CHAPTER 3

Survey Accuracy Standards and Procedures for Connecting Projects to the National Spatial Reference System

3-1. General. As outlined in Chapter 1, the designed, constructed, and maintained elevation of a project must be referenced to a consistent framework, or vertical datum. References to two primary and distinct reference datums are required:

a. Hydraulic or Water Level Datums. Water surface elevation relative to a locally defined hydraulic reference plane on a river, pool, lake, or tidal body, from which flood protection design elevations or navigation grades are derived.

b. Geodetic or Orthometric Datums. Three-dimensional horizontal and vertical frameworks defined relative to a federally recognized terrestrial and/or extraterrestrial (satellite-based) reference datum.

Throughout the life cycle of a project, these two reference datums must be accurately established, maintained, and defined relative to "Permanent Bench Marks" (PBMs) established at each project site, hereinafter termed “Primary Project Control Points" (PPCP). Supplemental, or "Local Project Control Points" (LPCP), and "Temporary Bench Marks" (TBM) used for construction orientation and grade, are established from these PPCPs. These PPCPs must be firmly connected to nationwide vertical reference frameworks—the NSRS, in coastal regions the NWLON, and defined datums in OCONUS areas. The following paragraphs in this chapter provide guidance on establishing PPCPs and LPCPs at each project site.

3-2. Definitions. The following definitions apply to terms used in this and subsequent chapters.

a. Geodetic Surveying. Survey measurements performed to relate project features to a nationwide reference datum (i.e., the NSRS), typically using static GPS observations over long baselines or precise geodetic differential leveling methods. Geodetic surveys discussed in this guidance are performed for nationwide geospatial reference purposes only; they are not applicable to local project design and construction surveys outlined in the next paragraph.

b. Topographic or Engineering and Construction Surveying. Surveys used to set project control monuments on levees and related flood protection structures, topographic surveys for planning and design, construction stake out, levee cross-sections, levee profiling, etc. Engineering and construction surveys are performed using total stations, differential levels, and/or GPS/RTN methods; following the techniques outlined in EM 1110-1-1005 (*Control and Topographic Surveying*). Procedures and accuracies generally follow "Third-Order" methods described in that manual. These surveys, or fixed control monuments/bench marks established therefore, are usually not included in the NSRS; however, there may be exceptions.

c. Primary Project Control Points (PPCP). Bench marks set on or near a project that are connected with and published in the NSRS, and are used to densify local project control monuments or develop project features. These NSRS bench marks may be established by the NGS, USACE, or other agencies. Each USACE project and water level gage should have at least one PPCP.

d. Local Project Control Points (LPCP). Monuments (PBMs, TBMs, hubs, etc.) used to reference project features, alignment, elevations, or construction. Monuments may be atop levees (e.g., PBMs set at levee sector "points of intersection" or PIs) or offset to the levee alignment. These monuments will usually have local X-Y-Z (SPCS) coordinates along with local project station-offset coordinates. LPCPs are usually not part of the published NSRS; however, they should be directly established from or relative to a PPCP described above. A minimum of three project control bench marks (PPCPs and/or LPCPs) are required for advertised construction plans and references to water level gages.

e. Project NSRS Network Accuracy. This refers to the spatial accuracy of a project's PPCP relative to NSRS points (bench marks) in the nearby geographical region. NSRS regional network accuracy is significant in defining relative orthometric and hydraulic gradient relationships between river gages or tidal gages. It is also significant in defining accuracy relationships between elevations of points established by various federal, state, or local agencies. The NSRS network accuracy is NOT significant or applicable to local project construction stakeout—see "Local Network Accuracy" below. Depending on the type of project and surrounding terrain gradients, required NSRS network elevation accuracies may range from ± 0.1 ft to ± 1 ft. The USACE has adopted a nominal NSRS accuracy standard of ± 0.25 ft.

f. Local Network Accuracy. (Engineering and construction accuracy). Spatial accuracy of a LPCP or project features relative to nearby local reference monuments on the project. Local project accuracy is critical for construction with X-Y-Z tolerances at the ± 0.05 ft level. Local accuracy tolerances are always much smaller than NSRS network accuracy tolerances.

g. Survey Accuracy Standards. Specified target positional accuracy tolerances for a project control monument/bench mark or other project feature (e.g., levee profile, intake structure, inverts, top of floodwall, ground shots).

h. Survey Specifications. Survey procedures and equipment requirements.

i. Uncertainty. The propagated network, instrumentation, and observation errors on a surveyed PBM or feature elevation. Roughly synonymous with "project" and "local" accuracies described above. Refer to Chapter 9 for a more detailed discussion of propagated elevation uncertainties on levee grades or navigation projects.

j. Global Positioning System (GPS) Surveys. "GPS surveys" referenced in this manual imply differential carrier phase GPS baseline measurements—also termed "DGPS" surveys. Code phase GPS or autonomous GPS positioning accuracies are not suitable for project control. A number of DGPS survey methods may be employed in establishing project control, variously termed "Static DGPS Baselines," "Real Time Network" (RTN), "Real Time Kinematic" (RTK),

"Post-Processed Kinematic" (PPK), and "Virtual Reference Network" (VRN). Refer to EM 1110-1-1003 (*NAVSTAR GPS Surveying*) for details on performing these carrier phase DGPS surveys.

k. Continuously Operating Reference Stations (CORS). The NGS coordinates a GPS network of over 1,400 Continuously Operating Reference Stations (CORS) throughout North America and over 1,800 worldwide, as of 2010. Each CORS site provides GPS carrier phase and code range measurements in support of three-dimensional positioning activities throughout the United States and its territories. The CORS system enables relative positioning accuracies to better than 0.25 ft relative to the NSRS, both horizontally and vertically.

l. Online Positioning User Service (OPUS). OPUS is an interactive/Internet-based NGS software system that processes static GPS baselines relative to the CORS. It provides near real-time X-Y-Z coordinates relative to the NSRS. OPUS processes GPS data files with the same models and tools which help manage the CORS network, resulting in "CORS/OPUS" coordinates which are both highly accurate and highly consistent with other users. A computed "CORS/OPUS" NSRS position on a bench mark can also be shared publicly via the NGS/NSRS database. Planned upgrades to OPUS may allow merging CORS baselines with conventional GPS network, topographic, and/or differential leveling observations.

3-3. Distinction between NSRS Control and Local Project Control.

a. Project control. A critical distinction must be made between:

(1) Geodetic Control. The regional “geodetic survey" process of referencing USACE project elevations to NAVD88 or NAD83 relative to nearby points on the NSRS (PPCP), and

(2) Local Engineering & Construction Control. Engineering and construction surveying requirements necessary to design, align, stake out, and construct a local flood or water control structure, a HSPP, or a navigation project relative to local project control (LPCP).

b. Control accuracy. Figure 3-1 illustrates the distinction between NSRS network and local project control accuracies. The PPCP has been connected to other adjacent points in the NSRS to an accuracy of ± 0.22 ft. This “NSRS Network Accuracy” is based on the adjustment statistics from the point’s connection, such as GPS baseline reductions, differential leveling loop closures, etc. The adjusted NSRS elevation of 298.72 ft is assumed absolute and is used to establish elevations on the two levee LPCP monuments shown in Figure 3-1. The elevations of these levee LPCPs may be determined by various topographic survey methods—levels, DGPS, RTN, RTK, or total station. Figure 3-1 depicts dashed lines from the PPCP to each local control PBM at Station 0+00 and Station 15+72.4; indicating GPS surveys were used to obtain elevation differences over each baseline. Given observed differential elevations over each baseline from the PPCP to Stations 0+00 and 15+72.4, NAVD88 elevations are transferred to these local monuments. Due to error propagation, these local LPCP elevations have a slightly larger NSRS “network” accuracy than the PPCP. However, their “Local Network Accuracy” of ± 0.1 ft is based on the observed GPS baseline closure accuracies. Had differential levels been run along the levee between stations 0+00 and 15+72.4, then the level misclosure would give an indication

of the relative accuracy. The LPCPs thus have both a local (relative) accuracy needed for construction and a NSRS network accuracy needed for regional engineering and mapping purposes. These resultant local and network accuracies may also be termed "uncertainties."

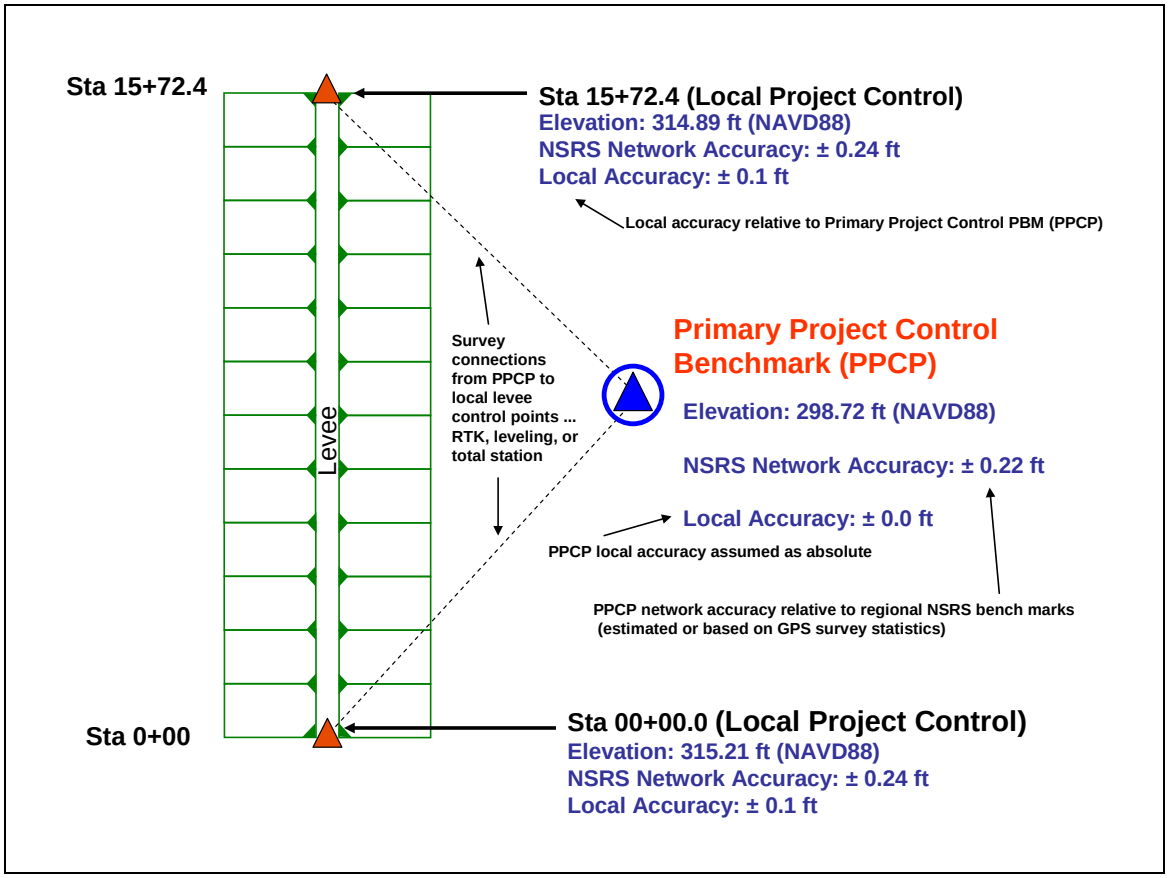


Figure 3-1. Distinction between Primary Project Control and Local Project Control points on a simple levee segment-- Network and Local Accuracies.
(Hydraulic stage or tidal datum relationships not shown)

c. Control survey method. The survey method used to connect local project control PBMs and TBMs is dependent on the accuracy requirements of the project. DGPS, RTK, or RTN methods (generally accurate to ± 0.1 ft) will normally suffice for design and construction of most USACE civil works projects. More accurate differential leveling may be required for water control structures, locks, dams, floodwalls, etc. If the above distinction between local and network project accuracies is not clearly understood, then unnecessary USACE resources may be expended performing higher accuracy “geodetic” surveys to achieve elevation accuracies that have no hydrologic or hydraulic engineering requirement; either within USACE or in conjunction with other agencies.

d. Control database. The "USACE Survey Monumentation Archival and Retrieval Tool" (U-SMART) database options allow linking PPCPs with LPCPs on a specific USACE flood risk management or navigation project. Details on U-SMART are discussed in Section 3-13.

3-4. Recommended Accuracy Standards for USACE Project Control. PPCP connections to the NSRS are made by field survey techniques—typically by traditional differential leveling or by differential GPS height observations between published NSRS PBMs and PPCPs.

a. PPCPs must be geospatially referenced such that designed protection elevations are:

(1) Consistent with federally mandated vertical datums (e.g., NAVD88, IGLD85).

(2) Consistent with federally mandated horizontal datums (e.g., NAD83).

b. The minimal accuracy standards in Table 3-1 apply to USACE PPCPs that are established relative to the regional NSRS network; that is these PPCPs are directly connected by differential leveling and/or GPS baselines to nearby NSRS points. These NSRS connection observations to PPCPs shall be submitted to NGS for inclusion in the NSRS. These are minimal accuracy standards that are believed adequate for most inland flood risk management and coastal projects. The accuracy standards in Table 3-1 do NOT apply to supplemental LPCPs, topographic, or construction surveys conducted from these primary points—see paragraph 3-3 on the critical distinctions between "primary" and "local" project control.

Table 3-1. Recommended Minimal or Target Accuracy Standards for Connecting Primary Project Control Points on USACE Projects to the US Department of Commerce NSRS Network.

	NSRS Accuracy (95%) [1]	Reference Datum (CONUS)
Vertical	± 0.25 ft (± 8 cm)	NAVD88
Horizontal	± 2 ft (± 60 cm) [2]	NAD83

[1] Accuracies are at the 95% confidence level relative to regional points published by NOAA on the NSRS.
[2] Horizontal accuracy is for global reference purposes—achievable DGPS derived accuracies are currently ± 0.2 ft typical.

c. These NSRS network accuracy standards at the ± 0.25 ft level are believed to be representative of the nominal accuracy requirements for the vast majority of USACE levee systems and related water control projects. These accuracies should support flood forecasting models, stage-discharge relationships, flood inundation modeling, channel design, levee freeboard design, risk assessment, and related river hydraulics work. Additional details on evaluating project accuracy requirements are covered in later sections of this chapter.

d. There may be levee or river segments where these standards are either too rigid or perhaps require tightening, as might be the case in high subsidence regions. This decision on the required project accuracy should be left to those performing hydrology and hydraulics studies over a watershed or flood risk management region. If such technical guidance is not available, then the criteria in Table 3-1 may be used by default. If more rigid accuracy standards are required, then refer to the guidance in Chapter 8.

e. It is also essential that the required survey accuracy be derived from realistic engineering applications associated with a flood risk management system or project. This is best summarized in Appendix A of FEMA's "*Guidelines and Specifications for Flood Hazard Mapping Partners*" (FEMA 2003) which emphasizes the need for establishing reasonable map accuracy and resolution specifications for flood insurance studies:

> *"The specified accuracy of FIRM work maps produced by Mapping Partners must be sufficient to ensure that the final FIRMs produced by FEMA can be reliably used for the purpose intended. However, the accuracy and resolution requirements of a mapping product must not surpass that required for its intended functional use. Specifying map accuracies in excess of those required results in increased costs, delays in project completion, and reduction in the total numbers of new or revised products that the Mapping Partner may generate. Mapping accuracy requirements must originate from functional and realistic accuracy requirements."*

The above statement makes it imperative that the project's functional and realistic accuracy requirements be defined based on the requirements of a flood system profile model or navigation project model. Once the functional accuracy requirement is defined, USACE surveyors can then define the appropriate survey specifications needed to meet that accuracy.

f. The required NSRS network accuracy of a primary or local project control point (and indirectly to any topographic feature on the project, such as a levee crest, floodwall cap, pump station invert, etc.) is also determined by the engineering requirement for regional consistency between these points. These regional network accuracy requirements relative to the NSRS may be contingent on compliance with one or all of the following:

(1) USACE, USGS, FEMA, NOAA or other agency hydrologic or hydraulic analyses, models, or water surface profiles between and within large river reaches/basins and river stage gages.

(2) USACE/FEMA/other flood inundation mapping study accuracies.

(3) Consistency with FEMA flood insurance study accuracies performed under FEMA's National Flood Insurance Program (NFIP)—Flood Hazard Maps, (Digital) Flood Insurance Rate maps (FIRM/DFIRM), etc.

(4) Consistency with Federal mapping accuracy standards in the project area—e.g., USGS.

g. NSRS network horizontal accuracy standards (± 2 ft) in Table 3-1 are obviously not critical for hydraulic engineering purposes. This nominal horizontal standard can be easily exceeded with minimal observation times using various DGPS methods. This would be done in cases where recovered bench marks do not have a horizontal position. When static DGPS observations are conducted at a point for elevation determination, horizontal accuracies relative to the NSRS will usually be around the ± 0.2 ft level.

3-5. FEMA Accuracy Standards for Flood Insurance Rate Maps. Since regional conformance with FEMA NFIP studies is an essential goal of any USACE flood risk management project and/or study, both USACE and FEMA must be on the same vertical datum—i.e., NSRS NAVD88—or, at minimum, have a firmly established relationship between different vertical datums. FEMA standards and specifications clearly detail this intent. Tables 3-2 and 3-3, taken from Appendix A (*Guidance for Aerial Mapping and Surveying*) of FEMA's "*Guidelines and Specifications for Flood Hazard Mapping Partners*" (FEMA 2003), illustrate the required FIRM/DFIRM accuracy requirements relative to the NSRS. In summary, FEMA NSRS regional elevation accuracy standards are (1) standard 2-foot equivalent contour interval accuracy ($Accuracy_z$ = 1.2 foot) appropriate for flat terrain, and (2) standard 4-foot equivalent contour interval accuracy ($Accuracy_z$ = 2.4 foot) appropriate for rolling to hilly terrain. In effect, USACE flood protection structure elevations should have relative NSRS regional network accuracies at or better than the above tolerances in order to be consistent with FEMA flood insurance studies, FIRMs, DFIRMs, etc. The USACE control survey standards and specifications in this guidance document will yield NSRS network accuracies well within these FEMA NSRS accuracy standards. These more precise USACE accuracy standards result from more rigorous hydraulic engineering and levee design requirements than those needed for NFIP studies.

Table 3-2. FEMA Vertical Accuracy Standards. (FEMA 2003)

NMAS Contour Interval	NMAS VMAS 90%	NSSDA $Accuracy_z$ 95%	NSSDA $RMSE_z$	ASPRS 1990 Class 1/2/3 Limiting $RMSE_z$
2 Foot	1 ft	1.2 ft	0.6 ft (18.5 cm)	0.7 ft (Class 1) 1.3 ft (Class 2) 2.0 ft (Class 3)
4 Foot	2 ft	2.4 ft	1.2 ft (37.0 cm)	1.3 ft (Class 1) 2.7 ft (Class 2) 4.0 ft (Class 3)

Table 3-3. FEMA Horizontal Accuracy Standards. (FEMA 2003)

NMAS Map Scale	NMAS CMAS 90%	NSSDA Accuracy $_r$ 95%	NSSDA RMSE $_r$	ASPRS 1990 Class 1/2/3 Limiting RMSE $_r$
1 " = 500 ft	16.7 ft	19.0 ft	11.0 ft	7.1 ft (Class 1) 14.1 ft (Class 2) 21.2 ft (Class 3)
1 " = 1,000 ft	33.3 ft	38.0 ft	22.0 ft	14.1 ft (Class 1) 28.3 ft (Class 2) 42.4 ft (Class 3)
1 " = 2,000 ft	40.0 ft	45.6 ft	26.3 ft	28.3 ft (Class 1) 56.5 ft (Class 2) 84.9 ft (Class 3)

3-6. USGS National Map Accuracy Standards. USGS topographic maps at 1:24,000 (1” = 2,000 ft) are generally designed to be accurate to one-half the contour interval on the map. Thus, for a standard 2 ft contour map, the estimated vertical accuracy is ± 1 ft (at a 90% confidence). The horizontal accuracy is specified at 1/30th of the scale, or ± 67 ft for a 1 in. = 2,000 ft (7.5 minute) quadrangle. The targeted NSRS network accuracy standards performed under this guidance will significantly exceed these USGS mapping accuracy standards.

3-7. Local Topographic, Engineering, and Construction Survey Accuracy Standards. Local levee alignment LPCP bench marks (e.g., PIs, PTs, PCs, gage references, etc.) and topographic features (levee profiles, cross-sections, etc.) should be positioned relative to the nearest PPCP that has been referenced to the NSRS. This PPCP(s) may be a published NGS bench mark or a USACE monument that has been connected to (and input into) the NSRS. These local project control surveys will typically be performed over short distances—for example, within range of an RTK base station, within the coverage of a GPS Real Time Network (RTN), or within a reasonable distance for differential leveling or total station observations. Field survey procedures will follow engineering and construction survey guidelines in EM 1110-1-1005 (*Control and Topographic Surveying*). Recommended survey accuracies of feature points are listed in Table 3-4.

Table 3-4. Recommended Local Project Elevation Accuracies for Flood Risk Management Project Features.

	Relative Accuracy (95%)	Reference Datum
Levee or floodwall control bench marks:	± 0.15 ft	NAVD88/NAD83
Hard topographic features:	± 0.3 ft	NAVD88/NAD83
Ground shots:	± 0.5 ft	NAVD88/NAD83
Construction stake out	± 0.01 to 0.05 ft	Local site
General floodplain mapping (GIS)	± 0.5 to 2 ft	NAVD88/NAD83

NOTES:

Local project control will typically have two horizontal references: (1) a local SPCS system, and (2) the construction station/chainage-offset system.

The above accuracies are not relative to the regional NSRS but are for local topographic and construction purposes. Elevations are reported relative to NSRS vertical datum.

The latest geoid model published by NGS will be used to estimate and correct local geoid undulations for all topographic densification using RTK/RTN methods. At longer distances greater than 3 miles from the RTK base, frequent calibration check points are recommended if a standard RTK/RTN site calibration/localization process is not feasible—see EM 1110-1-1005.

a. Local horizontal accuracies should generally be within the tolerances for vertical accuracies shown in Table 3-4. When using RTK/RTN methods, the horizontal accuracies will be slighter better—and over current RTK/RTN application distances, a ± 0.1 ft (± 3 cm) local relative accuracy should be achieved at any type of point located (assuming appropriate site calibration procedures are followed). For example, the horizontal distance between two levee PIs 2,000 ft apart will be accurate horizontally to the ± 0.1 to 0.2 ft level when these points are connected using either RTK/RTN or total station EDM observations, and usually better than ± 0.05 ft vertically when differential levels are run. These local (relative) accuracy levels are sufficient for any levee stationing stake out needed for construction or maintenance grading. Thus a PI monument will have a local project stationing-offset and elevation coordinate for maintenance and construction, and will also be referenced to the NSRS (NAD83 and NAVD88) for regional mapping orientation purposes.

b. As illustrated on Figure 3-1, NSRS network accuracies of any local bench mark (LPCP) or feature point will be slightly larger than the accuracy of the controlling (primary) NSRS bench mark—due to error propagation in the survey process. For example, if an RTK base is set over a NGS NSRS network point with an established (estimated or published) NSRS "network" accuracy of ± 0.22 ft, and a local project bench mark atop the levee on a PI is shot in with an estimated RTK "precision" of ± 0.1 ft, then the estimated (propagated) accuracy of the PI bench mark is roughly ± 0.24 ft— as computed from $[0.22^2 + 0.1^2]^{1/2}$. If this PI point is later occupied with an RTK base to cut in hard levee features or levee crest ground profiles, then the estimated (propagated) accuracy of these elevations would be roughly ± 0.26 ft relative to the regional NSRS—i.e., $[0.24^2 + 0.1^2]^{1/2} = \pm 0.26$ ft.

3-8. Hierarchy of Preferred Survey Methods for Establishing New Primary Bench Marks Relative to the NSRS. Published NSRS bench marks of Second-Order or higher order should be used as PPCPs when they are on or near a project. When no existing (or published) NSRS vertical control is available near the project, PPCPs must be set to an established density, accuracy, and observing specification. Newly established project control must also be published in the NSRS by forwarding geodetic observations and descriptive data to the NGS. The essential purpose for establishing this primary control is to provide assurance that navigation grades and flood protection structure elevations measured from these PPCPs will be adequately referenced to the NSRS (currently NAVD88). A variety of survey procedures may be used to establish new PPCPs. Table 3-5 details a hierarchy of survey methods by which project elevations and grades can be connected to the NSRS (and the NWLON if applicable). The order of preference in Table 3-5 is somewhat dependent on the mechanism for inputting data to the NSRS—item [II] being the simplest, and [III] and [IV] currently being the most difficult.

a. Preferred survey method. The survey method chosen from the Table 3-5 will have a major impact on the amount of field effort and cost. Preference [I] obviously requires minimal field work other than verifying the current adequacy and stability of the existing NSRS bench mark. The "CORS/OPUS method"—Preference [II]—at a new PPCP can be performed for economically using a one-man survey crew and OPUS-based software to input the data to the NSRS. Positioning this same point by NSRS networked baseline connections—Preference [III]—would require a 3- to 4-man survey crew. If Blue Book techniques are used to input this data into the NSRS, the total cost to establish this point could be 5 to 10 times the cost of Preference [II]. This cost will be significantly reduced when NGS develops software to replace the Blue Book. Differential leveling ties —Preference [IV]—will be cost-effective only over short lines where Third Order closure tolerances can be maintained. They will also require connections with at least two or more published NSRS bench marks. Higher-order instrumentation and procedures will be required over longer lines, significantly increasing field effort. Inputting level line data into the NSRS via Blue Book methods also requires significant administrative effort—the cost of which may exceed the cost of the field work for short lines. NGS is developing software that allows simplified input of leveling data to the NSRS. From the above, it is obvious that effort should be made to locate and utilize existing NGS NSRS vertical control as PPCPs—and establish as few as possible new points. When new primary points must be set, CORS/OPUS methods [II] should be used to the maximum extent possible.

Table 3-5. Preferred Hierarchy of Survey Methods for Establishing New PPCPs Relative to the NSRS.

Order of Preference	Survey Method	NSRS Input Method	Notes
[I]	Use existing NSRS control	not applicable	NSRS check surveys only
[II]	GPS: CORS/OPUS	OPUS input [1]	Restricted to CORS within 200 miles
[III]	GPS: Networked baselines to nearby NSRS marks if CORS/OPUS solutions cannot be performed	Blue Book or OPUS input [1]	Include any CORS baselines in adjustment
[IV]	Differential Leveling from NSRS points	Blue Book or OPUS input [1]	Setting primary points at levees or gages

[1] Various NSRS input methods via OPUS-based solutions are being developed by the NGS. Monitor NGS websites for the current versions of OPUS data input techniques to the NSRS.

b. PPCP coverage density. The density, or spacing, of PPCPs that are directly connected to the NSRS will vary with the geographic extent and type of project. Ideally, a PPCP PBM should be located as close as possible to the project—preferably on one of the project's reference PBMs. In general, each project should have at least one PPCP relatively close to the project and a published PPCP reference bench mark a short distance (< ¼ mile to minimize number of level setups) from a river or tide gage.

(1) Levee projects. Any suitable existing levee control monument may be used as a new PPCP. For extensive levee segments, PPCPs spaced every 15 to 20 miles will generally provide adequate coverage from which to perform any non-NSRS supplemental control observations to LPCPs needed to survey levee grades and features relative to NAVD88, such as by observing RTN/RTK or static DGPS baselines between the PPCP and the LPCPs. For projects that require

multiple PPCPs, the relative accuracy between PPCPs should adhere to the local survey accuracy requirements. Additional details on PPCP density requirements for large levee systems are covered in Chapter 6.

(2) Navigation and HSPP projects. Navigation projects should have a PPCP located as close as possible to the project since that PBM will likely be used for controlling surveys, grading, and dredging operations with RTN/RTK machine control techniques. Ideally a NOAA tidal PBM near the project site is designated as the PPCP and is used as both an RTK base and tidal calibration point. See Chapters 4 and 5 for details on establishing PPCPs on coastal projects.

c. Real Time Networks (RTN). Expanding use of RTN coverage throughout CONUS significantly minimizes the need for a dense network of PPCPs and LPCPs on project sites. Given most RTNs are directly referenced to the NSRS CORs stations, they are, in practice, a "PPCP," requiring only a sparse network of local PPCPs and/or LPCPs for site calibration of the RTN. RTNs, and successor GNSS technologies, are expected to eventually replace the need for monumented NSRS PPCPs; however local LPCP networks will likely still be required for construction site calibration and boundary referencing.

3-9. Preliminary Evaluation of Existing Project Control. For each project, a preliminary evaluation of the acceptability and reliability of existing project control and their reference datums must be made.

a. For example, the main issues to be evaluated for a project would include:

(1) That protection grade elevations are referenced to NAVD88 based on PPCPs published in the NSRS.

(2) That river gages owned and/or operated by the Corps (or other agency gages used by USACE) are referenced to NAVD88 based on control bench marks published in the NSRS, and that the relationship between the geodetic and hydraulic datums at the gage are firmly established and documented.

(3) That project drawings, CADD files, and related documents, contain full and complete metadata on PPCPs and LPCPs, and the relationship between the geodetic and hydraulic datums and any associated legacy datums.

b. Upon completing a preliminary evaluation for each project, it may be determined that no additional field survey work is required for connection to the NSRS. This would include:

(1) Projects that have been recently connected to the NSRS, such as those that were included in a NGS Height Modernization project.

(2) Projects with control firmly surveyed on NGVD29 and directly leveled to NSRS points that were subsequently readjusted to NAVD88.

(3) Projects that were recently connected to the NSRS by local sponsors, levee boards/districts, State DOT, or other local agency, but connections were not published in the NSRS.

c. If the initial assessment determines that the project datum is not referenced to the current NSRS, and a required accuracy tolerance is established, then the amount of field survey effort involved will be largely governed by the following factors:

(1) Availability, acceptability, and accessibility of existing (published or unpublished) vertical control in the region, including RTN networks.

(2) If GPS survey observations are required, the ability to use a CORS/OPUS elevation determination in lieu of observing extensive DGPS static baseline networks.

(3) Availability of expedited procedures for submitting bench mark descriptions and elevation data into the published NSRS, such as OPUS-based input methods.

d. The following paragraphs provide guidance on estimating the field survey scope required that will be needed to update a project datum to NAVD88 and, where applicable, publish the PPCP(s) for a project on the NSRS. These sections relate to the preference options listed in Table 3-5.

3-10. Utilizing Existing NSRS Control for USACE Primary Project Control PBMs. If published NSRS vertical control (Second Order or better) is available on or near a project, and at a density (spacing) adequate for supplemental topographic or geodetic surveying purposes (ideally well less than 15 miles distant from the project site, depending on available methods for surveying supplemental LPCPs), then there is effectively no need to establish a new NSRS primary project control reference point. These existing NSRS bench marks can be used to survey NAVD88 elevations on local control points (LPCPs) at the project site or to perform topographic or hydrographic survey operations—using standard topographic or geodetic survey methods, such as short-term static DGPS baseline observations, RTN/RTK techniques, differential leveling, total station traverse, etc. Optionally these LPCPs can be classified as PPCPs if they are positioned using one of the techniques listed in Table 3-5. The published NGS data for a PBM will be accepted as reliably connected to the NSRS after checks into one or more surrounding NSRS points. In effect, bench marks published by NGS on the NSRS will be accepted at "face value" after verification. If the NSRS bench mark does not have a horizontal position, this can be quickly obtained by a short-term CORS/OPUS observation. General criteria are shown in Table 3-6.

a. A recovered NGS NSRS bench mark will have some elevation uncertainty relative to the nationwide NSRS. Given limited USACE resources, it is not the intent of this guidance to investigate and minimize these published NSRS bench mark inaccuracies. It should be noted that existing NSRS bench mark elevations may have a greater relative uncertainty than elevations determined by height reductions based on recent GPS/CORS observations. In time, it is anticipated that all primary bench mark elevations will be observed and monitored relative to the nationwide CORS network.

Table 3-6. Recommended Criteria when Utilizing Published NSRS Control as the PPCP.

Check validity of published elevation	Yes
Nearby NSRS bench mark elevation check points	At least one – two recommended if feasible
Check survey tolerance between NSRS bench mark elevations	± 0.1 ft (± 3 cm) [1]
Survey elevation check methods	RTN/RTK, CORS/OPUS, differential levels, total station
NSRS input of check surveys	No
Recovery note on NSRS bench mark	Recommended—submit on-line to NGS or U-SMART
Horizontal position on vertical bench mark	Short term (< 2 hours) OPUS observation

[1] The acceptable tolerance between NSRS bench marks is project and site dependent, age of the marks, etc. Higher tolerances may be justified in some instances—use engineering judgment in determining acceptable tolerances.

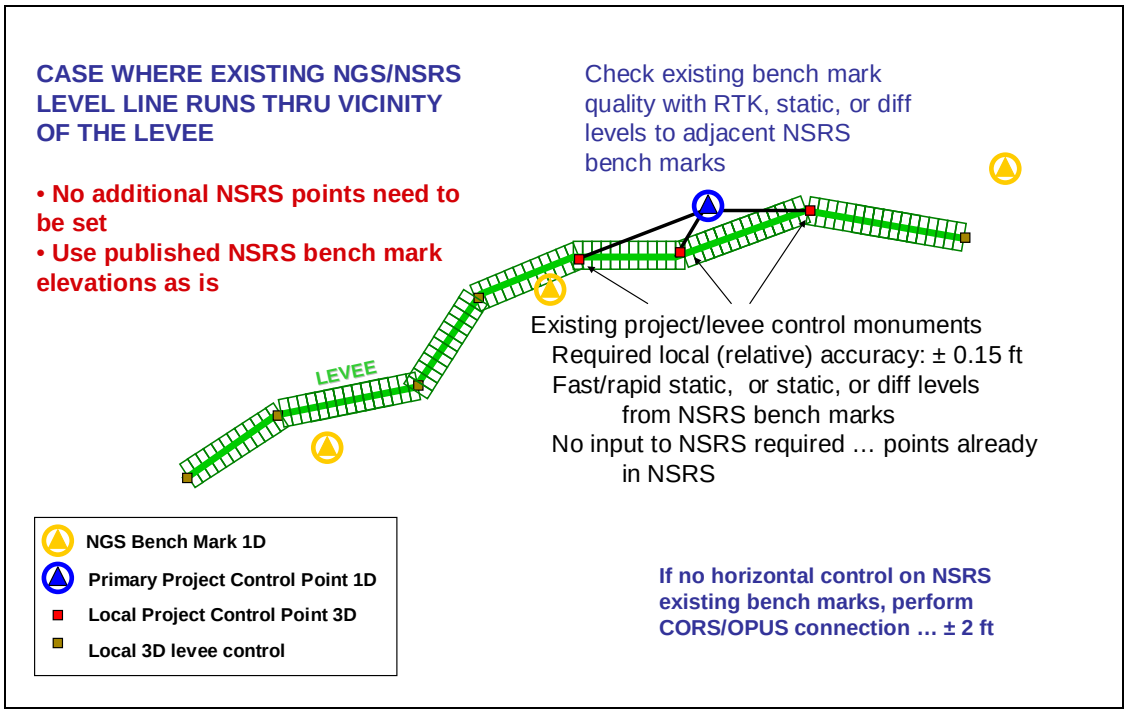


Figure 3-2. Published NSRS control within a levee project.

b. To illustrate a case where existing NSRS control can be used, Figure 3-2 shows a published NSRS line of levels running through a levee segment. In this case, the published NGS bench mark elevations will be accepted as the PPCP, and will be directly used for referencing NAVD88 elevations to supplemental LPCPs on the levee. No long-term static DGPS or CORS/OPUS observations will be required to adjacent points on the NSRS or CORS, other than a vertical tolerance check as indicated in Table 3-6. If the existing NSRS bench mark does not have published horizontal coordinates, a CORS/OPUS observation will provide a general horizontal reference for the PPCP.

c. The first step in evaluating NSRS coverage in a USACE project area is to access the NGS database and search for existing bench marks. This can be done graphically as shown in the screen capture in Figure 3-3. Alternatively, U-SMART can be used to view local NSRS points in a project area—see Figure 3-4. If a USACE levee system is located along a river system parallel with an NGS level line, then any of these bench marks can be directly used to provide NSRS (NAVD88) control on levee points—and only short-term RTN/RTK checks would be performed to confirm NSRS control accuracy and validity of the marks used as control. Per Table 3-6, a tolerance check between the NSRS bench marks of ± 0.1 ft would be considered reasonable.

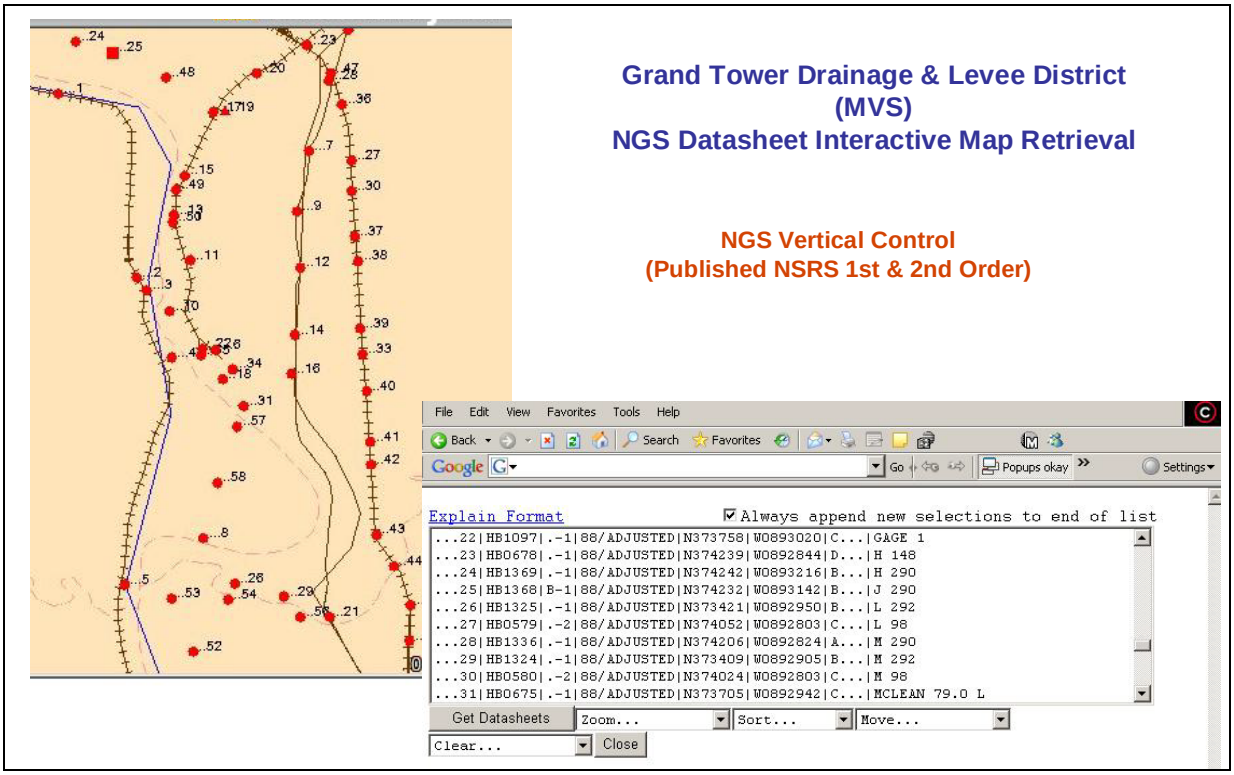


Figure 3-3. Survey control map from NGS web site.

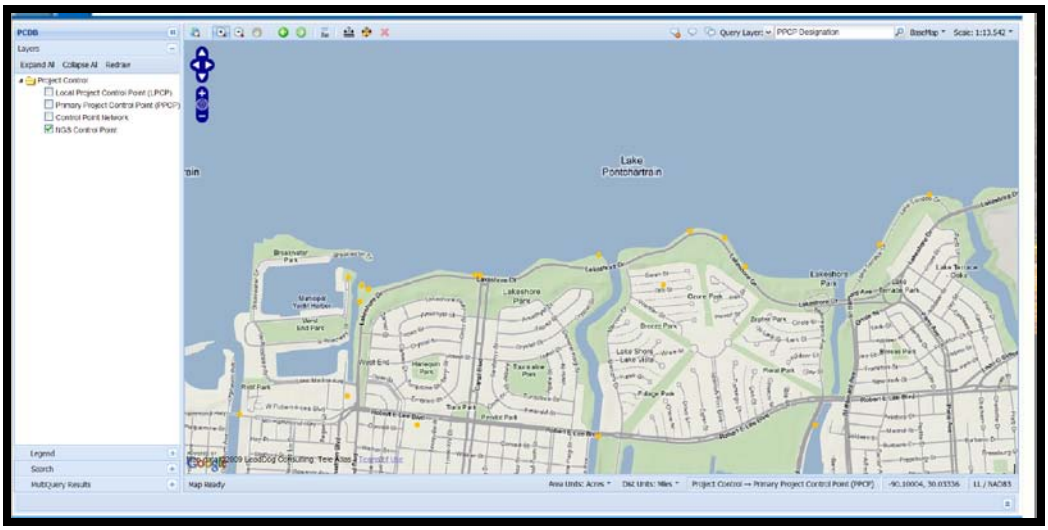


Figure 3-4. U-SMART map showing NSRS database points along Lake Pontchartrain shoreline.

3-11. CORS/OPUS Solutions for Primary Project Control Point Elevations. CORS/OPUS observations (Table 3-5 Preference [II]) will generally be the preferred survey method for relating USACE project control (PPCPs) to the NSRS. Static GPS observations are observed at a PBM relative to a network of CORS. The GPS observables are processed through OPUS and the PBM becomes part of the NSRS if descriptive data are forwarded to NGS—see Figure 3-5. CORS/OPUS solutions are a practical and efficient method of establishing primary project control to a vertical accuracy of ± 0.25 ft.

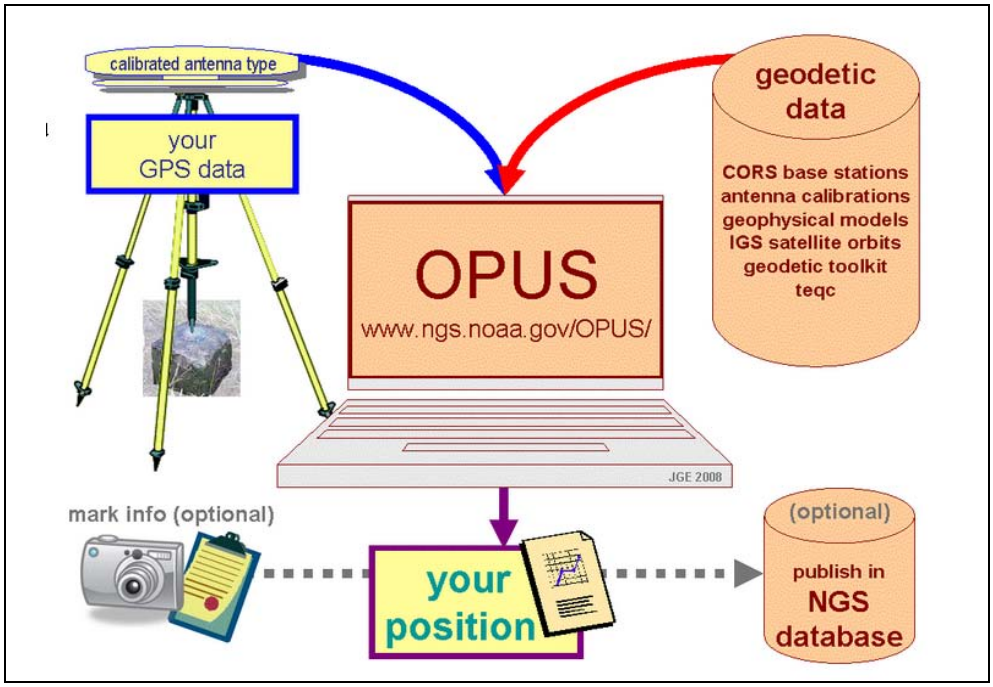


Figure 3-5. CORS/OPUS baseline processing and input to the NSRS database.

a. CORS/OPUS guidelines. When CORS/OPUS solutions are made to establish NAVD88 orthometric elevations on a PPCP, the NGS guidelines in Table 3-7 are recommended. These guidelines are current as of 2010—monitor the AGC and NGS web sites for future changes in these specifications. In the most populated regions in CONUS, CORS coverage is adequate for establishing NAVD88 orthometric elevations on PPCPs. These elevations usually can be obtained in less than one day with a one-man survey crew, and the resulting data can be efficiently input into the NSRS database using OPUS-based input procedures.

(1) CORS/OPUS observations for targeted ± 0.25 ft accuracies to the NSRS do not need to be pre-approved by the NGS; however, one should verify with NGS that the local geoid model is adequate to use to convert GPS ellipsoidal heights to orthometric heights. In most populated regions of CONUS where the NSRS vertical network is fairly dense, the geoid model should be adequate. In these areas, the geoid model accuracy is normally less than ± 3 cm and often closer to ± 1 cm. Thus, errors in the ellipsoidal-orthometric conversion will not be as significant. In mountainous areas or in high-subsidence regions, this may not be the case and NGS should be consulted in advance.

(2) In arriving at the estimated accuracy of a CORS/OPUS solution for an orthometric elevation, the error budget consists of (1) estimated accuracy of the geoid model, (2) the ellipsoid height measurement accuracy, and (3) base CORS station elevation accuracy. In many USACE Districts, < ± 5 cm estimated orthometric accuracies are currently being achieved. The OPUS Solution Report contains an estimate of the orthometric accuracy. Estimated orthometric accuracies exceeding ± 0.25 ft should not necessarily be rejected if "peak-to-peak" tolerances are acceptable. Especially note that valid CORS solutions exceeding some of the tolerances in Table 3-7 may be rejected for input to the NSRS.

Table 3-7. NGS Guidelines for CORS Ellipsoidal and Orthometric Elevation Measurements. (Primary Project Control Points -- ± 0.25 ft Orthometric Accuracy) [1]

Minimum number of CORS Stations within 200 miles	3
Minimum session time:	One ≥ 4-hour session required plus independent check session recommended. Total of two 4-hour sessions recommended [2]
Number of sessions	2 (see above)
Minimum observations	7,900
Observations used	> 70%
Ambiguities fixed	> 70%
Overall solution RMS	< 3 cm
HI measurements	Fixed height pole recommended; otherwise 3 measurements required in different units
Ephemeris	IGS precise or rapid (available next day)
Maximum Peak-to-Peak tolerances (ellipsoidal):	
Horizontal	< 4 cm
Vertical	< 8 cm
Geoid model	OPUS determined
Geoid model--estimated accuracy at site	NTE 3 cm (check w/NGS)
Data processing and NSRS database input	NGS OPUS-based

Table 3-7 (Concluded). NGS Guidelines for CORS Ellipsoidal and Orthometric Elevation Measurements. (Primary Project Control Points -- ± 0.25 ft Orthometric Accuracy) [1]

Notes:

[1] Some exceptions to the tolerances in these guidelines may be warranted in certain cases; however, a USACE acceptable CORS solution may be rejected for NSRS input. These guidelines are periodically being updated by NGS—they are current as of 2010. Contact AGC or the NGS OPUS web site for subsequent changes and updates.

[2] Since the purpose of the second 4-hour session is used as a check, other methods such as the use of RTN or RTK methods may be used to verify and check the first 4-hour observation. In remote areas it is still recommended that a second 4-hour observation session be done to eliminate the need to travel back to the site if the first 4-hour observation does not meet the requirements.

c. Sample OPUS Solution Report. Figure 3-6 below is an example of a 19-hour OPUS observation at a NOAA tidal bench mark in Georgia. The report statistics indicated the criteria in Table 3-7 were met. (Applicable assessment criteria that should be reviewed in the report are shown as bolded). Note that the 2.0 cm orthometric height accuracy is "peak-to-peak"—not the NSRS relative accuracy estimate.

Figure 3-6. Sample OPUS Solution Report.

```
9511 TIDAL F  [NOAA Tide Gage 867 9511 – Kings Bay, GA – Jacksonville District]
FILE: 71650290.09o 000105225

                              NGS OPUS SOLUTION REPORT
                              ========================

All computed coordinate accuracies are listed as peak-to-peak values.
For additional information: http://www.ngs.noaa.gov/OPUS/about.html#accuracy

      USER: damon.a.wolfe@usace.army.mil            DATE: May 05, 2010
RINEX FILE: 7165029a.09o                            TIME: 18:53:30 UTC


  SOFTWARE: page5  0909.08 master2.pl 0810233      START: 2009/01/29 00:01:00
 EPHEMERIS: igs15164.eph [precise]                  STOP: 2009/01/29 19:15:30
  NAV FILE: brdc0290.09n                         OBS USED: 48669 / 51797   :94%
  ANT NAME: TRM_R8_GNSS     NONE             # FIXED AMB:   259 /   293   :88%
ARP HEIGHT: 1.75                             OVERALL RMS: 0.017(m)
```

Figure 3-6 (Concluded). Sample OPUS Solution Report.

```
REF FRAME: NAD_83(CORS96)(EPOCH:2002.0000)            ITRF00(EPOCH:2009.0778)

         X:       808781.729(m)   0.013(m)            808781.030(m)   0.013(m)
         Y:     -5423271.976(m)   0.018(m)          -5423270.449(m)   0.018(m)
         Z:      3247037.568(m)   0.014(m)           3247037.378(m)   0.014(m)

       LAT:   30 48  6.91976      0.016(m)        30 48  6.94129    0.016(m)
     E LON:  278 28 55.57376      0.014(m)       278 28 55.55623    0.014(m)
     W LON:   81 31  4.42624      0.014(m)        81 31  4.44377    0.014(m)
    EL HGT:          -24.719(m)   0.014(m)             -26.202(m)   0.014(m)
 ORTHO HGT:            3.788(m)   0.020(m) [NAVD88 (Computed using GEOID09)]

                         UTM COORDINATES    STATE PLANE COORDINATES
                          UTM (Zone 17)         SPC (1001 GA E)
Northing (Y) [meters]     3407764.931            89071.578
Easting (X)  [meters]      450456.269           262082.476
Convergence  [degrees]    -0.26520537           0.33222763
Point Scale                0.99963028           0.99994753
Combined Factor            0.99963416           0.99995141

US NATIONAL GRID DESIGNATOR: 17RMQ5045607764(NAD 83)

                                BASE STATIONS USED
PID       DESIGNATION                        LATITUDE    LONGITUDE
DISTANCE(m)
DE6005 GNVL GAINESVILLE CORS ARP           N294111.557 W0821636.736  143609.7
DJ6111 SAV5 SAVANNAH 5 CORS ARP            N320818.937 W0814146.790  149170.2
DK4049 GASK SKIDAWAY ISLAND CORS ARP       N315915.255 W0810122.431  139632.1

                  NEAREST NGS PUBLISHED CONTROL POINT
BC2560      H 62 06                        N304808.555 W0813108.247     113.4

Horizontal network accuracy =    0.00212 meters.
Vertical network accuracy   =    0.00228 meters.

  STATE PLANE COORDINATES - U.S. Survey Foot
         SPC (1001    GA E)
Northing (Y) [feet]         292229.003
Easting  (X) [feet]         859848.923
Convergence  [degrees]      0.33222763
Point Scale                 0.99994753
Combined Factor             0.99995141
```

b. CORS/OPUS data submittal and NSRS publication. The guidelines in Table 3-7 must be followed in order to meet NGS QC and QA criteria for inputting CORS-derived bench mark elevations into the NSRS. The NGS publishes detailed procedures on their web site for submitting CORS/OPUS GPS observations and publishing station data in the NSRS database. A published PPCP datasheet processed through the OPUS database input system to the NSRS is shown in Figure 3-7.

SURVEY DATASHEET (Version 1.0)

PID: BBBS37
Designation: USACE V-LOWPAP-4
Stamping: V-LOWPAP-4 2K9
Stability: Monument will probably hold position well
Setting: Object surrounded by mass of concrete
Description: This monument is used to comply with the Comprehensive Evaluation of Project Datum (CEPD) initiative. This monument is a standard USACE Brass Cap set atop a 5/8" rebar in concrete. This point is +/- 10 feet southerly from the southerly edge of a pedestrian walkway attached to the Cass Street bridge crossing the Big Papillion Creek. The point is located on the left bank of said creek and is marked with a White Carsonite Post.
Observed: 2009-08-06T18:01:00Z
Source: OPUS - page5 0909.08

Close-up View

REF_FRAME: NAD_83 (CORS96)	EPOCH: 2002.0000	SOURCE: NAVD88 (Computed using GEOID03)	UNITS: m	SET PROFILE	DETAILS

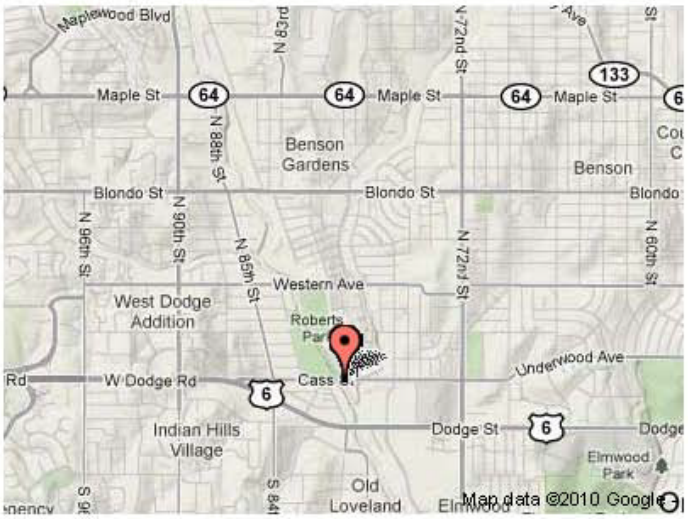
LAT:	41° 15' 47.39187"	± 0.035 m
LON:	-96° 2' 9.04502"	± 0.020 m
ELL HT:	290.587	± 0.034 m
X:	-504889.732	± 0.024 m
Y:	-4774966.285	± 0.034 m
Z:	4184627.958	± 0.029 m
ORTHO HT:	318.019	± 0.049 m

	UTM 14	**SPC** 2600(NE)
NORTHING:	4572209.641m	166359.449m
EASTING:	748310.334m	831967.948m
CONVERGENCE:	1.95591174°	2.62703272°
POINT SCALE:	1.00035890	0.99966752
COMBINED FACTOR:	1.00031330	0.99962196

CONTRIBUTED BY

david.d.salter
US Army Corps of Engineers

Horizon View



The numerical values for this position solution have satisfied the quality control criteria of the National Geodetic Survey. The contributor has verified that the information submitted is accurate and complete.

Figure 3-7. OPUS processed data sheet of a USACE PPCP. (Omaha District)

3-12. GPS Static Baseline Specifications for Networking Primary Project Control Point Connections to the NSRS. This section describes specifications to be used when CORS/OPUS solutions cannot be made (Preference [III] in Table 3-5) and networked static baseline observations must be observed and adjusted. Table 3-8 outlines the recommended GPS observing specifications needed to determine NAVD88 elevations relative to the NSRS based on a target accuracy of ± 0.25 ft. The DGPS static baseline observing specifications for network connections in Table 3-8 are largely tailored around current USACE EM 1110-1-1003 (*NAVSTAR GPS Surveying*) and NGS orthometric height guidelines for 2 cm to 5 cm accuracy orthometric network densification — *Guidelines for Establishing GPS Derived Orthometric Heights* (NOAA 2005). These GPS orthometric height guidelines in Table 3-8 have been modified to fit the nominal ± 0.25 ft accuracy requirements in Table 3-1.

a. GPS survey specifications. The following network connection specifications in Table 3-8 are intended to achieve the nominal target accuracy requirements for USACE primary project control. This is not to say that they will work in all cases, or in all locations, due to a variety of factors too numerous to list here. The bottom line is that on-site baseline reduction and processing software should readily (i.e., same or next day) identify the quality of the results from a constrained network adjustment statistical summary.

b. Data submittal to NSRS via Blue Book procedures. When OPUS-based NSRS submittal methods cannot be utilized, GPS observations and leveling observations to newly established PPCPs must be adjusted and submitted to the NSRS using NGS Blue Book procedures—"*Input Formats and Specifications of the National Geodetic Survey (NGS) Data Base*" (NOAA 1994). The Blue Book is a guide for preparing and submitting geodetic survey data for incorporation into the NSRS database. NOAA 1994 provides overall instructions and a checklist for submitting raw data, vector solutions, project and station data, station descriptions, applicable horizontal and vertical connections, least squares adjustments, a project sketch, and a project report. Additional guidance, tutorials, and required software are referenced therein with web addresses for downloading. It is recommended that the A-E performing the field surveys work directly with other firms that have an established record for producing accepted Blue Book submittals to ensure proper procedures and documentation are followed throughout the project.

c. Resultant accuracy estimates. Since the specifications in Table 3-8 have been modified from the NOAA 2005 specifications to meet USACE project orthometric accuracy requirements, it is important that published NSRS data sheets contain a statement to that effect. Including the estimated orthometric accuracy from the constrained network adjustment in that statement would be warranted.

Table 3-8. USACE Guidelines for Establishing GPS-Derived ± 0.25 ft Accuracy Orthometric Elevations on PPCPs using GPS Network Connections to NSRS Bench Marks.

Occupation time based on baseline distance to nearest two NSRS bench mark(s):

Distance	Time
< 20 km	30 min
20-40 km	60 min
40-60 km	180 min
60-80 km	240 min
80-100 km	300 min
> 100 km	> 5 hours

NGS pre-approval required	Yes (local NGS advisor, HQNGS, or NGS web site)
Number of days station occupied:	1 day (perform interim break-down and reset)
Dual-frequency receiver required:	Yes
NGS modeled geodetic quality antenna :	Yes (ground plane recommended)
Minimum number of observations per baseline:	2
Fixed-height tripods/poles:	Required
Satellite altitude mask angle (minimum):	10 degrees (collect) 15 degrees (process)
Maximum allowable VDOP:	5
Precise ephemeris:	Recommended, but not required
Geoid model:	Most recent
Add CORS baselines to adjustment:	Yes
Maximum distance to CORS points:	No restriction—weight accordingly with local NSRS baselines
NSRS input:	Blue Book or OPUS-based input

Table 3-8 (Concluded). USACE Guidelines for Establishing GPS-Derived ± 0.25 ft Accuracy Orthometric Elevations on PPCPs using GPS Network Connections to NSRS Bench Marks.

Notes:

Static (networked) DGPS baseline connections may be required in cases where the current geoid model has unacceptable accuracies in a particular region, such as in sparsely NSRS controlled mountainous areas, or in places where CORS stations are too distant—greater than 200 miles. Regardless, CORS baselines will be used in the adjustment if available.

DGPS network connection procedures will require considerably more field effort and must follow the guidelines in Table 3-8. Inputting networked DGPS observation data into the NSRS will currently require "Blue Booking." However, it is expected that an alternate "Blue Booking" methods (i.e., OPUS) eventually will be available from NGS for adjusting traditional networked data and inputting results into the NSRS.

At least two baselines tied to or "networked" with nearby NSRS points should be observed. These local baselines will be combined with CORS baselines, and adjusted using NGS software routines.

Proposed observation schemes for networked baseline observations to nearby NSRS points shall be pre-approved by NGS. Pre-approval may be obtained from the local NGS geodetic advisor or from designated NGS HQ staff. The format for submitting proposed schemes should follow the "Project Proposal Form" available from the NGS.

3-13. The USACE Survey Monumentation Archival and Retrieval Tool (U-SMART). The U-SMART system, a fast and user-friendly web-based system (Figure 3-8), facilitates compliancy with the requirement to link the proper geodetic, hydraulic, tidal, and legacy control to their respective projects. Each project is required to have a minimum of 3 control points, one of which must be directly connected to and included in the NSRS. These control points must also be connected to the local water surface datum/model used for engineering designs and studies. U-SMART provides the tools to link local control networks together and link the project to the appropriate gage and the local legacy control points used for deformation studies and historical surveys.

a. U-SMART running as part of the web-based CorpsMap system serves as the liaison between USACE project control and the NGS/NSRS database. The U-SMART system continually monitors the NGS database looking for spatial changes, and alerts the user of required updates to local control. Benefits of U-SMART include:

(1) Common source for all project control.

(2) No desk drawer control files or duplicates.

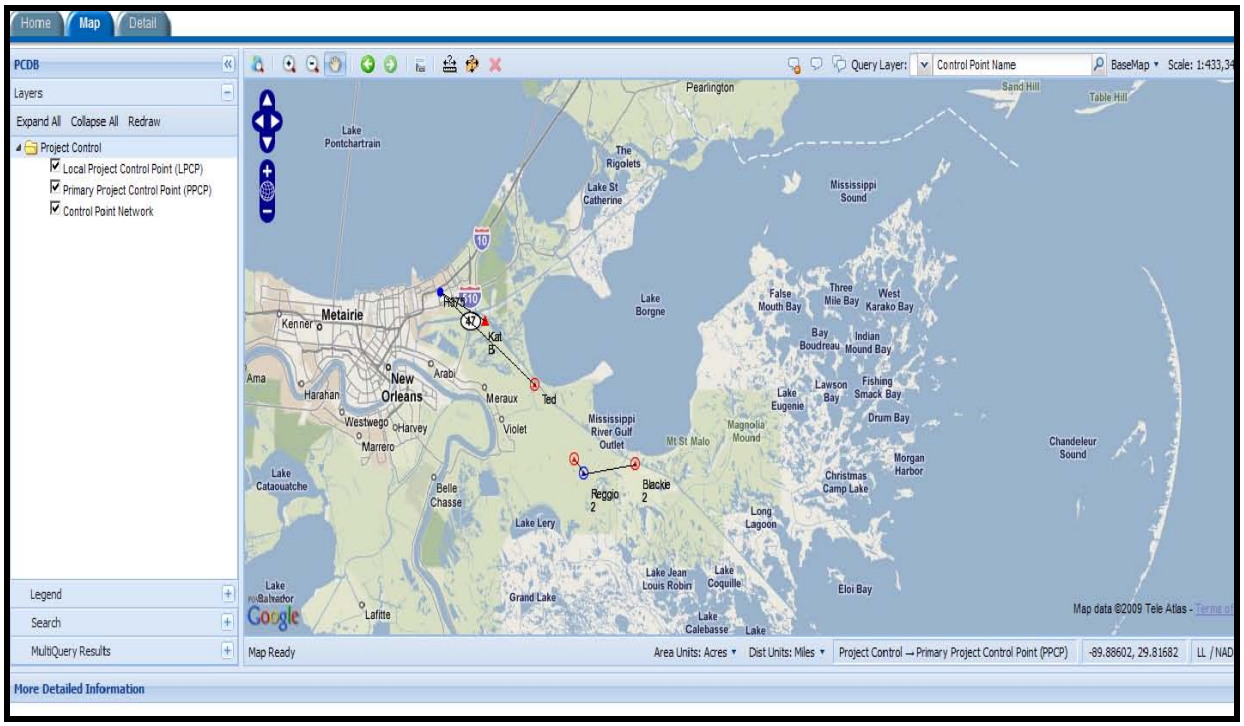


Figure 3-8. U-SMART web-based map interface indicating PPCPs and LPCPs.

(3) Entire District on same page.

(4) Compares coordinates against NGS database.

(5) Links project control to authorized projects.

(6) Links primary control to local project control networks.

(7) Minimized maintenance at the local level.

(8) Easy archival and retrieval.

b. Many USACE districts already have in place a system for archiving geodetic control which requires development, maintenance, and storage space. Many of these systems are not publicized, which limits their effectiveness in providing the common source of control information to USACE customers. Some districts with large resources have developed comprehensive systems to capture their survey control data while other districts with limited resources are still using hard copies in the old file cabinets. The 1990s vintage "SEMMS" control database system attempted to provide a national platform for USACE survey control; however, only a handful of districts are currently using it. It is critical that the data contained in the district's archives be maintained and available for designers, planners, and engineers to access. With a U-SMART central repository for USACE survey control, it is less likely that the wrong survey control will be used.

c. The Control Point Description Form (Figure 3-9) is used to input horizontal and vertical coordinates, images, and other information about the PPCPs and LPCPs in the U-SMART database. The form is a simple PDF document that allows the user to populate the appropriate fields depending on the purpose of the submittal. The form has several flavors and can be used for documenting newly established points, recovery notes, entering historical information on the mark such as local/legacy coordinates, and can also be used to edit existing information in the database. Easy to populate pulldowns, checkboxes, and radio buttons simplify the process of data entry. Maps, pictures, and images are also captured and archived with the form. Once the form is completed, the data is imported into U-SMART by the District Datum Coordinator or a representative with the delegated responsibility to insure the quality of the information.

d. For additional information on U-SMART contact the Army Geospatial Center. See the web link in Chapter 1.

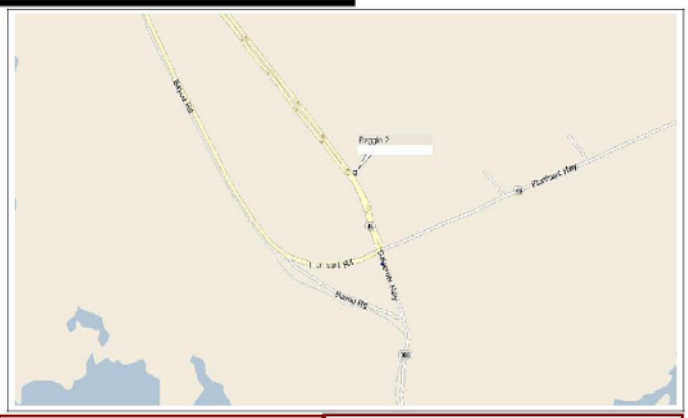
3-14. Methods for Determining the Relationship between Legacy Project Datums and NAVD88. Many of the legacy reference datums on USACE flood risk management projects, hurricane protection projects, river gages, reference pools, flow lines, flood stage, etc, are not referenced to the federal NSRS, and as such cannot be easily incorporated into hydrologic, hydraulic, flood inundation, and risk assessment models, or related to regional reference datums being used by other local, state, and federal agencies In CONUS the methodology used to shift historical or legacy survey data (e.g., NGVD29) to NAVD88 will vary depending upon many factors such as time, funding, accuracy requirements, etc. The most accurate and costly method is to re-observe each bench mark used for an old survey of interest. Even with the establishment of new elevations we can only estimate the changes that have taken place between then and now. The relationship between the surveyed features and the control marks may have also changed due to subsidence, settlement, or NSRS readjustments.

a. General. Transforming between legacy NGVD29 and NAVD88 is not straightforward, given NGVD29 has not been supported or updated by NGS since it was superseded in the early 1990s; thus, elevations still referenced to NGVD29 can have unacceptable vertical errors. Models have been developed for performing general "mapping grade" transformations from NGVD29 to NAVD88. These models (e.g., VERTCON and CORPSCON) were not intended to provide survey or construction quality accuracy, and must be used with caution given they are only coarse estimates. Floodwall or levee flood protection elevations should not be designed, constructed, or certified based on uncertain transformations from NGVD29 using CORPSCON.

b. Datum transform methods. Generally there are four methods to determine the datum/epoch shift. It is important to maintain the historical project files and source documents documenting what datum was used when, and how the project datums were derived. This is usually detailed down to the individual bench mark level of detail, documenting what bench marks were used and what elevations were used. Whichever method is used, transformations all have various elevation uncertainties, and it is important to have knowledge of the uncertainties of the final elevations used.

USACE Survey Marker Archive & Retrieval Tool Datasheet Type: New

Designation: Reggio 2
Project: MRGO
Stamping: Reggio 2
PID NGS: AT0804 COE:
State: Louisiana
County: St. Benard
District New Orleans
Nearest Town: Reggio
USGS Quad:
T.R.S.:
Nearest Hwy/Mi:
B/L Sta/Off:
Date Recovered: May 2007
By: Chustz
Condition/Stability: Good D
Setting/Monument Type: SS Rod
Owner:
GPS Suitable: (•) Yes ( ) No
Obstructions: [ ] N [ ] E [ ] S [ ] W



- Horizontal -
Datum: NAD83 (2002.00)
Lat: 29 50 40.71876 N
Lon: 89 45 32.43138 W
Local Accuracy: 1-cm
NSRS Accuracy: 2-cm
Survey/Computation Method: Static GPS Network
Date Observed: Sep 1, 2009

- Vertical -
Datum: NAVD88 (2004.65)
Elevation Ht: 4.9
Ellip Ht: -79.163 Ft
Local Accuracy: 2-cm
NSRS Accuracy: 5-cm
Survey/Computation Method: Static GPS Network
Date Observed: Sep 16, 2007 Geoid03

Description/Comments:
The station is 25.0 ft. northeast of centerline of north bound lanes of hwy, 3.6 ft. North from north end of a bridge concrete rail, 2.1 ft. northeast of a concrete curb and 1.5 ft. northwest of a concrete abutment wing. Station is a stainless steel rod accessed through a logo cap stamped- reggio2 1987, flush with top of logo sleeve cover missing otherwise in good condition.

Access: open

- Tidal/Hydraulic Gauge Relationships -
Owner/Code: USACE
Gauge ID: 56123 Epoch: 83-01

- Datum -	- Elevation -
LMSL	0.51
MLLW	-0.02
Select	
Select	

Zone: Northing: Easting: Convergence: CSF:

- Horizontal View -

- Close-Up View -

Required Fields In Red Reset Form Submit U-SMART ver 1.1 9/24/2009

Figure 3-9. Sample U-SMART datasheet at a PPCP. (New Orleans District)

(1) Field Measurements with Known Historical Elevation(s). This method will yield the most accurate values based on the historical reference bench marks. The reference bench marks will need to be recovered and occupied/surveyed using CORS/OPUS, RTN, RTK, or other methods, depending upon required accuracy. The difference between the legacy elevation used for the original survey and the NAVD88 elevation established from the new network will directly tie in the old work to the latest control. This will not account for relative differences between the project control and the project features, to include any differential subsidence or settlement that may have occurred after the legacy reference datum was established.

(2) Field Measurements without Known Historical Elevation(s). When the reference bench mark legacy datum has not been documented and unknown, some assumptions will be required, such as what bench mark was used and what its elevation was. Again, CORS/OPUS, RTN, RTK, or other methods depending upon required accuracy may be used to establish a new elevation on the reference mark. The historical elevation will have to be assumed based on what was available at the time of design. The difference between the assumed historical elevation and the newly established elevation will be used to shift the survey to the new datum/epoch.

(3) Common Published Marks in Survey Area. When time and money are constraints, the closest marks with published elevations in both datum/epochs can be used to determine an average shift for the area. This method contains many assumptions and therefore is the less accurate and contains more uncertainty but may be of use on some projects.

(4) CORPSCON or VERTCON conversions between NGVD29 and NAVD88. These conversions are approximate and do not account for subsidence or the changes in elevation from epoch to epoch. The conversion models were constrained to the published elevations at the time the conversion model was created (ca 1990). These models contained errors associated with the already deteriorating NGVD29 elevation accuracies in 1990. These methods should not be used for anything other than a simple datum shift, keeping in mind that subsidence is not accounted for.

c. FEMA guidance for converting to NAVD88. Appendix B in FEMA's "Guidelines and Specifications for Flood Hazard Mapping Partners" (FEMA 2003) contains standards and criteria for converting between NGVD29 and NAVD88 datums, including guidance for the conversion of unrevised flood elevations. These conversion standards are largely based on CORPSCON and VERTCON procedures. Methods for computing average datum conversions over a FIRM study region are defined. Maximum conversion tolerances of ± 0.25 ft are prescribed in this FEMA guidance.

3-15. Summary of USACE Survey Standards for Connecting Projects to Nationwide Reference Datums. Table 3-9 summarizes the recommended procedures and standards covered in this manual for connecting projects to the NSRS.

Table 3-9. Summary of Recommended Survey Standards for Referencing Grade Elevations on Navigation Projects, Multipurpose Projects, Levees, Floodwalls, and Related Retaining Structures.

	Inland Flood Protection & Navigation Projects [Rivers, lakes, reservoirs, pools, Great Lakes]	Coastal Hurricane & Shore Protection Projects Coastal Navigation Projects
Reference Datums:		
Hydraulic Reference Datum [1]	LWRP, pool, etc. (stage, flood profile) Hydraulically modeled from gages	Local MSL or Local MLLW (stillwater, surge, etc) Hydrodynamically modeled from NOAA tide gages
Geodetic (Orthometric) Reference Datum [1]	NOAA NSRS (NAVD88)	NOAA NSRS (NAVD88)
High subsidence or crustal uplift areas	NOAA Time Dependent Reference Network	NOAA Time Dependent Reference Network
Ellipsoid Reference Datum [Optional/Recommended Reference]	GRS80 (NAD83 NSRS)	GRS80 (NAD83 NSRS)
Legacy Geodetic or Tidal Datums	Sea Level, NGVD29, Cairo, MSL 1912, etc. Define relationship to NAVD88	MLW, Mean Low Gulf, Cairo, etc. Define relationship to NOAA Local MSL or Local MLLW

[1] The relationship between these two datums must be physically determined at PBM reference points and mathematically modeled throughout the project area.

Table 3-9 (Continued). Summary of Recommended Survey Standards for Referencing Grade Elevations on Navigation Projects, Multipurpose Projects, Levees, Floodwalls, and Related Retaining Structures.

	Inland Flood Protection & Navigation Projects [Rivers, lakes, reservoirs, pools, Great Lakes]	Coastal Hurricane & Shore Protection Projects Coastal Navigation Projects
Primary Project Control Points (PPCPs):		
Primary PBM published in NSRS	Yes	Yes (NOAA CO-OPS database if applicable)
Minimum PBMs required per project/segment	1	1
Spacing of primary PBMs NTE	15 – 20 miles (see Chapter 6)	15 - 20 miles (see Chapters 4 and 5)
Recommended min vertical accuracy	± 0.25 ft relative to NSRS	± 0.25 ft relative to NSRS
High subsidence or uplift areas	± 0.15 ft relative to NSRS	± 0.15 ft relative to NSRS
Recommended min horizontal accuracy (for mapping/GIS applications only)	± 2 ft relative to NSRS—NAD83	± 2 ft relative to NSRS—NAD83
GPS ellipsoid height observation at PPCP	Recommended	Recommended

Table 3-9 (Continued). Summary of Recommended Survey Standards for Referencing Grade Elevations on Navigation Projects, Multipurpose Projects, Levees, Floodwalls, and Related Retaining Structures.

	Inland Flood Protection & Navigation Projects [Rivers, lakes, reservoirs, pools, Great Lakes]	Coastal Hurricane & Shore Protection Projects Coastal Navigation Projects
Water Level Gages: [2]		
Primary gage reference PBM connected to	NSRS (NAVD88)	NSRS and NOAA CO-OPS tidal network
Minimum number of reference PBMs at gage	3	5 (NOAA tide gage)
Primary reference PBM metadata repository	NSRS and/or U-SMART	NSRS & NOAA CO-OPS database; U-SMART
Periodic gage inspection metadata repository	NSRS and/or U-SMART	NSRS & NOAA CO-OPS database; U-SMART
Update low water or tidal datums	per Division/District H&H requirements	per NOAA published revisions (typically 19 years, or 5 years in high subsidence areas)

[2] See Chapter 4 for additional details

Table 3-9 (Continued). Summary of Recommended Survey Standards for Referencing Grade Elevations on Navigation Projects, Multipurpose Projects, Levees, Floodwalls, and Related Retaining Structures.

	Inland Flood Protection & Navigation Projects [Rivers, lakes, reservoirs, pools, Great Lakes]	Coastal Hurricane & Shore Protection Projects Coastal Navigation Projects
RECOMMENDED STANDARDS:		
Local Project Control Points (LPCPs) for Design & Construction:		
PBMs spaced	as required	as required
Reference datum and/or NOAA tidal	Primary project control (NSRS)	Primary project control (NSRS)
Minimum number of PBMs for construction contract plans & specifications	3	3

Table 3-9 (Concluded). Summary of Recommended Survey Standards for Referencing Grade Elevations on Navigation Projects, Multipurpose Projects, Levees, Floodwalls, and Related Retaining Structures.

	Inland Flood Protection & Navigation Projects [Rivers, lakes, reservoirs, pools, Great Lakes]	Coastal Hurricane & Shore Protection Projects Coastal Navigation Projects
Site Plan Topography Accuracies:		
Reference datum	Local project PBM control	Local project PBM control
Hard topographic features: Floodwall cap elevations, culverts, inverts, first floors, boring references, etc.	± 0.3 ft	± 0.3 ft
Ground shots on levee (profiles or cross-sections)	± 0.5 ft	± 0.5 ft
Floodplain topography (general mapping)	± 0.5 ft to ± 2 ft relative to NSRS	± 0.5 ft to ±2 ft relative to NSRS
Construction stake out—set hubs to	± 0.01 to 0.05 ft	± 0.01 to 0.05 ft