Chapter 3
Corps Accuracy Standards, Quality Control, and Quality Assurance Requirements

3-1. Purpose

This chapter contains survey accuracy, quality control, and quality assurance criteria for USACE hydrographic surveys. These criteria are intended to provide Corps-wide consistency and uniformity in performing surveys on civil works projects.

Table 3-1. Minimum Performance Standards for Corps of Engineers Hydrographic Surveys (Mandatory)

PROJECT CLASSIFICATION		Navigation & Dredging Support Surveys Bottom Material Classification		Other General Surveys & Studies (Recommended Standards)
		Hard	Soft	
RESULTANT ELEVATION/DEPTH ACCURACY (95%)				
System	Depth (d)			
Mechanical	(d<15 ft)	± 0.25 ft	± 0.25 ft	± 0.5 ft
Acoustic	(d<15 ft)	± 0.5 ft	± 0.5 ft	± 1.0 ft
Acoustic	(15>d<40 ft)	± 1.0 ft	± 1.0 ft	± 2.0 ft
Acoustic	(d>40 ft)	± 1.0 ft	± 2.0 ft	± 2.0 ft
OBJECT/SHOAL DETECTION CAPABILITY				
Minimum object size (95% confidence)		> 0.5 m cube	> 1 m cube	N/A
Minimum number of acoustic hits		> 3	3	N/A
HORIZONTAL POSITIONING SYSTEM ACCURACY (95%)		< 2 m (6 ft)	2 m (6 ft)	5 m (16 ft)
REPORTED FEATURE HORIZONTAL LOCATION ACCURACY (95%)				
Plotted depth location		2 m (6 ft)	5 m (16 ft)	5 m (16 ft)
Fixed planimetric features		3 m (10 ft)	3 m (10 ft)	3 m (10 ft)
Fixed navigation aids		3 m (10 ft)	3 m (10 ft)	3 m (10 ft)
Floating navigation aids		10 m (30 ft)	10 m (30 ft)	10 m (30 ft)
SUPPLEMENTAL CONTROL ACCURACY				
Horizontal Control		3rd order (I)	3rd order (I)	3rd order (I)
Vertical Control		3rd order	3rd order	3rd order
WATER SURFACE MODEL ACCURACY		[½ depth accuracy standard]		½ depth accuracy
MINIMUM SURVEY COVERAGE DENSITY		100% Sweep	NTE 200 ft or 60 m	NTE 500ft (150m)
QUALITY CONTROL & ASSURANCE CRITERIA				
Sound velocity QC calibration		> 2/day	2/day	1/day
Position calibration QC check		1/day	1/project	1/project
QA performance test		Mandatory	Required (multibeam)	Optional
Maximum allowable bias		± 0.1 ft	± 0.2 ft	± 0.5 ft

3-2. USACE Hydrographic Survey Accuracy Performance Standards (Mandatory)

Table 3-1 contains the most critical technical performance standards for Corps hydrographic surveying activities. These standards are mandatory for "Navigation and Dredging Support Surveys." The standards for "Other Surveys and Studies" are recommended. These standards are designed to reflect current survey instrumentation, practices, and capabilities; however, it is fully recognized that exceptions to these standards will exist for some applications, or as technological advances occur--refer to Chapter 1 for waiver procedures. These standards are considered "minimum technical performance standards" and are independent of the measurement process employed. Explanatory notes and definitions for the classifications and standards are in subsequent sections of this chapter. More detailed standards are found in other chapters covering specific instrumentation, equipment and procedures.

3-3. Accuracy, Quality Control, and Quality Assurance

The standards in Table 3-1 represent the resultant elevation (or depth) accuracies of the data set collected on a survey. Various Quality Control (QC) procedures and Quality Assurance (QA) performance tests are performed to meet and confirm these accuracy requirements. The distinction between QC and QA is important.

a. Quality control. Throughout this manual a variety of QC procedures are prescribed for survey instrumentation and data collection techniques in order to minimize systematic and random errors in individual data points. Table 3-1 only specifies general speed of sound and position QC tests. Related QC tests include: bar checks, velocity casts, patch tests, instrument alignment tests, vessel velocity limitations, multibeam beam-width restrictions, and overlapping coverage. Recommended QC procedures are contained in this manual and in equipment manufacturer's operating manuals. These recommended QC procedures are based on past experience and practices by Corps districts and should not be waived without thorough justification and analysis. Performing all recommended QC procedures does not necessarily ensure that the resultant elevation data will meet the accuracy standards in Table 3-1, as measured by a QA performance test.

b. Quality assurance. QA tests are performed to verify the survey data meets the required accuracy standard. An ideal QA procedure compares observed X-Y-Z coordinate dataset values with coordinate values obtained from an independent source of higher accuracy for the same identical points -- reference FGDC Geospatial Positioning Accuracy Standards: Part 3--National Standard for Spatial Data Accuracy. Obtaining independent, higher-accuracy test points is either impractical or impossible for most hydrographic survey data collection systems. Thus, acceptable hydrographic QA performance tests typically compare two nearly independent sets of elevation data collected over the same area. The resultant statistical comparison between the two data sets is evaluated against the required elevation accuracy in Table 3-1. If a QA test indicates data does not meet the accuracy standard, then additional or more stringent QC procedures and calibrations may be required. QA performance tests are not always feasible or practical for all survey methods -- e.g., lead line surveys -- or the results may not be definitive due to few independent depth comparisons -- e.g., single-transducer cross-section surveys. QA tests are essential for acoustic multibeam surveys and typically compare more accurate vertical beam elevations and positions against those obtained from the outer portions of the array.

3-4. Project Classifications Relative to Accuracy Standards

The accuracy performance criteria in Table 3-1 distinguish between two general classes of USACE support surveys--those performed in support of navigation and dredging projects and those supporting general engineering studies. In general, accuracy requirements are more demanding for navigation projects where ship clearance and contract dredging payment issues are especially critical. Surveys for general hydraulic engineering studies, reconnaissance, planning, etc., usually do not require the same levels of accuracy. This distinction is not entirely rigid -- specific horizontal and vertical accuracy requirements should always be assessed and defined for each project. The accuracy standards in Table 3-1 are considered "minimum" -- they may not be applicable or adequate (i.e., accurate enough) for all projects, or the horizontal and vertical accuracy requirements for a particular project are unique. For example, hydraulic sections on a small drainage project may be require ± 0.1 foot elevation accuracies but only 20 ft horizontal accuracy. In cases where these standards are considered too rigid, then waivers must be requested from HQUSACE.

3-5. Navigation and Dredging Support Surveys

This classification applies to all surveys performed in support of the Corps navigation mission. It includes both deep-draft (> 15 ft) and shallow-draft (< 15 ft) navigation projects. Types of surveys include: project condition surveys of navigation channels, dredging contract plans and specifications surveys, dredging measurement, payment, clearance, and acceptance surveys, and river charting surveys. The two distinct sub-categories are based on the characteristics of bottom conditions and the potential for navigation hazards in the project. These sub-classifications, and related accuracy standards, are intended to correspond closely with recently revised international and Federal hydrographic surveying standards for navigation projects. In effect, the survey instrumentation requirements, accuracy standards, and quality control procedures vary as a function of bottom type in a navigation channel; as does the required accuracy of dredge measurement and payment. The standards in Table 3-1 are mandatory for this class of survey.

a. Hard bottom material and/or new work. This sub-category of surveys includes those involving newly authorized navigation projects containing hard bottom material, such as rock or highly compacted material, or maintenance dredging of existing navigation projects containing hard bottom or otherwise hazardous material. This would also include recurring condition surveys of these projects. This category may also include navigation projects where low under-keel clearances are anticipated over potentially hazardous bottom conditions, hazardous cargo is transported, or where bottom sediment could adversely impact naval vessels transiting a project. Mechanical or acoustic sweep methods must be employed to ensure 100% bottom coverage in order to detect small objects remaining above the required dredging prism. The most precise carrier-phase DGPS positioning and elevation measurement techniques must be employed for this class of project. In actuality, only a small number of Corps projects fall under this category--for example, projects such as Kill Van Kull, NJ, Port of Los Angeles/Long Beach, and St. Marys River, MI. A hard bottom classification does not require *in situ* bottom density sampling but should be based on a professional geotechnical opinion given local project knowledge, historical information, and project requirements.

b. Soft bottom material and/or maintenance dredging. This sub-category of surveys is intended to cover navigation projects containing soft sand/silt bottoms not judged to be hazardous to vessel hulls; or in projects with soft, featureless, and relatively continuous channel bottoms where gaps in coverage between survey lines are unlikely to yield potential hazards/strikes. The vast majority of the Corps 926 deep- and shallow-draft navigation projects and 12,000 miles of maintained waterways fall within this category--e.g., inland and intracoastal navigation systems and most coastal harbor projects. Accuracy, QC, and QA standards are slightly relaxed for this class of projects. Vessel positioning is usually accomplished using nationwide or local DGPS -- e.g., USCG Radiobeacon System. Dredge measurement, payment, and acceptance surveys are typically performed by cross-section methods using single beam acoustic transducer systems. Acoustic multi-transducer or multibeam sweep systems may optionally be used on deep-draft projects.

c. Underwater investigation surveys. These surveys include precise investigation surveys of/around locks, dams, power plants, abutments, piers, jetties, bulkheads, and other structures. Detailed investigation surveys of hazardous objects lying within the authorized navigation prism or project depth should follow the accuracy standards prescribed for navigation and dredging surveys. If full bottom coverage and/or object detection sweeping is required, then the standards for the most precise (Hard Material) sub-category of surveys should be followed. On critical surveys, 200% acoustic coverage is usually recommended.

3-6. Other General Surveys and Studies

This category includes all other hydrographic surveys not directly associated with construction measurement, payment, and acceptance functions, or surveys not associated with a navigation project or data that is incorporated directly or indirectly into a Corps, NIMA, or NOAA navigation chart. Examples of these surveys include: general reconnaissance or planning surveys/studies, flood control project surveys, reservoir sedimentation surveys, flood plain boundary surveys, hydrological and hydraulic surveys, coastal engineering surveys, beach surveys, environmental investigations, geotechnical investigations, and disposal area surveys. The accuracy standards shown in Table 3-1 are not mandatory for this class of surveys.

3-7. Resultant Elevation/Depth Accuracy Standard

In Table 3-1, the root-mean-square (RMS) elevation accuracy performance standards are evaluated at the 95% confidence level (1.96-σ), and are specified for a reduced depth, relative to a local reference datum. An accuracy reported at the 95% confidence level means that 95% of the elevations in the dataset will have an error with respect to true ground elevation that is equal to or smaller than the reported accuracy value. It includes all propagated error components that make up a reduced elevation (i.e., local geodetic datum errors, tide/stage modeling-extrapolation-interpretation errors, dynamic-latency/roll/pitch/heave errors, acoustic measurement errors, including velocity, refraction, and beam forming errors, etc.). It also includes any horizontal errors propagated through the vessel positioning system employed (e.g., DGPS, tag line, total station). Different depth measuring systems have widely varying accuracies. Typically, mechanical and acoustic depth measurement accuracy degrades with increasing depth. Multibeam system accuracies degrade as beam angle increases. Other factors, such as tide or water surface model uncertainty, can further compound the assumed depth-accuracy relationship. The depth-dependent accuracy standards shown in Table 3-1 attempt to accommodate the differing project depths found on USACE navigation projects, and the typical survey equipment and procedures used on these projects. They also recognize that shallow-draft projects (< 15 ft) generally have more accurate tide/stage or water level surface models than deep-draft projects in coastal (tidal) areas. Likewise, deep-draft projects over 40 ft will typically have less accurate tidal modeling.

a. Mechanical depth measurement methods in less than 15 feet of water include lead line, differential leveling, total station, etc. Beyond 15 feet of depth, mechanical depth measurement accuracy significantly degrades, so these devices are now rarely used for dredging and navigation surveys in these greater depths.

b. Acoustic methods include single-transducer, multiple-transducer, or multibeam systems. Accuracy standards for project depths less than 15 feet are intended to include shallow draft or inland navigation projects where tide/stage and sea state corrections are minimal. Depths over 40 feet are intended to include coastal entrance channels or other offshore areas subject to significant tidal phase, tidal range, and sea state variations. The elevation accuracy standards are only applicable for project depths less than 80 feet or 25 m.

c. In areas with uncertain datum reference planes, undefined tidal modeling, or subject to large hydraulic grade or weather induced water surface anomalies, centimeter-level carrier-phase DGPS elevation measurements may be necessary to achieve the more stringent accuracy requirements.

d. The elevation accuracy standard is assessed by computing the standard deviation between two overlapping surveys--multibeam or single-beam cross-line check comparisons. The process is described in Chapter 4.

3-8. Horizontal Positioning System Accuracy Standard

The horizontal positioning system accuracy standards indicated in Table 3-1 are prescribed to ensure that data shown on contract drawings or river charts meet minimal feature location accuracy standards. In reality, this horizontal accuracy standard is a QC procedure in that horizontal errors propagate into the resultant elevation accuracy. The standard is a two-dimensional radial (circular) error measured at 95% confidence region accuracy, and is specified for the transducer location relative to a local project or nationwide geodetic framework. It includes all propagated error components that make up the overall position error budget (i.e., local geodetic network accuracy, electronic positioning system/DGPS accuracy, dynamic-latency/roll/pitch errors, antenna-transducer translation errors, etc.). This positioning system accuracy is not the reported horizontal accuracy of the projected depth feature--see paragraph 3-10 below. Nationwide code phase DGPS networks will generally achieve the 2-meter accuracy standard at reasonable distances from the reference station; however, in some cases, more accurate total station or carrier-phase DGPS positioning may be necessary to ensure less than 2-meter positional accuracy is consistently obtained so that a resultant feature is located within the required tolerance.

3-9. Object and Shoal Detection Standards

The performance standard is based on detection of object of cubic side dimensions indicated, using either mechanical or acoustic sweeping/scanning methods. Demonstration testing of the acoustic detection system's capability should be specified/required on critical projects. This would entail deployment of an artificial object with the required dimensions. A minimum of three acoustic returns must be received from a shoal or object to confirm its existence. These acoustic hits may be obtained on a single pass or, more conclusively, over successive passes. Reconfirmation of a strike above project grade by successive passes on different courses is strongly recommended for dredging clearance surveys.

3-10. Reported Feature Horizontal Location Accuracy

Topographic and planimetric features shown on navigation drawings or charts should be located so as not to exceed ~~to~~ the indicated accuracies in Table 3-1. Feature positional accuracies (and elevation accuracies) are estimated and reported at the 95% RMS level, and are usually averaged for a project--refer to FGDC Geospatial Positioning Accuracy Standards--Part 1: Reporting Methodology. The reported horizontal accuracy of a recorded (geospatially plotted) depth(s) should account for the various propagated error components that are contained in the positioning system and echo-sounding beam forming systems. The positional accuracy of a recorded depth will generally degrade as depth increases, and in the outermost arrays of a multibeam system. Estimating the overall (average) resultant horizontal accuracy of recorded depths is project dependent, and must factor in the overall horizontal error budget--see Chapter 4 for additional guidance. Fixed planimetric features include dredging limits, bulkheads, piers, etc. Fixed navigation aids are lighthouses, ranges, beacons, daymarks, etc. In general, code-phase DGPS accuracy is sufficient for positioning fixed navigational features. These accuracies of fixed features do not apply to design or construction of marine facilities or structures. Contract plans for such facilities require conventional topographic or photogrammetric mapping accuracies--see EM 1110-1-1000 (Photogrammetric Mapping) and EM 1110-1-1005 (Topographic Surveying).

3-11. Supplemental Control Accuracy

These standards refer to supplemental control surveys performed to extend project control for other applications. This would include control for traditional tag line or range-azimuth surveys of areas where DGPS is obscured, beach renourishment surveys, or surveys to transfer elevations to supplemental gages or staffs. Technical guidance for control surveys may be found in Chapter 11 (Accuracy Standards for

Engineering, Construction, and Facility Management Surveying and Mapping) of EM 1110-1-2909 (Geospatial Data and Systems) and EM 1110-1-1005 (Topographic Surveying).

3-12. Tidal or Water Level Surface Modeling Accuracy

These standards refer to the accuracy by which the water surface elevation is determined at the point a depth measurement is observed. Tide or stage uncertainty can often be the major error component in the resultant accuracy of an elevation measurement. It includes the precision which a tide or river stage is interpolated or extrapolated (i.e., modeled) relative to a reference gage. In areas where modeling techniques are inadequate, where the project area is distant from the reference gage, or with large tidal range and phase variations, carrier-phase DGPS techniques may be necessary to meet the required standard.

3-13. Survey Density

a. Hard Material. Full bottom coverage (i.e., 100%) may be obtained using any of the following methods: mechanical bar sweep, multi-transducer acoustic sweep, acoustic multibeam sweep, or side-scan sonar sweep. Sweep alignment may be run in any direction. Double (200%) coverage may be specified on critical navigation projects.

b. Soft Material. In soft material, either multibeam or single-beam survey systems may be used. Multibeam systems are recommended for deep-draft navigation projects. If single-beam systems are deployed, cross-section spacing shall not exceed the 200-foot standard, where cross-sections are run perpendicular to the channel alignment. 100-foot sections are recommended for most dredging measurement and payment projects. If single-beam longitudinal sections are run, additional (denser) sections shall be required along channel side slopes. Some condition surveys may not require side slope coverage. Cross-section spacing may be increased on condition surveys of shallow-draft projects containing soft, uniform bottoms. Other exceptions would include general project condition surveys of narrow intracoastal waterways or undefined river channels where longitudinal or centerline surveys are conducted for shoal investigation or reconnaissance purposes.

c. Other Surveys and Studies. Standard specified for single-beam echo sounder, cross-sections run either perpendicular to or longitudinal with the project alignment. Full coverage LIDAR or acoustic sweep systems may optionally be used if available.

3-14. Quality Control and Quality Assurance Criteria

Table 3-1 contains four of the more critical quality control and quality assurance criteria required for USACE hydrographic surveys. Other supplemental quality control calibrations required for individual system components are described in manufacturer's operation manuals and in later chapters of this manual. The QC and QA criteria listed in Table 3-1 are based on generally accepted procedures currently in practice. More detailed guidance on QC/QA tests can be found in chapters dealing with the specific survey systems.

a. Sound velocity calibrations. Sound velocities for all acoustic systems shall be observed at the minimum intervals shown in Table 3-1. Velocity measurements by bar check, ball check, and/or velocity meters are mandatory. Some equipment (e.g., multibeam) may require more calibrations than that indicated, based on QA performance results.

b. Horizontal position calibration. Criteria are specified for local or regional code or carrier phase DGPS positioning system. Generally, only a position verification (i.e., blunder) check is required, either at known project control point or from redundant USCG beacon positions. Other positioning systems require more demanding calibrations, as indicated in subsequent chapters.

c. Quality assurance performance test. QA performance tests shall be performed in order to verify compliance with the depth accuracy standard. Performance tests are required for multibeam systems and are optional (but recommended) for single-beam systems. Procedures and criteria for QA performance tests are found under the chapters covering single-beam, multiple-transducer, and multibeam systems.

d. Maximum allowable bias. The maximum bias between two surveys is indicated in Table 3-1. This bias is determined by computing the mean difference between two overlapping surveys--multibeam or single-beam cross-line check comparisons.

3-15. Related Standards

Following is a list of international, Federal, and USACE standards that may have application to navigation data collected on Corps projects. Additional standards are listed in Chapter 6.

a. EM 1110-1-2909 (Geospatial Data and Systems), Chapter 11 (Accuracy Standards for Engineering, Construction, and Facility Management Surveying and Mapping). This chapter of EM 1110-1-2909 provides technical guidance on engineering surveying and mapping accuracy standards used in engineering and construction. It is intended for use in developing specifications for geospatial data used in various project documents, such as architectural and engineering drawings, master planning maps, construction plans, navigation project condition charts and reports, and related GIS, CADD, and AM/FM products.

b. FGDC Geospatial Positioning Accuracy Standards, Part 3: National Standard for Spatial Data Accuracy. This FGDC standard is used to evaluate and report the positional accuracy of spatial data produced, revised, or disseminated by or for the Federal Government. According to Executive Order 12906, Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure, *"Federal agencies collecting or producing geospatial data, either directly or indirectly (e.g. through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the FGDC process."* Related FGDC standards include:

(1) FGDC Standards for A/E/C Surveys. Federal Geographic Data Committee (FGDC)**,** Facilities Working Group, Geospatial Positioning Accuracy Standards PART 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management. This standard is currently in draft form. The Corps of Engineers (HQUSACE) was the primary developer for this standard; thus it reflects most Corps civil works and military construction activities. It provides recommended accuracy tolerances for site plan mapping supporting engineering and construction. It also contains recommended control survey accuracy standards for these projects. Its application to hydrographic surveying would be depiction of topographic and planimetric detail adjacent to projects.

*(*2) FGDC Standards for Nautical Charting Surveys. Federal Geographic Data Committee (FGDC)**,** Bathymetric Subcommittee. Geospatial Positioning Accuracy Standards PART 5: Standards for Nautical Charting Hydrographic Surveys, (July 2000 Draft). This document provides minimum standards for the horizontal and vertical accuracy of features associated with hydrographic surveys that support nautical charting. Such features include, but are not limited to, water depths, objects on the seafloor, navigational aids, and shoreline. The scope of these standards includes the coastal waters of the U.S. and its territories. A copy of the latest draft (July 2000) of this standard is at Appendix B.

c. International Hydrographic Organization (IHO) Standards for Hydrographic Surveys. Special Publication No. 44, Fourth Edition, Monaco, (1997 Draft). IHO is an intergovernmental consultative and technical organization working to support the safety of navigation and the protection of the marine environment. The purpose of this standard is to specify minimum criteria for hydrographic surveys in order that hydrographic data collected is sufficiently accurate and that the spatial uncertainty of data is adequately quantified to be safely used by mariners (commercial, military or recreational) as primary users. The FGDC Part 5 standard at Appendix B was taken directly from this IHO standard. Therefore, these two standards are nearly equivalent.

d. FGDC Bathymetric Subcommittee. National Hydrography Data Content Standard for Coastal and Inland Waterways – January 2000 (Draft). This document contains a catalog of hydrographic feature terms and definitions pertaining to navigation of coastal and inland waterways, as they relate to charting and electronic chart display applications. The standard does not address data distribution formats, extraction criteria, or accuracy reporting methods beyond inland and coastal waterways. This standard does not currently address hydrographic symbology. However, in future versions/releases it is planned to add standard symbology information. A copy of the latest draft of this standard is at Appendix C.

e. International Hydrographic Organization's S-57 (IHO S-57) Appendix A, Object Catalog for Digital Hydrographic Data.

f. National Institute of Standards and Technology, Federal Information Processing Standard Publication 173 (Spatial Data Transfer Standards), U. S. Department of Commerce, 1992.

g. North Atlantic Treaty Organization's (NATO) Digital Geographic Information Exchange Standard (DIGEST) Part 4, Feature Attribute Coding Catalog (FACC). This is a comprehensive coding scheme for features, their attributes and attribute. This allows for joint naval operations between sovereign countries and requires naval personnel to have familiarity amongst traditional S-57 and FACC.

h. CADD/GIS Technology Center *(Tri-Service) Spatial Data Standard (SDS).* Primarily used for civil and military installation mapping and facility management.

i. U.S. Army Corps of Engineers (USACE) Regional Engineering and Environmental Geographic Information System (REEGIS). A data dictionary for inland waterways developed by the Mississippi Valley Division for engineering, navigation and flood control structures along the Mississippi River.

3-16. Mandatory Requirements

Mandatory Corps accuracy standards, QC criteria, and QA requirements are identified in Tables 3-1 and in subsequent explanatory paragraphs in this chapter.