sounding from further processing steps. Daily review and flagging of features is strongly recommended to maintain an organized and complete survey. Many of these editors would be used outside of single boat day processing. Supporting sensor data can also be flagged as being rejected, either with or without interpolation.

Subset Editor is the most frequently used HIPS editing tool and allows the most flexibility in addressing a problem that is concentrated in one geographic area. During single-boat day processing, the hydrographer would use the subset editor to complete a rough cleaning of the data and analysis for errors. When reviewing an entire survey area for holidays and fliers, hydrographers have the option to use "Subset Tiles" to track editing progress in the Subset Editor. Once defined, subset tiles may be flagged as either "Complete" (green), "Partially Complete" (yellow), or "Incomplete" (red) to identify areas that have been investigated, need a second review, or have not yet been edited, respectively.

In some cases, it may be beneficial to review individual sonar pings in a specific line of survey data. This type of line-by-line editing can be performed in HIPS Swath Editor. If potential problems in either attitude or position data are noticed, the Attitude Editor or Navigation Editor tool can be used to review individual sensor time-series data.

The Subset Editor enables the hydrographer to review and edit a “subset” of the entire sounding dataset and corresponding BASE surface data by geographic area. Subsets are rectangular and will contain all soundings acquired within the geographic boundaries of the subset. Rotating a subset can be useful to obtain a profile view when inspecting data along slopes or dredged channels.

When using Subset Editor, the hydrographer should be aware of the data display settings particularly vertical exaggeration, and whether rejected soundings are displayed. The hydrographer must take care not to “over-clean” data in this fashion. Displaying rejected soundings allows the user to see data that has been previously rejected, typically, by a filtering routine in Swath Editor or editing by another hydrographer. Viewing rejected data is often valuable when investigating the validity of a possible feature. Individual soundings or groups of soundings may be selected and flagged in Subset Editor. Available data flags and each flag’s purpose in OCS hydrography are as follows:

- Reject: Flag anomalous soundings as “rejected” to suppress them from being included in subsequent processing steps such as in the calculation of BASE surface grids.

- Reject Swath: This flag sets the “rejected” flag for all soundings in a selected swath. Use this function to reject a single ping or a continuous section of flawed sonar pings.

- Outstanding: This flag may be set for any data point that holds particular hydrographic significance. Typically, if the identity, extent, or validity of a feature is uncertain, it should be flagged as “outstanding.”

- Examined: This can be used by the surveyor as a means of marking a sounding for future reference. This flag can also be used to separate a group of soundings for non-standard data analyses.

- Designate: Applying the “Designate” flag to a sounding will force the BASE surface grid node closest to that sounding to assume the exact depth value of the designated sounding, ignoring all other soundings within the area of influence of this node.

4.2.11.1.1.10 *SWATH EDITOR*

The Swath Editor enables the hydrographer to review and edit a single swath of data from four orthogonal directions as well as from a three-dimensional perspective.

Data problems that appear to be limited to the extent of a single line of data are often best addressed using Swath Editor. As when using Subset Editor, individual soundings or groups of soundings may be selected and flagged in Swath Editor. The Swath Editor also allows the user to view amplitude (i.e., backscatter or side scan) data from a multibeam echo sounder. Amplitude data can provide valuable insight for determining if a particular sounding or group of soundings is a real feature.

4.2.11.1.1.11 *ATTITUDE EDITOR*

The Attitude Editor allows the hydrographer to review and edit heading (gyro), heave, pitch, and roll data. The Attitude Editor displays each sensor’s time-series data for a single survey line. CARIS HIPS and SIPS provides three means of editing attitude data: rejecting (with or without interpolation), filtering, and smoothing.

For data problems of limited extents in time, rejecting is generally the preferred editing method. There are two options for rejecting attitude data: “Reject-with interpolation” and “Reject-break interpolation.” Rejecting data with interpolation will fit a straight line from the last good data point before the segment rejected to the first good data point after the segment is rejected. Caution should be exercised when using this tool. Rejecting and interpolating sections of attitude data across the peaks of a signal will result in distorting the maximum observed amplitude at that time (Figure 4-18).

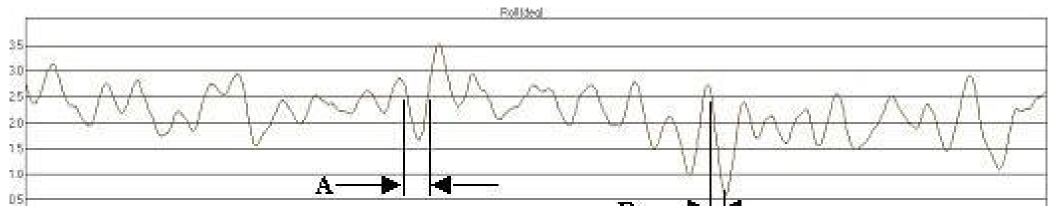


FIGURE 4-18 INTERPOLATION ACROSS REGION 'A' WILL MOST LIKELY CREATE AN ARTIFACT OF ITS OWN, WHEREAS INTERPOLATION ACROSS REGION 'B' WILL NOT ADVERSELY IMPACT THE SOUNDING DATA.

Rejecting without interpolation should be used to edit attitude data corruption occurring over an extended period of time. A general rule of thumb is to divide the allowable data gap distance for the survey by the vessel speed in meters-per-second to determine when to begin breaking interpolation. The Hydrographer should note that breaking interpolation will create a gap in the data. When the files are merged, this option rejects all sounding data recorded during the time period in which sensor data were rejected, thus leaving a holiday in data coverage.

For attitude data problems that are systematic throughout the time series, filtering or smoothing is typically the best editing approach. The hydrographer is cautioned that filters are powerful tools and should be used with great care. The control window has multiple synchronized sensor graph windows so that more than one type of sensor data can be displayed in the same graph window.

4.2.11.1.1.12 *NAVIGATION EDITOR*

The Navigation Editor allows the hydrographer to review and edit the vessel's navigation time series. The navigation time series can be edited in CARIS HIPS and SIPS using rejection with or without interpolation. When rejecting data, the Navigation Editor tool offers two interpolation methods: linear and Bezier.

Linear interpolation is suitable if the majority of the navigation positions are clean and do not deviate significantly from neighboring positions. Bezier interpolation is suitable if the original data are noisy. Linear interpolation simply calculates new positions over the rejected segment by connecting bounding positions with a straight line. Bezier interpolation calculates new positions over the rejected segment by fitting a Bezier curve through bounding positions, producing a resultant curve that may not necessarily connect or pass through all navigation positions on the line.

To help expedite data inspection, the Navigation Editor provides "spike detection." This tool will search the navigation time series for user-defined "jumps" in speed and time. Each jump will be highlighted so that the hydrographer can decide how best to edit the data. Large jumps in speed, calculated as distance traveled divided by the time between fixes, can detrimentally affect the vessel's dynamic draft computation. Data artifacts due to speed jumps will be more pronounced if the slope of the vessel's speed versus dynamic draft is steep. A general rule-of-thumb is to interpolate speed jumps if they exceed the TPU modeled for vessel speed in the HVF, but this becomes less critical if a vessel's speed versus dynamic draft slope is small. Because speed and time jumps are directly related and speed is used to determine dynamic draft, it is unnecessary to separately edit time jumps.

4.2.11.1.1.13 *SURVEY-WIDE PROCESSING*

The difference is the context in which these steps are accomplished. During survey-wide processing, survey bathymetry and imagery data are examined in context with existing chart information and any additional supporting data available. Survey-wide data analysis can be performed relative to the ellipsoid or chart datum that is most appropriate.

Many of the steps involved in processing hydrographic surveys are iterative and may be conducted in parallel with each other. Efficiency can be increased by conducting many of the survey-wide processing steps concurrently with boat day processing for global quality control and general survey completeness. These processes include:

1. Verifying adequate investigation of charted features within the survey sheet limits;
2. Reviewing the data for DtoNs; and
3. Verifying that data coverage meets the assigned specifications.

Reviewing these points daily will help to ensure a complete survey and a timely submission.

4.2.11.1.1.14 *ASSESS BATHYMETRY FEATURES*

Bathymetric contacts should be periodically assessed and a determination made as to whether further "development" is necessary. Developing a bathymetric contact typically refers to acquiring additional MBES data over the feature to increase sounding density and determine or verify a least depth. However, other methods of obtaining a least depth may be used such as a single beam or DLDG.

Bathymetric contacts are often easily identified, and corresponding HDCS data can be flagged during the examination of the surface depth or standard deviation layers. Soundings flagged "examined," "outstanding," or "designated" can then be highlighted using the HIPS "Display Critical Soundings" command.

Comparisons should also be made between sounding data and existing charted depths. If survey soundings indicate deeper water than the charted depth(s), the charted depth should be treated as a feature and additional data acquired, as necessary, to verify that the charted depth is incorrect. Bathymetric features should be evaluated for significance and data coverage.

4.3 Acoustic Backscatter Processing

NOAA hydrographic field units typically acquire three types of acoustic backscatter data: side scan sonar (SSS), MBES backscatter, and MBES "side scan," which is an option on some systems.
The procedures outlined in this section are required only for SSS imagery being used to meet object detection criteria and are not applicable to MBES imagery data unless noted to be about a specific MBES system or backscatter data.

4.3.1 Imagery Object Detection

Imagery data are acquired and processed to detect objects that may be of navigational significance (Figure 4-19). Determination is based on contact type, position, and estimated height above the seafloor based on the acoustic shadow in the imagery. Imagery data acquired for hydrographic surveys are geographically referenced, allowing for the identification of the contact's position. The accuracy of this position will vary depending on whether the sonar was towed or hull-mounted. If the SSS imagery shows that a contact is significant, the location should be marked and added to the development plan. Further investigation is to determine the item's least depth and acquiring a more accurate position for charting.

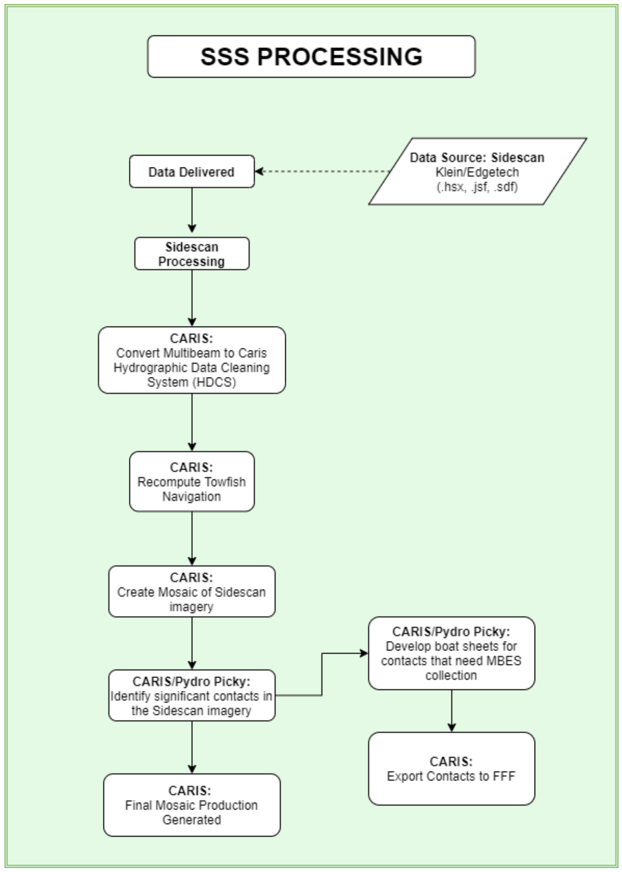


FIGURE 4-19 BASIC DATA PROCESSING FLOW CHART FOR SSS DATA

4.3.2 Daily Batch Processing

When SSS imagery is collected, this is unaltered data that is still formatted by the acquisition software. Several processing tasks need to be performed on "raw" imagery before any detailed evaluation can occur. Some of these daily tasks are interdependent, and the specific sequence is critical. The recommended ordering of daily batch processing tasks is as follows:

1. Conversion;
2. Filter, if applicable;
3. Recompute Towfish Navigation, if applicable;
4. Slant Range Correction: and
5. Add to Mosaic.

Processing of SSS imagery data can be completed in Pydro Explorer's automated processing interface, Charlene, or using the HIPS and SIPS internal batch tool.

4.3.2.1 Conversion

CARIS SIPS supports many different data formats that may be used to record imagery. During conversion, SIPS uses raw data to create files in CARIS' proprietary format which will be used in subsequent CARIS processing routines. These files in CARIS SIPS format are referred to as "SIPS files" or "HDCS files."

When SSS data is collected using towed configurations, the tow fish's position can be recorded in raw data.

This is done by calculating the amount of cable out and towfish depth or water depth and towfish altitude. A towfish position can be recalculated during post-processing by knowing the cable out, and either towfish depth/water depth and towfish altitude can be reprocessed during the Recompute Towfish Navigation. Either method of positioning should be adequate for standard SSS operations. However if re-computing towfish navigation, the hydrographer should first review and edit, if necessary, cable out and towfish depth.

For hull-mounted configurations, sonar offsets should be accounted for in the HVF as vessel RP to tow point values. Re-computing towfish navigation must be performed for vessel RP to tow point to be applied. For hull-mounted configurations (i.e., no cable out data recorded), towfish navigation will be recomputed using a cable-out value of zero.

If an error is discovered in the HVF during SSS post-processing, re-conversion may not be required to correct the data. If unsure whether data repairs are necessary, the field unit should consult HSTB.

The following sections contain guidance for converting common raw imagery data.

4.3.2.1.1 SENSOR DATA FORMAT (SDF)

Sensor Data Format (SDF) may be used to store data from Klein System 3000 or Klein System 5000 side scan sonar systems. Conversion parameters will vary slightly depending upon the SSS system used to acquire the data. The SDF data format is generated by Klein Associates' proprietary software package, SonarPro.

If data were acquired using a Klein 5000 dynamically focused multibeam-side scan sonar, the user must choose whether or not to convert hidden beams. There are five beams on each channel (port and starboard) of the Klein 5000. Based on the range scale and towfish speed, the system will determine the number of beams necessary to achieve 100% coverage. Typical range scales and speeds used for hydrographic surveying require that 3–4 beams be used. Selecting "convert hidden" forces all five beams to be converted and may improve imagery in high yaw-rate conditions (e.g., in turns or for hull-mount configurations) or aid in detection of very small objects during activities such as search and recovery. However, for a basic hydrographic survey, converting hidden beams is not necessary to meet survey specifications and can introduce data management problems by significantly increasing file sizes.

Towfish depth is used to calculate towfish navigation in SIPS. Both the Klein 3000 and 5000 systems are equipped with a pressure sensor installed in the towfish body to determine towfish depth. Each towfish will have a pressure sensor rated for 100, 300, or 1000 psi, depending on the anticipated operating depths. The hydrographer must know the pressure sensor rating for the specific towfish used to acquire data.

Both the Klein System 3000 and System 5000 towfish are equipped with a magnetic-based heading sensor. This sensor's data are logged as SSGyro. Typically, a magnetic compass does not indicate true headings and must be corrected for magnetic declination (variation) and deviation to obtain a true heading. Electrical interference could also contribute to a loss of both the accuracy and precision of the SSGyro. Because of these inaccuracies, it is not recommend using towfish heading sensor values (SSGyro) for processing survey data.

Various side scan sonar systems may record imagery at different resolutions. Both Klein System 3000 and System 5000 imagery data are recorded at a resolution of 12 bits. When converting SDF files, choosing an 8-bit conversion will reduce the data resolution. Even though the recorded resolution is 12 bits, choosing the option to "Preserve 16-bit" will retain the original resolution.

4.3.2.1.2 ACOUTSTIC BACKSCATTER IMAGERY

Acoustic backscatter is the reflection of a signal back in the direction it originated (the multibeam sonar). It is computed by measuring the amount of sound that is reflected by the seafloor, lost through the water and received by the sonar (Figure 4-20). In hydrography, backscatter data are collected from bathymetric surveys to better determine the characteristics of the seafloor. Different bottom compositions scatter sound energy differently and can provide insight into the roughness, softness, or hardness of a surface. A stronger return signal indicates a hard bottom such as a rocks, whereas a weaker signal indicates a soft bottom such as sand.

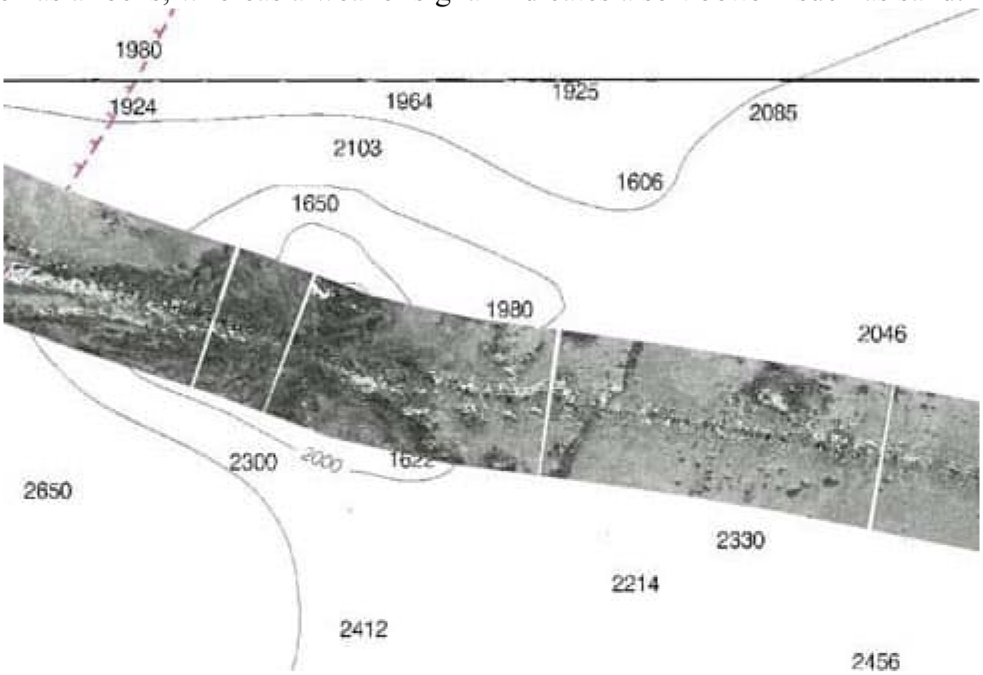


FIGURE 4-20 AN EXAMPLE OF A BACKSCATTER MOSAIC

This imagery differs from that produced by a side scan sonar in a variety of ways, such as positioning methods or sea state impacts. Side scan imagery is the actual intensity of a return signal while backscatter is the reflectivity of measurement.

Most field units have the ability to collect and produce backscatter data, and most field units are required to submit backscatter mosaics when submitting their surveys.

The backscatter products are archived at the National Centers for Environmental Information (NCEI) in a Generic Sensor File (*.gsf) created by FMGT. The *.gsf files can be created from RESON *.7k files, Kongsberg *.all files, and *.XTF files. The *.gsf files are the most straightforward backscatter products for NOAA stakeholders because the files contain both backscatter and processed bathymetry (Figure 4-21).

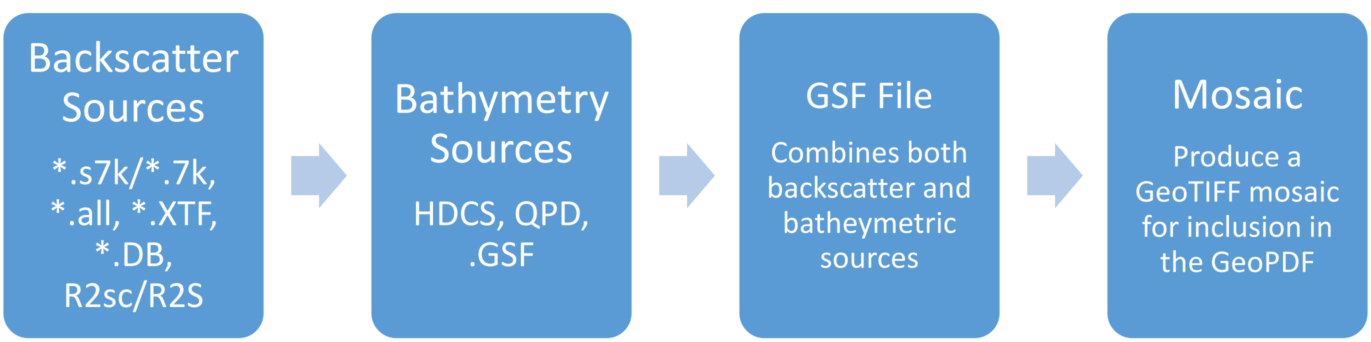


FIGURE 4-21 WORKFLOW PROCESSING TO PRODUCING A BACKSCATTER MOSAIC

Klein 5000/5000V2 Systems that are logged view Sonar Pro 12.1, an .SDF file is produced.

Charlene can process *.SDF, *.HSX, *.JSF, *.XTF, and .GSF raw data files for side scan data (Figure 4-22).

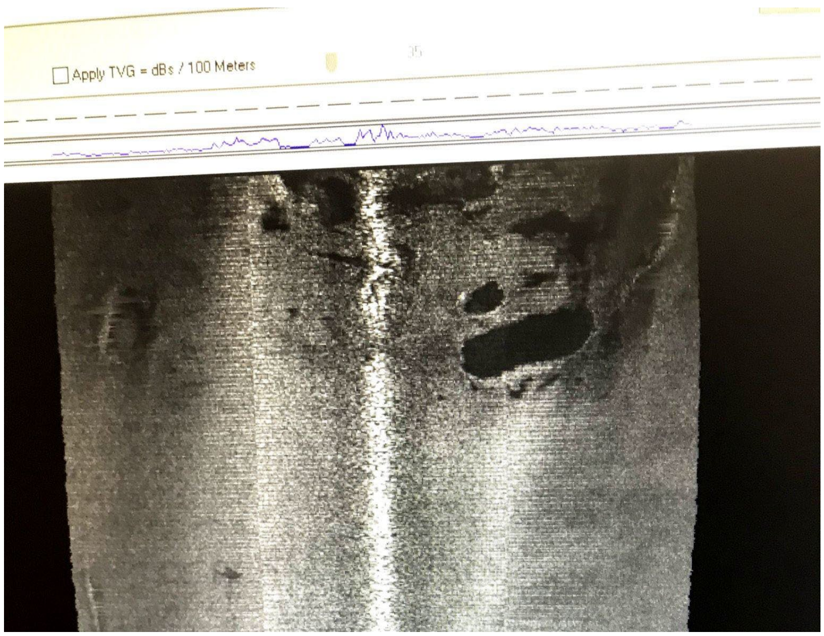


FIGURE 4-22 THERE ARE A VARIETY OF PRODUCTS THAT CAN BE PRODUCED FROM SSS SYSTEMS

4.3.2.1.3 CONVERT SIDE SCAN

Some SSS systems will simultaneously log data from multiple frequencies. During conversion, each frequency will be associated with a pair of sonar channels, and the user must indicate which channels are to be processed. The sonar system used by the field unit will determine the raw data file type; conversion methods will vary.

For SSS data logged in Hypack that produces a *.HSX file, in post-processing the frequency (low or high) will need to be selected to convert SSS data. The positioning information is drawn from either the cable out entered, or from the HVF for pole/hull-mounted systems. Device numbers will need to be entered exactly as the devices are listed in the .HSX file and should be Nav/Gyro=0, Port Transducer=1 and Cable Out=2.

Data collected using Klein and producing a *.SDF file are a little more straightforward. The cable out value is pulled from the pressure sensor within the system, and high frequency is processed.

Data collected using an Edgetech sonar will produce a *.JSF. For conversion, the towfish position is calculated by the cable out and the sensor altitude. These values are pulled from the SSS HVF for hull-mounted and pole-mounted systems.

Various side scan sonar systems may record imagery at different resolutions. Klein 5000 imagery data are recorded at a resolution of 12 bits. When converting XTF files, choosing an 8-bit conversion will reduce the data resolution. Even though the recorded resolution is 12 bits, choosing the option to "Preserve 16-bit" will retain the original resolution.

4.3.2.1.3.1 *CONVERT LAYBACK/CABLE OUT DATA*

NOAA hydrographic field units typically record cable out during towed SSS acquisition to facilitate re-computing navigation, if necessary. To preserve decimeter accuracy for cable out values, the field unit may use one of the two following options:

- Configure the vessel's cable counter to output values in decimeters and log an integer value to the "cable out” field. However, SIPS assumes cable out data are in meters when re-computing. During conversion, the user can enter a “multiplier” of 0.1 to the “cable out” data that would reconvert the values to meters.

- Configure the acquisition system to log cable out in meters and decimal meters, to the “layback” field. In this scenario, the user must remember to convert data from the “layback” field even though the data are values for cable out. SIPS will assume data from either data field is cable out if towfish sensor depths are non-zero. Similarly, if no towfish depths are converted, SIPS will interpret this as a zero sensor depth and assume data from either data field are layback values.

To determine towfish depth, the Klein 5000 SSS calculates a value from an integrated pressure sensor. If the hydrographer intends to use cable out to re-compute navigation for an SSS system that does not have a pressure sensor, the towfish depth will need to be calculated based on water depth logged to an AUX field and towfish altitude. Typically, NOAA hydrographic field units will not need to calculate a sensor depth in this fashion.

4.3.2.1.3.2 *FILTER*

HIPS does not provide filtering tools to automatically flag/reject “bad” imagery data. However, as when processing bathymetry, filtering can be performed on attitude and navigation data. Time-series data for gyro (heading), cable out and sensor depth, as well as bottom tracking, must be reviewed line-by-line and edited as necessary. If the SSS system is configured to calculate sensor depth based on sensor height and an auxiliary SBES depth, these sensors will also need to be reviewed.

4.3.2.1.4 RECOMPUTE TOWFISH NAVIGATION

Side scan sonar is typically configured either as towed, hull-mounted, or pole-mounted. Regardless of system configuration, the hydrographer has the option of either computing the sensor position during data acquisition or re-computing towfish navigation during SIPS processing. If a towfish position is computed during acquisition and stored in the raw data format, this information can be converted directly into the SIPS towfish navigation data structure. If, in addition to ship navigation either cable out and towfish depth or horizontal layback is recorded, the side scan sensor position can be calculated in SIPS via Recompute Towfish Navigation. OCS strongly recommends re-computing towfish navigation using cable out and towfish depth to determine the towed sensor position. This process enables the hydrographer to review and edit, if necessary, the ship position data, cable counter data, and towfish depth or bottom tracking (if used to determine towfish depth) before calculating a towfish position.

If horizontal layback or tow cable length data are not available or if the Recompute Towfish Navigation step is not executed, then the towfish navigation data recorded during acquisition will be used to georeference imagery. If, additionally, towfish navigation were not recorded during data acquisition, then the side scan sensor position data are assumed to be the same as the ship navigation data.

When using a hull-mounted configuration, navigation data for the sensor is typically determined by using ship navigation data and entering the vessel RP-to-towfish offset in the tow point section of the HVF. The tow point Z id relative to the waterline, and the tow point x/y is relative to the reference point.

However, SIPS will only apply the tow point offset when navigation is recomputed. For this type of configuration, Recompute Towfish Navigation must be performed with a cable out value of zero.

If no cable out data were converted, SIPS will assume cable out to be zero.

4.3.2.1.5 SLANT RANGE CORRECTION

Side scan sonar is initially logged as a series of time-indexed intensity values for each ping, (i.e., the across-track axis represents time). These data are considered “raw” side scan and are displayed with the central portion of the image representing the water column and a digital line along either the port or the starboard leading edge indicating the logged bottom track. Some sonar systems will track the bottom very accurately while others require that these data be edited or re-digitized. Any errors in the bottom track should be edited before slant range correcting, as these data determine sonar height during the slant range correction process.

When data are slant range corrected, an estimate of the speed of sound through seawater is applied to the two-way travel time for each intensity value. This produces an estimated ray length that, when combined with the known sonar height (from the digitized or logged bottom), is used to produce the across-track distance to a pixel using simple trigonometry. Slant range-corrected data are displayed with the water column removed and the across-track scale representing distance from nadir.

During the process of slant range correction, the resolution value will default to the minimum value appropriate for the sonar system. If this resolution is not feasible, it will default to 0.10 meters. Resolution may be manually increased, but increased resolution means a larger file size. The hydrographer will be required to make some arbitrary decisions regarding beam pattern correction and despeckling. The "Beam Pattern" function attempts to equalize the differences in pixel intensity from nadir to the outer ranges of the sonar swath. The Despeckle function detects isolated bright spots and streaks in the raw sonar file and smooths them by averaging the neighboring pixels. Applying these options will produce a more attractive mosaic when creating constituent products and should not hide small contacts during data processing.

4.3.2.1.6 ADD TO MOSAIC

A survey-wide side scan mosaic should be created and maintained during daily processing to evaluate data coverage, identify any gross systematic errors, and plan future data acquisition.

If a 200% side scan survey is being conducted, a separate mosaic should be created to demonstrate coverage for each 100%.

In addition to planning future SSS acquisition, the first 100% mosaic can be used to delineate areas of high contact density where complete MBES coverage is more appropriate than 200% SSS. The hydrographer is reminded that assigned feature investigation radii that extend beyond the basic survey limits must be entirely covered with a 200% side scan, complete or object detection multibeam, or a combination thereof to be disproved by sonar data. These radii should be considered when evaluating survey coverage.

When creating a mosaic, the hydrographer will be prompted for several pieces of information. Maximum across-track and altitude ratios can be used to systematically remove areas of poor quality data from the mosaic, such as when outer edges are affected by thermocline. These features will not reject the imagery data, but they will remove portions indicated for all lines in the mosaic.

Options such as interpolation and shine-thru may be used at the hydrographer's discretion. These features may enhance the overall mosaic and can be desirable for creating constituent products.

4.3.2.2 Boat day Processing

"Boat day Processing" as described in this chapter refers to that portion of the hydrographic data processing that is performed on a single vessel's data that were acquired during a single day of data acquisition. For ships and launches, this portion of the processing is typically accomplished during the "night processing" shift. For field parties, this processing step may be either saved for foul-weather days or accomplished by a shore party member in charge of their unit's daily data processing.

The goal of imagery Boat day Processing is to identify contacts that warrant further investigation and record these contacts in the digital data. This process is completed using SIPS Side Scan Editor.

4.3.2.2.1 SIDE SCAN EDITOR

Imagery data should be reviewed twice using CARIS SIPS Side Scan Editor. The initial reviewer should identify any object that warrants further investigation, often referred to as a "significant contact", and record these items into the digital data. The second review serves as a quality control, and should add any significant contacts that were overlooked during the initial check. Two of the most frequently used tools to determine contact significance are "Measure Shadow" and "Measure Distance."

"Measure Shadow" can be used to determine the height of an object by measuring its acoustic shadow and calculating the object's approximate elevation off the seafloor. This tool can only be used when viewing data in slant range corrected mode. "Measure Distance" is used to measure the distance between two points. This tool is helpful in determining the overall size of contacts, which may determine their significance. For example, a very large item, even if it does not protrude significantly from the seafloor, may still be historically or geologically significant and should therefore be investigated (Figure 4-23). The Measure Distance tool can be used when viewing both "raw" (i.e., not slant range corrected) and slant range corrected data.

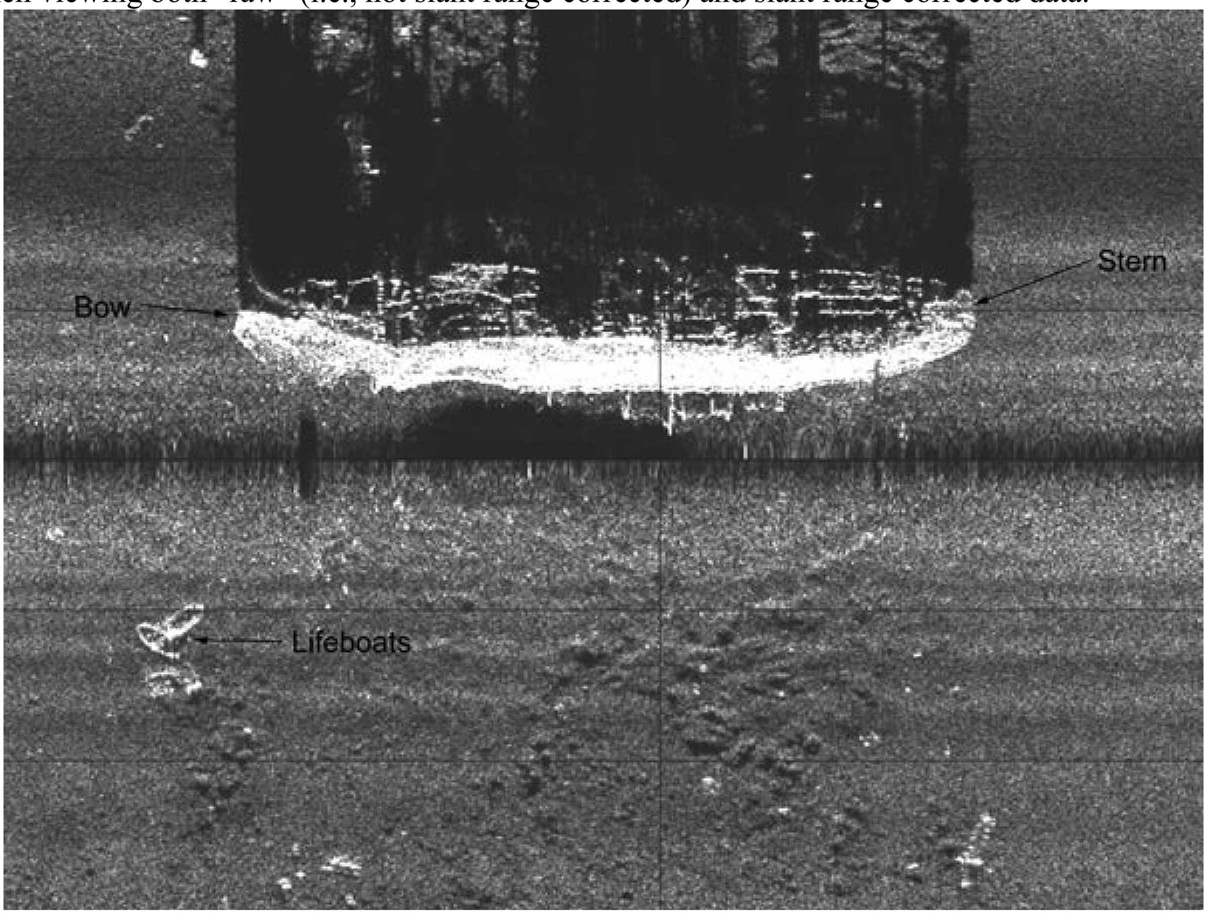


FIGURE 4-23 AN EXAMPLE OF A SIGNIFICANT FEATURE FOUND BY SIDE SCAN OF THE PASSENGER FREIGHT ROBERT E. LEE

All significant contacts should be recorded in the digital data by creating a contact in SIPS. (Refer to the CARIS HIPS and SIPS Users Guide for detailed information on how to create a contact.) The general OCS practice for determining significance of an imagery contact is stated in the HSSD.

The hydrographer must always consider the location of a contact when determining significance. For example, in a major channel where vessels transit with minimal underkeel clearance, a contact less than one meter high could be significant.

When a contact is recorded in SIPS, the item is geocoded and attributes are attached to it in the Side Scan Editor. Each contact should be attributed as thoroughly as possible. A contact file is created for each survey line and is stored in the line folder within the Project directory structure.

4.3.2.2.2 SURVEY-WIDE PROCESSING

"Survey-wide Processing" for imagery data consists of evaluating total coverage and assessing side scan contacts determine which items warrant further investigation or development, and attributing each contact accordingly. These processes would include verifying adequate investigation of charted features and assigned items within (or partially within) the survey sheet limits, reviewing the data for Dangers to Navigation (DtoNs), and verifying that data coverage meets the assigned specifications. Reviewing these points on a daily basis will help to ensure a complete survey and a timely submission.

4.3.2.2.3 REVIEW SURVEY-WIDE MOSAIC

Survey-wide mosaics are typically reviewed during Boat day processing to assess coverage and ensure that no significant data gaps, referred to as "holidays," are present in the imagery. Pydro has a variety of tools available to assist with SSS Mosaic QC. Both the Fieldsheet and GeoTiff images should be digitally filed for submission with the completed survey data. If the survey requires 200% side scan coverage, a separate final mosaic should be created for each 100%.

4.3.2.2.3.1 *ASSESS IMAGERY FEATURES*

Throughout the survey process, imagery contacts should be periodically assessed and a determination made as to whether "development" is necessary. Developing an imagery contact typically refers to investigating the item with MBES to determine a least depth. However, other methods of obtaining a least depth may be used, such as SBES (via star pattern development) or lead line. Some types of side scan sonar systems can acquire co-located imagery and bathymetry data.

Any significant contact suspected to be a DtoN should be expedited through the investigation/development process and a DtoN report submitted, if necessary.

Any contact measuring greater than 1m in height of the seafloor is considered significant. Other features that may not meet this height criterion may be considered significant; refer to the HSSD.

The determination of whether to develop an item from imagery data is considered a preliminary assessment of contacts. This preliminary contact evaluation should not be confused with the finalization of imagery data where the goal is to verify that all contacts have been addressed.

4.4 Feature Processing and Analysis

A feature is an object that merits individual attention distinct from the bathymetric model of the seafloor.
In a general sense, the bathymetric model of the seafloor will be represented on the chart using soundings and contoured depth areas. Everything else (e.g., buoys, rocks, wrecks, piles, docks) are features. During the acquisition of a hydrographic survey, the hydrographer will encounter many objects that may merit individual attention and treatment.

In some cases, this object will be of significant navigational interest and will eventually be portrayed as a distinct cartographic symbol on a chart. An example of this type of feature is a prominent wreck. Once discovered, the wreck will likely require further investigation. Investigation should be done using the high-resolution multibeam. This may also involve side scan sonar and diver investigation. This additional information is collected and used to fully describe and categorize the wreck. Once processed, this information is passed to the Atlantic and Pacific Hydrographic branches and Marine Chart Division in formatted reports and digital data files. These data will aid the cartographer in correctly charting the feature.

In other cases, further investigation may indicate that the feature is not navigationally significant and should not be charted as a distinct cartographic symbol. An example of this type of feature might be an object detected with side scan sonar that subsequent multibeam coverage found to be not of navigational concern (a patch of gravel, for example). This feature does not require attribution or reporting unless the hydrographer believes it may indicate something of potential navigational significance.

In some other cases, the hydrographer may wish to call out an object for individual cartographic treatment even if the depth of the object is well represented in the bathymetric data set. For example, a large glacial erratic boulder on an otherwise flat and featureless sandy bottom may be of particular navigational significance, especially if there is a bottom trawl fishing fleet in the area. This object may be selected by the hydrographer and recommended for charting as an isolated feature rather than simply through soundings and contours.
These examples demonstrate that the feature processing pipeline is used to:

1. Gather together information on features that may eventually be added to the chart,
2. Aid in assessing the feature's navigational significance, or
3. Provide a mechanism for reporting this feature analysis to the Hydrographic Branches.

Four basic sources of feature information must be analyzed and resolved when processing a hydrographic survey: bathymetry, side scan imagery, detached positions (DPs). The ability to resolve a feature depends heavily on viewing data in its full context. Data should be reviewed daily to identify items that are DtoNs, and processing should be expedited to the greatest extent possible.

Non-DtoN features should be evaluated and classified periodically as the survey progresses toward completion. Ultimately, all features should be evaluated, classified, developed (if necessary), and resolved.

Field units can use a variety of software to analyze and document survey features. CARIS BDB and Pydro are generally used for feature correlation for side scan sonar (SSS) contacts. Pydro explorer's SHAM processes features and is the only way to batch process ERS features with VDatum support.

Pydro is also used for generating survey reports for DtoNs. All software packages can be used to process S-57 features and populate their attributes. The user may switch between software types by importing and exporting S-57 *.000 files.

4.4.1 Processing Software

4.4.1.1 CARIS Software
CARIS HIPS and SIPS and Bathy DataBASE (BDB) are used to bring together various data types, including features, images, and bathymetry into a georeferenced user interface. These are good tools for managing line and area features such as reefs, foul areas, and piers.

CARIS HIPS and SIPS and BDB can read several data types, including the following:

- ENCs, or other S-57 databases (.hob, *.000);
- Raster displays: (.kap, .tif);
- Vector files (.shp, .dxf, .des); and
- Pydro *.000 files.

Within each project there can be numerous types of information to assist in processing and analyzing potential features. Charts, georeferenced images, CARIS HIPS and SIPS generated data products, and the like assist in feature analysis while the features themselves are housed in non-standard *.000 files called HOB files. Each feature within a HOB file follows the S-57 encoding specifications and has extended attributes to provide further flexibility in processing and to support data interoperability between the various workflows that may be used in the field.

HOB files are interoperable with Pydro and HYPACK by importing and exporting S-57 *.000 files. HOB files have editable attributes and *.000 do not.

HYPACK is used when acquiring and processing feature heights gathered by laser.

4.4.2 Significant Features

4.4.2.1 Dangers to Navigation (DtoNs)

The primary characteristic of a DtoN is navigational significance. When reviewing survey data for potential DtoNs, the hydrographer must consider the types of vessels operating in the area as well as vessel routes, both typical and seasonal. Much of the final selection of DtoNs is subjective and requires a bit of cartographic interpretation as well as a navigational perspective of the chart. Examination of newly acquired survey data for potential DtoNs should be performed on a daily basis.

The following guidelines can be used to identify potential DtoNs; however, each item should be further evaluated for significance within that specific geographical area.

4.4.2.1.1 WATER DEPTH

Historically, the selection of DToNs has been concentrated in areas with water depths of 20 meters or less. This remains a good rule of thumb, but this depth range should be evaluated in the context of navigational significance, vessel traffic and typical routes through the area. For example, features in water deeper than 20 meters may be DtoNs along routes for supertankers.

4.4.2.1.2 POTENTIAL DANGER TO NAVIGATION HEIGHT

Typically, survey features and soundings indicating a depth discrepancy of 1 meter or greater are first evaluated for DtoN potential. Again, this guideline should not be followed blindly. Vessel traffic must be considered. If vessels transit the area with minimal under-keel clearance, a discrepancy of only 1/3 meter could be critical, or, if a deep inland bay or harbor is accessible only by shallow restricted channels, a large feature within the deep-water area may not be a hazard since only small vessels could access the area. Several potential DtoNs can be located within a small bay. It is important to consider the vessel traffic in the area.

An example of this is in Keystone Harbor on Whidbey Island in Puget Sound, WA. This small harbor features many shoal soundings, but because of vessel traffic, in this case a state ferry, each sounding within the dredged area is considered a DtoN (Figure 4-24).

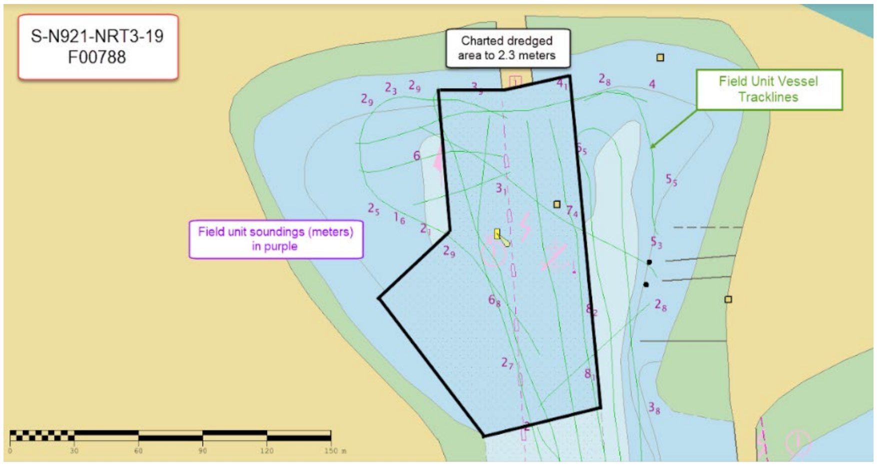


FIGURE 4-24 SHOWS A SOUNDINGS WITHIN THE 2.3 METER DREDGED AREA WOULD BE CONSIDERED DTONS.

4.4.2.1.3 PROXIMITY TO EXISTING FEATURES

Many new or uncharted features are potential DtoNs. The hydrographer must consider each new item's proximity to existing features (e.g., rocks, reefs, fish havens, shoreline, foul areas) and the item's significance concerning these adjacent features.

An existing feature (fish haven with an authorized minimum of 15 feet) affects the significance of a potential DtoN (Figure 4-25). In this example, an item intended for the fish haven may have been erroneously deposited outside the haven's geographical bounds, a very realistic scenario. Despite the discrepancy with regard to the charted 43-foot depth, the adjacent Fish Haven to the south/southwest and shoal to the east would deter prudent mariners from approaching the area. Likewise, a large depth discrepancy adjacent to a reef or foul area would quite possibly not be a DtoN.

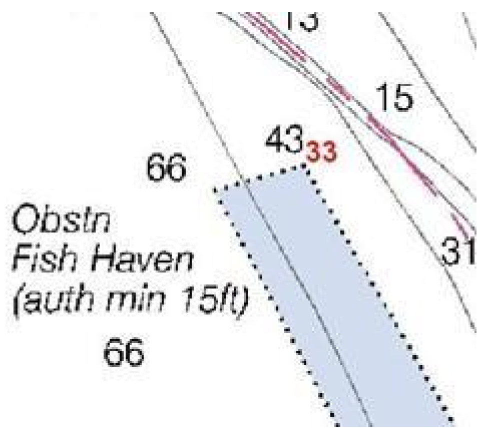


FIGURE 4-25 POTENTIAL DTON ADJACENT TO FISH HAVEN.

4.4.2.1.4 DENSE GROUPS OF DTONS

The density of DtoNs reported should not exceed what can be legibly portrayed on the largest scale chart of the area. If numerous DtoN candidates are identified in close proximity, the hydrographer could report either the most significant item or the group of DtoNs as an area feature (e.g., designate the entire area "foul"). When determining the most significant DtoN in a group, the item having the most shallow depth will typically be chosen. However, this may not be the case if, for example, the item is located on a slope. Typically, if two potential DtoN are adjacent on a slope, the most seaward sounding will be selected for submission (Figure 4-26). The 2-fathom sounding is more shallow but the 4-fathom sounding extends further offshore. In this case, the 4-fathom sounding would be submitted. Although both soundings would supersede the 5.7¾ -fathom charted depth, it can be reasonably inferred that there is a continuous slope toward shore, therefore depths shallower than 4 fathoms would be expected.

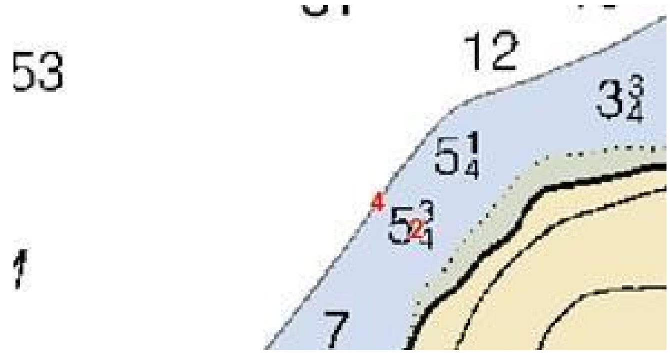


FIGURE 4-26 TWO POTENTIAL DTON'S LOCATED ON CLOSE PROXIMITY.

4.4.2.1.5 CHARTED FEATURE REMOVAL REQUEST

A Charted Feature Removal Request, often referred to as an "anti-DtoN," is used to expeditiously remove charted features that are hindering operations in major shipping corridors and have been adequately disproved. Only navigationally critical items should be submitted as Charted Feature Removal Requests. These requests should be submitted using the same procedure indicated for DtoNs in this manual.

4.4.2.1.6 DANGER TO NAVIGATION SUBMISSION

All DtoN selections should be reviewed by the Chief-of-Party before submission. If approved, DtoNs must be flagged properly in Pydro, which can then generate a DtoN report. All Pydro PSS Metadata should be completed generating a DtoN report so that this information will be included in the report. Additionally, the DtoN must be stamped with the actual ping time and not the time they were discovered in boat or office processing. The Pydro DtoN report is generated in a Zip archive that contains an Adobe *.pdf text report, an*.xml file containing the survey data for that feature, and a DtoN Images folder containing all the relevant report images and charts (if applicable).

Additional actions, as noted below, are required when reporting DtoNs in the following two cases.

1. If the potential DtoN will directly impact commercial shipping routes and/or is located within an area of Army Corps of Engineers' authority, the appropriate NOAA Navigation Manager should be consulted before submitting the DtoN. If the Nautical Data Branch of MCD discovers a DtoN located in a Corps of Engineers' authority that has not been submitted to the Navigation Manager, then Nautical Data Branch (NDB) personnel will cease processing the DtoN and recommend that the submitting party inform the Navigation Manager.
2. If a DtoN report includes a potentially historically-significant wreck, the field unit should provide a courtesy copy of the report sections about that specific feature to the corresponding NOAA Navigation Manager and State Historic Preservation Officer. If a potentially historically-significant wreck is identified outside of state waters, notify the current Sanctuaries Historical/Archaeological contact.

Once submitted, all DtoNs will be expedited through MCD to the Coast Guard for publication in the Local Notice to Mariners. Within 3 days of DtoN report submission, MCD's Nautical Data Branch (NDB) will send an email to the field unit confirming that the DtoN data have been received and processed. MCD will also notify the submitting party of any changes made to the Dangers to Navigation Report by return email.

4.4.2.2 Maritime Boundary Points

The HSD OPS Project Manager or the NRB Technical Assistant will assign Maritime Boundary rocks to the field unit for investigation. The hydrographer should investigate the items and document the results according to the Maritime Boundary requirements in the Descriptive Report.

4.4.2.2.1 CULTURAL OR HISTORICAL SUBMERGED FEATURES

In the course of acquiring or processing hydrographic data, features on the seafloor may be discovered that are of potential cultural or historical significance. These include wrecks of ships or aircraft, the recognizable debris from wrecks, or other items that may appear anthropogenic in origin and have some associated cultural or historical significance.

The Chiefs-of-Party must always promptly assess the discovery of any features for significance to local surface navigation and report these accordingly. Any feature determined to be a danger to navigation should be immediately reported through the standard DtoN reporting process.

It is Marine Chart Division (MCD) policy that all features recommended for charting by the Chief-of-Party be applied to the appropriate nautical charts. The Chiefs-of-Party must continue to recommend for charting all features determined to be significant to surface navigation as well as features determined to be significant or hazardous to other marine chart users engaged in activities such as fishing or trawling. This includes features that may have potential cultural or historical significance. This policy follows the MCD Nautical Charting Manual.

All features, which appear to be of cultural or historical significance and appear anthropogenic in origin, do require special consideration during the hydrographic surveying process. Data and information from these features must always be protected and may only be released per the HSSD, the field units command, and the hydrographic branches unless specified by the Project Instructions (or other written instructions from OCS):

1. Do not attempt to determine the cultural or historic significance of any features. And do not expend any operational effort toward identification beyond what is necessary for assessment as a Danger to Navigation.

2. Do not speculate about a known or newly discovered feature’s potential cultural or historical significance either publicly or in writing. Do not identify by name or otherwise associate with a name, any cultural or historical feature in the Descriptive Report (DR), or any part of the survey’s data.
3. Do include an image, SSS or bathymetry, of the feature in the Pydro feature report for recognition by a historian or preservation official.

OCS, as a unit of a federal agency, has responsibilities under section 106 of the National Historic Preservation Act (NHPA, 16 U.S.C. 470 et seq.) to take into account the effects of its undertakings on historic properties. The process for federal agencies in complying with the NHPA is laid out in 36 C.F.R. Part 800, which prescribes consultation with the State Historic Preservation Officer (SHPO). Also OCS may consult with other NOAA offices or governmental agencies.

4.4.3 Survey Feature Management and Analysis

4.4.3.1 Target File Processing

Several types of survey data such as shoreline features, manually measured depths, and bottom samples are positioned using target files. These files cannot be read directly into CARIS; thus, Pydro has been developed to handle the bulk of target file processing. Target file processing is typically used during feature acquisition with a laser finder.

4.4.3.1.1 S-57 STANDARD

S-57 is shorthand for the International Hydrographic Organization (IHO) Special Publication No. 57, "IHO Transfer Standard for Digital Hydrographic Data." The S-57 standard details what S-57 objects and related attributes and geometry are permissible for official navigational charts produced by hydrographic offices around the world allowing hydrographic data to be transferred seamlessly from one user to another.

An S-57 file is a database of feature object classes and associated attributes that used a 6-letter acronym naming convention. Multiple object classes are often required to describe a single real-world feature. For example, a lighted lateral buoy with a horn is described with three object classes in S-57: BOYLAT (buoy, lateral), LIGHTS (lights), and FOGSIG (fog signal).

Attribute types under each object class are used to indicate the specific makeup of the feature (e.g., COLOR (colors), COLPAT (color pattern; applicable if dealing with more than one color), CATFOG (category of fog signal).

4.4.3.1.2 S-57 OBJECTS

S-57 feature designation and attribution are assigned in CARIS HIPS and SIPS or BDB through the feature editing function. In CARIS select the feature type (i.e., point, line, or area) on the Feature Creation menu. Select the appropriate feature object class on the Object Acronym list. The details of the object class are displayed below in the Dictionary Information. The S-57 attributes are in upper case; the extended attributes are in lower case, and the mandatory attributes are distinguished with red color, assuming the hydrographer is using the NOAA customized extended attribute files.

Certain attributes do not require manual editing; instead, the attribute is linked to the digital data present in the CARIS feature data (e.g.. VALSOU, value of sounding, is associated with the depth).

4.4.3.1.3 S-57 ATTRIBUTION

An S-57 feature attribution is required for features to be compiled with the submission of the survey; S- 57 feature attribution is required for all new, updated, and items to be deleted that represent a real-world feature recommendation for inclusion on the official navigational chart. The hydrographer should edit the S-57 object/attribute instances to describe each real-world feature as completely as possible.

The S-57 files are attributed and commented on by the field unit in CARIS HIPS and SIPS in a .HOB file and then exported to a *.000 file for submission.

4.4.3.1.4 ATTRIBUTING AND FLAGGING

Features must be attributed/flagged correctly in the processing software for the cartographers to compile the survey to a chart for processing and QC. The hydrographer may use the Query functions in CARIS BDB or HIPS and SIPs. Refer to the HSSD for attribution requirements.

Features that were addressed and not edited in any way maintain the original SORDAT and SORIND. Descriptive attribution of Retain along with an explanatory Remark should be added. This will alert the processing branch to either retain the charted feature or that the feature is depicted accurately if from another source.

For features that were repositioned or the geographic position or shape is altered, the original feature that has a position error is given the descriptive term Delete, maintaining the original SORDAT and SORIND, given an appropriate Remark and Recommendation. The repositioned feature in the Final Feature File is assigned the new SORDAT and SORIND, will contain a Remark stating that it was repositioned, and be given the descriptive term, New.

There are two programs available in Pydro's QC Tools, Scan Features and VALSOU Check, to assist in correct feature attribution.

4.4.3.1.5 EXAMPLES OF FEATURE ATTRIBUTION USING THE NOAA CUSTOMIZED ATTRIBUTES ASSIGNED FEATURES

The following is an example of features that were "Assigned" in the CSF but not addressed. The reasoning should be detailed in the item's Remarks attribute. These features maintain the original SORDAT and SORIND.

Example 1: An obstruction area was Assigned but not addressed due to a high sea state making the area unsafe for operations. The feature is attributed as Not Addressed, and an explanatory statement is included in the Remark field.

Example 2: A charted rock was Assigned but not addressed due to the feature being inshore of the navigable area limit line of the survey. The feature is attributed as Not Addressed, and an explanatory statement is included in the Remark field, such as "inshore NALL."

Features addressed and not edited in any way maintain the original SORDAT and SORIND. Descriptive attribution of Retain along with an explanatory Remark should be added. This will alert the processing branch to either retain the charted feature or that the feature is depicted accurately if from another source.

Example: A GC rock is Assigned and investigated during shoreline verification and found to correctly portray the feature. No existing attribution such as height is changed. The feature is given descriptive attribution of Retain and a Remark.

4.4.3.1.6 FEATURE CORRELATION

In an NOAA hydrographic survey new features should be correlated between MBES and S-57 data. The existing data are typically classified in one of the following five categories:

- Items from Bathymetry: Sounding data (MBES or SBES) which have been identified as a measurement of the least depth on a feature in CARIS HIPS and SIPS. "Designated" soundings can be selected to force the gridded surface to honor the true depth of the seafloor.

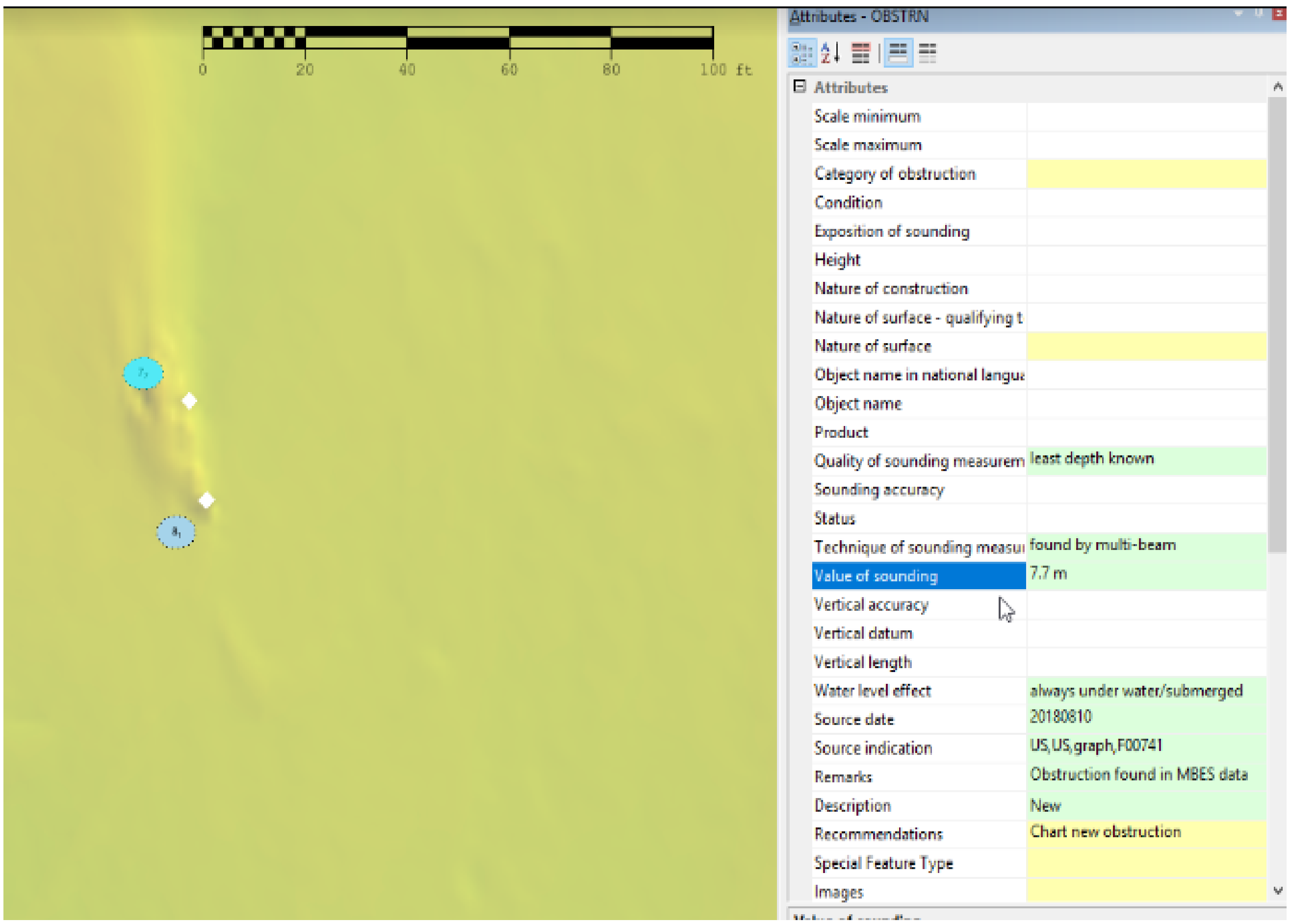
- Items from Imagery: A potentially significant feature that has been identified in SSS data, chosen as a contact in CARIS HIPS and SIPS during post-processing, and to be evaluated for further investigation and/or development.

- Detached Positions (DP): Detached positions are used to position point features such as shoreline items, bottom sample locations, DLDG depth determinations, and lead line or pole soundings. DPs are subdivided into echo sounder and non-echo sounder types. Echo sounder DPs are used for data with a corresponding depth determined by SBES, MBES, or another system that is referenced to a point other than the water's surface and requires the application of vessel offsets. Non-echo sounder DPs are used to provide positions for data either with no associated depth information or reference to the water's surface such as DLDG determined depths and heights of shoreline features.

- Geographic Positions (GP): Geographic positions refer to point data used for various purposes and not otherwise classified. These points are typically uploaded from a portable GNSS system, manually digitized in CARIS, HYPACK, or Pydro, or created by inserting "generic" data into Pydro.

For all the correlating items that represent the same feature as the Primary item, set the status flag to Secondary. If an item has been automatically correlated to a Primary item but does not appear to be the same feature, assign it as Primary. That is, use the Primary item status to segregate features. If your survey makes use of side scan sonar, this means you will often encounter disparate features through items from imagery before having the supporting item(s) from bathymetry. Set the status flag to Primary for such items, knowing that if they prove to be navigationally significant, a bathy item will take precedence as the Primary item when available.

Designated soundings must be imported to S-57 features, and the VALSOU updated with the value of the designated sounding (Figure 4-27).



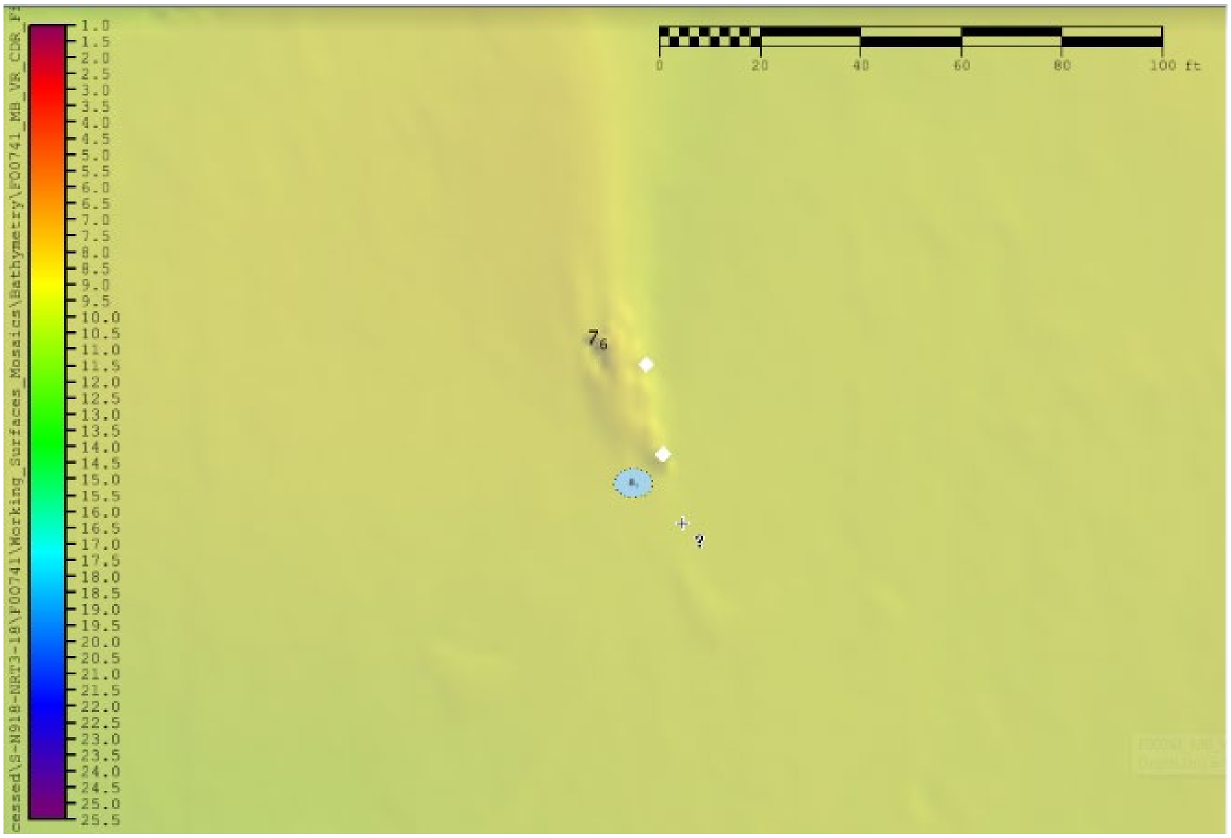


FIGURE 4-27 A S-57 FEATURE MUST BE IMPORTED FROM A DESIGNATED SOUNDING. THE VALSOU MUST BE UPDATED WITH THE DESIGNED SOUNDED VALUE

4.4.3.2 S-100

The S-100 standard is a framework document intended for the development of digital products and services for hydrographic, maritime, and GIS communities. It is comprised of multiple instances that are based on the geospatial standards developed by the International Organization for Standardization. The S-100 data framework is to serve the next generation of electronic charts.

S-100 will allow users to easily update their systems and will facilitate data interleaving (inputting tidal and weather information) and data replacement.

NOAA's Precision Navigation Program has built a prototype data gateway for users to discover, visualize, and disseminate NOAA marine navigation products and services. The initial prototype will include data that have been built on the IHO's S-100 framework of standards for surface currents and high-resolution bathymetry. This data gateway will provide the capability for machine-to-machine dissemination allowing users' existing navigation software to automatically discover if NOAA has made new data available and ingest it directly into the system. The integrated datasets will reduce the number of websites a mariner visits when planning, transiting, and approaching a port allowing them to make decisions efficiently.

Additionally, NOAA's marine navigation services will help ship operators optimize their routes and better plan the timing of the ship's transit to save fuel, reduce lightering, and reduce port wait times based on environmental conditions. The Precision Navigation team is on track to roll out a beta version of the website to a selected user community in summer 2020.

4.4.4 Deliverables

The following should be delivered within the feature files with a survey. The hydrographer should adhere to the HSSD: Data Directory Structure for the proper submission directory structure. The information in this section primarily explains what type of files get submitted.

1. Feature Data:

(a) Final Feature File in *.000 format - (HXXXXX_Final_Features _File*.000); The *.000 final features layer contains the original source data with survey updates.

2. Multimedia Photographs and images are quite helpful to the cartographers during compilation. Multimedia is delivered with the final feature file in the Multimedia folder. The photographs and images are correlated or linked (depending on software) to the features.

(a) Photographs of the feature observed during an investigation such as new extents of piers, piles, and rocks.

(b) Images of screenshots of acquired data.

i. MBES: ex: least depth on rock or wreck from CARIS 3-D viewer

ii. Side Scan Sonar Contact Images

Note: A copy of the side scan sonar contact images should be delivered in the CARIS HDCS line file.

3. Side Scan Sonar (SSS) Contacts in *.000 format: All SSS contacts, both significant and insignificant, should be delivered in *.000 format and submitted in the S-57 Features Folder. The side scan sonar contact points should be delivered as the S-57 feature object cartographic symbol ($CSYMB) with the attribution described above in the HSSD.

4.5 Obtaining and Identifying Current Charts

The hydrographer should bear in mind that the most current official charts may not be the ones listed in the PIs. Often, versions of ENCs used for vessel navigation will be more current. Any chart corrections from the National Geospatial Intelligence Agency's (NGA) Notice to Mariners (NTM), the US Coast Guard's Local Notice to Mariners (LNM), and Canadian Hydrographic Service (CHS) that have not yet been applied should also be considered.

The most up-to-date RNC and ENC charts can be downloaded using several tools from OCS's Chart Locator. NOAA offers a joint display of both Notice to Mariners and Local Notice to Mariners in a single table for a single chart that is easy to use and read. For additional chart correction information, the database of Notice to Mariners corrections can be queried online and Local Notice to Mariners corrections can be reviewed online.

4.5.1 Electronic Navigational Charts (ENC)

The ENC Update Application Date is the date that the full ENC Cell was first posted or reposted. This date is similar to the Edition Date of a raster chart. ENC Cells are re-posted when the updates grow too large or a large section of the cell is rebuilt. The Issue Date identifies when the last correction was applied. All notices have been applied through that date, similar to a "cleared" date for raster charts. If using an ECDIS system or viewer software to read the ENC, these dates can be found in the ENC Cell properties.

Some viewer manufacturers have erroneously reversed the Update Application Date and Issue Date. Because an edition must exist before it can be corrected, the later of these two dates will always be the issue date.

The most current ENC can be downloaded from MCD at OCS's Chart Locator and can be downloaded in bulk by state.

4.5.2 NOAA Custom Chart

NOAA Custom Chart (NCC) is currently in development. NCC allows the user to create charts of custom scaling, depth contours, and geographical locations. Hydrographers are encouraged to test the Custom Chart Prototype and submit constructive feedback. The information for the produced charts is pulled from the latest ENC data.

Moving forward, the hydrographer will be able to set appropriate default depth contour labels and depth shades for the vessel that is collecting data. The chart produced should have a maintained color palette from RNCs. Buoys, beacons, and lights will soon be standardized to the RNC symbols.

4.6 Junction Survey Comparisons

If the designated limits for a survey junction with modern data from another survey, the area of overlap should be compared and discussed in the Descriptive Report. Consider a standard junction comparison acceptable if the sounding variance is 1 meter or less between the present and junctioning surveys. Agreement is considered poor if the sounding variance is greater than 1 meter. In such cases, the hydrographer should attempt to determine the cause(s) of significant discrepancies and explain these variances in the Descriptive Report.

There are various ways to process a junction between two surveys. A difference surface can be created and analyzed in CARIS HIPS and SIPS or Pydro's Compare Grids tool can be used.

5 Chapter 5: Data Management and Survey Deliverables

The purpose of this chapter is to suggest data management and deliverable practices for field units conducting hydrographic surveys. These requirements have been established to safeguard hydrographic data during field operations, support efficient office processing, and expedite the application of survey data to NOAA's navigational products.

5.1 Data Management

Hydrographic surveys produce an extensive amount of data, so proper data management is critical. Two primary components of data management are addressed in this chapter: data security, data release, and storage and data filing and organization. It is the field unit's responsibility to manage all survey data such that their security and integrity are not compromised during operations, and to efficiently transmit these data to AHB, PHB, or other designated recipient(s).

5.1.1 Data Security, Release and Storage

Hydrographers should take special care to ensure that hydrographic data security is carried out and released according to Line Office policy. All hydrographic personnel should always consider possible liability issues that may be associated with the dissemination of preliminary data. Further guidance is given below in this section, and contact information for these authorities will be identified in the Project Instructions.

Additionally, data and reports generated while conducting hydrographic surveys are official records that must be cataloged and archived. Because the majority of these data and reports are in digital format, a field unit's digital data storage systems must be configured, operated, and maintained with care. Precautions should be taken against data loss due to careless handling, accidental corruption, or system failure.

5.1.1.1 Data Security

It is the field unit's responsibility to maintain all survey records in a manner that ensures data are accessible only to the appropriate survey personnel and system administrators. Tracking procedures should be used to identify which personnel have performed specific tasks for all data acquisition, processing, and manipulation. Data security can be maintained within a field unit via a combination of procedural checklists and logs as well as establishing computer user accounts with password protection.

Field units may receive requests for survey data from constituents and private parties. Field units should obtain approval from the Chief of Party, Project Manager, and HSD/NRB Chief before releasing any preliminary data or products to parties outside of OCS.

Any preliminary data product released must be clearly annotated.

A copy of all products released to the public should be included in the Public Relations Constituent Products folder of the survey submission package. The field unit should document all survey records or constituent products officially transmitted using a digitally signed NOAA standard form Letter Transmitting Data (NOAA Form 61- 29), which can be created in Pydro using the "Transmission Letter" tool. A digital record of all transmittal letters created and received should be maintained by the field unit.

5.1.1.1.1 SPECIAL DATA HANDLING REQUIREMENTS

Special handling requirements will be described in the Project Instructions from HSD/NRB Examples of situations requiring special data handling are below.

All newly discovered uncharted shipwrecks are treated as significant and vulnerable historic resources. This treatment entails following the data handling guidance in this manual. Raw or processed data from sources external to NOAA are not to be made available to the public at any time.

Certain homeland security survey data have special handling requirements prescribed by the US Naval Oceanographic Office and OCS as described in the NAVMETOCCOMINST 3142A documents.

5.1.1.2 Data Release

Field units or HSD/NSD office personnel should be aware that the policy information mentioned here is set forth such that the release of raw/working data does not provide a company an unfair competitive advantage within its industry or incur liability issues that may be associated with the dissemination of this data. These policies are also set to adhere to the National Historic Preservation Act of 1996 and the Archaeological Resources Protection Act of 1979. Information about all newly uncharted navigationally significant and potentially historical man made features, particularly position coordinates, is considered sensitive material. The field should not release this information to the general public without permission from HSD.

HSD's processes to plan hydrographic surveys, acquire, process, quality control, and compile hydrographic data to create products (Figure 5-1).

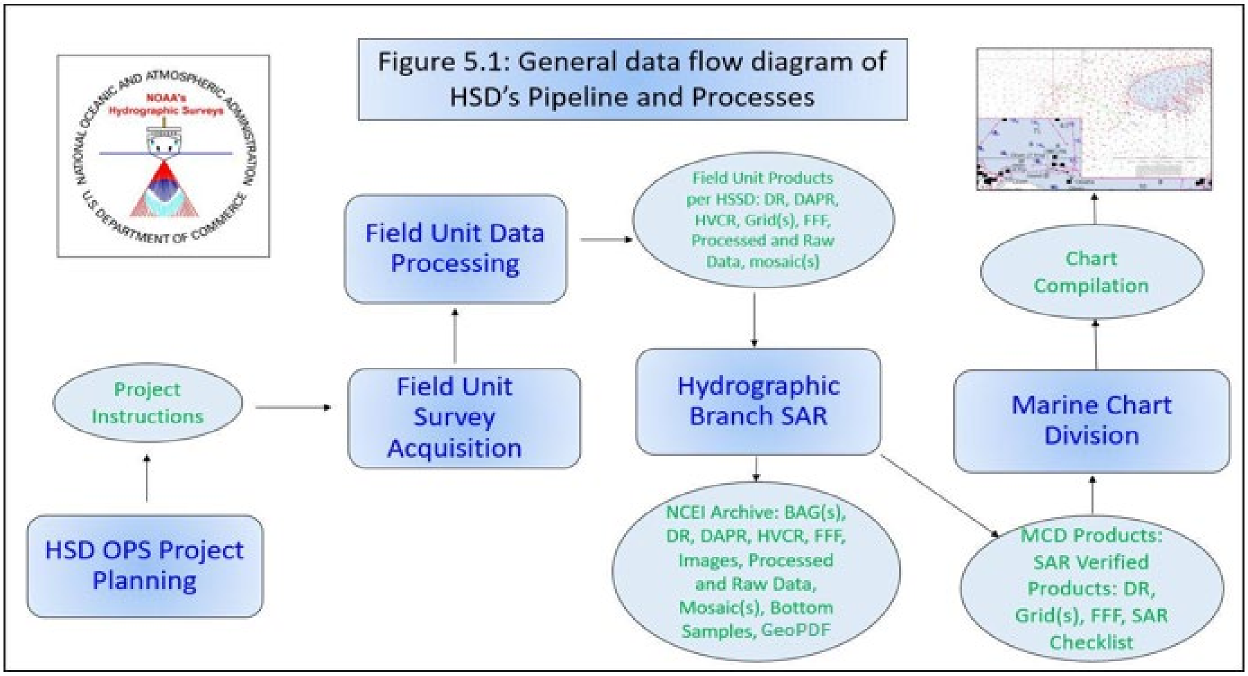


FIGURE 5-1 GENERAL FLOW DIAGRAM OF HSD'S PROCESSES.

There are three defined stages for Mission Data (see the OCS policy for more information about each of these stages):

- Raw Data: Data as they are originally collected manually, from sensors, or received from other sources such as other federal agencies.
- Working Data: Data on which processing has been performed that change the information contained in the data but which is not yet processed to a level deemed as complete and suitable for public release (e.g., data that have undergone a Survey Acceptance Review (SAR)).
- Data Product: Data that have been processed or accepted without further processing and are considered to be suitable for release to the public and which OCS acknowledges as official (e.g., BAG after approval).

Because of the increase in requests for digital data at all stages, HSD is working with the National Centers for Environmental Information (NCEI), which stores these data, to release the data to the public at the following stages in the HSD pipeline:

1. After the submitted data have undergone a SAR, has been deemed non-sensitive, and AHB/PHB has sent it to NCEI (Post-SAR); and
2. After HSD acknowledges the data as official.

All personnel should note that new releasable data available for public access through NCEI will be in the BAG format. The BAG format was developed to create an open-source exchange format for gridded data; therefore, any public requester should be able to use data in this format.

Only approved data at NCEI can be released to a requester.

HSD/NSD office personnel, responding to a request, should direct the requester to a point of contact at NCEI (which can be identified by HSD). Official data are available via NCEI. It should be noted that field units should NOT release raw or processed data to a requester outside of OCS without HSD approval. Field units should NOT create specialized products in response to a data request unless authorized by the HSD OPS Project Manager, or HSD OPS Branch Chief, or HSD Chief, NSD/NRB Chief. Data requests for processed data that remain with the field unit must comply with the guidance in this manual and ensure that an effort is made to meet the needs of the requester without being unnecessarily time consuming.

If the field unit's Chief Hydrographer determines the requester has reasonable cause to warrant the release of raw data which remains with the field unit and have not been sent to AHB/PHB, then they must obtain written approval by the appropriate Division Chief (i.e., the Chief, Hydrographic Surveys Division or Chief, Navigation Services Division) to release these data. Raw data, if release is approved, should be distributed with a disclaimer describing in general:

- Things that have not been completed (e.g., list correctors that haven't been applied);
- Use of the raw data that is not appropriate; and
- Anything else the Chief Hydrographer or Chief of HSD/NSD feels necessary to include.

Additionally, metadata should be provided in conformance with applicable standards and such metadata should be entered into the appropriate national metadata database. Finally, an official record of raw data distributions should be made and preserved (contact the Chief of HSD/NSD for more information).

Likewise, if the Chief of AHB/PHB is requested to distribute Pre-SAR (unapproved data) or feels the requester has reasonable cause to warrant the release of processed data which are in line to undergo a SAR, field units or HSD/ NSD office personnel responding to a request must obtain written approval by the appropriate Division Chief to release this data. Pre-SAR data, if release is approved, should have a disclaimer letter that accompanies the data and indicates major flaws to discourage its use and further requests. Before releasing this data, three steps should be taken:

1. The data or a transmittal document should be marked appropriately taking into consideration the recipients intended use. Suitable markings might be: "Preliminary Data—Contents may change," or, "Draft—Not to be used for navigation," or, "Working File—Processing has not been completed and significant corrections may yet be applied or correction processes yet to be completed."
2. The recipient should be counseled as to the known condition of the data, the nature of possible changes, and other known considerations that would help the recipient use the data in a prudent manner.
3. The data provider should mark the data set or accompanying transmittal document indicating to whom the file was provided and that the recipient was counseled as to the status of the data. The provider should then prepare and preserve an official record (Contact the Chief of HSD/NSD for more guidance; this should be in line with how NCEI records requests.) that the data were provided, to whom, for what use, on what date, that counseling was provided, and who made the determination and released the data.

5.1.1.3 Data Storage

All storage devices and media used for OCS hydrographic survey data should be approved by HSD and/or HSTB. Field units should not implement new data storage technology or media without first consulting HSD and/or HSTB to verify that the system is both based on proven technology and is compatible with equipment at other NOAA sites that may need to access the survey data.

NOAA's hydrographic survey ships are typically equipped with Network Appliance (NetApp) data storage systems. The NetApp system consists of a dual redundant array of independent disks (RAID) arrays with independent control heads. Each NetApp system should be set up in a mirrored crossover configuration with daily and weekly snapshots to provide data redundancy and recoverability in case of partial system failure. With this type of system redundancy, if one controller fails, the data will remain secure, but user access will be temporarily lost. The second controller can be used but must be manually activated, generally requiring on-call assistance by NetApp. Also changes between the two systems are written every 15 minutes, so up to 15 minutes of changes may be lost. Data recoverability is provided by "point-in-time" snapshots of the data that can be used to restore directories that have been inadvertently deleted or have become corrupt. OCS strongly recommends physically separating the two NetApp control heads to prevent catastrophic data loss from a point event such as an isolated fire.

NOAA's Navigation Response Teams (NRT) use different types of data storage systems to meet their specific mission needs. Typical NRT data storage systems consist of Dell servers and can include the PowerEdge server or a blade-style Dell server. The storage devices are set up in a RAID configuration for disk failure protections but do not perform snapshots. Backups should be performed regularly to an external hard drive. This type of system combination should be configured to automatically compare the two drives for differences periodically throughout the day. If any new data are found on the network-attached storage (NAS), those files should be automatically mirrored onto the external hard drive.

5.1.1.3.1 DATA BACKUP REQUIREMENTS

Regardless of the data storage system used, each NOAA hydrographic field unit must ensure that all survey data that have not been previously submitted to and accepted by either AHB or PHB are routinely backed up. Backups should be performed such that a complete system failure would result in no more than 1 day of data lost. For example, weekly full backups and daily incremental backups would ensure that the maximum loss of data would only be those files modified or created in the time between the previous incremental backup and the failure. The method used to backup data may vary and could include CDs, DVDs, or a redundant drive system. Many backup systems, such as the NetApp, can be configured to perform scheduled backups automatically. It is the responsibility of the field unit to verify that their backup solution is operational throughout the field season. Below are examples of effective and proven backups used in the field.

If using a NetApp system, OCS recommends it be configured to retain six daily snapshots and two weekly snapshots, providing access to files up to 20 days old (best case).

5.1.1.3.2 DATA TRANSFER

Data can be transferred from field units using portable hard drives. However, field units should ensure that data transfer media are compatible with the data recipient's equipment. Regardless of the method used for data transfer, there will always be a risk of damage, loss, or corruption of data during the transfer process. It is recommended that field units retain a backup of any data transmitted until a successful transfer has been confirmed by the recipient.

When survey data have been submitted to NCEI, AHB, or PHB, field units are required to retain a backup of this data until NCEI or the hydrographic branch has acknowledged that the data have been successfully archived and the Survey Acceptance Review has been completed (Survey Acceptance Review only pertains to processed data). Even after data have been successfully transferred, it is recommended the field unit retain copies of the final survey products created (e.g., DR, DAPR, FFF, bottom samples, surfaces and mosaics, public outreach materials) on removable storage media if additional operations will be conducted in that general project area.

5.1.1.4 Naming Conventions

All required naming conventions are listed in the HSSD. It is critical that file naming conventions be standardized to quickly communicate what information a file contains.

Any files submitted that will be unfamiliar to the receiving hydrographic branch and/or do not follow standard naming conventions should be accompanied by a separate digital text document fully describing the file(s). This text file should be named "read me."

5.2 Survey Deliverables

Survey deliverables refer to all data, reports, and products associated with an OCS hydrographic survey that will be approved and submitted by an NOAA field unit. When submitting a survey to HSD's Hydrographic Branch, (AHB or PHB), the data deliverables should include all data and information necessary for office verification, including the ability to manipulate data, if necessary, thorough documentation of the field unit's survey procedures and results and recommendations for the survey. Some survey deliverables, such as DtoN Reports, the Request for Tides, Coast Pilot Review, and NODC files, have additional and/or unique submission requirements. All required HSD hydrographic survey deliverables and any specific submission requirements are briefly described in the following sections.

5.2.1 Survey Data Submission Directory Structure

Because surveys are submitted to the hydrographic branches from several NOAA field units and each survey includes data from numerous sources, standardized data submission practices should be used to support efficient office processing and verification. Field units using Charlene should have this generated automatically at project creation.

There is a standard file submission structure outlined in the HSSD; this section will explain the specific information to be contained in each folder.

5.2.1.1 OPR-X###-XX-##

This folder should be named to identify the project name. OPR-X###-XX-## is the standard project name, but there are other project naming conventions such as S-N###-NRT#-YY.

5.2.1.2 Sheet Name (E.g. HXXXXX, FXXXXX)

This folder should be named to identify the registry number of the survey being submitted. It should contain only survey-specific data and reports that have been approved for submission by the Chief-of-Party. At a minimum, the following sections explain the subsections that are to be included.

5.2.1.2.1 RAW DATA

The raw file structure can be created using Pydro explorer's Charlene. Within Charlene there is a "Create Launch Transfer Drive" tool specifically designed to create the following folder structure on a portable hard drive.

Having strong file management is critical when conducting a hydrographic survey and it is important to start with proper file paths for raw data (Figure 5-2).

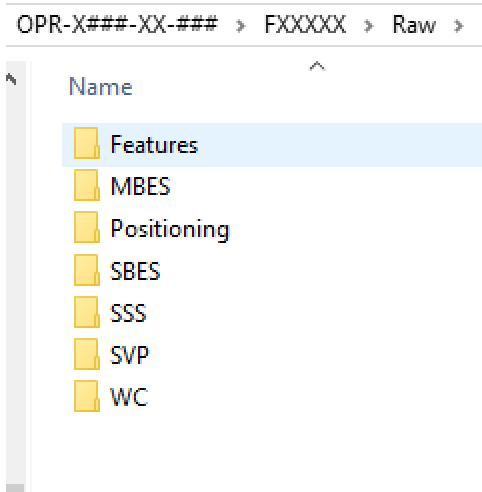


FIGURE 5-2 EXAMPLE OF THE RAW FILE STRUCTURE

To complete boat day processing with Charlene, this file structure is required to transfer and process data.

When submitting data, any folder that does not have data in it should have a text document titled "Readme" stating "This folder is intentionally left empty".

1. **Features:** Includes any digital boat sheets, notes, or images found from the field.
2. **MBES:** This folder should include raw multibeam data.
    a. **Vessel:** Such as 280X_EM2040 or NRTX_S300X_EM2040C (name pulled from HVF)
        i. **20YY-DN#**
3. **Positioning:** This folder should include position data files with the naming convention YYYY_DDD_VSSL*.000 (ex. 2010_123_S220*.000). Files should be unlimited in size but not more than 24 hours long. Base Station Files in native format if the native format is other than RINEX
    a. **Vessel:** Such as 280X_EM2040 or NRTX_S300X_EM2040C (name pulled from HVF)
        i. **20YY-DN#**
4. **SBES** - This folder should include raw single-beam data
    a. **Vessel:** such as 280X_EM2040 or NRTX_S300X_EM2040C (name pulled from HVF)
        i. **20YY-DN#**
5. **SSS**: This folder should include raw side scan data.
    a. **Vessel:** Such as 280X_EM2040 or NRTX_S300X_EM2040C (name pulled from HVF)
        i. **20YY-DN#**
6. **SVP**: This folder should include raw sound speed data files
    a. **Vessel:** Such as 280X_EM2040 or NRTX_S300X_EM2040C (name pulled from HVF)
        i. **Raw:** Contains the raw file format of the cast such as .cnv or .csv
            1. **20YY-DN#**
        ii. **NODC:** Contains .nc file type of each cast taken
            1. **20YY-DN#**
7. **WC**: This folder should include only raw water column data collected by the field unit.
    a. **Vessel:** Such as 280X_EM2040 or NRTX_S300X_EM2040C (name pulled from HVF)
        i. **20YY-DN#**

5.2.1.2.2 PROCESSED

The following is the folder structure required for submission. This file structure will be created when processing using Charlene. Keeping your data organized and in submission format throughout the post-processing is critical to ensuring all the information gets submitted properly (Figure 5-3).

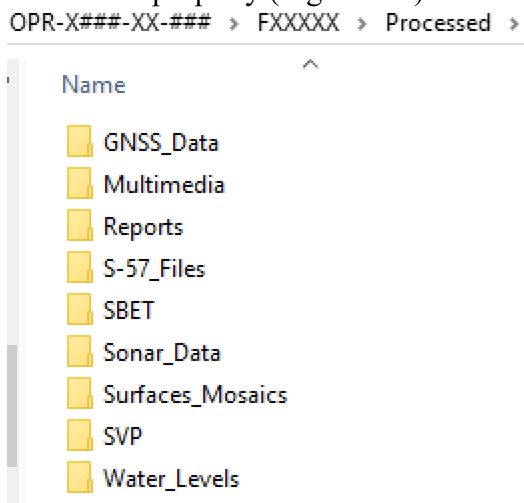


FIGURE 5-3 FOLDER STRUCTURE FOR SUBMISSION OF PROCESSED DATA

1. **GNSS_Data:** This folder should include the Post-Processed Kinematic (PPK) GNSS data. This directory should include the PosPac project data.
2. **SBET**: This folder should include the SBET QC Log, and SBET and SBET RMS export output and "smrmsg" files.
3. **Multimedia**: This folder should contain bathymetric data images (two-dimensional and three-dimensional) or digital photographs that are associated with a feature in the Final Feature File (FFF). Also this folder should contain a copy of the side scan sonar (SSS) contact images for both significant and insignificant contacts. A copy of the SSS contact images should remain in the CARIS HDCS line file.
    a. Naming conventions are outlined in the HSSD.
4. **Reports**: This folder includes two main subfolders, the Project folder and Survey folder, separating the documentation related specifically to the project and the specific survey.
    a. **Project**: This folder should be named to identify the project number under which the submitted survey is assigned. It should contain subfolders for documents and reports that apply to all surveys completed for a given project over the course of the year specified. At a minimum, the following subfolders should be included:
        1. **Data Acquisition and Processing Report (DAPR)**: Include the Data Acquisition and Processing Report for the project (in *.pdf format) and any supporting information as defined by the HSSD. The DAPR file should be named according to the project number (e.g., OPR-A###-AA-YY_DAPR.pdf.). The DAPR folder should include a separate sub-folders for both the DAPR Report and DAPR Appendices.
        2. **Horizontal and Vertical Control Report (HVCR)**: Include the Horizontal and Vertical Control report for the project (OPR-A###-AA-YY_HVCR.pdf) and any supporting information as defined by the HSSD and section 5.2.2.2.3 of this manual. No report is necessary if no HorCon and/or VerCon were conducted; however, a text document stating that no HorCon and/or VerCon operations

were conducted should be placed in this folder in lieu of an HVCR. The HVCR folder should include separate subfolders for both the Digital_A-Vertical_Control_Report and Digital_B-Horizontal_Control_Data. The Digital_B-Horizontal_Control_Data sub-folder should include subfolders for ATON data and Base Station data.

3. **Project Correspondence:** Include all project-level correspondence such as documented telephone conversations and email correspondence that pertain to the project's survey being submitted.

b. **Survey**: This folder should be named the survey's registry number as assigned. The folder should contain specific documentation specifically related to the survey.

   i. **Descriptive _Report**: This folder should contain the Descriptive Report for the survey in a .pdf format which includes the digitally signed DR and DR Appendices. The Descriptive Report folder should include two subfolders for the Report and Appendices.

      1. **Report**: The DR should include a Cover Sheet, Title Sheet, and the report body Sections A–D, followed with Approval Sheet Section E.
      2. **Appendices:** The appendices should include two subfolders:
         a. I: Water Levels: Include all documents and information from CO-OPs per HSSD
         b. II: Supplemental Survey Records and Correspondence: Include all documents and information per HSSD

   ii. **Public Relations and Constituent Products:** This folder should contain survey-related products generated by the field unit for dissemination to other NOAA offices or outside organizations. Include any plots, "one-pagers," (in *.pdf format) created for public relations, and any other preliminary products released to constituents, navigation managers, or the public in the native format provided.

   iii. **Separates:** This folder should contain a subfolder for each Separate Report identified below:

      1. **Acquisition_Processing_Logs**: This folder should contain all acquisition and processing files associated with the survey being submitted. (Note: Acquisition and Processing Log files may be combined into one file and delivered in one combined folder.)
         a. **Acquisition_Logs**: Logs compiled by the field unit during data collection and acquisition.

   iv. **Detached_Positions**: This folder should include all single point detached positions reports.

   v. **Processing_Logs**: If processing using Charlene, excel reports are automatically created for each day processed. Additionally Charlene will create and update a compiled processing sheet with up-to-date data. Some information included in this log is the quantity of data collected (# of MBES lines), data size, and total Lineal Nautical Miles (LNM).

c. **Digital_Data:** This folder should include Crossline Comparison and Sound Speed data.

   i. **Crossline_Comparison:** This folder should contain documentation to support a mainscheme-to-crossline comparison performed following the HSSD.

   ii. **Sound_Speed_Data_Summary:** Include all digital information records associated with sound speed collection during this survey. This is only required if the data are not processed and submitted using CARIS. The Sound Speed Data Summary includes location information and frequency of casts.

5. **S-57_Files**: Includes two subfolders for the Final Feature File and the Side Scan Sonar (SSS) Contacts. Both files should be submitted in the S-57 format (**.000).
   a. **Final_Feature_File (FFF):** The FFF should be submitted per HSSD. The folder is to include the required S-57 and extended attribution and linked images. The only file in here should be HXXXX_FFF*.000
   b. **Side_Scan_Sonar_Contacts:** Side Scan Contacts with the required attribution as referenced in HSSD
6. **SBET:** Contains individual SBET (SBET.out) and RMS (smrsg.out) for each day of processed data.
   a. **Vessel:** Such as 280X_EM2040 or NRTX_S300X_EM2040C (name pulled from HVF)
      i. **20YY-DN#**
7. **Sonar_Data**: This folder should contain all post-processed survey data. The submitted sonar data should be subdivided based upon data type, such as multibeam echo sounder, single beam echo sounder, side scan sonar, and water column data.
      i. **HXXXXX_GSF:** Location for Non-CARIS users to submit processed data in Generic Sonar Format (GSF) data.
      ii. **HDCS_Data:** Where processed survey data from CARIS is located
         1. **HXXXXX_MB:** Location for processed multibeam project data
         2. **HXXXXX_SB:** Location for processed single beam project data
         3. **HXXXXX_SSS:** Location for processed side scan sonar project data
         4. **HXXXXX_WC:** Location for processed water column data
         5. **VesselConfig**: This folder should include copies of each HIPS Vessel File (*.HVF) used to process data for the survey and any applicable DeviceModels.xml files. Any modifications made to these files during survey operations should be documented in the corresponding Descriptive Report and/or DAPR.
8. **Surfaces_Mosaics**: This folder should include the final bathymetric surfaces and acoustical imagery mosaics. All preliminary surfaces should be removed from this folder before data submission. Refer to HSSD for guidelines, naming conventions, and file formats.
9. **SVP**: This folder should include only the processed CARIS **.scp files applied to the survey data being submitted. Files should be separated into subfolders by vessel hull number and day.
   a. **Vessel:** Such as 280X_EM2040 or NRTX_S300X_EM2040C (name pulled from HVF). Included here is the master*.scp final.
      i. **20YY-DN#**
10. **Water_Levels**: This folder should include only the project tide files (tide zone file (*.zdf), TCARI (*.tc), GNSS tide files (SEP Models), and tide/water level (CARIS*.tid) files applied to the survey data at the time of submission. Files should be named so that the type of tide/water level data (i.e., predicted, preliminary, and/or verified) is identified and recognizable.

5.2.2 Digital Data

All data should be submitted to AHB or PHB in digital format. This requirement includes documents that can be easily scanned into *.pdf files, such as memos, system calibration reports, and DP reports. Only data that pertain to the survey being submitted should be included in the digital data deliverables. All preliminary, temporary, or working data files should be removed before submission.

Before submitting digital data, the field unit should verify that all files are present and none have become corrupted during transfer to a portable media.

To ensure that a complete data recovery is possible in case of lost mailings or media problems, the procedures below should be followed by each field unit when submitting final digital survey data to AHB or PHB:

- Verify that backups of all data being submitted have been made and are securely stored. Backups must be in a format that can be readily restored at the receiving hydrographic branch.
- Review the content of all backups and deliverable digital media to ensure they are complete, accurate, and structured according to OCS specifications.
- Retain the backup for a survey until notified by AHB or PHB that the data have been successfully archived and the Survey Acceptance Review has been completed. (Survey Acceptance Review is only required for processed data.)

5.2.2.1 Reports and Field Products

Various reports and field products will be generated in conjunction with an OCS hydrographic survey. Survey reports can be divided into three tiered categories. Field Unit Reports refer to those providing information that encompasses the entire field unit and its operations. Project Reports are those containing information that applies to all surveys completed (or to be completed) within a project for a specific year. Project Reports may reference information contained in Field Unit Reports, provided the referenced document is clearly identified and readily available for review. Survey Reports contain information specific to only one survey and may reference information contained in both Field Unit Reports and Project Reports, provided the referenced documents are clearly identified and readily available for review.

This section of the FPM provides an overview of reports and products to be submitted in conjunction with every hydrographic survey completed by a field unit. Each of these reports should be delivered to the hydrographic branch that supports that field unit unless a different recipient is explicitly identified either in this manual or the Project Instructions.

5.2.2.1.1 SURVEY PROGRESS AND VESSEL UTILIZATION REPORTS

The Weekly Progress Report (formerly Progress Sketch), should be submitted no later than Monday (close-of-business Eastern Time), each week of field acquisition, emailed to the assigned HSD/NSD Project Manager or COR with a CC to progress.sketches@noaa.gov. Reference HSSD for additional specifications for the weekly report and for the Monthly Progress Report.

1. Project Summary: this is a summary of the surveys (SNM, LNMs, Start/End, etc.)
2. Survey Progress Estimate: This will be used to track the estimated monthly survey LNM and SNM acquisition and processing progress by area within a given month. For each month that data are acquired on a survey sheet (as well as sheets that are still incomplete), the cumulative percentage completed through the end of that month should be entered in the spreadsheet. Any modifications to the initial survey sheet layout must be reported.
3. Vessel Utilization Report: The purpose of this form is to collect data that will highlight the areas that are having the greatest effect on productivity and may need additional resources. A brief description of the various columns is below:
    a. Days at Sea (DAS): Defined by the Office of Marine and Aviation Operations, any day in which a vessel is at sea for at least 1 hour during a 24-hour period in support of an assigned project.

DAS includes days of arrival and departure, times anchored (except during port calls) or hove-to drifting on the working grounds, and occasions when a survey ship (even though moored) deploys 25% or more of its total complement including officers and crew in field survey activities.

b. Transit (hours): Ship travel time from port to the project area or within the project area (i.e., from one anchorage to another but does not include launch transit time between ship and survey area). Transit hours are in support of surveys but should not be counted as planned/actual survey hours.
c. Ship/launch planned and actual survey hours; Number of hours planned at the beginning of each day for each platform ***if all equipment is operating properly and if the authorized number of skilled personnel are available***.
d. Comment: Short description of survey activities and lost productivity.
e. Vessel Utilization: Percentage automatically calculated
f. Weather/Safety Stand-down (hours): Hours of production lost due to weather or safety stand-down (divided between ship and launches)
g. Reason: reason why operations were not conducted.
    i. Weather: Hours of production lost due to weather
    ii. Safety Stand-down (hours): or safety stand-down (divided between ship and launches)
    iii. Mechanical/Unscheduled Maintenance or Equipment Issues (hours): Hours of production lost due to unscheduled repairs to non-survey equipment
    iv. Downtime due to Survey Equipment Issues (hours): Hours of production lost because of problems related to survey equipment
    v. Downtime due to Personnel Shortage (hours): Hours of production lost because of a shortage of personnel or a shortage of personnel with requisite skill levels

It is understood that the determination of planned survey hours is very subjective and dependent upon numerous factors including the requirement to process acquired data in a timely fashion and the availability of vessels and personnel.

5.2.2.1.2 DATA ACQUISITION & PROCESSING REPORT (DAPR)

A Data Acquisition and Processing Report should be created to describe the data acquisition and processing procedures, quality control procedures, and any major deviations from OCS standard survey practices implemented throughout a project. The DAPR should be completed following HSSD rules and can be submitted to the Chief of HSTB before to the first project and the hydrographic branch that will be receiving data for the project.

The DAPR should be submitted simultaneously with, or before, the first survey of the project completed that year. For projects that span multiple years, a new DAPR should be generated each calendar year. Information contained in the HSRR memo may be referenced in the DAPR to meet reporting requirements set forth in the HSSD.

5.2.2.1.3 HORIZONTAL & VERTICAL CONTROL REPORT (HVCR)

The Horizontal and Vertical Control Report should be completed in accordance with HSSD and submitted to the appropriate hydrographic branch before or not later than the submission of the last survey of a project. For projects that span multiple years, a new HVCR should be generated each calendar year.

No report is necessary if no HorCon and/or VerCon were installed or conducted; however, a “read me” text document stating that no HorCon and/or VerCon operations were conducted should be placed in this folder in lieu of an HVCR.

5.2.2.1.4 TIDE & WATER LEVEL DATA PACKAGE

In accordance with the HSSD, field units that have installed and serviced water level stations in support of an OCS survey project should provide the following Tide and Water Level Data Package to CO-OPS. The following information is an explanation of what information is to be submitted where.

1. Transmittal letter created in PydroGIS (PDF format)
2. Field Tide Note (PDF format), if applicable
3. Calibration test documentation from an independent source other than the manufacturer for each sensor used to collect water level or ancillary data (PDF format)
4. E-Site Report, Water Level Station Xpert Site Report, or Tide Station Report (NOAA Form 77-12), or equivalent
5. (E-Site report application is in web-based electronic format, Water Level Station Xpert Site Report or Tide Station report in Microsoft Excel format); contractor-created site reports are acceptable as long as the reports provide the same required information.
6. US Geological Survey quadrangle map (7.5 minutes) indicating the exact location of the station, with map name and scale shown (JPEG and PDF format)
7. Sensor test worksheet (JPEG and PDF format; applicable for acoustic gauges)
8. Sensor elevation drawing (JPEG and PDF format) showing seafloor, pier elevation, and sensor elevation if the sensor is mounted vertically; for stations with Aquatrak sensors, provide the Aquatrak Sounding Well Diagram.
9. Water level transfer form (applicable for Great Lakes stations only, in JPEG and PDF format)
10. Large-scale bench mark location diagram of the station site 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 bench mark sketch should include an arrow indicating north direction, a title block, and latitude and longitude (derived from the handheld GNSS) of the gauge, and the NOAA chart number or Quad map name (JPEG and PDF format).
11. New or updated description of how to reach the station from a major geographical landmark (in Microsoft Word and PDF format); refer to User’s Guide for writing bench mark descriptions, NOAA/NOS, Updated January 2003.
12. Bench mark descriptions with handheld GNSS coordinates (in Microsoft Word and JPEG format); refer to User’s Guide for writing bench mark descriptions, NOAA/NOS, Updated January 2003.
13. Digital photographs of bench mark disk faces, setting, bench mark locations from two different perpendicular cardinal directions, station, DCP, equipment, underwater components, and vicinity (JPEG and PDF format); as a minimum, photographs should 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 view showing the bench mark disk (face) stamping. Bench mark photo file names start with the mark designation followed by either “face” or “location” and direction of view, with the jpg extension (e.g., 8661070 B location south. jpg). All other station component photo file names start with the station number and view name (e.g., 8661070 tide station view south).
14. Level records (raw levels) including level equipment information (electronic files) and field notes of

precise leveling, if applicable.
15. Level abstract (electronic file for optical and barcode levels).
16. Datum offset computation worksheet or Staff/Gauge Difference Worksheet as appropriate showing how sensor "zero" measurement point is referenced to the bench marks.
17. Calibration certificates for Invar leveling rods, if applicable (in PDF format).
18. Staff-to-gauge observations, if applicable (in Microsoft Excel and PDF format).
19. Agreements, MOU, contract documents, utilities/pier agreements, and so as, as applicable (in PDF format).
20. Other information as appropriate, or as specified in the contract (in PDF format).
21. Water level data download.
22. All required GNSS deliverables (OPUS published data sheet and bench mark photos) as specified in CO-OPS "User's Guide for GNSS Observations at Tide and Water Level Station Bench Marks; completed CO-OPS Evaluation Criteria for Water Level Station Documentation Check-Off List Standing Project Instructions for Coastal and Great Lakes Water Level Stations (included in DAPR Appendix 3)

5.2.2.1.5 COAST PILOT REVIEW

Within the interactive Coast Pilot web version, users can click on geographic names (highlighted in green text) to view features and click on the image/table for quick viewing on NOAA's nautical charts.

Should the field unit come across any type of information that you feel would benefit the users of our Coast Pilot volumes, please submit the information to the Nautical Publications Branch. Don't hesitate to suggest items for inclusion/exclusion. If any field unit has a question or inquiry about certain features or general Coast Pilot questions, please email Coast.Pilot@noaa.gov.

Submission requirements are listed and should be completed in accordance with the HSSD.

5.2.3 Survey Reports

In addition to good data, it is critical for field units to document their methods, procedures, and findings. There is a variety of reports that get submitted with processed survey data that are explained in this section.

5.2.3.1 Descriptive Report (DR)

For each survey, a Descriptive Report should be completed in accordance with HSSD. The DR should contain information regarding the specific survey and its processed data. Information within the project-specific DAPR may be referenced in the DR, and any deviation from the DAPR should be documented in the DR.

The descriptive report must be in .XML format, which is created in Pydro Explorer's XmlDR. This program allows users to check for spelling errors, insert tables and figures, and ensure that all required information is included in the report.

5.2.3.2 Compare Grids

Point and surface data comparison statistics can be compiled and reported in Pydro Explorer's Compare Grids utility. This tool compares two surfaces for crossline comparisons and junction surveys (e.g., a mainscheme only surface and a crossline only surface). The output of this process contains four files. Two of the files associated with CSAR surfaces allow for comparing the IHO maximum allowable error. These surfaces are to be opened in CARIS, and displayed. The Colour File FracAllowError [Range] (Figure 5-4). Screenshots are to be included in the DR.

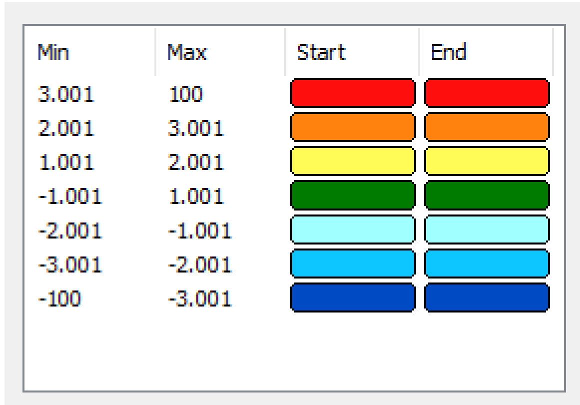


FIGURE 5-4 COLOR MAP USED BY THE FRACALLOWERROR [RANGE] TO SHOW ALLOWABLE TVUMAX ERROR TOLERANCE.

The other files are plots to be used in the DR and included in the submission file structure.

5.2.3.3 Survey Outline

Upon completion of data acquisition for a survey, submit a final survey outline to survey.outlines@noaa.gov in accordance with the Project Instructions and HSSD.

5.2.3.3.1 ATON REPORTS

If there are many ATON reports that need to be submitted for a given area, then the field unit may contact the U.S.C.G. Waterway Management for the area and determine a better format to submit bulk information.

Often, the field unit will provide a spreadsheet containing the information similar to that in the S-57 attribution. Correspondence of this event should be submitted in the project directory.

5.2.3.3.2 PUBLIC RELATIONS AND CONSTITUENT PRODUCTS

Any preliminary survey products, including public relation documents (e.g., charts, sounding plots, images, mosaics, DTMs) created by the field unit at the request of any parties outside of OCS (e.g., pilots, harbormasters, port authorities, other NOAA offices), that detail any surveyed information or significant discoveries made during a project are important documents that often support NOAA public relations and presence in an area. These documents can and will be used in various ways that are often unknown to the field unit that provided that product. Therefore, each document must contain a minimum amount of metadata to inform both the recipient of the document and NOAA offices of the origin and particulars of the data. A digital copy (preferably PDF) of any preliminary product delivered to a local constituent should be included with the survey deliverables.

The minimum elements suggested in each document are:

1. Title bar or block (include the name of the local area in the title);
2. Date and registry number of the survey;
3. Field unit acquiring the data;
4. Type of equipment used to acquire the data (e.g., EM710, EM2040C, Edgetech 4125);
5. If a sounding plot, a statement stating: Soundings in (feet, fathoms or meters) at (e.g., MLLW, ITRF 00) corrected using (predicted tides, preliminary observed tides, verified observed tides,

Vdatum, ellipsoidally referenced);
6. A scale bar with units;
7. Legend (e.g., red = 0–10 feet/fathoms, yellow = 10–20 feet/fathoms);
8. A north arrow (if applicable);
9. Graticules (labeled Lat/Long grid);
10. A disclaimer stating: "Data reflect the state of the seafloor in existence on the day and at the time the survey was conducted. The survey and the chart have not been updated for the inclusion of the latest Local Notice to Mariners. Preliminary data subject to office review. NOT FOR USE IN NAVIGATION"; and
11. Contact information and/or NOAA website.

Before releasing any preliminary survey data to parties outside of OCS, personnel should first obtain approval from the Chief-of-Party and notify the appropriate chief (HSD Chief, HSD OPS Chief, or Chief of NRB). In addition to the local constituent, the product should be digitally submitted to the regional Navigation Manager and the Chief of HSD OPS or Chief of NRB in a timely fashion.

All supplemental correspondence, including these preliminary data products, are to be included in Appendix II of the DR. In addition to a digital copy of the product, it is prudent for the field unit to provide a copy of any correspondence referring to the product, and any of the files and workspaces used to create the product.

5.2.4 NODC Files

Reference HSSD NCEI Sound Speed Data. All NODC files associated with the project should be zipped into a single file and transmitted as an email attachment to NODC.Submissions@noaa.gov with a courtesy copy to the HSD/NSD Project Manager.

Copies of the correspondence should be included in DR Appendix II.

The file names will indicate the cast date and time and have an extension ending in "a" for CTD casts and "d" for sound speed versus depth profilers, as shown below.

- Filename examples - YYDDDHHMM.ssa or YYDDDHHMM.ssd, where:
- YY = 2-digit year
- DDD = day-of-year
- HH = hour of day (UTC)
- MM= minutes of the hour
- ss = ship code

5.2.5 Transmittal Procedures

Final survey data submitted to either AHB or PHB should be complete and not require supplemental data from other surveys in the project. All survey data submitted should be packaged to safeguard against loss or damage and be accompanied by a hard copy transmittal letter (NOAA Form 61-29, Letter Transmitting Data).

Pydro Explorer's Transmission Letter tool provides a user interface to create a Letter Transmitting Data (LTD). This tool computes the number of directories, number of files, size of the data in bytes, finds and lists a MD5 file, and creates a manifest of the files in XML and binary format. This method is the primary method for creating LTDs.

A digital copy of the transmittal letter(s) should be submitted via email to the cognizant hydrographic branch at the time the data are transferred using either LTDSubmission.AHB@noaa.gov or

LTDSubmission.PHB@noaa.gov as appropriate. If shipping more than one package, a separate transmittal should be used for each package. The transmittal letter should indicate the contents of the package and list all digital media being submitted. If additional pages are needed for the transmittal letter, the project number and survey registry number should be included on each page. Transmittal letters and file verification manifests can be created in Pydro using the Transmission Letter tool.

All data should be shipped to the appropriate hydrographic branch at one of the following addresses:

a. NOAA, National Ocean Service
   439 West York Street
   Atlantic Hydrographic Branch, N/CS33
   Norfolk, Virginia 23510-1114

b. NOAA, National Ocean Service
   7600 Sand Point Way N.E.
   Pacific Hydrographic Branch,
   N/CS34 BIN C15700, Bldg. 3
   Seattle, Washington 98115-0700

6 Table of Acronyms

AHB: Atlantic Hydrographic Branch
AST: Assistant Survey Technician
ASV: Autonomous Surface Vessel
ATON: Aid to Navigation
AUV: Autonomous Underwater Vehicle
AWOIS: Automated Wreck and Obstruction Information System
BAG: Bathymetric Attributed Grid
BASE: Bathymetry Associated with Statistical Error
BOEM: Bureau of Ocean Energy Management
CCOM/JHC: Center for Coastal and Ocean Mapping/Joint Hydrographic Center
CEF: Chart Evaluation File
CM: Center of Motion
CO: Commanding Officer
CO-OPS: Center for Operational Products and Services
CORMS: Continuously Operating Real-Time Monitoring System
CORS: Continuously Operating Reference Station
CSF: Composite Source File
CST: Chief Survey Technician
CTD: Conductivity Temperature Depth
CUBE: Combined Uncertainty and Bathymetry Estimator
DAPR: Data Acquisition and Processing Report
DAS: Days at Sea
DCP: Data collection platform (e.g., tide buoy)
DGPS: Differential Global Positioning System
DIG: Digilink Data File Format
DLDG: Divers least depth gauge
DOT: Department of Transportation
DOY: Day of Year
DP: Detached Position
DQA: Data Quality Assurance
DR: Descriptive Report
DTM: Digital Terrain Model
DtoN: Danger to Navigation
DXF: Drawing eXchange file format, a text representation of the binary format
EEB: Electronic Engineering Branch
EEZ: Exclusive Economic Zone
ENC: Electronic Navigational Chart
ERS: Ellipsoidal Referenced Survey
ERTDM: Ellipsoidally Referenced Tidal Datum Model
ERZT: Ellipsoidally Referenced Zoned Tides
ET: Electronics Technician
FAA- Federal Aviation Administration
FFF: Final Feature File
FGMT: Fledermaus geocoder toolbox
FOD: Field Operations Division
FOO: Field Operations Officer
FPM: Field Procedures Manual

GAMS: GPS Azimuth Measurement Subsystem
GAR: Green, Amber, Red
GC: Geographic Cell
GNSS: Global Navigation Satellite System
GOES: Geostationary Operational Environmental Satellite
GP: Geographic Position
GPS: Global Positioning System
GSF: Generic Sonar Format
HDCS: Hydrographic Data Cleaning System
HIC: Hydrographer in Charge
HIPS: Hydrographic Information Processing System
HorCon: Horizontal Control
HPPOC: Historic Preservation Points of Contact
HSD: Hydrographic Surveys Division
HSRR: Hydrographic Systems Readiness Review
HSSD: Hydrographic Survey Specifications and Deliverables
HSTB: Hydrographic Systems Technology Branch
HSX: Hypack Hysweep File Format
HTD: Hydrographic Surveys Technical Directive
HVCR: Horizontal and Vertical Control Report
HVF: HIPS Vessel File
IAPPK: Inertially Aided Post-Processed Kinematic
IHO: International Hydrographic Organization
IMU: Inertial Motion Unit
IOCM: Integrated Ocean and Coastal Mapping
ITRF: International Terrestrial Reference Frame
JPEG: Joint Photographic Experts Group
LNM: Linear Nautical Miles
LNM: Local Notice to Mariners
LTD: Letter Transmitting Data
MBAB: Multibeam Acoustic Backscatter
MBES: Multibeam Echo Sounder
MCD: Marine Chart Division
MHW: Mean High Water
MIST: Mobile Integrated Survey Team
MLLW: Mean Lower Low Water
MRU: Motion Reference Unit
MVP: Moving Vessel Profiler
NAD 83: North American Datum of 1983
NALL: Navigable Area Limit Line
NAS: Network Attached Storage
NAVOCEANO: US Naval Oceanographic Office
NCC: NOAA Custom Charts
NCEI: National Centers for Environmental Information
NGA: National Geospatial Intelligence Agency, formerly NIMA & DMA
NGDC: National Geophysical Data Center
NGS: National Geodetic Survey
NMEA: National Marine Electronics Association

NMFS OLE: National marine Fisheries Service Office of Law Enforcement
NOAA: National Oceanic and Atmospheric Administration
NODC: National Oceanographic Data Center
NOS: National Ocean Service
NPB: Nautical Publications Branch
NRB: Navigation Response Branch
NRT: Navigation Response Team
NSD: Navigation Services Division
NTM: Notice to Mariners
NTRIP: Network Transport of RTCM over Internet Protocol
NWLON: National Water Level Observation Network
OCS: Office of Coast Survey
OMAO: Office of Marine and Aviation Operations (NOAA)
ONMS: Office of National Marine Sanctuaries
OOD: Office of the Deck
OPS: Operations Branch, Hydrographic Surveys Division
OPS: Operations Officer
OPUS DB: Online Positioning User's Service Database
PDBS: Phase Differencing Bathymetric Sonar
PDF: Portable document format
PDOP: Positional Dilution of Precision
PHB: Pacific Hydrographic Branch
PI: Project Instructions
PMVD: Poor Man's Vertical Datum
POD: Plan of the Day
POS/MV: Position and Orientation System for Marine Vessels
PPK: Post Processed Kinematic
PPP: Precise Point Positioning
PPS: Pulse per second
PRF: Project Reference File
PS: Physical Scientist
RAID: Redundant Array of Independent Disks
RINEX: Receiver Independent Exchange Format
RMS: Root Mean Square
RNC: Raster Navigational Chart
RP: Reference Point
RSD: Remote Sensing Division
RTCM: Radio Technical Commission for Maritime Services
RTK: Real-Time Kinematic
RTX: Real-Time Extended
SAR: Survey Acceptance Review
SBES: Singlebeam Echo Sounder
SBET: Smooth Best Estimate and Trajectory
SDF: Sonar Data File
SHPO: State Historic Preservation Officer
SNM: Square Nautical Miles
SOP: Standard Operating Procedure
SSS: Side Scan Sonar

SSSAB: Side Scan Sonar Acoustic Backscatter
ST: Survey Technician
SVP: Sound Velocity Profiler
TCARI: Tidal Constituent and Residual Interpolation
TPU: Total Propagated Uncertainty
UAS: Unmanned Aerial Systems
UNCLOS: United Nations Convention on the Law of the Sea
UNH: University of New Hampshire
USACE: United States Army Corps of Engineers
USCG: United States Coast Guard
USCG LNM: United States Coast Guard Local Notice to Mariners
USGS: United States Geological Survey
USM: University of Southern Mississippi
USN: United States Navy
UTM: Universal Transverse Mercator
VDatum: Vertical Datum (NOAA Tool/Model)
VerCon: Vertical Control
WAAS: Wide Area Augmentation System
WC: Water Column
XO: Executive Officer
XTF: Extended Triton Format
ZDF: Zone Definition File

7 Appendices

7.1 **Appendix 1:** HVF and Offsets

This guide sheds light on the HVF, offsets, reference points, and potential configurations for how we use them on NOAA platforms. Hopefully this document will increase understanding about the role of the HVF, and how we use it to determine uncertainty and relative positions.

Maintained by HSTB. Please contact with the East or Pacific field support liaisons with any questions, comments, or concerns.

Acronyms
HVF: HIPS Vessel File
NAV: Navigation (source of navigation/motion data). Refers to the antenna in *TPU: Offsets*
MRU: Motion Reference Unit (the IMU)
IMU: Inertial Motion Unit
TX: Transmitter
RX: Receiver
RP: Reference Point
RF: Reference Frame
SVC: Sound Velocity Correction
Trans: Location of TX relative to your reference point. May or may not be included depending on sonar setup.
Trans2: Location of RX relative to your reference point. May or may not be included depending on sonar setup.
SVP: Location of TX relative to your reference point. Necessary for positioning sonar for sound velocity correction (hence the name)
Dual head Kongsberg sonar: this would be the location of the RX-port relative to the reference point
SVP2: Location of the RX relative to your reference point. Necessary for positioning sonar for sound velocity correction (hence the name)
Dual head Kongsberg sonar: this would be the location of the RX-stbd relative to the reference point

Frequently Asked Questions:

What is the HVF, and what does it do?

The HIPS Vessel File (HVF) can account for the offsets of all the survey components, as well as the associated uncertainty we have for each of those measurements. For some of our configurations, such as those with a single transducer, some offsets are accounted for and recorded in the POS file, which is written directly into the raw sonar file. We use the HVF to factor in associated uncertainty with manufacturer equipment (see Chapter 4 Appendices FPM, CARIS), lever-arms created from the offsets (not double applying, just measuring lever arm), and SVC.

What is navigation?

In the HVF, Navigation generally refers to the location of the *origin* of motion and position data. We have two devices on our vessels that are capable of tracking motion: the IMU and the GPS antenna. Most often for our purposes, the term "navigation" will refer to the IMU, as opposed to the GPS antenna. Here, navigation is the *origin of output* from the positioning system: the TX for single transducer vessels, and the IMU for multi-transducer vessels. There is one exception: in the HVF > *TPU: Offsets*, navigation explicitly refers to the GPS antenna. This is designated as "NAV to Transducer," whereas the IMU is "MRU to Transducer."

How do Vessel and Real-time Uncertainty differ? Which draws from the HVF?

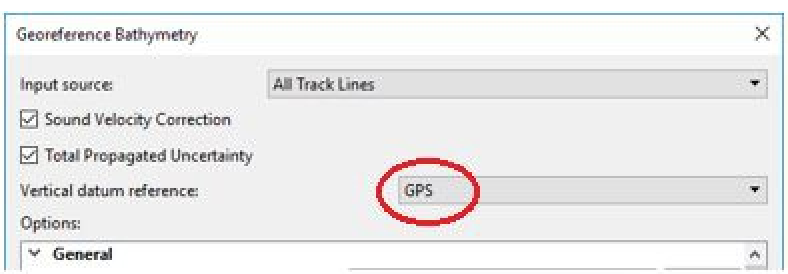
Vessel: Scalar approximation of lever-arms taken from HVF or user-entered values in processing dialogs.

Real-time: Computed from the uncertainty calculated in the POS file, echosounder, and spatial tidal uncertainties (TCARI). The POS file accounts for offsets from the GPS antenna to the reference point.
Our workflow uses real-time uncertainty for navigation and height uncertainty, from the SBET RMS and delayed heave from the *.000 file, as well as sonar uncertainty. All other uncertainties are derived from vessel settings. If "Vessel" were selected for uncertainty, it would not use any uncertainty from SBETs or *.000 files, and only use the offsets entered into the HVF to create lever-arms, and apply the calculated uncertainty.

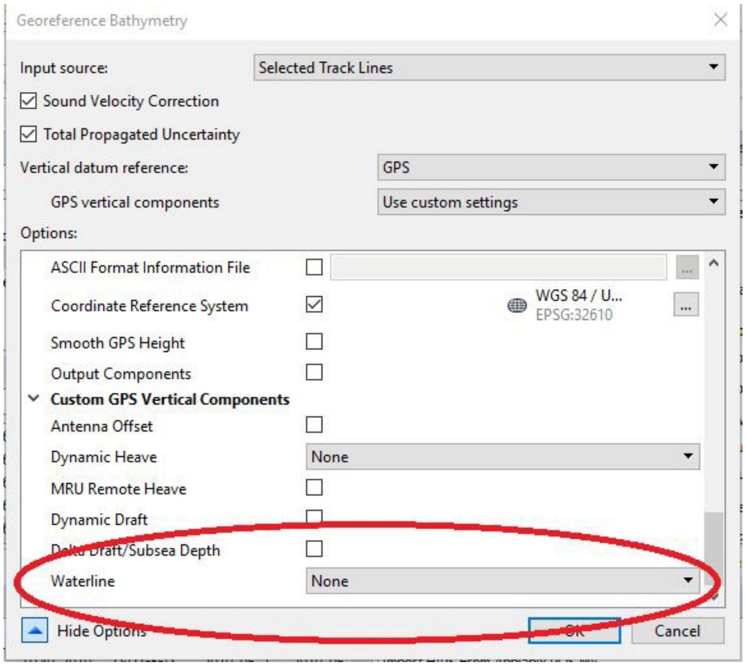
I often see "Roll, Pitch, and Heave" grouped together in the HVF. How do these relate to attitude and motion?
Attitude refers to the roll, pitch, and yaw of a vessel, the rotational movement *around* the x/y/z axis. Yaw, the heading motion, is largely accounted for with the GAMS solution.
Heave refers to the translational movement *along* the z access around the in-situ water level. Our post-processed SBETs correct for **altitude**, which is the vertical height relative to the ellipsoid. Ultimately, it is this corrected ellipsoid altitude value that we apply to the data, though heave is still applied separately from altitude as the higher frequency component. Surge and sway are the corresponding translational movements to the x and y axis.

Post-processed SBETs provide slightly improved attitude data, but it is a negligible difference. We do not apply these SBET attitude values when applying heave through the SBET. Altitude (from our motion of heave) is the most difficult component to accurately derive from a GPS system, and improves significantly in post-processing. Our patch test values, which directly impact attitude, are already written into the initial POS file applied to the raw **.all file for single multibeam installations. Patch test values can also be entered into Kongsberg SIS or the HVF.

How are draft and waterline accounted for?
HVF Draft = Dynamic Draft. This is a table loaded into the HVF based on your ERDDM (Ellipsoidally Referenced Dynamic Draft Model) – how much the vessel squats when it moves through the water at different speeds. Ultimately this does not matter for ERS surfaces, but it does matter when computing tidally reduced surfaces and the GPS surfaces in Georeference Bathymetry in CARIS (GPS Tide in CARIS 10 and earlier). HVF Draft does not factor into SVC.
HVF Waterline = How far the sonar sits below the water. The waterline offset is initially written into the **.all files via SIS, such that real-time depth display accurately reflects the waterline. When data are processed in



CARIS, however, we use this waterline input from the HVF for the sound velocity correction to raw data in CARIS. In CARIS 11, this is set to Waterline = None in Georeference Bathymetry. In CARIS 10, we choose to not apply during the Merge process so as not to double apply in Merge and SVC. Apply = NO during Merge for CARIS 10.

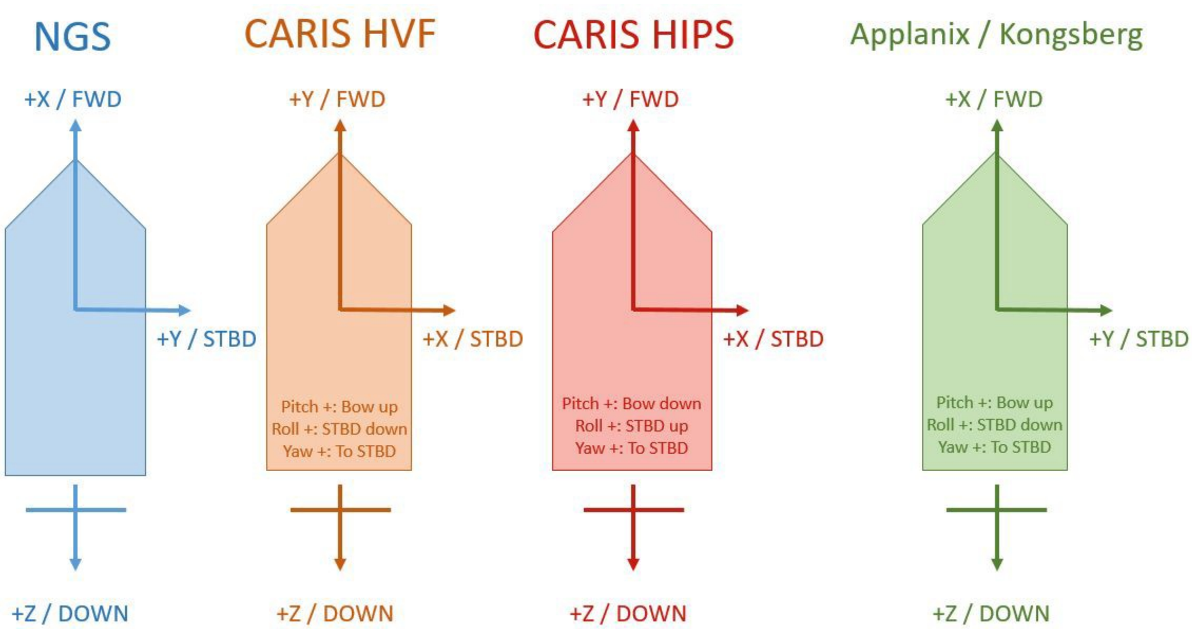


Georeference Bathymetry, CARIS 11

For Ellipsoidally Referenced Surveys, the "yes/no" state of the Georeference Bathymetry GPS Dynamic Draft option *must agree with* "yes/no" state of the HVF "Apply" for draft.

Reference Frames

Differences in Reference Frames



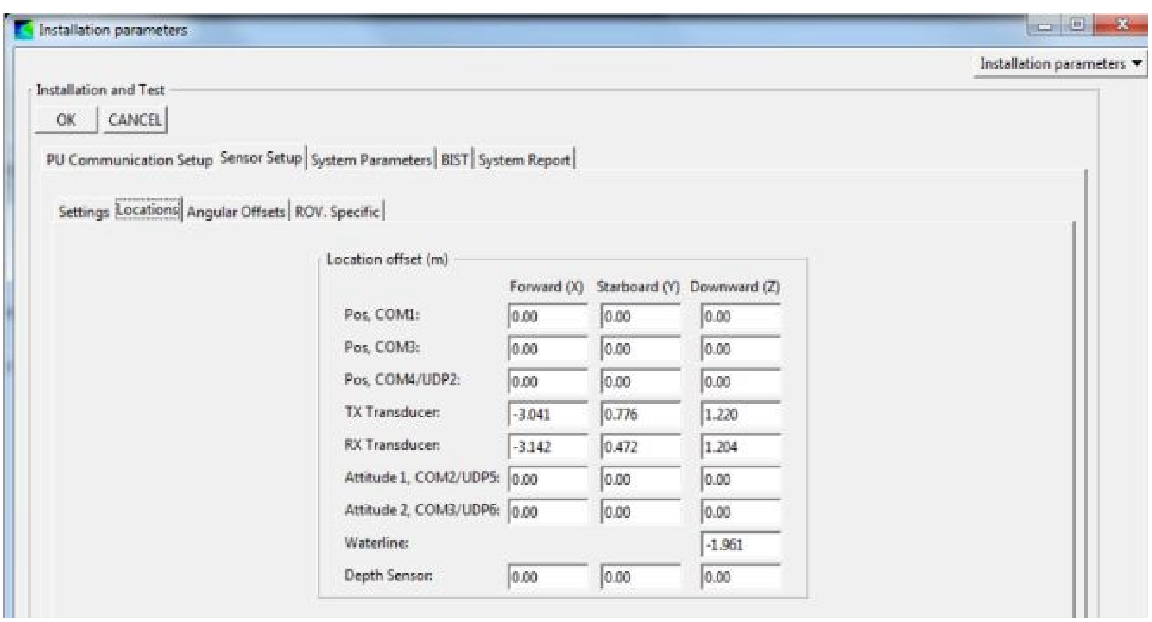
When entering values in different software it is important to remember what reference frame values are coming from, and the reference frame where they are going. Be careful to identify what a frame is being referenced to, whether it is the transducer face, IMU, or even the granite block. Please double check the configuration of the original NGS survey: some may have differing orientations. For example, Vessel S3002 has Z as (-) Down configuration.

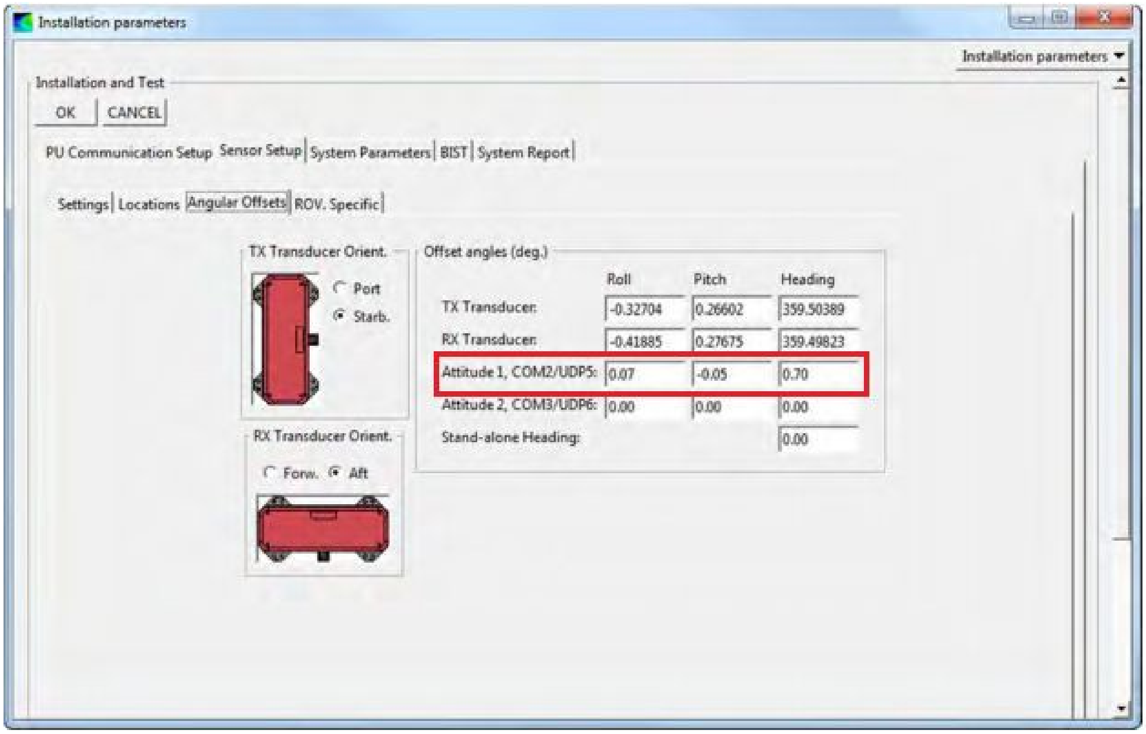
CARIS HVF, POS Lever-Arms, SIS, and Mounting Angles: what goes where
Green = RP is TX **Purple = RP is IMU**
Offsets between the IMU and Transducer
POS:
The “Ref. to IMU Target” Box as Transducer -> IMU (RP =Tx)
HVF: TPU Values → Offsets → MRU to Trans
SIS: Installation Parameters → Locations
Enter values when RP is the IMU, otherwise left as 0.

Offsets between NAV and RP
POS: The “Ref. to Primary GNSS Lever Arm” Box as Primary Antenna → **Transducer** or **IMU** location
HVF: TPU Values → Offsets → Nav to Trans and MRU to Trans. *Note: uncertainty from this source is not applied in the standard NOAA Workflow. This is only applied when TPU Uncertainty Source = Vessel. Nav refers to GNSS antennas for this entry.*

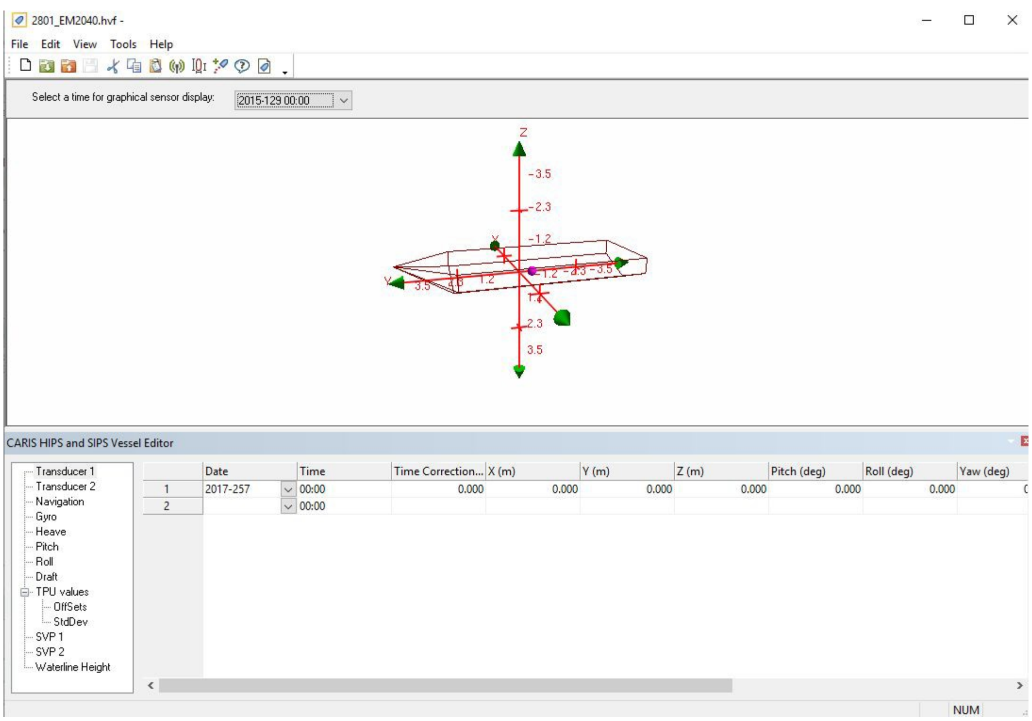
Waterline
POS: Not entered
HVF: Waterline, ***Apply* = *No*** (Draft: Apply = Yes)
SIS: Installation Parameters → Locations
For initial data visualization and display in SIS. Data ultimately uses the waterline value entered in the HVF value during processing.

Patch Test Values & Angular Offsets
POS: The “IMU w.r.t Ref Frame” Box (RP = TX), otherwise 0 (RP =IMU).
HVF: not entered, **unless they are not in POS (RP = IMU). Patch Values in HVF only in this scenario.**
SIS: Installation Parameters → Locations
Tx/Rx: only for measured/surveyed offsets
Attitude: patch test values




Installation parameters
Installation parameters
Installation and Test
OK
CANCEL
PU Communication Setup
Sensor Setup
System Parameters
BIST
System Report
Settings
Locations
Angular Offsets
ROV. Specific
TX Transducer Orient.
Port
Starb.
RX Transducer Orient.
Forw.
Aft
Offset angles (deg.)
Roll
Pitch
Heading
TX Transducer:
-0.32704
0.26602
359.50389
RX Transducer:
-0.41885
0.27675
359.49823
Attitude 1, COM2/UDP5:
0.07
-0.05
0.70
Attitude 2, COM3/UDP6:
0.00
0.00
0.00
Stand-alone Heading:
0.00

The HVF


2801_EM2040.hvf -
File
Edit
View
Tools
Help
Select a time for graphical sensor display:
2015-129 00:00
CARIS HIPS and SIPS Vessel Editor
Transducer 1
Transducer 2
Navigation
Gyro
Heave
Pitch
Roll
Draft
TPU values
OffSets
StdDev
SVP 1
SVP 2
Waterline Height
Date
Time
Time Correction...
X (m)
Y (m)
Z (m)
Pitch (deg)
Roll (deg)
Yaw (deg)
1
2017-257
00:00
0.000
0.000
0.000
0.000
0.000
0.000
2
00:00
NUM

Since the Kongsberg data read into HIPS is already corrected, the Transducer values in the HVF must be set as follows:

- The *X/Y/Z* offsets are zero because the Kongsberg data acquisition has already applied static draft and shifted the swath profile to the vessel reference point.
- The *Roll /Pitch /Yaw* transducer mounting rotations are typically zero because the Kongsberg data acquisition has already applied patch test calibration results.

From the CARIS HVF Guidance 6.4 (2020)

Transducer 1: Transducer Face

All zero (0). **Our reference point is the transducer**, so there are no offsets entered here. The X/Y/Z offsets are zero, as Kongsberg has already applied static draft and shifted swath profile to vessel reference point. If your patch test values are *not* in POSMV, you would enter those patch test values here under Pitch/Roll/Yaw. The time correction is applied in SIS, under *Installation Parameters > Settings > Attitude Delay*.

	Date	Time	Time Correction...	X (m)	Y (m)	Z (m)	Pitch (deg)	Roll (deg)	Yaw (deg)	Manufacturer	Model	Serial Number
1	2017-257	00:00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	Kongsberg	Kongsberg EM	
2		00:00										

Systems with multiple transducers (IMU= RP), these values will still be zero. We have already documented and accounted for the offset of RP to TX in SIS (*Installation Parameters > Sensor Setup > Locations tab*), displayed below. Patch test values are also in the *Angular Offsets* tab in SIS.

Transducer 2: Transducer Face (only on EM2040, dual systems)

All zero (0). Our reference point is the transducer. In the case of a dual-dual head system (FH), this is still zero.

	Time Correction...	X (m)	Y (m)	Z (m)	Pitch (deg)	Roll (deg)	Yaw (deg)	Start beam num
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1,001
2								0

Systems with multiple transducers (IMU as the RP), this is the offset between the IMU and the RX. These values are all zero, as we already built this into SIS and the**.all record.

Navigation: Location of the navigation source

All zero (0). Navigation is the location of the source of attitude and motion to the RP. This is typically the IMU. Time correction should be zero - we already built this offset into SIS (*Installation Parameters > Settings > Attitude Delay*). Having this "zeroed out" does not indicate the IMU is the reference point. This shows that the reference point is the MBES data origin. We have already shifted the IMU to the RP by accounting for it in the POSMV offsets. In vessels without an IMU, navigation may refer to the antenna.

Systems with multiple transducers (IMU as the RP), this is still zero.

	Date	Time	Time Correction...	X (m)	Y (m)	Z (m)	Manufacturer	Model	Serial Number	Comments
1	2017-257	00:00	0.000	0.000	0.000	0.000	Applanix	POS/MV 320 V5		new launch (RP=EM2040TX)
2		00:00								

Gyro:
All zero (0). Sensor providing heading orientation. Can input gyro error associated with various headings. We do not use the gyro for our source of navigation, so this remains blank.

	Date	Time	Time Correction...	Error	Manufacturer	Model	Serial Number	Comments
1	2017-257	00:00	0.000	Edit	(null)	(null)	(null)	(null)
2		00:00		Edit				

Heave: movement along Z (vertical up-down)
Kongsberg applies dynamic heave, pitch, and roll to swath data during survey.
This is the offset from the transducer to the IMU (same as in SVP, but signs reversed), and determines the lever arm to apply to heave calculations.

Apply = No, so as not to double-apply. Can be left as zero (0) for small vessels (launches, NRTs), but should be entered for larger vessels (ships).

CARIS 10: should be entered. CARIS 11: can be zero, pulls from the **.all file.

Small Vessel

	Date	Time	Time Correction...	Error (m)	X (m)	Y (m)	Z (m)	Apply	Manufacturer	Model	Serial Number	Comments
1	2017-257	00:00	0.000	0.000	0.000	0.000	0.000	No	(null)	(null)	(null)	(null)
2		00:00										

Large Vessel

	Date	Time	Time Correction...	Error (m)	X (m)	Y (m)	Z (m)	Apply	Manufacturer	Model	Serial Number	Comments
1	2019-159	00:00	0.000	0.000	13.598	-0.495	-1.282	No	(null)	(null)	(null)	(null)
2		00:00										

	X (m)	Y (m)	Z (m)	Apply	M
0.000	13.598	-0.495	-1.282	No	(n

Pitch: rotation around X (back-forth)
Note: This is in the CARIS reference frame. Movement rotating around X Axis = Pitch **All zero (0).** Kongsberg applies dynamic heave, pitch, and roll to swath data during survey. Apply = No, so as not to double-apply.

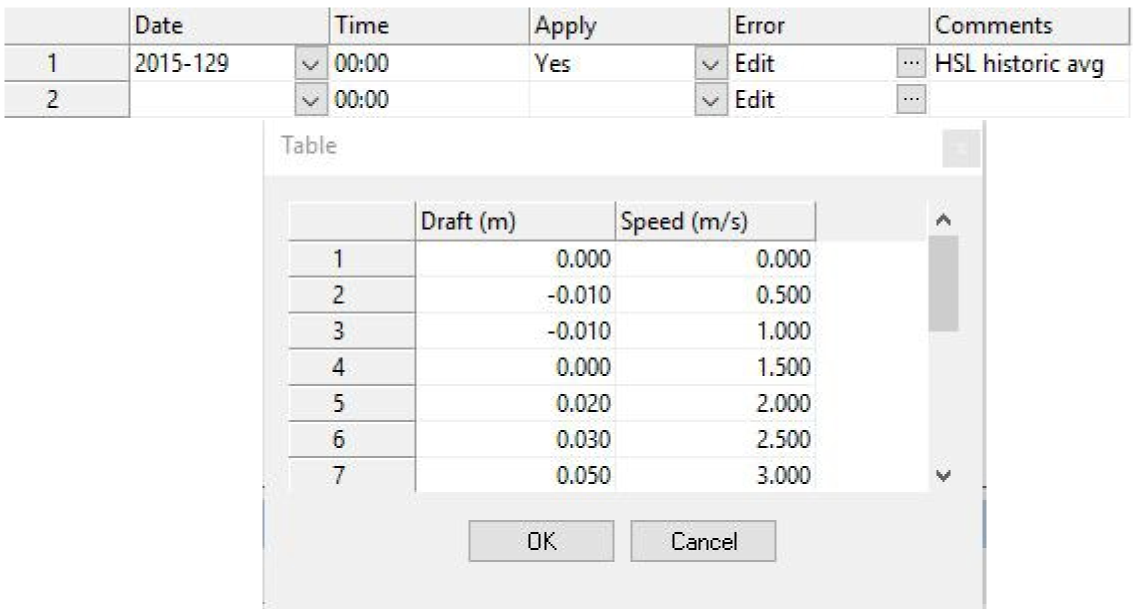
	Date	Time	Time Correction...	Error	Apply	Manufacturer	Model	Serial Number	Comments
1	2017-257	00:00	0.000	0.000	No	(null)	(null)	(null)	(null)
2		00:00							

Roll: rotation around Y (side-to-side)
Note: This is in the CARIS reference frame. Movement rotating around Y Axis = Roll **All zero (0)**. Kongsberg applies dynamic heave, pitch, and roll to swath data during survey. Apply = No, so as not to double-apply.

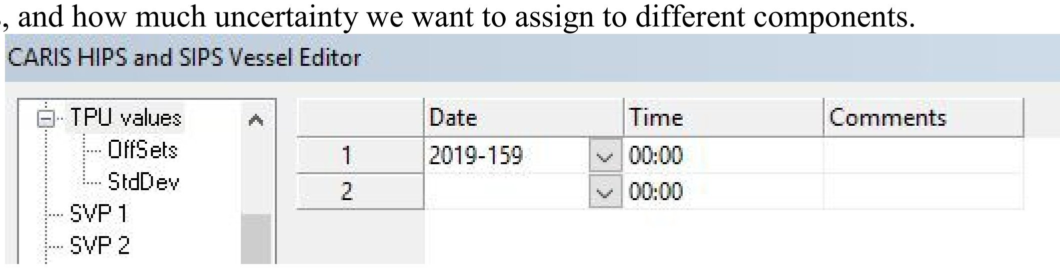
	Date	Time	Time Correction...	Error	Apply	Manufacturer	Model	Serial Number	Comments
1	2017-257	00:00	0.000	0.000	No	(null)	(null)	(null)	(null)
2		00:00							

Draft: Dynamic Draft of the vessel

Apply=Yes. This is the table where we account for dynamic draft of the vessel, generated from the ERDDM. When you merge data, this will account for the difference between the static draft and instantaneous draft in the final depth calculations.
Important for non-ERS data. **NOTE**: Speed is in meters/second.
In CARIS 10, the "yes/no" state of Compute GPS Tide Dynamic Draft option must agree with "yes/no" state of the HVF "Apply" for draft. This is automatically detected in CARIS 11.



TPU values: Total Propagated Uncertainty
Our TPU is one of the most critical components of the HVF. It's where we document our confidence in our measurements, and how much uncertainty we want to assign to different components.



TPU values shows the configuration install dates, consists of OffSets and StdDev

OffSets
The physical location of different components on the survey vessel. We already account for these offsets in POS; these values allow us to calculate the uncertainty associated with lever-arms when we derive uncertainty from Vessel. Greater distance between Transducer, Nav, and IMU = larger lever arm = greater uncertainty. Fill in the appropriate offsets, with Trans Roll = patch test roll.

A note on Trans Roll: this will be flagged yellow in the Charlene Offset Report if left as 0, as it is looking for a match for the patch test roll value. However, our current workflow does not recommend using the patch test value for the HVF. Therefore, leaving Trans Roll as "0" will not meaningfully impact uncertainty associated with data. This matters more for major mounting offsets, where the transducer is angled away from nadir at 5 degrees or more.

Remember, this is in the CARIS reference frame, which is X/Y flipped from the POSMV reference frame.
MRU = Motion Reference Unit, or the IMU. **Nav** = Navigation Source, or the antenna. **Trans** = Transducer
Trans2 = Receiver
Trans Roll = Transducer Roll, mounting roll offset. Offset is positive = rotating Tx away from starboard (starboard down).

	MRU to Trans X ...	MRU to Trans2 ...	MRU to Trans Y ...	MRU to Trans2 ...	MRU to Trans Z ...	MRU to Trans2 ...	Nav to Trans X (...	Nav to Trans2 X ...	Nav to Trans Y (...	Nav to Trans2 Y ...	Nav to Trans Z (...	Nav to Trans2 Z ...	Trans Roll (deg)	Trans Roll (deg)
1	0.203	-0.102	0.136	0.036	0.535	0.519	0.203	-0.102	0.136	0.036	0.535	0.519	0.000	0.000
2														

	MRU to Trans X ...	MRU to Trans2 ...	MRU to Trans Y ...	MRU to Trans2 ...	MRU to Trans Z ...	MRU to Trans2 ...
1	0.203	-0.102	0.136	0.036	0.535	0.519
2						

Nav to Trans X (...	Nav to Trans2 X ...	Nav to Trans Y (...	Nav to Trans2 Y ...	Nav to Trans Z (...	Nav to Trans2 Z ...	Trans Roll (deg)	Trans Roll (deg)
0.203	-0.102	0.136	0.036	0.535	0.519	0.000	0.000

StdDev: Uncertainty in device and offset reported measurements
These values measure the confidence that we have in our measurements of vessel and equipment performance. These are provided by the manufacturer, established by OCS, or estimated through repeated measurements. The recommended values can be found in HSSD 5.2.3.6, FPM Chapter 4 appendices, and from [CARIS's TPU guidance](). Note that these values are 1-Sigma (~RMS) even though manufacturers often report 95% values in their spec sheets. Halve the 95% values before entering in the HVF.

	Motion Gyro (d...	Heave % Amp	Heave (m)	Roll (deg)	Pitch (deg)
1	0.020	5.000	0.050	0.020	0.020
2					

Position Nav (m)	Timing Trans (s)	Nav timing (s)	Gyro Timing (s)	Heave Timing (s)	Pitch Timing (s)	Roll Timing (s)
1.000	0.005	0.005	0.005	0.005	0.005	0.005

	Roll Timing (s)	Offset X (m)	Offset Y (m)	Offset Z (m)	Vessel Speed (m...
1	0.005	0.010	0.010	0.010	0.080
2					

Loading (m)	Draft (m)	Delta Draft (m)	MRU Align StdDev gyro	MRU Align StdDev Roll/Pi...
0.025	0.020	0.010	0.200	0.100

SVP 1: Transducer
Ray-traces based on sound velocity profile applied as specified by the user. For Kongsberg data, the center of rotation is the RP. The pitch, roll, and yaw offsets of the transducer are already accounted for in the POS file. Because the transducer is the RP, these values are all zero. Offsets and patch values are set to zero. Should match offsets in SIS. Pitch, Roll, and Yaw offsets would only refer to large mounting offsets on the order of 10s of degrees, and will be zero for NOAA vessels.

	Date	Time	Offset X (m)	Offset Y (m)	Offset Z (m)	Pitch (deg)	Roll (deg)	Azimuth	Comments
1	2017-257	00:00	0.000	0.000	0.000	0.000	0.000	0.000	
2		00:00							

Systems with multiple transducers (IMU as the RP), list the offsets from the RP to the TX. NOTE: must swap X/Y from Kongsberg to CARIS, and swap angles of pitch/roll.

	Date	Time	Offset X (m)	Offset Y (m)	Offset Z (m)	Pitch (deg)	Roll (deg)	Azimuth
1	2019-159	00:00	-13.598	0.495	1.282	0.363	4.274	0.899
2		00:00						

SVP 2: Receiver

Offset between the RP and the center of the receiver. *Note: no input for EM2040C*.

The transducer is the RP (zero) = patch values set to zero.

	Offset X (m)	Offset Y (m)	Offset Z (m)	Pitch (deg)	Roll (deg)	Azimuth
1	-0.305	-0.100	-0.016	0.000	0.000	0.000
2						

Systems with multiple transducers (IMU as the RP), this is the offset between the IMU and the RX. Should match offsets in SIS.

	Offset X (m)	Offset Y (m)	Offset Z (m)	Pitch (deg)	Roll (deg)	Azimuth
1	0.472	-3.142	1.204	0.164	0.225	359.430
2						

Waterline Height

Offset between the waterline and the RP. Negative value = waterline above the RP, which should be the case for all RP = TX systems.

Apply = no, this offset is already applied in SIS and we do not want to double apply the waterline. This is the waterline that is used for referencing in processed data. During SVP calculations, the waterline value WILL be taken into account, so it is still important to populate this value.

	Date	Time	Apply	Waterline (m)	Comments
1	2017-257	00:00	No	-0.631	(null)
2		00:00			

Offsets in the POSMV

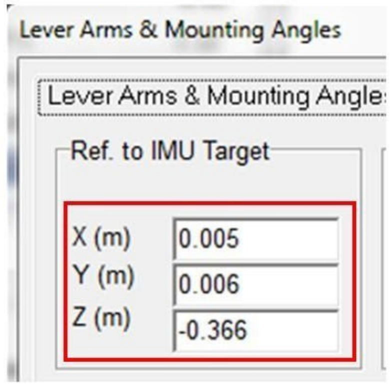
Ref. to IMU Target

Offsets between the IMU and the transducer.

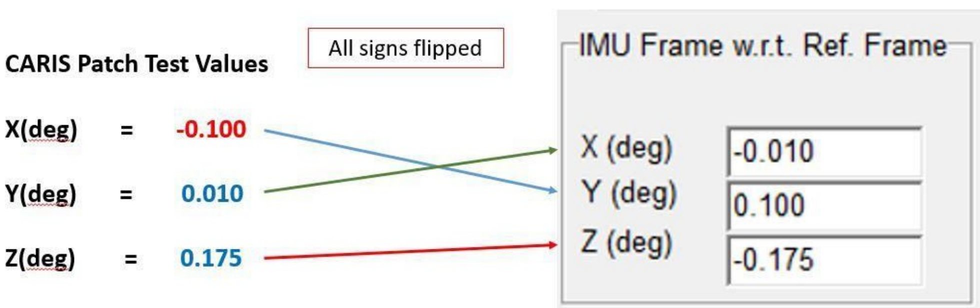
Systems with multiple transducers (IMU as the RP), this is zero.

Calculated Values for TRANS as Reference Point

	NORTH	EAST	DOWN
CL3	0.429	0.002	-0.657
CL4	-0.451	0.004	-0.626
MPP	-0.007	-0.438	-0.637
MPS	-0.009	0.444	-0.646
BMS	-1.560	1.148	-1.382
BMP	-1.560	-1.160	-1.367
CL2	3.840	-0.013	-2.770
GPSBMP	3.859	-0.851	-2.660
GPSBMS	3.845	0.835	-2.664
CL1	6.397	0.004	-1.617
GPSS	4.239	0.826	-3.153
GPSP	4.225	-0.864	-3.150
TRANS	0.000	0.000	0.000
HULLA	-0.463	0.003	-0.030
HULLF	0.456	0.005	-0.009
IMU	0.005	0.006	-0.366
BASELINE	0.014	1.690	-0.003



IMU Frame w.r.t Ref. Frame
This is left blank while collecting your patch test data, then populated values from the patch test. The signs of the rotations are flipped because this represents that the IMU is misaligned, since the transducer is aligned with the reference frame.



Systems with multiple transducers (IMU as the RP), this is zero. The IMU is the reference frame.

Ref. to Primary GNSS Lever Arm
This is populated with the RP to Primary (Port) GNSS Antenna offsets. You can enter the measured GAMS lever arm (distance between primary to secondary antenna), and let the GAMS calibration further refine these measurements. Everything else in the POS stays blank.

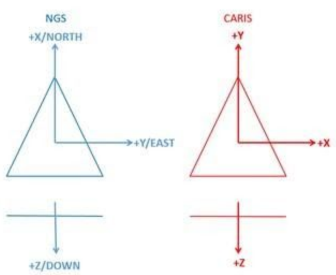
Calculated Values for TRANS as Reference Point

	NORTH	EAST	DOWN
CL3	0.429	0.002	-0.657
CL4	-0.451	0.004	-0.626
MPP	-0.007	-0.438	-0.637
MPS	-0.009	0.444	-0.646
BMS	-1.560	1.148	-1.382
BMP	-1.560	-1.160	-1.367
CL2	3.840	-0.013	-2.770
GPSBMP	3.859	-0.851	-2.660
GPSBMS	3.845	0.835	-2.664
CL1	6.397	0.004	-1.617
GPSS	4.239	0.826	-3.153
GPSP	4.225	-0.864	-3.150
TRANS	0.000	0.000	0.000
HULLA	-0.463	0.003	-0.030
HULLF	0.456	0.005	-0.009
IMU	0.005	0.006	-0.366
BASELINE	0.014	1.690	-0.003

Ref. to Primary GNSS Lever Arm

X (m)	4.225
Y (m)	-0.864
Z (m)	-3.158

Remember the X and Y are switched between NGS and CARIS

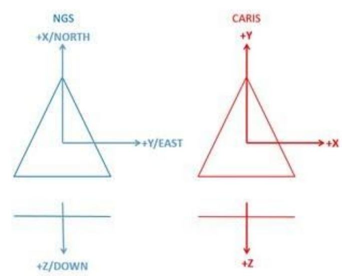


Also remember the HVF wants IMU to TRANS, while the NGS Survey is going TRANS to IMU, so the values must be flipped.

Calculated Values for TRANS as Reference Point

	NORTH	EAST	DOWN
CL3	0.429	0.002	-0.657
CL4	-0.451	0.004	-0.626
MPP	-0.007	-0.438	-0.637
MPS	-0.009	0.444	-0.646
BMS	-1.560	1.148	-1.382
BMP	-1.560	-1.160	-1.367
CL2	3.840	-0.013	-2.770
GPSBMP	3.859	-0.851	-2.660
GPSBMS	3.845	0.835	-2.664
CL1	6.397	0.004	-1.617
GPSS	4.239	0.826	-3.153
GPSP	4.225	-0.864	-3.150
TRANS	0.000	0.000	0.000
HULLA	-0.463	0.003	-0.030
HULLF	0.456	0.005	-0.009
IMU	0.005	0.006	-0.366
BASELINE	0.014	1.690	-0.003

Remember the X and Y are switched between NGS and CARIS



Also remember the HVF wants NAV to TRANS, while the NGS Survey is going TRANS to NAV, so the values must be flipped.

	MRU to Trans X...	MRU to Trans Y...	MRU to Trans Z...	Nav to Trans Xm)	Nav to Trans Ym)	Nav to Trans Z (...	Trans Roll (deg)
1	-0.006	-0.005	0.366	0.864	-4.225	3.150	0.000
2	-0.006	-0.005	0.366	0.864	-4.225	3.150	0.000

7.2 **Appendix 2:** Lead Line and Sounding Pole Construction

(Excerpted from the NOAA hydrographic manual, July 1976, with modifications)

Traditional Lead Line Construction

Material

Standard lead line material is mahogany-colored tiller rope with a phosphor-bronze wire center. The center consists of six strands of seven 33-B (S-gage) wires each. The wire core is flexible and should not break after continual use and coiling. The rope is size 8 (about 0.24 inches in diameter) and is made of waterproofed, solid-braided, long-staple cotton. The braid should be tight enough that broken wire strands will not protrude through the covering and injure a leadsman's hands. Material for lead lines may either be requisitioned from the Marine Centers or be purchased from a well-equipped marine supply dealer.

Fabrication and Marking

Depending on the depths at which they will be used and on the size of the vessel, lead lines should be 30–60 meters long. Each lead line is identified by a consecutive number stamped on a metal disk attached at the inboard end of the line. Identification is made when a line is initially graduated. This number is to be retained throughout the life of the lead line or until re-marking is necessary. The braided covering of an unseasoned lead line tends to shrink when wet causing the wire core to buckle and the strands to break. Broken strands are likely to protrude through the covering and cause hand injuries. To prevent rupturing the core with repeated use, pre-season each lead line as the following explains.

Prepare the lead line by soaking it in salt water for 24 hours. While the line is still wet, work the cotton covering along the wire by hand until the wire protrudes from the covering. The wire should protrude about 1/3 meter for each 20 meters of line. This is a tedious procedure requiring the cooperative efforts of several people. The covering can be pushed back and slackened only a few inches at a time; this length of slack must be pushed nearly the full length of the line before the next small section can be started. The excess protruding wire is cut off. The covering must not be worked back too far, or it will form bulges along the wire. Lead lines so prepared will maintain an almost constant length for future use.

Next, dry the line under tension (about 50 lbs.) then soak again for 24 hours. Never boil a lead line because this destroys the waterproofing of the cover.

After attaching a lead to the line, the line should be wetted down again and placed under a tension equal to the weight of the lead; this tension is maintained while the line is being graduated. Temporary marks made at this time can be used for later permanent marking. Graduation marks on a new lead line may be laid off with a steel tape. The best method, however, is to mark the distances permanently on a suitable surface such as on the deck of a ship or on a wharf if the survey party is shore based. Permanent markings are convenient when verifying the graduations in the future. Lead lines for NOAA hydrographic surveys should be graduated in meters, with intermediate marks to permit readings to the nearest decimeter. Each meter should be marked by a seizing of black thread, with a leather strip clearly indicating the numerical value for even meter intervals. Each even decimeter (0.2, 0.4, 0.6, and 0.8) is marked by a seizing of white thread. Odd tenth readings are estimated. Waxed linen thread should be used to secure marks to the lead line in such a manner that there can be no possibility of slippage. Do not insert the thread through the braided covering of the line.

Verification

When checks of traditional lead lines are made, the lead lines must be wet and under a tension equal to the weight of the attached lead in water. The testing standard should be a good, recently calibrated steel tape or premeasured graduation marks on deck or ashore. Replace or re-mark lead lines if the errors exceed 0.1 meter.

Sounding Leads

Each survey unit should have one or more leads. Leads come in standard weights of 5, 7, 9, 14, and 25 pounds and are requisitioned from the Marine Centers. Various methods may be used to attach the lead to the lead line. The preferred method is to have a galvanized thimble at the lower end of the lead line to which the lead can be attached by a shackle.

Traditional Sounding Pole Construction

Material

A sounding pole is made from a 5-meter length of 1.5 inch- (3.81 cm) round lumber capped with a weighted metal shoe at each end to hasten sinking. Shorter poles may be used depending on the depth conditions.

Fabrication and Marking

Any convenient system of marking that is symmetrical toward both ends and will minimize reading errors may be used. The following marking system is recommended:

Mark each meter and even decimeter graduation (0.2, 0.4, 0.6, and 0.8) permanently by cutting a small notch in the pole. Paint the entire pole white, and then paint odd decimeter graduation marks black.

Verification

Sounding poles must be verified against a known standard, such as a survey quality metal tape, to ensure that depth markings are unambiguous and accurate

7.3 **Appendix 3:** Sample HSRR Memo

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Office of Coast Survey
Silver Spring, Maryland 20910-3282

XX March 20XX

MEMORANDUM FOR: Holly Day
Chief, Navigation Services Division

CAPT Earl E. Bird, NOAA
Chief, Hydrographic Services Division

FROM: LCDR Sandy C. Shore, NOAA
Commanding Officer, NOAA Ship MAY DAY

SUBJECT: NOAA Ship MAY DAY Hydrographic Systems Status Summary

The hydrographic systems of NOAA Ship MAY DAY were reviewed using the Office of Coast Survey's Hydrographic Specifications and Deliverables (HSSD) and Field Procedures Manual (FPM) Hydrographic Systems Readiness Review (HSRR) procedures in March 20XX. The review process took place in Lake Washington and Shilshole Bay in the vicinity of Seattle, WA and was conducted by a Hydrographic Systems Review Team comprised of the following people:

LT Chris P. Bacon, Operations Officer, NOAA Ship MAY DAY
LTJG Al K. Seltzer, Operation Officer in Training, NOAA Ship MAY DAY
Estelle Hertz, Chief Survey Technician, NOAA Ship MAY DAY
Dan Druff, Senior Survey Technician, NOAA Ship MAY DAY
Ella Vader, Physical Scientist, AHB

The Review Team's findings are summarized in this memorandum and reflect the condition of NOAA Ship MAY DAY systems on the review date. These findings have been divided into three categories of deficiencies:

CATEGORY 1: These deficiencies indicate the failure or absence of vital equipment or preparations of systems essential to acquisition and/or processing of hydrographic data. The vessel will be required to cease or limit hydrographic survey operations due to the following deficiencies:

1. Side scan sonar (SSS) towfish S/N 1234567 failed to detect the 1 m^3 test object nine out of 10 times during calibration. No evidence of damage was noted on the towfish. After three unsuccessful attempts to complete the SSS calibration, EEB was contacted and the towfish returned to the manufacturer for evaluation and any necessary repairs.
2. Calibration and testing of 2902's Edgetech 4125 was unable to be completed by this date. The side scan sonar cable has an inconsistent connection with the tow fish. A new cable and spare is on back order for another 6 months. The system should be tested once the cable arrives.

CATEGORY 2: These deficiencies indicate noncompliance with established policies, directives, instructions, or accepted hydrographic practice not addressed under Category 1. The following deficiencies do not prevent the field unit from conducting an efficient hydrographic survey and should be corrected in as timely a manner as funding, time, and/or professional assistance permit:

1. Conductivity, temperature, and depth (CTDs) sensor S/N 8675309 is overdue for calibration. This equipment was stored in the warehouse and was overlooked when sending the field units CTDs to the manufacture for calibration. The values output are on par with similar sensors.
2. Mr. Dan Druff had serval critical trainings required for qualifications canceled due to shipyard scheduling; including commercial driver license class A and motorboat safety. To make up this training, Mr. Dan Druff will be absent for field work later on this season (~ 6 weeks) and the field unit will require an augmenter.

CATEGORY 3: These deficiencies are associated with observations during the course of the review that merit consideration for corrective actions. These observations are included for review and dialogue related to potential problem areas and hydrographic operational efficiency. It is important to assure that resources (funds, skills, and time) are available at the operating level to meet the needs identified in this report and to sustain the efficient operation, upkeep, and repair of the field unit's hydrographic systems:

1. Due to shipyard limitations, the field units Lead Line calibration was not completed for this year. The field unit maintains the lead line calibration report from last year, and the lead line was not used over the previous field season. Lead line is not the field unit's primary source for collecting hydrographic data.
2. Due to response to travel limitations, the Field Procedures Workshop was canceled this spring. This workshop creates the ability for coworkers that work across the country to meet and build relationships. Opportunities for augmentation this upcoming field season should be recognized as beneficial, encouraged, and advocated for.