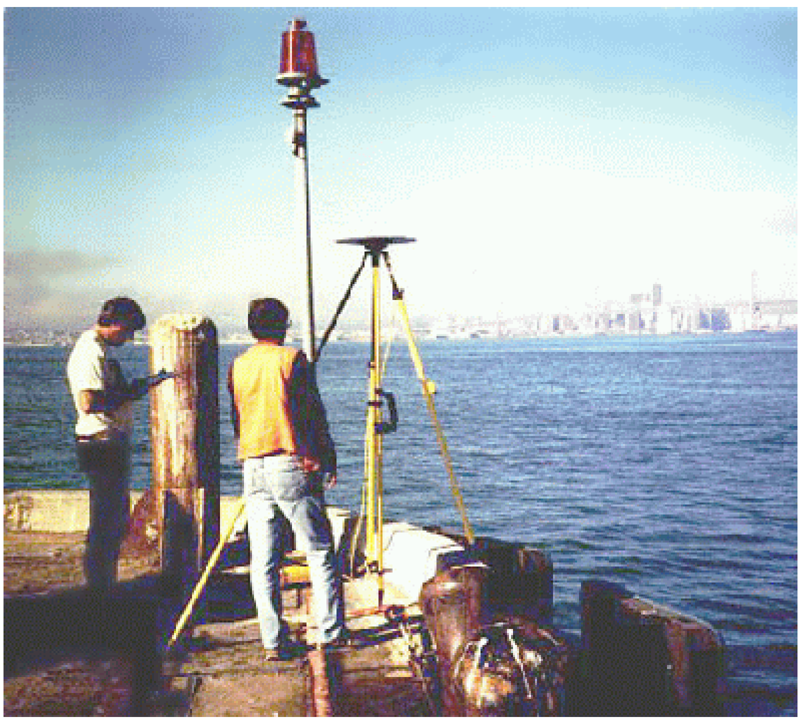
Version 10, June 16, 2003

SCOPE OF WORK
HEIGHT MODERNIZATION AND LIDAR SURVEYS

for

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE
NATIONAL GEODETIC SURVEY



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1. INTRODUCTION

This Scope of Work lists requirements for ground surveys needed to support the Height Modernization Program (HTMOD), which is administered by the National Geodetic Survey (NGS), National Ocean Service (NOS), National Oceanic and Atmospheric Administration (NOAA). In addition, LIght Detection And Ranging (LIDAR) survey(s) may be required.

2. ADMINISTRATION

2.1 SPECIFICATIONS - This Scope of Work provides general standards and specifications for the surveys required by NGS. In addition, the Contractor shall be issued a set of Project Instructions for each survey. **The Project Instructions will take precedence over this Scope of Work since the Project Instructions provide detailed and often unique information about each Height Modernization Project.** The requirements for reporting deviations, unusual circumstances, etc., described in the following paragraphs, apply to the Scope of Work and to the Project Instructions.

2.2 CONVENTIONS - The following conventions have been adopted for these project specifications. The verb "shall" means that compliance is required. The verb "should" denotes a recommendation. The contraction "N/A" means not applicable. The term "position" means horizontal position (latitude and longitude) unless specified otherwise. The term "elevation" means the distance of a point above a specified datum, measured along the direction of gravity. The term "vertical" refers to the direction in which the force of gravity acts. The term "height" means the distance, measured along a perpendicular, between a point and a datum. See
Section 4. Use the U.S. Survey Foot (3.28083333333 feet = 1 meter) for any length conversions.

2.3 GENERAL REQUIREMENTS - The Contractor shall provide all labor, equipment, supplies, material, and transportation to produce and deliver data and related products as required under this Scope of Work, except as shown in Section 3.

2.4 MODIFICATIONS - All requests for modifications shall be submitted by the Contractor in writing to the Contracting Officer (CO) prior to the Task Order due date and as soon as possible. Send a copy to the NGS Points of Contact (POC) listed in Section 14.

2.5 UNUSUAL CIRCUMSTANCES - The Contractor shall notify the CO and NGS of any unusual circumstances that occur during the performance of this Scope of Work or Project Instructions which might affect the deliverables or their quality (see Section 6). Especially note any deviation from this Scope of Work or Project Instructions.

2.6 REPORTS - Thorough reporting is required. The Contractor shall submit a weekly project status report (see Section 13.5) and a Project Completion Report (see Section 10.9) to the contacts in Section 14. In addition, a Quality Control Plan (see Section 6), a HTMOD Survey Plan (see Section 10.3), and/or a LIDAR Survey Plan (see Section 11.3) shall be submitted.

2.7 ORIGINAL DATA - Observation logs and other original records generated during this project are legal records which will be retained for data accountability and stored in the National Archives. Original logs and records shall be submitted and shall be original, legible, neat, clear, accurate, and fully completed in indelible black ink. Original data shall be saved, unmodified, whether in hand-written or computer-recorded form. In the original records (paper or digital), nothing is to be erased or obliterated. All available spaces on the recording forms should be completed. If a mistake is made on a form, draw a single line ~~through the mistake~~ and write the correction above or to the side. If space is too limited to permit a field correction, restart with a new log sheet; however, do not recopy the form in the office in order to make a "clean" copy. An explanatory note should be made for all corrections to the original recorded figures. It is essential that all hand-recorded information be neat and legible. All editing of computer-recorded data shall be done on a copy of the original. Submit the original version of the data, not a handmade copy, a photo-copy, or a digital copy.

3. GOVERNMENT SUPPLIED MATERIALS

The following items will be supplied, if applicable:

3.1 TRANSMITTAL LETTER,

3.2 PROJECT INSTRUCTIONS,

3.3 BRASS DISKS - Disks with factory NGS standard lettering,

3.4 LOGO CAPS - Caps for 3D rod marks, with standard NGS lettering (fits 5" or 6" inside diameter, schedule 40 PVC pipes)

See Attachment A for explanations of items listed above.

4. REFERENCE SYSTEMS

The following Reference Systems shall be used:

4.1 HORIZONTAL REFERENCE - The North American Datum of 1983 and year of the latest observations which is abbreviated NAD83 (YYYY). Note: the year of observations is on the NGS Data Sheet next to the latitude and longitude.

4.2 VERTICAL REFERENCE -

Orthometric heights - The North American Vertical Datum of 1988 (NAVD 88); for information on NAVD 88, see: http://www.ngs.noaa.gov/PUBS_LIB/NAVD88/navd88report.htm

Ellipsoidal heights - NAD 83 (GRS 80)

4.3 REFERENCE SYSTEM - Use the National Spatial Reference System (NSRS), see http://www.ngs.noaa.gov/INFO/OnePagers/One-Pager_NSRS.pdf .

Survey control shall be tied to the NGS National Continuously Operating Reference Station (CORS) system. For information on CORS, see: http://www.ngs.noaa.gov/CORS/ .

For information on the High Accuracy Reference Network (HARN), see:
http://www.ngs.noaa.gov:80/faq.shtml .

4.4 GEOID MODEL - GEOID 99, or a later, current version

For GEOID information see: http://www.ngs.noaa.gov/GEOID/GEOID99/ .

For explanations of many of the terms in Section 4, see: http://www.ngs.noaa.gov:80/faq.shtml .

5. REFERENCES AND GLOSSARY

5.1 REFERENCES - Note, the Contractor shall become thoroughly familiar with the following references:

a. NOAA Technical Memorandum NOS NGS-58 “Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm).”
Available on-line at: http://www.ngs.noaa.gov/PUBS_LIB/NGS-58.html .

b. A Guide for Establishing GPS-Derived Orthometric Heights (Standards: 2 cm and 5 cm). For information see Attachment B.

c. Input Formats and Specifications of the National Geodetic Survey Data Base, the "Blue Book." Available on-line at: http://www.ngs.noaa.gov/FGCS/BlueBook/ .
d. NOAA Manual NOS NGS 1 "Geodetic Bench Marks." Available on-line at: http://www.ngs.noaa.gov/PUBS_LIB/GeodeticBMs.pdf .

e. File Naming Convention - See Web site in Section 8.2.

f. Visibility diagram - For information about visibility obstruction diagrams, see: http://www.ngs.noaa.gov/PROJECTS/FBN/ (click on "Forms," then click on "Visibility Obstruction Diagram").

5.2 GLOSSARY - Geodetic Glossary, NGS, 1986 (not available on the WWW). For a printed copy, telephone NGS at (301) 713-3242 or email: info_center@ngs.noaa.gov

6. QUALITY CONTROL

The Contractor shall check all data to ensure that it is complete, reliable, and accurate. Note, accuracy requirements may be in the Project Instructions. The Contractor's personnel shall become thoroughly familiar with the Scope of Work; the Attachments; the Project Instructions; the definitions of surveying terms; and the material covered in the other references and publications, as required. See Section 5 for a list of References and Glossary.

QUALITY CONTROL PLAN - Prior to beginning survey work on this project, the Contractor shall submit a written Quality Control Plan (QCP) **covering all work**. The QCP shall describe how the Contractor shall meet the technical specifications required for the project. The QCP shall include at least the following requirements: a check of all manual computations (including check marks and initials), a check of all manual data computer entries, a check of file formats, and a check of all reports and data submitted. The contractor shall also describe how data will be backed up and how it will be ensured that original data are not modified. See Section 13, Deliverables.

Comments on quality control and a copy of the Quality Control Plan will be included in the Final Project Report.

7. DATA FORMATS

7.1 HTMOD ORIGINAL DATA - Original, raw digital data shall be submitted and their formats shall be documented in the Final Project Report. Original paper records shall also be submitted; see Section 2.7. Observations for positioning marked points shall be submitted in Blue Book format.

7.2 HTMOD FINAL DATA - Final project data shall be submitted in Blue Book format, or in other formats specified by this SOW (for example, digital photographs).

7.3 LIDAR DATA - Submit original unprocessed data and processed data. Provide an explanation of all file formats.

8. DATA MEDIUM AND FILE NAMING CONVENTION

8.1 DATA MEDIUM - CD-ROM.

8.2 FILE NAMING CONVENTION FOR GPS GROUND SURVEYS- See the naming convention for FBN projects on NGS' Web site at: http://www.ngs.noaa.gov/PROJECTS/FBN/

8.3 FILE NAMING CONVENTION FOR LIDAR SURVEYS - Provide an explanation for all file names and formats.

9. SURVEY METHODOLOGY

GPS ground surveying methods shall be used for HTMOD work specified in References A and B, Section 10, and the Project Instructions. If a LIDAR survey is required by the Project Instructions, LIDAR data shall be collected from an airborne platform(s) with ground GPS survey support; see Section 11.

10. SURVEY WORK FOR HEIGHT MODERNIZATION

10.1 PURPOSE - Height Modernization brings the horizontal, vertical, and gravity control networks together in a unified national positioning system, joined and maintained by GPS technology and administered by NGS. A state-of-the-art National Spatial Reference System (NSRS), with NAVD 88 as its elevation reference, can provide the Nation with a common, consistent set of real-time geographical coordinates (reference points). The application of this national positioning system can provide:

a. Improved aircraft navigational aids and approach and landing procedures,
b. Advanced surface transportation control and monitoring,
c. Highly efficient fertilizer and pesticide spreading, resulting in reduced run-off water pollution,
d. More accurate modeling of storm surge and pollution trajectories,
e. Increased accuracy for improved resource management decision making, and
f. Improved disaster preparedness and earthquake detection.

A Height Modernization project may include: planning, reconnaissance, mark recovery, mark setting, GPS observations, spirit leveling, LIDAR observations, data processing, data analysis, data adjustment, data submittal in specified formats, preparing reports, writing manuals and other training aids explaining the work, and providing training on how to accomplish the work.

10.2 RECONNAISSANCE - Reconnaissance shall be performed in accordance with NGS-58 and "A Guide for Establishing GPS-Derived Orthometric Heights" (see Section 5.1) and by following the guidelines in Attachment D, Height Modernization Station Selection Guidelines.

a. CONTROL STATIONS - The following types of control stations (survey marks) will be considered for use in these projects:

1. HORIZONTAL:
   - All control stations with a stability quality code of A or B (see Attachment D for an explanation of stability codes), and
   - All high accuracy GPS control stations including: CORS, FBN, CBN, HARN, and PACS.
2. VERTICAL:
   - All first-order and second-order NAVD 88 vertical control stations (bench marks) within the project area, sufficient to provide vertical control for the project.

All horizontal and vertical points used as control must be part of the NSRS.

b. DATABASE SEARCH - NGS and U. S. Coast and Geodetic Survey (USC&GS) (former name for NGS) station descriptions are contained in the NGS database and are available via the NGS Web site. A database search shall be made for all control stations within the project area (defined in the Project Instructions) meeting any of the above criteria. Directly access the NGS Integrated Data Base (NGSIDB) using the NGS Web site at: http://www.ngs.noaa.gov/datasheet.html. Note, the Project Instructions may also require searching the databases of other organizations (for example, a state survey office).

c. MARK RECOVERY

1. SEARCH - The contractor shall make an extensive physical search in the field for all control stations found in the above database search(s). See Attachment K for diagrams of NOAA survey disks. Before an existing mark is used, its description shall be thoroughly checked to confirm the station's identity, stability, and location, and to provide input for an updated description or recovery note. Stamping shall not be done on existing disks or logo caps. The contractor shall prepare digital updated descriptions or recovery notes for all NSRS marks searched for and all marks used in the project. See paragraph below entitled "MARK RECOVERY DEFINITION."

2. VISIBILITY - All horizontal and vertical stations selected must have adequate GPS satellite visibility. The visibility should be minimally restricted from 15 degrees above the horizon to the zenith, in all directions; see Attachment D for details. Minor obstructions are acceptable, but must be depicted on the Visibility Obstruction Diagram. For new stations, select a site relatively free of present and future anticipated obstructions. Utility poles in the GPS field of view are tolerable, and they provide security and a reference to help locate the mark. Set new marks at least 2 meters from a pole, to the south if possible. Likewise, existing marks within 2 meters of a pole should not be used. Marks should not be set or used if within 5 meters of a chain link fence.

3. MARKS OF OTHER ORGANIZATIONS - Other marks may be used if they meet the stability, visibility, spacing, accuracy, and other requirements.

4. MARKS ON PRIVATE PROPERTY - The Contractor shall contact property owners and obtain permission before using or setting a mark on private property. Take care to return the landscape to the original condition. Do NOT include the name and phone number of the property owner in the station description unless the land is owned by a business, or the owner requests to have the information included in the description.

5. HORIZONTAL CONTROL - A sufficient number of high accuracy stations (as required by NGS-58 and/or Attachment B) shall be recovered to provide horizontal control for the project. If the distribution is inadequate, the contractor shall then recover A-order, B-order, first-order, or second-order horizontal control stations (in that order) **established with GPS**, limiting the search to the number and/or area needed to provide enough control for the project. If there is still insufficient horizontal control for the project, the contractor shall extend the area of the search until enough control is found. Notify NGS of this situation immediately.

6. VERTICAL CONTROL - A sufficient number of high accuracy stations shall be recovered to provide vertical control for the project. If the distribution is inadequate, the contractor shall expand the recovery area. Consult "Guidelines for Establishing GPS-Derived Orthometric Heights," SOW, Attachment B to determine the required number and spacing of bench marks

7. BENCH MARK SPIRIT LEVEL TIES - If the reconnaissance indicates that the number and/or distribution of bench marks with good sky visibility is inadequate, spirit level ties may be made to transfer an elevation from a bench mark to a nearby existing or new survey point that does have good sky visibility. Every effort should be made to recover existing bench marks before using this method. Transferring elevations to existing horizontal control marks is preferable to setting new marks. Temporary marks shall not be used. The project instructions may require these ties to be made using first-, second-, or third-order specifications and standards. For third-order ties, see Attachment N.

8. MARK RECOVERY DEFINITION - The "recovery" of a control station includes a physical visit to the station to determine its usability by checking its identity, ascertaining its unmoved position, and determining its condition, stability, visibility, etc. and to prepare a digital updated description or recovery note in NGS format. To ascertain its identity, check the mark type, disk type, and stamping against the NGS data sheet. To ensure its position, measure the distances from the reference marks and/or the distances from the reference points and Witness Post. Also, the angle between the reference marks could be checked. Station descriptions and recovery notes must be submitted in computer-readable form using WDDPROC software available on-line at: http://www.ngs.noaa.gov/PC_PROD/DDPROC4.XX/ddproc.index.html. See detailed instructions in Attachment H.

9. MARKS RECOVERED BUT NOT USABLE - For marks which are recovered but are positively not usable due to complete tree canopy, etc., the recovery requirements may be reduced to just a simple recovery note such as, "RECOVERED AS DESCRIBED. THE MARK CAN NOT BE OCCUPIED BY GPS DUE TO COMPLETE TREE CANOPY." For marginally usable marks, fulfill the normal recovery requirements including Visibility Diagram, photographs, etc. because the mark may be needed depending on other marks in the area.

d. VISIBILITY DIAGRAM - For all marks, recovered and proposed, the contractor shall prepare a visibility obstruction diagram using the form found at: http://www.ngs.noaa.gov/PROJECTS/FBN/ (click on "Forms," then click on "Visibility Obstruction Diagram").

e. PENCIL RUBBINGS - Rubbings are no longer required during the recovery of a survey mark. Rubbings are required at the time of each observation at that station.

f. PHOTOGRAPHS

1. RECOVERED STATIONS- The contractor shall take at least three photographs of each existing control station per Attachment I.
2. PROPOSED SITES OF NEW STATIONS - Two photos, see Section 10.2g.
3. NEW STATIONS AFTER SET - Three photos, see Section 10.4.
4. CONCRETE MARK HOLE - One photo, see Section 10.4.

g. PROPOSED NEW STATION SITES - It is highly preferable to use existing marks rather than set new marks. The contractor shall propose sites for new stations as required and propose the type of mark to be set in the "Comments/recommendations" column of the "Station Table", see Section 10.3. Preliminary digital descriptions shall be prepared as well as visibility diagrams. Take two photographs of proposed sites, one at eye level, oriented vertically downward showing the ground in the area of the proposed mark (photo #2) and one oriented horizontally showing the nearest satellite obstruction or identifying feature if no obstructions (photo #3). After the mark is set, capture photo #1 and update others as required. Note, see Attachment I for digital photograph requirements.

h. GPS POSITIONS - Obtain a hand-held GPS (pseudo-range) position for all marks found and for proposed sites for new marks. Include this position in the text of recovery notes and descriptions. Data format: DDD MM SS.ss. Upon returning to the station, the Contractor shall use the description to find the station and not rely strictly on the GPS position.

i. DESTROYED SURVEY MARKS - Metal survey disks which have been moved, are very loose, or otherwise damaged so that they can no longer serve as survey marks are to be removed, have updated recovery notes written describing the mark as destroyed, and the disk sent to NGS. A mark shall not be described as destroyed unless the disk is found and returned to NGS.

j. DAMAGED SURVEY MARKS - Any existing disk which is selected to be used should be repaired if found loose or with edges exposed. Any work done to repair a disk shall be described completely in the digital recovery note. Extreme care shall be taken not to alter the existing horizontal or vertical position of the disk. Disk longevity can be increased substantially by simply adding highway epoxy or the equivalent when the edges of a disk are exposed, thus preventing ice from forming under the disk and/or a vandal from prying the disk from its location.

For all marks used in this survey, perform mark maintenance as stated above, including replacing logo cap lids if missing. Contact NGS for recommendations in unusual cases. Notify NGS of any other marks that need mark maintenance. Examples of mark maintenance problems include: loose disk, exposed edge of disk, missing logo cap, missing logo cap lid, exposed edge of concrete monument, or imminent danger of destruction.

k. MARKS NOT FOUND - As stated in Section 10.2c, the contractor shall make an extensive physical search for all control stations found in the database search(s). If the mark is not found, enter the number of person-hours spent searching into the digital recovery note. Do not state that the mark is destroyed simply because it was not found. If strong evidence exists that the mark has been destroyed, state the evidence.

10.3 HTMOD SURVEY PLAN - After reconnaissance but prior to mark setting or observations, the contractor shall submit a HTMOD Survey Plan (one paper copy and one digital copy).

to the NGS Point of Contact (POC). NGS will review the Plan as soon as possible, normally within ten work days, and will send the contractor written comments and/or approval. The contractor shall not begin mark setting or data collection until the Plan is approved by NGS. The Plan will include at least the following sections:

ITEM	FORMAT
a. Text with summary of survey planning,	Paper & digital
b. Station table (see details below and sample at Attachment M),	Paper & digital
c1. Original recovery notes on NGS Station Description/ Recovery Note Form	Paper
c2. Digital recovery notes from WDDPROC	Paper & digital
d1. Original descriptions on NGS Station Description/ Recovery Note Form	Paper
d2. Digital preliminary station descriptions (WDDPROC)	Paper & digital
e. GPS satellite visibility diagrams, for old and proposed new stations,	Paper
f. Project Sketch, to scale (different symbols for old and new station locations), and indicating how stations are connected during the primary, secondary, & local surveys,	Paper & digital
g. Digital photographs, print all for one mark on one page	Paper & digital
h. Proposed instrumentation (receivers and antennas),	Paper & digital
i. Proposed data collection and processing software, and	Paper & digital
j. Detailed GPS observation plan	Paper & digital.

Note, printouts of the NGS station data sheet are not required.

The Station Table will include the station designation (name), PID (Permanent Identifier), type (FBN, PACS, etc.), establishing agency, order, stability, condition at recovery, and comments/recommendations. For new stations, include the proposed name in the “Name” column, identify them as “proposed” in the “Type” column, and **indicate the proposed type of mark (rod, concrete, disk in bedrock) in the “Comments/Recommendations” column.** For existing stations, the name and PID must be used exactly as listed in the NGS database and must be this way in all survey records. For existing stations found but not proposed to be used, state the reason(s) in the “Comments/Recommendations” column. See sample in Attachment M.

If the existing high accuracy GPS horizontal control stations are of sufficient accuracy and distribution, the primary network of 5-hour sessions may not be required. Contact NGS.

10.4 MARK SETTING - After the HTMOD Survey Plan is approved by NGS, the Contractor may begin field work. Marks shall be set to NGS specifications for type, length, material, stability, stamping, driving, etc. outlined in “Geodetic Bench Marks” and Attachments E, F, and G. Per Attachment G, Section C11, the rod is driven to refusal, or until a driving rate of 60 seconds per foot is achieved. After this is achieved, the minimum acceptable length for the required “B” stability rod mark is normally 4 meters; see reference “Geodetic Bench Marks,” page 27, Table 3 (in other words, a rod driven to refusal that is less than 4 meters long is not acceptable). The preliminary station descriptions shall be updated after the mark is set, and photograph #1 (close-up, see Attachment I) shall be captured along with updates of other photographs, as required. For concrete marks, take a photograph after the hole is dug and before the concrete is poured showing a level rod in the hole (to show the depth of the hole). The file name for this photo will start with “RE” for reconnaissance; see Attachment I.

10.5 GPS POSITIONING PROCEDURES - GPS data shall be collected using GPS equipment meeting the following criteria: the receiver model shall have been evaluated against the Federal Geodetic Control Subcommittee (FGCS) test network, shall be a state-of-the-art, dual-frequency receiver with high quality C/A code or P code pseudo-ranges, shall be capable of measuring full wavelength L2 carrier phase, shall function acceptably in an Anti-Spoofing environment, and shall consist of a geodetic quality antenna with ground plane designed to reduce multi-path, and shall have an antenna model that has been calibrated by NGS.

> **a. TRIPODS - Fixed height tripods must be used.** Tripods with multiple height settings should be set to the highest position. All tripods shall be tested for stability, plumb alignment (straightness of center pole), and height verification at the beginning and end of the project. All tripods shall be examined for stability with each use. Ensure that hinges, clamps, and feet are secure and in good repair. Also, check, and adjust if necessary, the position of the bubble in the circular vial.
>
> b. GUIDELINES - The Contractor shall follow guidelines for establishing GPS-derived heights documented in NOAA Technical Memorandum NOS NGS-58 (ellipsoidal) and Attachment B (orthometric). **Note, use 45 minute observation periods rather than the 30 minutes specified in NGS-58 for stations other than “control stations and primary base stations.”**

c. OBSERVATION FORM - The Contractor shall use the NGS GPS observation form found at: http://www.ngs.noaa.gov/PROJECTS/FBN/ (Click on "Forms," then click on "GPS Observation Log").

d. PENCIL RUBBINGS - The contractor shall capture a pencil rubbing of a marks' stamping (disk or logo cap) each time the mark is occupied for observations. Use the form found at: http://www.ngs.noaa.gov/PROJECTS/FBN/ (Click on "Forms," and then click on "Pencil Rubbing Form"). When not feasible to make the required rubbing, a sketch of the mark shall be substituted accurately recording all markings.

10.6 VECTOR PROCESSING (See also NGS-58)

a. CONTROL AND BASE STATIONS - Vector processing shall be performed using the latest version of NGS software package PAGE-NT or equivalent. The equivalent of PAGE-NT is subjective, and is based on the software's ability to correct for the same systematic errors that PAGE-NT corrects, apply the NGS required antenna phase pattern variations, and reproduce the same results as PAGE-NT. This determination will be made by NGS.

The NGS PAGE-NT software package and User's Manual are available via anonymous FTP from NGS (see Attachment C). Follow the vector processing guidance below and the PAGE-NT User's Manual.

Vectors shall be processed using a 15-degree elevation mask

The grouping of vectors into processing sessions for each day of observations is determined by two factors: 1) the required reference station and 2) the distance of each solved station from the reference station. This vector distance determines the final solution type to be run in PAGE-NT. Reference station requirements are detailed in the sections below. Use the following table for grouping vectors into sessions according to vector length:

PAGE-NT Final Solution Type Determination

Vector Distance for Processing Session	Final Solution Type
less than 5km	L1 Fixed
5-100km	Ion-Free Fixed

IGS precise orbit data and NGS National CORS data must be used in data processing. For information on downloading CORS data and ephemeris data from NGS via the Internet, see Attachment C.

International Earth Rotation Service Terrestrial Reference Frame (ITRF) station coordinates shall be used for all vector reductions. Information about ITRF is available on the NGS Web site, under "PRODUCTS and SERVICES." See: http://www.ngs.noaa.gov/products_services.shtml . The current ITRF epoch must be used in computations. If ITRF coordinates are not available for the reference stations, transform coordinates from NAD 83 with NGS program HTDP.

The Antenna Height value entered into the PAGE-NT "Station Information" menu "Up" field is the distance from the monument to the Antenna Reference Point (ARP). For example, 2.000 meters is the Height-of-Instrument for some fixed height tripods. The monument for a CORS is generally coincident with the ARP; therefore, 0.000 is entered for a CORS station unless an offset is listed on the CORS coordinate sheet. PAGE-NT will automatically add a constant factor for the ARP to L1 phase center distance when it merges the data.

Review the PAGE-NT generated plots and text outputs to analyze each processing session. PAGE-NT's overall RMS-of-fit of the post-fit, double-difference residuals should not exceed 2.0 cm. Investigate individual satellites with a relatively high RMS or where integers can not be fixed. Also review the files for input errors such as improper reference station coordinates, antenna height errors, or improper station names. Check all manual input and indicate that it has been checked by placing "check marks" next to each entry; the checker shall also initial each page.

b. SECONDARY AND LOCAL STATIONS - For these stations, vector processing can be performed using the GPS manufacturer's latest version of the vector processing software package, with NGS approval.
Vectors shall be processed using a 15-degree elevation mask.
Refer also to publication NGS-58.

10.7 VECTOR ANALYSIS - For control and primary network requirements, the difference in ellipsoid height between repeat observations shall not exceed 5.0 cm.

For secondary and local network requirements, the difference in ellipsoid height between repeat observations shall not exceed 2.0 cm. See NOS NGS-58 for further explanation.

10.8 ADJUSTMENT PROCESSING - For computation of the positions and ellipsoid heights, the control and primary networks will be combined into one top level network, and the secondary and local networks shall be combined into one lower level network. The control used will include all CORS, FBN/CBN stations, and any stations adjusted in previous levels of the project. Four adjustments are required for each of these two levels of the network, each consisting of: (1) free (minimally constrained) with one control station fixed, (2) constrained with all CORS stations fixed, (3) constrained with all control stations fixed (horizontal and ellipsoidal heights), and (4) final free with accuracies.

For computation of the orthometric heights, the top level and lower level networks shall be combined and adjusted as one network. Two adjustments are required for this network: (1) free with one control station (with NAVD 88 orthometric height) fixed, and (2) fully constrained with all vertical control fixed.

For further explanation see NGS-58 and Attachment B. Regarding the fully constrained vertical adjustment, the contractor shall begin by performing an adjustment with all bench marks fixed and analyzing the results to determine which bench marks agree and which don't. After non-fitting bench marks are eliminated, a new adjustment will be performed and the results sent to NGS, with explanations, for approval.

CHECKING PROGRAMS - Execute the following four programs and submit the output:

> COMPGB - tests the consistency and compatibility of the two required files, i.e., the B-file (GPS Project and Station Occupation Data) and the G-file (GPS Vector Data Transfer file) for a GPS project.
>
> OBSDES - compares a horizontal Blue Book Description data set with its respective Blue Book Observation data set. OBSDES produces a list of error messages along with the description data set record and observation data set information.
>
> OBSCHK - checks the Blue Book B-file and the G-file.
>
> CHKDESC - validates all descriptions in a description (*.DSC) file.

10.9 DATA SUBMITTAL - Final project data shall be submitted in Blue Book format. The Project Sketch, descriptions, photos, project adjustments, reports, etc., shall be both paper and digital, if possible. Submit all original data records, see Sections 2.7, 7.1, 10.3, and 13.

10.10 MANUALS AND TRAINING - The contractor may be required to produce manuals and other training aids (such as Power Point presentations) explaining the Height Modernization process in portions or in its entirety. In addition, the contractor may be required to conduct training courses using the above materials.

11. SURVEY WORK FOR LIDAR SURVEYS

11.1 PURPOSE - LIght Detection And Ranging (LIDAR) airborne surveys may be required. This work may include the survey of LIDAR calibration sites, airports, shoreline, and/or ground control. These types of work may require high data density and high data accuracy. In addition, data for the tops of features and/or ground surface may be required. LIDAR calibration may be required over calibration test sites, and ground control in the operational area may be required. Standard safety procedures and regulations shall be followed.

11.2 RECONNAISSANCE - The project area will be defined in the Project Instructions. Project planning shall be based on parameters supplied in the Project Instructions. Very high accuracy and very high density spot spacing may be required. One or more ground GPS base stations within 40km of the project area shall be required. The contractor shall perform a database search for high accuracy GPS control stations in the project area and then perform ground recovery of the required station(s). See Section 10.2 for additional information on database searches and mark recovery.

11.3 LIDAR SURVEY PLAN - After reconnaissance but prior to observations, the contractor shall submit a LIDAR Survey Plan to the NGS POC. NGS will review the Plan as soon as possible, normally within five work days, and will send the contractor written comments and/or approval. The contractor shall not begin data collection until the Plan is approved by NGS. The Plan shall include at least the following sections:

a. Text with summary of survey planning,
b. Flight line layout,
c. Flight parameters: altitude, speed, scan angle, scan rate, forward tilt, laser pulse rate, beam divergence, aircraft, etc.,
d. Planned spot spacing, size, and accuracy,
e. Plan for calibration,
f. List of hardware (brand and models) and software (brand and versions), and
g. Ground Station Table (see below).
h. Summary of data collection procedures, and
i. Summary of data processing procedures.

The Ground Station Table will include the station designation (name), PID (Permanent Identifier), type (FBN, PACS, etc.), establishing agency, order, stability, condition at recovery, and comments/recommendations. Include proposed name and monument type of any new stations to be set and identify them as “proposed” in the “type” column. For existing stations, the name and PID must be used exactly as listed in the NGS database and must be this way in all survey records.

11.4 AIRCRAFT GPS POSITIONING AND ORIENTING PROCEDURES - All LIDAR data will be positioned using kinematic GPS and oriented with an inertial system. The contractor will report heights of antenna, and model and serial numbers of all equipment used.

The inertial system must be capable of outputing and recording the sensor attitude, in all three axes, at least 200 times per second and to provide data accurate to 25 arc seconds.

KINEMATIC GPS - All LIDAR data shall be positioned using airborne kinematic GPS using at least two GPS receivers. Receivers must be dual-frequency, geodetic quality receivers which are capable of collecting carrier phase data at one second intervals for post-processing and time-tagging LIDAR data. Data shall be collected from a minimum of four satellites, (five or more preferred) at both the aircraft and the ground GPS station. All data must be collected with a PDOP of less than seven. The GPS receivers must be equipped with the appropriate type of antenna. The vector from the aircraft GPS antenna to the LIDAR data collection point must be accurately measured. The entire LIDAR-GPS system should be capable of determining the three-dimensional position of the LIDAR data collection point within 0.5 meter relative to the National Spatial Reference System (NSRS). The aircraft should maintain GPS satellite lock throughout the entire flight mission. If satellite lock is lost, on-the-fly ambiguity methods may be used to recapture lock while airborne. Report these instances, procedures used, and any other unusual occurrences.

11.5 GROUND STATION POSITIONING PROCEDURES - The ground GPS station must be a monumented station accurately tied to the NSRS, positioned to 0.1 meter accuracy or better, and should be within or near to the project area. An existing or new station may be used. Additional ground GPS receivers may be required. The contractor shall collect, process, and submit the ground and airborne GPS data, both original data and final processed data.

a. EXISTING GROUND STATION - Set up the ground-based receiver over a known, permanently marked, high accuracy NSRS survey point and run it continuously during the photo mission. For an existing NSRS station, write a digital recovery note in NGS format and take three photographs as specified in Attachment I (use the FBN station option). Prepare a GPS visibility diagram. Carefully measure the height of antenna.

b. NEW GROUND STATION - A new station must be positioned relative to the NSRS by tying to one or more NGS CORS by static, dual-frequency geodetic GPS methods. If the distance to the nearest NGS CORS is less than 50 miles, use at least two independent sessions, each two hours long. If the distance to the nearest NGS CORS is greater than 50 miles, use at least two sessions, each four hours long. NSRS stations other than an NGS CORS may be used with NGS approval. Make a separate tripod set-up and height measurement for each GPS session. Take extreme care in recording the accurate height of the antenna.

For a new station, write a digital station description in NGS format. The station shall be marked with a permanent mark to NGS specifications. Take three photographs as specified in Attachment I (use FBN station option). Prepare a GPS visibility diagram. Data shall be submitted in NGS "Blue Book" format. For additional specification guidance on mark setting, GPS observations, data processing, and data submittal, see the "General Specifications for Aeronautical Surveys, Volume I, Establishment of Geodetic Control on Airports" at: http://www.ngs.noaa.gov/AERO/aerospecs.htm#vol1. Also, static observations may be processed using the NGS "On-Line User Positioning Service" (OPUS) found at: http://www.ngs.noaa.gov/OPUS/index.html .

11.6 LIDAR DATA COLLECTION - The contractor shall perform daily (preferably for each flight) equipment calibrations.

11.7 LIDAR DATA PROCESSING - When the project instructions call for high accuracy, the contractor shall take special care in processing the LIDAR data, especially with regard to editing spikes, which may actually be real features. Data processing, especially data cleansing and filtering methods, shall be fully described in the Final Project Report.

11.8 LIDAR DATA ANALYSIS - The contractor shall prepare a data quality analysis, including an error budget, and include this in the Final Project Report. This analysis will include a comparison of LIDAR data with ground truth data.

11.9 LIDAR PRODUCTS - Required products may include: contour maps, Digital Elevation Models (DEM), Triangulated Irregular Networks (TINS), and intensity images.

12. FINAL PROJECT REPORT

12.1 HTMOD - The Final Project Report for HTMOD surveys shall contain at least the following sections:

a. An overview discussion of the planning, field work, data collection, data processing, adjustment, and data error analysis. This discussion should include a summary of the results, problems encountered, conditions affecting progress, and any unusual circumstances. Include comments on any deviations from the HTMOD Survey Plan, Project Instructions, or this SOW (include comments from weekly Status Reports).

b. A written description and analysis of the quality control performed; tables showing check positions; a listing and analysis of all unusual circumstances, discrepancies, and deviations; and the Quality Control Plan.

c. A listing of personnel who worked in the field and/or were involved with the data processing for this project.

d. A listing of the brand, model number, and serial number of all survey equipment (GPS receivers, antennas, levels, etc.) used in the project. List the quantity, brand, type, and height of fixed height tripods used. Include any instrumentation used for differential leveling if done.

e. A listing of all software, including version, used during the project.

f. A final station list: use a table format to list each station and each observation session for the station.

g. A final Project Sketch (Vector Diagram): update the vector diagram submitted with the HTMOD Survey Plan (see Section 10.3). Submit only a large size, readable plot (approximately 24 x 32 inches). Include processing session designations on the vectors if feasible. Note, a digital vector diagram may be required.

h. The vector processing scheme, observation time for the vector, solution type (ion-free, fixed, etc.), and final RMS for the vector. Provide any comments on problems encountered or anomalies with the processing session.

i. A list of the comparison of all repeat base lines.

j. A detailed description of the project adjustment. Discuss each of the adjustments separately, including fixed control and the source of the coordinates, ellipsoid heights, and NAVD 88 elevation used.

k. A completed Project Submission Checklist, see Attachment J. Also available on-line at: http://www.ngs.noaa.gov/FGCS/BlueBook/ (Click on "Annex L" and scroll down to page 9).

l. Recommendations for future projects.

12.2 LIDAR - The Final Project Report for LIDAR surveys shall contain at least the following sections:

a. A written summary of the project with sub-section covering: planning, field work (aerial and ground), data collection, calibration, data processing, calibration analysis, data error analysis, and product creation. This discussion shall include a summary of the results, problems encountered, any unusual circumstances, and conditions affecting progress. Include comments on any deviations from the LIDAR Survey Plan, Project Instructions, or this SOW (include comments from weekly Status Reports).

b. A written description and analysis of the quality control performed; tables showing check positions; a listing and analysis of all unusual circumstances, discrepancies, and deviations; and the Quality Control Plan.

c. A table showing each flight line with at least the following information: date, time, altitude, airspeed, scan angle, scan rate, laser pulse rates, weather, and comments.

d. A listing of personnel who worked in the field and/or were involved with the data processing for this project.

e. A listing of the brand, model number, and serial number of all equipment (including LIDAR, GPS receivers, antennas, etc.) used in the project. Also list the quantity, brand, type, and height of fixed height tripods used.

f. A listing of all software, including version, used during the project.

g. A final station list: use a table format to list each station occupied and each observation session for the station.

h. A map showing the coverage of the project.

i. Recommendations for future projects.

13. DELIVERABLES TO NGS

13.1 LABOR, EQUIPMENT, ETC. - The contractor shall provide all labor, equipment, supplies, materials, and transportation to produce and deliver the products as required under this Scope of Work, except as shown in Section 3. Note, government supplied items are listed in Section 3.

13.2 GOVERNMENT SUPPLIED ITEMS - The contractor shall return all government supplied records (listed in Section 3) and all unused survey marks and logo caps to NGS.

13.3 QUALITY CONTROL PLAN - Before any field work begins, the Contractor shall submit to NGS a Quality Control Plan covering all work (see Section 6). NGS will review this plan and respond with an approval or comment letter (or email) as soon as possible, normally within ten working days. If a QC Plan was submitted as part of the original submission in response to the Federal Business Opportunities announcement, this requirement may be simply an update of the earlier version. Submit paper and digital copies.

13.4 SURVEY PLAN - Before any mark setting or GPS observations begin, the Contractor shall submit a HTMOD and/or LIDAR Survey Plan (see Sections 10.3 and 11.3) to NGS. NGS will review this plan and respond with an approval or comment letter (or email) as soon as possible, normally within ten working days. Field work may commence after the Contractor receives the approval letter (or email) and the Task Order, if required. See Section 10.3 for a listing of which items are to be submitted on paper and which in digital format.

13.5 PROJECT STATUS REPORTS - The Contractor shall submit project status reports via email to the NGS contacts in Section 14 every Monday afternoon by 2:00 P.M. Eastern Time, from the date of the Task Order until the work is complete. These reports shall include the percentage complete for each of the major portions of the work, the status of other work, where work is underway, where work is completed (with dates completed), and any unusual circumstances and/or deviations from this Scope of Work. Include the expected date of completion. This report should be brief and contain the current information in the text of the email. Be sure to include the prime contractor's firm name on all reports.

13.6 HTMOD PROJECT SKETCH (VECTOR DIAGRAM) - Submit a vector diagram showing all computed vectors. Submit only a large size, readable plot (approximately 24 x 32 inches).   Include processing session designations on the vectors if feasible. Submit a paper version and a digital version, if possible.

13.7 FIELD LOGS - Submit the original version of all the observation logs, pencil rubbing forms, hand-written station descriptions/recovery notes, visibility diagrams, digital photographs, etc.

13.8 VECTOR PROCESSING OUTPUT - Submit paper copies of the COMBINED.SUM files for any processing sessions that were difficult to process or produced questionable results. Submit paper copies of any other files requested by NGS for quality control.

13.9 REPORTS - Submit a Final Project Report covering HTMOD surveys; see Section 12.1. Submit a Final Project Report for LIDAR surveys; see Section 12.2

13.10 HTMOD ADJUSTMENT AND CHECKING PROGRAMS - Submit a paper copy of the output for programs COMPGB, NEWCHKOB, OBSCHK, OBSDES, CHKDESC, BBACCUR, and ELLACC. Submit paper copies of all ADJUST files. Also, submit the digital data sheet or coordinate file for stations used for fixed control during the adjustment (CORS log/coordinate sheets, NGS data sheet for HARN and bench mark coordinates, etc.).

13.11 ORIGINAL HTMOD DATA - Submit all the original, raw data, RINEX data, precise ephemeris, and vector files. Include the CORS RINEX data files used for processing. For all RAW and RINEX data files not named by their occupied station four character ID, submit an index of station names to RAW and RINEX file; see Section 10.9.

13.12 DESCRIPTIONS - Submit the finalized description file from the NGS WDDPROC software. Submit both paper and digital formats. This includes the recovery notes submitted with the Survey Plan and the final version of the descriptions of new marks, written after the marks are set. Note, descriptions and recovery notes should be written by one person and checked, in the field, by another.

13.13 ORIGINAL LIDAR DATA- One file for each flight.

13.14 LIDAR PROCESSED DATA - Data and products as required by Project Instructions. May include: contour maps, DEMs, TINS, intensity images, and/or edited data files.

13.15 LIDAR PLANNING INFORMATION - Including flight maps and any other planning documents.

13.16 TRANSMITTAL LETTER - For all hardcopy data being sent via express mail, regular mail, etc., prepare a transmittal letter listing all items being sent. Include a copy of the transmittal letter within the data package and send a second copy to the receiving office via FAX or mail. The receiving office will check the data package against the letter, sign and date it, and FAX it back to the sender. Be sure to include the prime contractor's firm name on all transmittals and communications. See sample Transmittal Letters in Attachment L.

14. POINTS OF CONTACT - Send all technical reports, comments, questions, data, etc. to the first POC.

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Contracts Technical Manager
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ATTACHMENT A

EXPLANATIONS OF GOVERNMENT SUPPLIED MATERIALS

A.1 TRANSMITTAL LETTER

A letter containing a list of all items shipped to the contractor for a particular survey, the date the items were shipped, and the name and address of the individual who shipped them. The contractor is responsible for verifying the receipt of all items listed and returning a signed copy of the transmittal letter to the address listed.

A.2 PROJECT INSTRUCTIONS FOR GROUND SURVEYS

A set of instructions which is specific to a particular survey. The Project Instructions will typically contain the following sections:

- A. Project
  - i. Project Name
  - ii. Geographic Limits
  - iii. Project Identification Number
  - iv. Size of project/ number of points
  - v. Point of Contact
- B. Control

  Information on all existing horizontal and vertical control points in the project area on CD-ROM.

A.3. CD-ROM CONTAINING NGS DATA SHEETS FOR CONTROL STATIONS IN DSDATA FORMAT

NGS data sheets will be provided to the contractor on a CD-ROM. DSDATA is the traditional format of NGS data sheets. Information in this format can be manipulated by NGS programs DSX, DSSELECT, etc.

A.4. BRASS DISKS and LOGO CAPS

NGS will supply standard, pre-stamped disks with the NGS logo or pre-stamped logo caps. These disks or logo caps shall be used by the contractor for NGS projects only. The Contractor should notify NGS of the approximate quantity required.

ATTACHMENT B

A Guide for Establishing GPS-Derived Orthometric Heights (Standards: 2 cm and 5 cm)

Version 1.3

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September 2001

A GUIDE FOR ESTABLISHING GPS-DERIVED ORTHOMETRIC HEIGHTS
[Standards: 2 cm and 5 cm]
Version 1.3

Preface:

In November 1997, guidelines were developed by the National Geodetic Survey (NGS) for performing Global Positioning System (GPS) surveys that are intended to achieve **ellipsoid height *network* accuracies** of 5 cm at the 95 percent confidence level, as well as **ellipsoid height *local* accuracies** of 2 cm and 5 cm, also at the 95 percent confidence level (Zilkoski et al. 1997). See Appendix A for information about local and relative ellipsoid height accuracies and Appendix B for information on the basic requirements for 2-cm ellipsoid height standards.

The following guidelines were developed by NGS for performing GPS surveys that are intended to achieve **orthometric height *network* accuracies** of 5 cm at the 95 percent confidence level, as well as **orthometric height *local* accuracies** of 2 cm and 5 cm, also at the 95 percent confidence level. These guidelines were developed in partnership with Federal, state, and local government agencies, academia, and private surveyors.

We are confident that these guidelines, if followed, will result in achieving the intended accuracy. Additional analysis may show that some of these guidelines can be relaxed in the future. These guidelines are intended for establishing vertical control networks.

Note: these guidelines assume that for the survey project area in question, NGS has completed the establishment of a high accuracy reference network at 100-kilometer spacing or that a state-wide High Accuracy Reference Network (HARN) has been established, i.e., there are A- or B-order stations distributed throughout the state at an approximate spacing of 50 km or else there are Federal HARN stations or GPS Continuously Operating Reference Station (CORS) sites located within 75 km of the project area.

An effort should be made to connect to stations which were previously determined using these guidelines (or equivalent).

Introduction:

Since early 1983, NGS has performed control survey projects in the United States using GPS satellites. Analysis of GPS survey data has shown that GPS can be used to establish precise relative positions in a three-dimensional Earth-centered coordinate system. GPS carrier phase measurements are used to determine vector base lines in space, where the components of the base line are expressed in terms of Cartesian coordinate differences (Remondi 1984). These vector base lines can be converted to distance, azimuth, and ellipsoidal height differences (dh) relative to a defined reference ellipsoid.

During the past decade, results from projects have clearly shown that GPS survey methods can replace classical horizontal control terrestrial survey methods. However, until recently, there was a problem in obtaining sufficiently accurate geoid height differences to convert GPS-derived ellipsoid height differences to accurate GPS-derived orthometric height differences (Zilkoski and Hothem 1989, Hajela 1990, Milbert 1991). The interest in obtaining accurate GPS-derived orthometric heights has increased during the last several years (Parks and Milbert 1995, Kuang et al. 1996, Satalich 1996, Zilkoski and D'Onofrio 1996, Henning et al. 1998, Martin 1998). Can the accuracies achieved for these orthometric height differences now provide a viable alternative to classical geodetic leveling techniques? With the completion of the general adjustment of the North American Vertical Datum of 1988 (NAVD 88) (Zilkoski et al. 1992), computation of an accurate National high-resolution geoid model, GEOID99 (*Smith and Roman 2000*), and development of NGS' Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards: 2 cm and 5 cm) (Zilkoski et al. 1997), the answer is yes -- GPS-derived orthometric heights can now provide a viable alternative to classical geodetic leveling techniques for many applications.

Orthometric heights (H) are referenced to an equipotential reference surface, e.g., the geoid. The orthometric height of a point on the Earth's surface is the distance from the geoidal reference surface to the point, measured along the plumb line normal to the geoid. Ellipsoid heights (h) are referenced to a reference ellipsoid. The ellipsoid height of a point is the distance from the reference ellipsoid to the point, measured along the line which is normal to the ellipsoid. At the same point on the surface of the earth, the difference between an ellipsoid height and an orthometric height is defined as the geoid height (N).

Several error sources that affect the accuracy of orthometric, ellipsoid, and geoid height values are generally common to nearby points. Because these error sources are in common, the uncertainty of height differences between nearby points is significantly smaller than the uncertainty of the absolute heights of each point.

Orthometric height differences (dH) can then be obtained from ellipsoid height differences by subtracting the geoid height differences(dN):

$$dH \approx dh - dN.$$

Adhering to NGS' guidelines, ellipsoid height differences (dh) over **short base lines**, i.e., less than 10 km, can now be determined from GPS phase measurements with 2-sigma uncertainties that are **typically better than +/- 2 cm.** This is now possible because of the availability of a greater number of satellites, more accurate satellite orbits, full-wavelength dual-frequency carrier phase data, improved antenna designs, and improved data processing techniques. It should also be noted that the GPS-derived ellipsoid height guidelines documented by Zilkoski et al.(1997)were intentionally designed to produce ellipsoid heights slightly better than 2 cm, i.e., about 1.4 cm, so that they could also be used when generating 2-cm GPS-derived orthometric heights. The requirement that each base line must be repeated and agree to within 2 cm of each other, and because they must be obtained on two separate days during different times of the day provide a final GPS-derived ellipsoid height better than 2 cm at the 2-sigma level. The requirement that spacing between local network station cannot exceed 10 km helps to keep the relative error in geoid height small, i.e., typically less than 0.5 cm. Adding in the small error for the uncertainty of the geoid height difference and controlling the remaining systematic differences between the three height systems will produce a GPS-derived orthometric height with 2-sigma uncertainties that are typically +/- 2 cm.

In many areas of the United States, geoid height differences can be determined with uncertainties that are typically better than 1 cm for distances of as much as 20 km and less than 2-3 cm for distances from 20 to 50 km (Zilkoski and D'Onofrio 1996, and Henning et al. 1999). The small values for the differential geoid height uncertainties have been demonstrated in tests in several regions of the United States. Larger uncertainties can be expected in other areas, depending on the density of the observed gravity network and uncertainties in the determination of observed and interpolated gravity anomalies.

When high-accuracy field procedures are used, orthometric height differences can be computed from measurements of precise geodetic leveling with an uncertainty of less than 1 cm over a 50-kilometer distance. Less accurate results are achieved when third-order leveling methods are employed. Depending on the accuracy requirements, GPS surveys and present high-resolution geoid models can be employed as an alternative to classical leveling methods. In the past, the primary limiting factor was the accuracy of estimating geoid height differences. With the computation of the latest National high-resolution geoid model, GEOID99, and the development of the 2- and 5-cm guidelines for estimating GPS-derived ellipsoid heights (Zilkoski et al. 1997), the limiting factor is ensuring that the NAVD 88 orthometric height values used to control the project are valid. Strategically occupying bench marks with GPS that have valid NAVD 88 height values is critical to detecting, reducing, and/or eliminating blunders and systematic errors between the three height systems.

The 3-4-5 System:

There are three basic rules, four control requirements, and five procedures which need to be adhered to for estimating GPS-derived orthometric heights. This document describes these rules, control requirements, and procedures required for estimating GPS-derived orthometric height to meet 2- and 5-cm standards. It is the intent of this document to keep the explanation of rules, requirements, and procedures to a minimum. Detailed explanations can be found in the referenced reports.

Basic **Rules** for Estimating GPS-Derived Orthometric Heights:

There are three basic rules that a user must follow when estimating accurate GPS-derived orthometric heights:

Rule 1: Follow NGS' guidelines for establishing GPS-derived ellipsoid heights when performing GPS survey (Zilkoski et al. 1997),

Rule 2: Use NGS' latest National Geoid Model, i.e., GEOID99, when computing GPS-derived orthometric heights (Smith and Roman 2000), and

Rule 3: Use the latest National Vertical Datum, i.e., NAVD 88, height values to control the project's adjusted heights (Zilkoski et al. 1992).

Basic **Control Requirements** for Estimating GPS-Derived Orthometric Heights:

When the user follows the three basic rules above, there are only four basic control requirements for estimating GPS-derived orthometric heights:

Requirement 1: GPS-occupy stations with ***valid*** NAVD 88 orthometric heights, stations should be evenly distributed throughout project.

Requirement 2: For project areas less than 20 km on a side, surround project with ***valid*** NAVD 88 bench marks, i.e., minimum number of stations is four; one in each corner of project. *[NOTE: The user may have to enlarge the project area to occupy enough bench marks even if the project area extends beyond the original area of interest.]*

Requirement 3: For project areas greater than 20 km on a side, keep distances between ***valid*** GPS-occupied NAVD 88 bench marks to less than 20 km.

Requirement 4: For projects located in mountainous regions, occupy ***valid*** bench marks at base and summit of mountains, even if distance is less than 20 km.

[NOTE: Valid NAVD 88 height values include, but are not limited to, the following: bench marks which have not moved since their heights were last determined, were not misidentified, and are consistent with NAVD 88.]

Basic **Procedures** for Estimating GPS-Derived Orthometric Heights:

When the user follows the three basic rules and four control requirements stated above, there are only five basic procedures that need to be followed for computing accurate GPS-derived orthometric heights.

Procedure 1: Perform a 3-D minimum-constraint least squares adjustment of the GPS survey project, i.e., constrain one latitude, one longitude, and one orthometric height value.

Procedure 2: Using the results from the adjustment in procedure 1 above, detect and remove all data outliers. *[NOTE: If the user follows NGS' guidelines for establishing GPS-derived ellipsoid heights, then the user will already know which vectors may need to be rejected and following the GPS-derived ellipsoid height guidelines should have already reobserved those base lines.]*

The user should repeat procedures 1 and 2 until all data outliers are removed.

Procedure 3: Compute differences between the set of GPS-derived orthometric heights from the minimum constraint adjustment (using the latest National geoid model, i.e., GEOID99) from procedure 2 above and published NAVD 88 bench marks.

Procedure 4: Using the results from procedure 3 above, determine which bench marks have ***valid*** NAVD 88 height values. This is the most important step of the process. Determining which bench marks have valid heights is critical to computing accurate GPS-derived orthometric heights. *[NOTE: The user should include a few extra NAVD 88 bench marks in case some are inconsistent.]*

All differences between valid bench marks need to agree within 2 cm for 2-cm surveys and 5 cm for 5-cm surveys. *[NOTE: For most small areal extent, e.g., 20 km by 20 km, in the conterminous United States, using NGS' latest National Geoid Model should produce satisfactory results (see Hennings et. al, 1998). There may, however, appear to be a systematic tilt over large areas, i.e., 50 km by 50 km, but with NAVD 88 vertical control occupied with GPS every 20 km, this tilt should be accounted for in the final constrained adjustment. The user should estimate local systematic differences between GPS-derived heights and leveling-derived heights by solving for the geoidal slope and scale. [See Vincenty (1987)and Zilkoski 1993].*

Procedure 5: Using the results from procedure 4 above, perform a constrained adjustment fixing one latitude and one longitude value and all ***valid*** NAVD 88 height values.

The user should always ensure that the final set of heights weren't distorted by the adjustment process. If the user followed the procedures outlined above, then this should not occur, but there is a fairly simple way of checking for blunders.

The user should compute the differences between the final set of GPS-derived orthometric heights from procedure 5 and the minimum constrained set of heights from procedure 2. The differences <u>between neighboring stations</u> should be small, i.e., 1 cm (see Henning et al., 1998). If these differences exceed 2 cm, it is possible that an incorrect or invalid station value was held fixed.

During the last decade, several NGS reports have been prepared that describe these procedures in more detail (Zilkoski and Hothem, 1989; Zilkoski, 1990a; Zilkoski, 1990b; Zilkoski, 1993;and Henning, et. al, 1998). These reports are available from NGS' web site at http://www.ngs.noaa.gov. Although, it should be mentioned that because of improvements in high resolution geoid models, the implementation of the full constellation of GPS, the completion of the NAVD 88 project, improvements in GPS equipment and processing software, and the development of guidelines for estimating GPS-derived ellipsoid heights, the minimum steps outlined in the above reports only need to be considered when a problem is detected when performing the five procedures. However, the reports, even thought they are slightly out of date because of improvements in geoid models and technology, should provide the necessary information for the user to understand how to perform the five procedures stated in these guidelines. In particular, the report titled “NGS/Caltrans San Diego GPS-Derived Orthometric Height Cooperative Project” demonstrates the minimum steps required to estimate and evaluate a GPS-derived orthometric height project. Today, the 10 steps are simplified into five procedures, but they may still need to be considered when doing some projects. Appendix C contains a list of the 10 steps outlined in the San Diego GPS Project report and appendix D contains a brief description of the five procedures using a sample project.

Submission of Data to the National Geodetic Survey:

"Input Formats and Specifications of the National Geodetic Survey (NGS) Data Base," commonly called the "Blue Book," is a user's guide for preparing and submitting geodetic data for incorporation into NGS' data base. Survey data that are entered into NGS' data base become part of the National Spatial Reference System (NSRS), formerly the National Geodetic Reference System. The guide comprises three volumes. Volume I covers classical horizontal geodetic and Global Positioning System (GPS) data, volume II covers vertical geodetic data, and volume III covers gravity data. Beginning with this edition, the three formerly separate volumes are distributed as a set, since a great deal of information is common to each volume. Because some of the chapters and annexes are identical in all three volumes, the original numbering design has been retained.

The formats and specifications are consistent with the aims of the Executive Office of the President, Office of Management and Budget's (OMB) Circular A-16, as revised in 1990. A major goal of the circular, which is titled "Coordination of Surveying, Mapping, and Related Spatial Data Activities," is to develop a national spatial data infrastructure with the involvement of Federal, state, and local governments, and the private sector. This multilevel national information resource, united by standards and criteria established by the Federal Geodetic Control Subcommittee (FGCS) of the Federal Geographic Data Committee (FGDC), will enable the sharing and efficient transfer of geospatial data between producers and users.

Survey data that are submitted to NGS for incorporation into NSRS should be properly formatted and follow the guidelines outlined in this report.

The “Blue Book” and most of the documents referenced herein may be obtained from NGS web site at http://www.ngs.noaa.gov/FGCS/BlueBook/ or

NOAA, National Geodetic Survey, **N/NGS12**
1315 East-West Highway, Station 9202
Silver Spring, MD 20910-3282
Telephone: (301) 713-3242; Fax: (301) 713-4172
Monday through Friday, 7:00 a.m. - 4:30 p.m. Eastern Time.

Data Submission to NGS:

1. The project accession number is of the form GPS-xxx. (The project accession number ***will be assigned by NGS when draft project plans are submitted to NGS for evaluation prior to the start of the project***.)

2. A project report and the data elements listed in Appendix L of "Input Formats and Specifications of the NGS Data Base" must be transmitted to NGS. Quality checks for conformance to NGS format standards shall be performed using software programs COMPGB and OBSDES.

3. Latitude, longitude, and ellipsoid heights, as well as X, Y, and Z coordinates shall be provided in both NAD 83 and ITRF coordinate systems. GPS-derived orthometric heights shall be provided in NAVD 88.

Guideline Updates:

These Guidelines will be updated as the results of future projects and other procedures are reviewed. There may be other procedures that will also achieve the standards. The user should note which procedures in this document were not followed and note how errors and systematic biases were detected, reduced, or eliminated by the new procedure. NGS welcomes the opportunity to examine alternate procedures and supporting data that demonstrate the ability to achieve the accuracy standards stated in this document. If you have such data or would like to comment, please contact Dave Zilkoski or Edward Carlson, telephone 301-713-3196, or write:

National Geodetic Survey, N/NGS2
NOAA, 1315 East-West Highway
Silver Spring, Maryland 20910-3282
email: Dave.Zilkoski@noaa.gov or
Ed.Carlson@noaa.gov or
Curt.Smith@noaa.gov

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Appendix A. -- Definitions

Accuracy

Local Accuracy - The local accuracy of a control point is a value expressed in cm that represents the uncertainty in the coordinates of the control point relative to the coordinates of the other directly connected, adjacent control points at the 95 percent confidence level. The reported local accuracy is an approximate average of the individual local accuracy values between this control point and other observed control points used to establish the coordinates of the control point.

Network Accuracy - The network accuracy of a control point is a value expressed in cm that represents the uncertainty in the coordinates of the control point with respect to the geodetic datum at the 95 percent confidence level. For National Spatial Reference System (NSRS) network accuracy classification, the datum is considered to be best supported by NGS. By this definition, the local and network accuracy values at CORS sites are considered to be infinitesimal, i.e., to approach zero.

Stations

Base Stations

Primary - Stations evenly distributed that surround the local network. These stations relate the local network to NSRS to the 5-cm, or better, standard through simultaneous observations with control stations. They can be newly established stations and be part of the local network.

Secondary - Stations evenly distributed throughout the local network that ensure that the local network does not contain a significant medium wavelength (20-30 km) ellipsoid height error through simultaneous observations with primary base stations. These stations may be newly established stations and are part of the local network. They are located between Primary Base Stations.

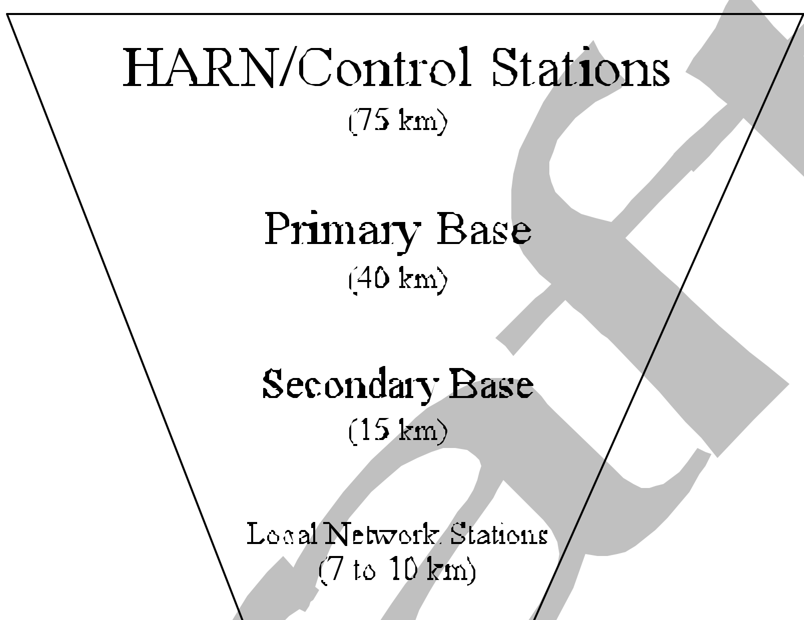
Control Stations

A- or B-order three-dimensional stations that surround the project area in at least three different quadrants. These stations relate the local network to the National Spatial Reference System through simultaneous observations with primary base stations. They must be referenced to NSRS and they provide the network accuracy. They may be newly established stations in the survey project if A- or B-order specifications and procedures are used to establish them. These procedures are not covered in this document, please contact NGS for additional information.

Local Network Stations

These stations include all other stations that are not base (primary or secondary) or control stations. They are part of the local network. They provide the local accuracy standard through simultaneous observations between adjacent stations.

Appendix B. -- GPS Ellipsoid Height Hierarchy and Basic Requirements for 2-cm standard



HARN/Control Stations

O CS1

O CS2 **<-------------------- 75 km ------------------>** O CS3

Primary Base Stations

O CS1

PB1

PB2 <---------------------- 40 km ---------------------> PB3

O CS2 CS3 O

Basic Requirements

o 5 Hour Sessions / 3 Days

o Spacing between primary base stations cannot exceed 40 km.

o Each primary base station must be connected to at least its nearest primary base station neighbor and nearest control station.

o Primary base stations must be traceable back to 2 control stations along independent paths; i.e, base lines PB1 - CS1 and PB1 - PB2 plus PB2 -CS2, or PB1 - CS1 and PB1 - PB3 plus PB3 - CS3.

Secondary Base Stations

O

PB1

SB1 ***SB2***

SB3 <---------- 15 km ----------> SB4

PB2 PB3

O O

Basic Requirements

o 30 Minute Sessions / 2 Days / Different Times of the Day

o Spacing between secondary base stations (or between primary and secondary base stations) cannot exceed 15 km.

o All base stations (primary and secondary) must be connected to at least its two nearest primary or secondary base station neighbors.

o Secondary base stations must be traceable back to 2 primary base stations along independent paths; i.e., SB1- PB1 and SB1- SB3 plus SB3 - PB2,
or SB1 - PB1 and SB1 - SB4 plus SB4 - PB3.

o Secondary base stations need not be established in surveys of small areal extent.

Local Network Stations

O

PB1

LN1

SB1 ***LN2*** ***LN3*** SB2

LN4 **LN5**

LN6<--7 km -> LN7

SB3 SB4

PB2 PB3

O O

Basic Requirements

o 30 Minute Sessions / 2 Days / Different Times of the Day

o Spacing between local network stations stations (or between base stations and local network stations) cannot exceed 10 km.

o All local network stations must be connected to at least its two nearest neighbors.

o Local network stations must be traceable back to 2 primary base stations along independent paths; i.e., LN1 - PB1 and LN1 - LN2, plus LN2 - SB1, plus SB1 - SB3 plus SB3 - PB2, or LN1 - PB1 and LN1 -LN3, plus LN3 - SB2 plus SB2 - SB4 plus SB4 - PB3.

APPENDIX C. – 10 Minimum Steps Required to Estimate and Evaluate a GPS-Derived Orthometric Height Project.

These steps are documented in the report titled “Minimum Steps Required When Estimating GPS-Derived Orthometric Heights,” Proceedings of the GIS/LIS ‘90 Fall Convention, Anaheim, California, November 7-10.

The minimum steps required when analyzing GPS-derived orthometric heights are listed below.

1. During the project’s planning stage, perform a detailed analysis of the geoid in the area of the survey in order to determine if additional gravity and/or leveling data are required to adequately estimate the slope of the geoid and changes in slope.

2. During the project’s planning stage, perform a detailed study of the leveling network in the area, i.e., plot all leveling lines, note the age of leveling, determine if bench marks can be occupied by GPS receivers, etc.

3. Perform a 3-D minimum constraint least squares adjustment of the GPS data and compare GPS-derived coordinates with results of higher-order surveys.

4. Using the best available geoid heights, compare adjusted GPS-derived orthometric height differences obtained from step 3 with leveling-derived orthometric height differences.

5. Detect and remove all data outliers determined in steps 3 and 4.

6. Analyze the local geoid in detail.

    a. Plot the modeled geoid heights in the area.
    b. Plot the estimated slope of the geoid using differences between GPS-derived ellipsoid height differences and leveling-derived orthometric height differences (dN = dh - dH) obtained in step 4.

7. Estimate GPS-derived orthometric heights and local systematic errors in the geoid heights by solving for the geoidal slope and scale using the method described in Vincenty (1987) and demonstrated in Zilkoski and Hothem (1989) and Zilkoski (1990a).

8. Compare adjusted GPS-derived orthometric height differences from step 7 with leveling-derived orthometric height differences to determine scale and rotation parameters.

9. Compare GPS-derived orthometric heights by performing a 3-dimensional least squares adjustment holding fixed all appropriate orthometric height values of published bench marks (and approximate GPS-derived coordinates computed from higher-order surveys and solving for appropriate scale and rotation parameters.

10. Use the results from steps 1 through 9 to document the estimated accuracy of the GPS-derived orthometric heights.

APPENDIX D. – Brief Description of Guidelines Using Sample Project.

Using GPS, Geoid99, and NGS Guidelines to Obtain Reliable, Accurate Orthometric Heights in Support of Photogrammetric and Surveying Project in Baltimore County, Maryland

Three Basic Rules

The project fulfilled the three basic rules by :

Following NGS’ guidelines for establishing GPS-derived ellipsoid heights (Standards: 2 cm and 5 cm);

using GEOID99, the latest National Geoid Model; and

using NAVD 88, the latest National Vertical Datum.

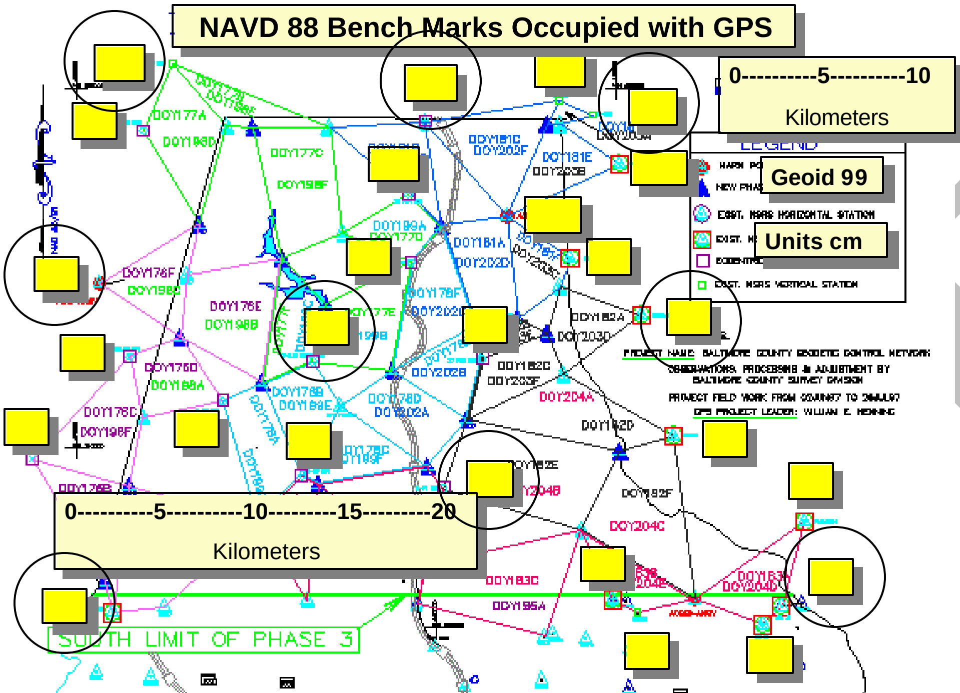
Four Basic Control Requirements

BCR1: Occupy stations with known NAVD 88 orthometric heights (Stations should be evenly distributed throughout project)

BCR2: Project areas less than 20 km on a side, surround project with NAVD 88 bench marks, i.e., minimum number of stations is four; one in each corner of project

BRC3: Project areas greater than 20 km on a side, keep distances between GPS-occupied NAVD 88 bench marks to less than 20 km

BRC4: Projects located in mountainous regions, occupy bench marks at base and summit of mountains, even if distance is less than 20 km



BCR1: Stations with large blocks have NAVD 88 heights and they are evenly distributed throughout the project area.

BCR2: This requirement is not applicable because the project is greater than 20 km on a side. [If the project was less than 20 km on a side, then there should be at least four stations with NAVD 88 heights, i.e., four large blocks , one in each corner of the project.]

BCR3: Circled bench marks are mandatory. The analysis must determine that the bench marks have valid NAVD 88 heights. Other bench marks can be substituted but the user must adhere to the 20 km requirement.

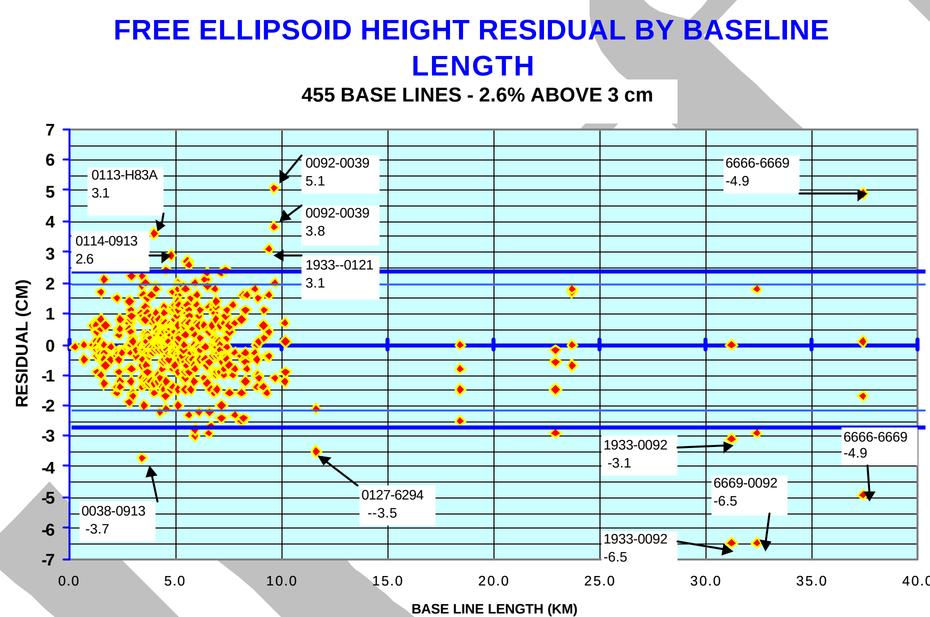
[NOTE: Valid NAVD 88 height values include, but are not limited to, the following: bench marks which have not moved since their heights were last determined, were not misidentified, and are consistent with NAVD 88.]

BRC4: This requirement is not applicable because project is not in a mountainous region. [If the project was in a mountainous region then bench marks should be located at the base and summit of the mountainous region.]

Five Basic Adjustment Procedures

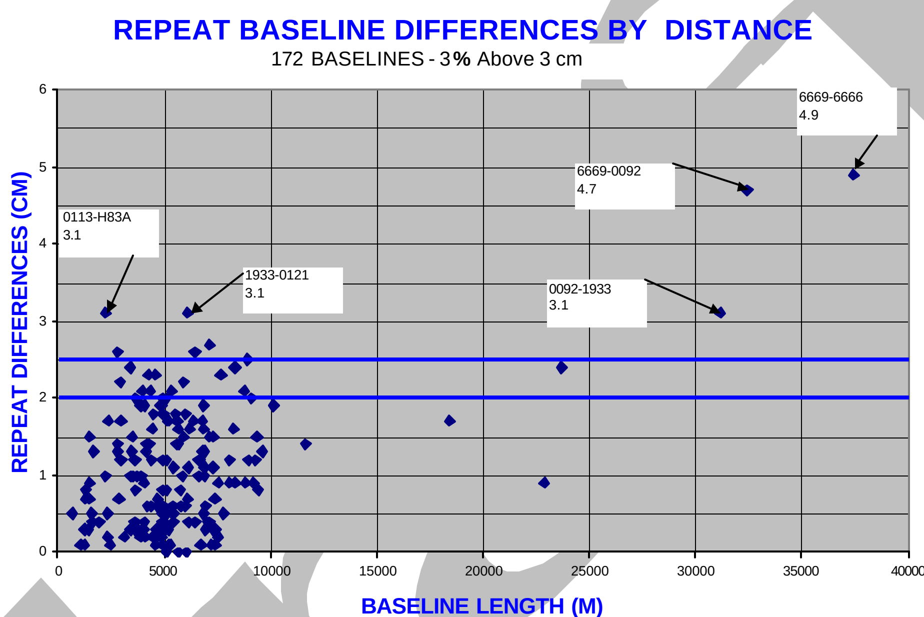
BAP1:Perform a 3-D minimum-constraint least squares adjustment of the GPS survey project, i.e., constrain one latitude, one longitude, and one orthometric height value.

BAP2:Using the results from the adjustment in procedure 1 above, detect and remove all data outliers. The user should repeat procedures 1 and 2 until all data outliers are removed.

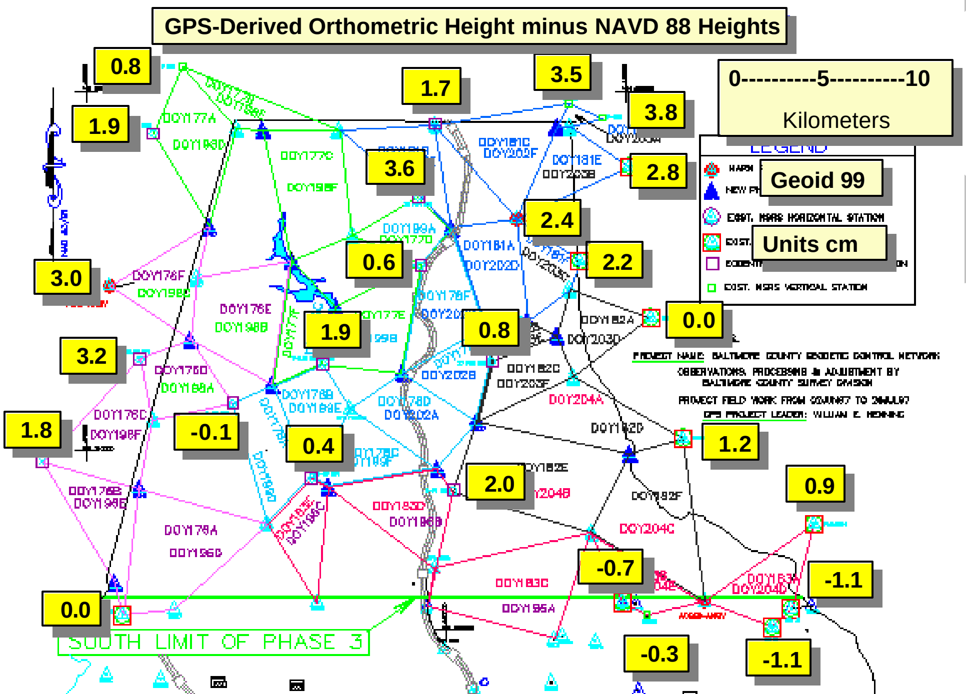


Note: After performing the minimum constraint adjustment, the user should plot the ellipsoid height residuals (or dU residuals) and investigate all residuals greater than 2 cm.

Note that the station pairs that have large residuals, i.e., greater than 2.5 cm, also have large repeat base line differences. The NGS guidelines for estimating GPS-derived ellipsoid heights require the user to reobserve these base lines. Following NGS guidelines provides enough redundancy for the adjustment process to detect outliers and apply the residual on the appropriate observation, i.e., the bad vector.

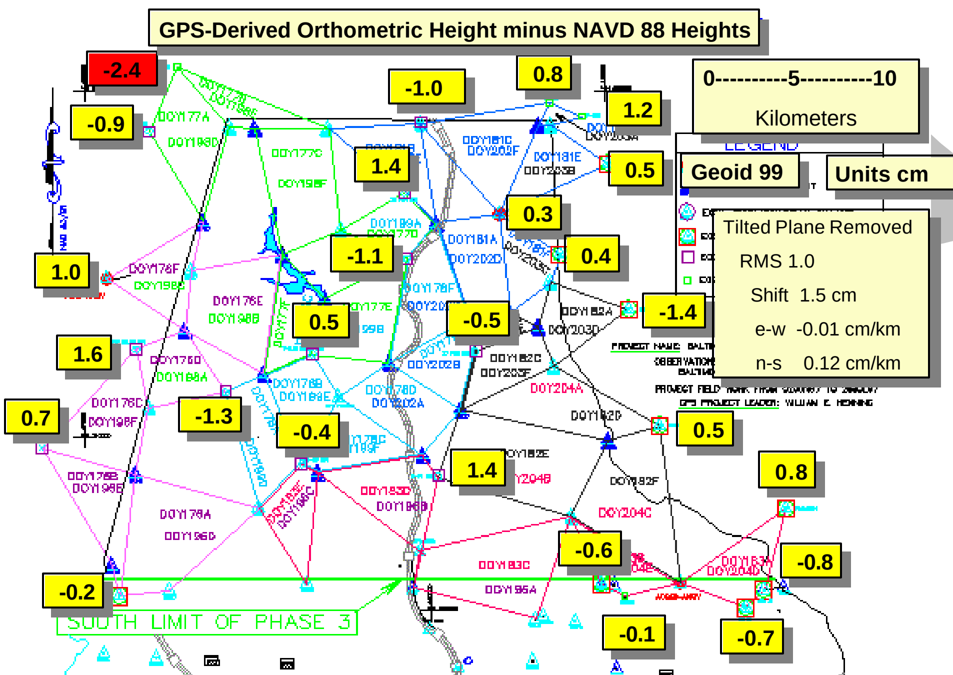

REPEAT BASELINE DIFFERENCES BY DISTANCE
172 BASELINES - 3% Above 3 cm
REPEAT DIFFERENCES (CM)
BASELINE LENGTH (M)
0113-H83A
3.1
1933-0121
3.1
0092-1933
3.1
6669-0092
4.7
6669-6666
4.9
0
1
2
3
4
5
6
0
5000
10000
15000
20000
25000
30000
35000
40000

BAP 3: Compute differences between the set of GPS-derived orthometric heights from the minimum constraint adjustment from procedure 2 above and published NAVD 88 bench marks.



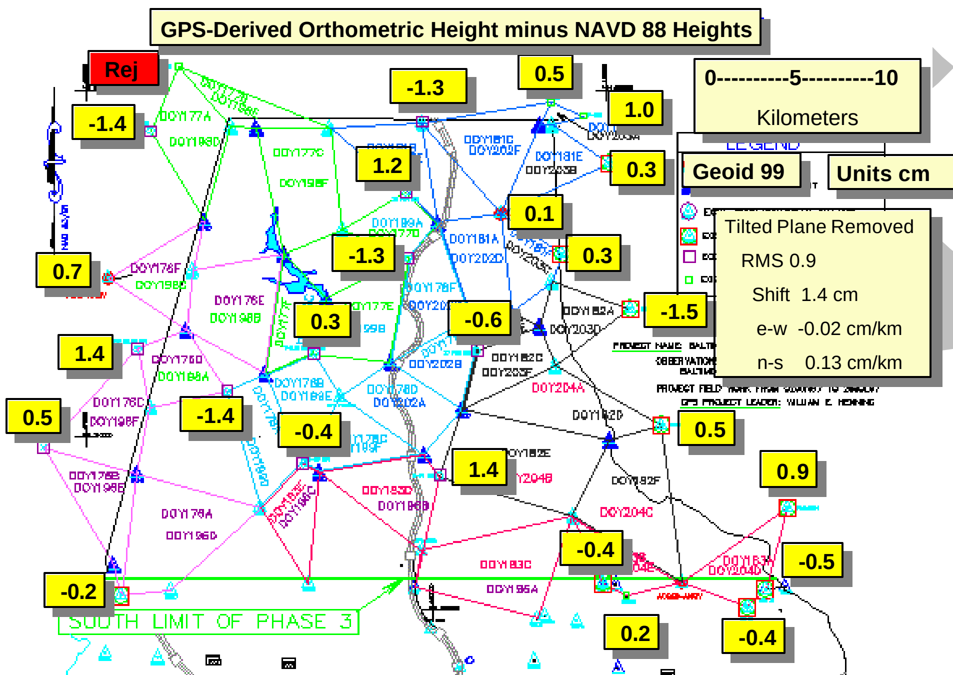
Note: All height differences are under 5 cm and most are less than 2 cm. Almost all relative height differences between adjacent station pairs are less than 2 cm. However, most of the height differences appear to be positive relative to the southwest corner of the project

BAP 4: Using the results from procedure 3 above, determine which bench marks have ***valid*** NAVD 88 height values. All differences between valid bench marks need to agree within 2 cm for 2-cm surveys and 5 cm for 5-cm surveys



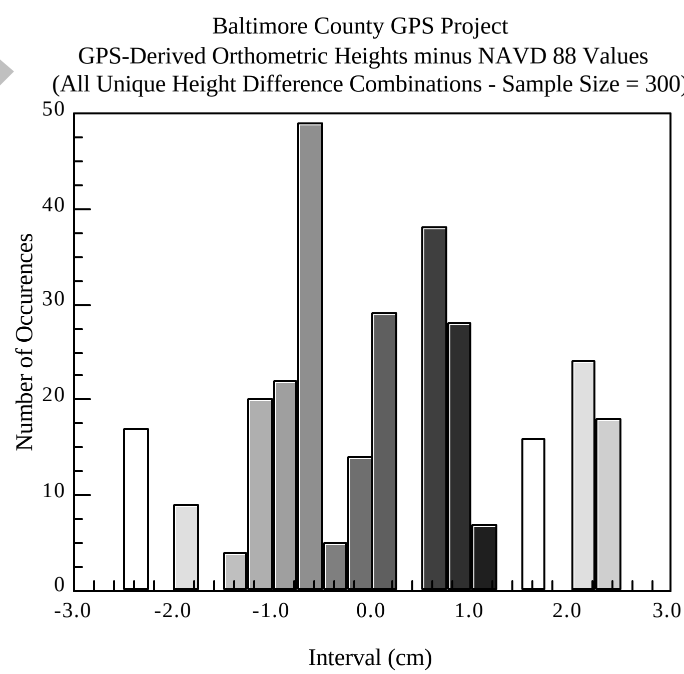
Note: To detect and remove any systematic trend, a tilted plane is best fit to the height differences (Vincenty 1987, Zilkoski and Hothem 1989). After a trend has been removed, all the differences are less than +/- 2 cm except for one and almost all relative differences between adjacent station are less than 2 cm.

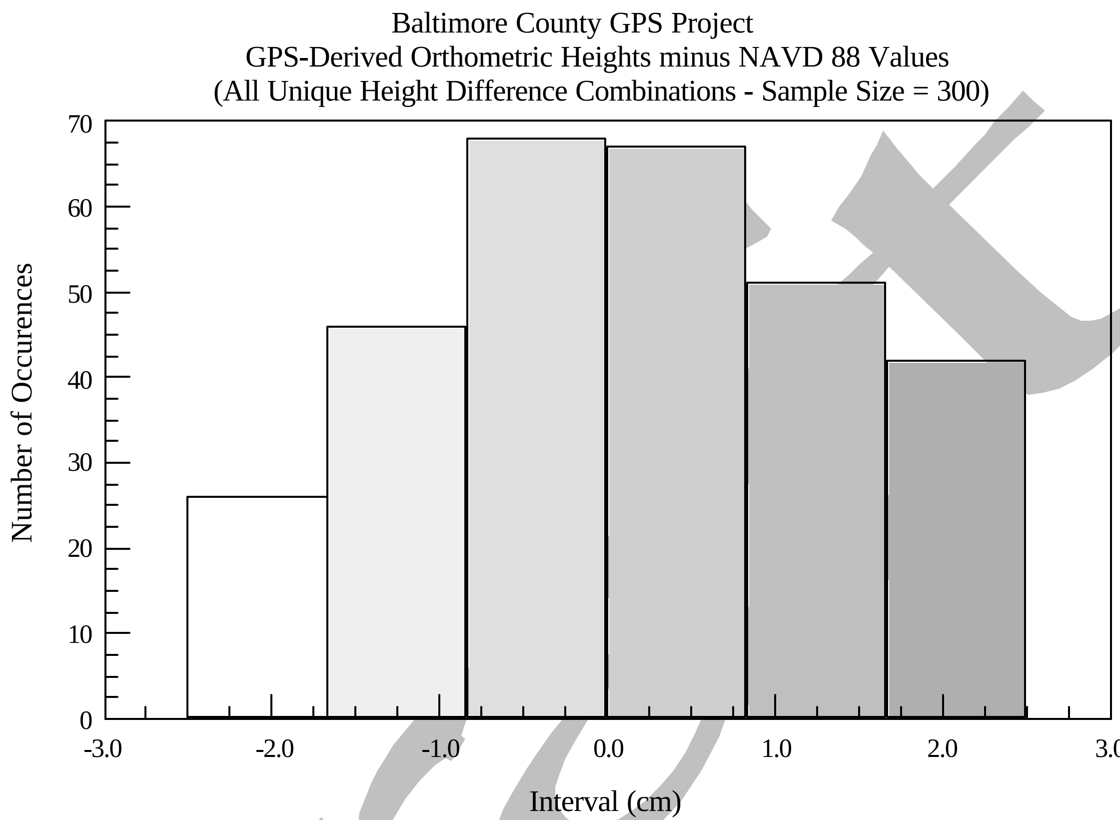
BAP 5: Using the results from procedure 4 above, perform a constrained adjustment fixing one latitude and one longitude value and all ***valid*** NAVD 88 height values.



Note: After rejecting the largest height difference (-2.4 cm), of all the closely spaced station pairs, i.e., less than 10 km, only three are greater than 2 cm, one is greater than 2.5 cm and none are greater than 3 cm.

There are 25 stations with both GPS heights and NAVD88 heights. This makes 300 unique comparisons. Of these comparisons, 59 are greater than 2.0 cm but only 34 are greater than 2.1 cm, and none are greater than 2.5 cm.




Baltimore County GPS Project
GPS-Derived Orthometric Heights minus NAVD 88 Values
(All Unique Height Difference Combinations - Sample Size = 300)
Number of Occurences
0
10
20
30
40
50
60
70
-3.0
-2.0
-1.0
0.0
1.0
2.0
3.0
Interval (cm)

ATTACHMENT C
World Wide Web Sites

NGS Height Modernization Web Site can be accessed at:
http://www.ngs.noaa.gov/initiatives.shtml#HeightMod

NGS Home Page can be accessed at: http://www.ngs.noaa.gov
There NGS presents a wealth of information on its data products, software programs, and user services, as well as links to other helpful sites on the Web.

CORS and IGS Ephemeris Data can be accessed at: http://www.ngs.noaa.gov/CORS/
Information on the National CORS system and access to CORS and Precise Ephemeris data downloads are available on the NGS web site. Use the "User Friendly CORS" utility to download customized RINEX data sets and IGS ephemeris. The latest coordinate files and other metadata for each CORS site is also available. The "Data Availability" feature can be used to determine if a CORS site is missing data for a particular time period.

USCG Navigation Center GPS Web Site can be accessed at: http://www.navcen.uscg.gov/
This site provides information on the status of the GPS constellation and provides NANU message postings and notices for outages at WAAS and DGPS sites.

GPS ANTENNA CALIBRATION Site: http://www.ngs.noaa.gov/ANTCAL/
Provides information on which antennas have been calibrated.

PAGE-NT - PAGE-NT is a menu-driven suite of programs used to process GPS data and is suitable for projects requiring the highest accuracy. A User's Manual, the software, and sample data set can be downloaded from the NGS anonymous ftp server:

ftp ftp.ngs.noaa.gov
login: anonymous
passwd: your complete email address

Once logged on, go to the /pub/pnt6 directory and download all the files using binary transfer mode. The input1 and results1 directory contain the sample data sets.
Follow the setup instructions in the PAGE-NT User's Manual.

ADJUST - The ADJUST and ADJUST UTILITIES software package can be downloaded from the NGS home page (http://www.ngs.noaa.gov) by accessing the "PC Software" link. Check the web page for the latest version of each program. The software performs a least squares adjustment on horizontal, vertical angle, and/or GPS observations. The program comprises six data checking programs in addition to the adjustment software. This software package has numerous options, such as choice of ellipsoid, and includes sample input data. Also available is the source code.

ADJUST UTILITIES - Suite of programs that are used in conjunction with PC program ADJUST. This group of programs includes:

BBACCUR provides a formatted listing of the external and internal accuracies which have been computed by program ADJUST-- sorted in numerical ascending order of external accuracy. Output from program ADJUST, run with accuracies, is used as input.

CLUSTER is used to identify geodetic stations which are common to two data sets with respect to name or a given position tolerance.

ELEVUP creates a bfile which combines the bfile output from the constrained horizontal adjustment with the bfile output from the constrained vertical adjustment. This new bfile contains *80* records with adjusted positions from the horizontal and *86* records with the ellipsoidal heights from the horizontal adjustment and the orthometric heights and geoid heights from the vertical adjustment.

ELLACC computes ellipsoidal height order and class for a project. Output from program ADJUST, run with accuracies, is used as input.

MAKE86 adds *86* records to the bfile. If the existing *80* records contain orthometric heights, these are added to the new *86* records.

MODGEE scales the standard errors assigned to the observations in the gfile. Input is a gfile and the scaling factor.

QQRECORD adds qq records to the Afile (used by program ADJUST) to compute accuracies for all observed lines. Either the gfile (for GPS projects) or the bfile (for classical terrestrial projects) can be used as input.

Data Sheet Utilities -

DSDATA is the Digital Data Sheet extraction program. Extracts individual or groups of data from a DSDATA file. Includes options to extract by Station Identifier, Station Name, Area, and more.

Other Software Programs - Below is a select listing of other software that is currently accessible through the Web. For the full and most recent list of NGS programs, visit the NGS PC Software web page. On-line interactive versions of some of these programs are available in the NGS PC Software Website at: http://www.ngs.noaa.gov/PC_PROD/pc_prod.shtml

COMPGB tests the consistency and compatibility of the Blue Book B file (GPS project and station occupation data) and G file (GPS vector data transfer file).

CR8BB reformats GPS project information to fit the requirements of the National Geodetic Survey data base. The file created, which is called the B-file, contains project information, station information, and survey measurements. The CR8BB software functions independently of the type of GPS receivers used in a project.

CR8SER extracts data from a GPS Blue Book G file to create a station serial number file (serfil) for GPS observations.

WDDPROC organizes control point descriptions in accordance with the National Geodetic Survey's description file (D-FILE) format.

DSWIN is Windows-based software for data sheet viewing and extraction. It displays a list of county names as found on your CD-ROM. Click on a county and a list of stations appears. Click on a station from the list and a data sheet appears. You may save the data sheet to a file or print it. The search feature allows for filtering the station list by: Point Radius, Min/Max Box, Station Name, or PID. You can also filter by type of control, such as first-order bench marks only.

GEOID99 Computes geoid height values for the conterminous United States, Alaska, Puerto Rico, Virgin Islands, and Hawaii. Suitable for conversion of NAD 83 GPS ellipsoidal heights into NAVD 88 orthometric heights.

HTDP is a horizontal time-dependent positioning software program which allows users to predict horizontal displacements and/or velocities at locations throughout the United States. This software also enables users to update geodetic coordinates and/or observations from one date to another.

INVERSE3D is the three dimensional version of program INVERSE, and is the tool for computing not just the geodetic azimuth and ellipsoidal distance, but also the mark-to-mark distance, the ellipsoid height difference, the dx, dy, dz (differential X, Y, Z used to express GPS vectors), and the dn, de, du (differential north, east, up using the FROM station as the origin of the neu coordinate system). The program requires geodetic coordinates as input, expressed as either: 1) latitude and longitude in degrees, minutes, and seconds or decimal degrees along with the ellipsoid heights for both stations, or 2) rectangular coordinates (X, Y, Z in the Conventional Terrestrial Reference System) for each station. The program works exclusively on the GRS80 ellipsoid and the units are meters. Both types of coordinates may be used in the same computation. The program reads input geodetic positions as positive north and positive west.

LOOP determines the loop misclosures of GPS base lines using the delta x, delta y, delta z vector components computed from a group of observing sessions.

ATTACHMENT D

HEIGHT MODERIZATION STATION SELECTION GUIDELINES

Generally, station selection shall be based on the following criteria. Specific requirements are project dependent and the following criteria will be supplemented by those project-specific requirements.

Unless specified otherwise, the overall Height Mod project shall consist of stations spaced on average approximately 5 km apart. The actual station spacing shall be flexible enough to allow for optimum station selection but may not exceed the spacing limits specified in NOS-NGS-58.

Horizontal control stations shall be distributed in accordance with NOS-NGS-58. Vertical control staions shall be distributed in accordance with the "Guidelines for Establishing GPS-Derived Orthometric Heights." Existing survey monuments that don't qualify as horizontal or vertical control may be used for local network stations instead of setting new marks. In fact, it is preferred that existing marks be used, as it saves the time and expense of setting new monuments, as long as the existing monument meet the criteria listed below.

The following are a list of considerations for every monument (new or old, control station or local network station) in the project. The intent is to ensure that stations will be stable and usable years after the survey is completed. Each of the considerations are important, and so, they are not prioritized.

* Adequate GPS satellite visibility (unrestricted at 15 degrees above the horizon). Minor obstructions may be acceptable, but must be depicted on the Visibility Obstruction Diagram.

* Accessable by vehicle (two-wheel drive preferred).

* Stability, bedrock being most preferred. See below.

* Permanency.

* Ease of recovery.

* Minimal multi-path.

* Appropriate geographic location and spacing.

* Location allows efficient use by surveying community.

* Accessable by public. Public property should be utilized where feasible.

* No known potential conflict with future development.

* Aerial-photo identifiable.

Stability

Stability quality codes A, B, C, and D are defined in the Blue Book, Volume 1, Annex I, with examples given below. Only codes A and B are recommended, however concrete posts may be selected with code C stability if the mark is deemed stable from review of soil conditions and average frost depth.

Quality code A = expected to hold an elevation. Examples: rock outcrops; rock ledges; bedrock; massive structures with deep foundations; large structures with foundations on bedrock; or sleeved deep settings (10 feet or more) with galvanized steel pipe, galvanized steel, stainless steel, or aluminum rods.

Quality code B = probably hold an elevation. Examples: unsleeved deep settings; massive retaining walls; abutments and piers of large bridges or tunnels; unspecified rods or pipe in a sleeve less than 10 feet; or sleeved copper-clad steel rods.

Quality code C = may hold an elevation but subject to ground movement. Examples: Metal rods with base plates less than 10 feet deep; concrete posts (3 feet or more deep); large boulders; retaining walls for culverts or small bridges; footings or foundation walls of small to medium-size structures; or foundations such as landings, platforms, or steps.

Attachment E – Concrete Marks

(From NGS OPERATIONS HANDBOOK and
MANUAL OF GEODETIC TRIANGULATION, S.P. 247)

CONCRETE CHARACTERISTICS

1. **Genera**l. Concrete should have properties that make it workable, strong and durable. Workability refers to the ease with which concrete can be effectively placed, consolidated, and finished, while remaining free from segregation. Workability depends on the proportions of the ingredients and the shape of the individual particles of aggregate. Strength refers to the ability to withstand external forces without rupturing. For survey monuments, high strength is not the most important property, although strong concrete usually indicates that it is durable. Durability is the ability to withstand deterioration over a long time and is primarily influenced by the watertightness of the cured concrete.

2. **Destructive Force**s. Several forces can lead to the weakening or deterioration of concrete. The freezing of water in cured cement exerts great pressure against the inner walls of the pores, tending to break down the concrete. In fresh concrete, the expansion of freezing water breaks the bonds developing between solid particles, making the concrete weak and porous. Leaching and chemical attack also have detrimental effects on concrete. Leaching occurs over a long period when water slowly percolates through concrete and dissolves some of its constituents. Chemical attack is particularly common in alkali soils. Dense, impervious concrete is resistant to these destructive forces.

3. **Ingredient**s. The quality of the ingredients and their proportions help determine how dense and impervious the cured concrete will be. The ingredients include aggregate, cement, and water. The aggregate should be clean (free from silt and clay, harmful chemicals, and organic matter) and well-graded, i.e., it contains proportionate amounts of many particle sizes. In specifying mix proportions the aggregate is usually divided into two parts -- sand (particle size less then 2/3 cm) and gravel (particle size greater than 2/3 cm). Both parts should be well-graded. Aggregates that are porous, split easily, or are otherwise weak or permeable result in poor concrete. Examples of poor aggregates include shale, claystone, sandstone, and micaceous rocks.

Portland cement is designated by one of five types. Type I is for general use where no special properties are needed. Type III is a high-early-strength type for use when concrete will be curing during cold weather. Type V is used where the concrete will be subject to an alkali environment. Types II and IV are not suited for setting marks. Local concrete companies should be contacted to determine the best concrete type to use in the work area.

The water used in a concrete mix should be relatively free of impurities such as acids, alkalies, salts, oil, organic matter, and silt. These can decrease the strength and durability of cured concrete. As a rule, do not use water that you would not drink.

4. **Mixing, Placing, and Curin**g. Pre-mixed concrete materials may be used. If raw materials are used, the suitable proportions (by bulk volume) of cement to sand to gravel are 1:2:3. If the gravel is made up of fragmented or angular particles, use a little less gravel and proportionately more sand. Add only enough water to make the mix workable. About half the water added to the mix is used in the chemical reaction (hydration) that causes the past to harden into binder. If too little water is used, however, the mix will not compact properly and spaces will be left in the mass. **A good indication of the right amount of water is that the mix neither runs nor falls off the shovel but sluggishly slides off and flattens upon hitting the ground**.

5. **Cold Weather Precaution**s. The freezing of fresh concrete has a damaging effect because the expansion of water as it freezes separates the solid particles in the mix. This reduces the strength of the bond and makes the concrete more porous and correspondingly less durable.

Three protective measures should be taken in cold weather, either singly or in combination. First, use warm ingredients. During the first 24 hours after a mix has been placed, it develops little heat of its own to prevent freezing. After 24 hours some heat is developed as a product of the chemical reactions occurring in the mix. The use of warm ingredients is especially beneficial during the first 24 hours. Note, however, that mixing water above 165 degrees F could cause a flash set. To keep the aggregate and cement warm, store them indoors.

Second, use Type III (high-early-strength) cement or special additives that speed curing. Calcium chloride is good for this in amounts not exceeding 2 pounds per 94-pound sack of cement. The calcium chloride should be dissolved in the mixing water instead of mixing it with the other ingredients. Other additives include Thoroguard and Trimix. If a large number of concrete marks are being installed by mass production using a "ready-mix" contractor, fast-curing additives should not be added until the concrete is delivered on site.

Third, insulate the finished mark for a week after the concrete is poured. One method is to cover the mark with boards resting on supports. This is covered with paper or plastic, then by a layer of straw, styrofoam, or similar insulating materials above 15 centimeters thick and finally by a layer of soil 15 to 30 centimeters thick. Pile snow loosely on top if it is available.

CONCRETE MONUMENTS (Note, portions of this paragraph apply to concrete collars around rod marks as well as to concrete monuments.)

STEPS:

1. Obtain property owner permission prior to proposing new mark locations.

2. Install a tall stake (lath) at each proposed site for a new mark. Write the proposed station name on the stake.

3. Obtain clearance from “MISS UTILITY” types services (underground utilities) before digging.

4. Drill or dig a 12 - 14 inch diameter hole in the ground 3.5 to 8+ feet deep. The depth depends on frost penetration in that area. The minimum depth is 3.5 feet. Keep the sides of the hole as smooth as possible. The rounded, bottom portion of the monument must extend at least one foot below the frost line. See NOAA Manual NOS NGS1, *Geodetic Bench Marks* which contains a diagram showing average frost line depth.

5. Enlarge the bottom portion of the hole using a shovel such as a "sharp-shooter" (also called "drain spade") so that the hole is at least 2 inches larger in radius than the main shaft of the hole. This will make the bottom of the monument bell-shaped; see diagram.

6. Remove or tamp down the loose dirt at the bottom of the hole.

7. Remove any loose dirt that might fall into the hole during concrete installation. A layer of loose dirt from the sides or top of the hole, mixed with the concrete will create a fracture line (or plane) which could lead to the monument breaking, thus destroying the mark.

8. Procure a round, cardboard form 12 inches in diameter to line the top 12 - 18 inches of the hole. Test fit the form in the top of the hole. This form will help avoid any shoulders or mushrooming effect near the top of the monument which might afford purchase for frost heave. The form will also help make a neater looking monument. A cardboard, biodegradable, 12-inch diameter form is commercially available. Allow the form to protrude from the ground 2 - 6 inches.

9. Mix the concrete well before it is placed, otherwise the minute particles of cement will not be sufficiently wet and the aggregate will not be completely covered with paste. Prior to adding water, mix the ingredients well. Then, slowly add water and continue to mix. Do not make the mixture too wet.

10. Dampen the hole before concrete is added so moisture will not be drawn from the fresh concrete into the surrounding soil. In no case should it be so wet as to be muddy

11. Place concrete in the hole. Continuously tamp the mix into a compact mass so it becomes less pervious and consequently more durable. Do not contaminate the interior of the monument with dirt.

12. Place the form into the hole when the level of the concrete is approximately one foot below the surface. Continue to be careful not to allow any dirt to fall into the hole.

13. Add concrete until the top is even with or slightly below the surface of the ground. This helps ensure that the monument is not struck by lawn mowers or snow plows, etc.

14. Smooth off the top of the monument with a trowel. Create a gentle slope towards the outside so that rain water will drain off. Bevel the outside edge of the monument.

15. Stamp the disk prior to installing it in a concrete monument or a drill hole. Stamp the disk on a stamping block which has a curved surface that matches the curvature of the underside of the disk. Neatly stamp the station designation (name) above the triangle, centered below "HORIZONTAL CONTROL MARK," and then stamp the year below the triangle, centered above "THE DIRECTOR."

16. Set the disk into position in the top center of the monument with the top of the triangle below the name pointing north (so that a visitor facing north will be able to read the disk's lettering). Placing a small amount of concrete on the underside of the disk before setting helps ensure that air is not trapped under the disk.

17. Press the disk into the concrete until the disk edge touches the concrete. Then tap the disk with the handle end of the trowel **until the top edge of the disk is flush with or slightly recessed into the concrete** (to the point that vandals can not get a pry bar under the disk). Do not recess the disk a greater amount because this makes a hollow that will collect rainwater and possibly shorten the life of the mark due to freezing action.

18. Clean the disk. Sprinkle some dry cement on the exposed surface of the disk, then rub it with a clean rag or short bristled brush using circular strokes. This will clean the disk, removing all excess mortar from its surface and recessed letters. Rubbing the wet mortar around the edge of the disk in the same manner is done intentionally to finish its surface and help prevent cracking. Brush away loose cement and make sure that the finished product has a neat appearance.

19. Cover the mark for at least 7 days. This prevents rain from making the mix too wet and from ruining the finished surface. It also prevents the surface from drying too rapidly, leaving too little water for complete hydration. In addition, it prevents debris from sticking to the surface of the wet concrete. A 12 inch diameter lid is available that fits on the 12 inch cylindrical form. This lid will also keep out the dirt during the next step and final clean-up.

20. Replace dirt round the form and tamp into place. At the surface, replace dirt and sod around the form and tamp into place.

21. Rake the area until neat and remove excess materials. Do not leave any construction or other materials at the site. Leave the area as neat or neater than when you arrived. Note, the protruding form and lid shall be removed later during survey observations.

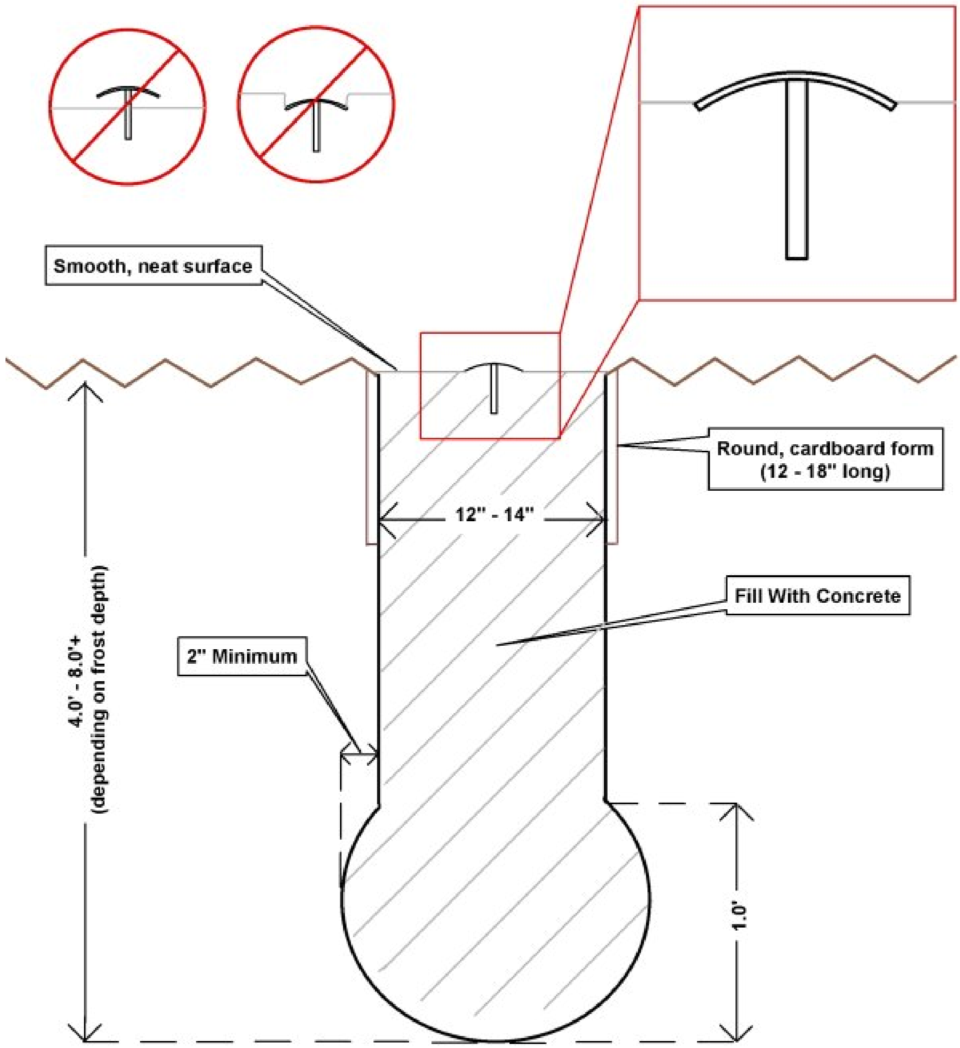
22. Remove excess dirt and dispose of it properly. In some rural areas there may be a logical spot to dump the extra soil where no one will notice. If the mark is in an area consisting of groomed lawns, the dirt shall be removed from the site.

23. Remove excess concrete from the site. Proper planning should minimize excess concrete. Any excess shall not be dumped on-site.

24. Installation of NGS Witness Posts is at the option of the firm. Generally do not use Witness Posts in areas of high population density nor on airports. They are very useful to future surveyors in more remote areas.

25. Do not add magnetic materials to the monument.

Standard NGS Concrete Monument



Cross Section Through Round Monument

Attachment F
Setting a Surve Disk in Bedrock or a Structure

From NOAA Manual NOS, NGS 1, *Geodetic Bench Marks*

Sound bedrock is the most desirable setting for geodetic survey control points. Besides the ease and cost effectiveness with which a disk can be installed in bedrock, it provides the most stable setting that can be used in terms of both underground activity and disturbances inflicted by people. Always use bedrock when a suitable outcrop exits. As a rule of thumb, the bedrock is considered potentially good if the distance between joints and fissures is greater than 1 meter. The National Geodetic Survey geodetic control disks are made of brass or bronze. They are about 9 centimeters in diameter and have a spherical surface to support the foot of a leveling rod and a center point for plumbing survey equipment. Information is imprinted on this surface to identify the monument and to aid the user in obtaining data on it. This logo is recessed so that it does not interfere with the leveling rod or other survey equipment. A deformed shank, about 7.5 centimeters long, is silver-soldered or otherwise attached to the bottom surface of the disk to help prevent the disk from being dislodged.

The step-by-step procedure for setting the disk in bedrock utilizing cement is as follows:

1. Stamp the station designation and setting year on the top surface of the disk using 4.75 millimeter (3/16- inch) alpha-numeric steel dies.

2. Pick a fairly level and accessible spot on the outcrop that is intact with the bulk of the rock. A simple test can be performed to help determine the condition and integrity of the rock by placing ones hand in the area that the disk will be set, then striking the outcrop with a moderately heavy hammer and feeling for vibration. Sound outcrop will force the hammer to rebound with each impact and vibration through the rock should be minimal at best.

3. Drill a 2.5 centimeter diameter hole about 10 centimeters into the bedrock and recess the area around the top of the hole to a diameter slightly larger than that of the disk. When the installation is completed, the top of the surface of the disk should sit level and slightly below the surface of the surrounding rock. Chisel a drain channel through the low edge of the drilled recess to allow water to drain from around the finished mark. *Cautio*n: Safety goggles should be worn when drilling into bedrock or masonry.

4. Remove the rock powder from the hole and recessed area, flush and fill the hole with clean water, then pour cement into it. Mixing of the ingredients is done right in the hole. By adding more water and cement, make enough mortar so that an extra amount is available to place on the underside of the disk. When the mortar is completely mixed, it should be thick but still workable, like heavy mashed potatoes.

5. Clean the disk by wetting then rubbing all surfaces with cement to remove unwanted oils; rinse. Fill the depression on the underside of the disk with mortar using a trowel. Hold the disk loosely upside-down by the end of the shank then gently tap the domed surface of the disk from

below with the handle of the trowel several times to allow the mortar to settle and trapped air to escape. This is very important because it will prevent the existence of highly undesirable voids under the disk once it is in place.

6. Place the shank of the disk into the drilled hole and press the mark firmly into place. A slight rotation of the disk back-and-forth and gentle tapping with the end of the trowel handle helps settle the disk completely and evenly into the drilled recess in the bedrock. The disk is considered set when the slight back-and-forth movement stops and the disk sets firmly in place. Work excess mortar around the outer edge of the disk, making sure that it is smooth and slightly overlapping the top outside edges of the disk for security. An exposed edge of the disk would provide an area which could be used by someone or the elements to dislodge it. Fresh mortar on the upper surface of the disk can be easily cleaned off and out of any stamping.

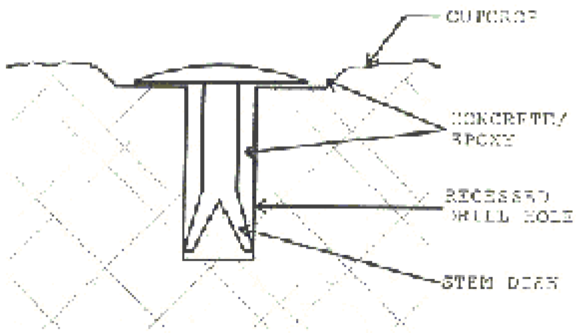
7. Sprinkle some dry cement on the exposed surface of the disk, then rub it with a clean rag or short bristled brush using circular strokes. This will clean the disk very nicely, removing all excess mortar from its surface and recessed letters. Rubbing the wet mortar around the edge of the disk in the same manner is done intentionally to finish its surface and help prevent cracking. Brush away loose cement and make sure that the finished product has a neat appearance.

8. While the mortar is still wet, it must be covered to prevent heavy rains or other foreign debris from ruining its surface and to conceal the disk from people who might tamper with it. A piece of wood, cardboard, heavy paper, or similar biodegradable item will suffice.

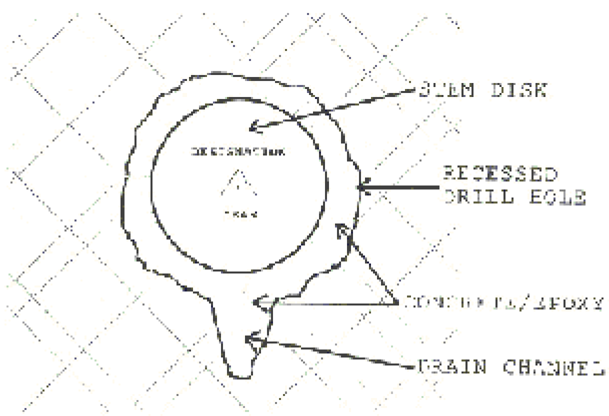
9. The installation is complete when all accumulated trash has been picked up. Leave the site clean and in good order.

Highway grade epoxy may be used in place of cement if it meets ultraviolet standards and will hold up to all weather conditions. The setting procedures are similar to those described previously except that the drilled hole, though needing to be extremely clean, cannot be wet.

DISK IN OUTCROP



SIDE VIEW



TOP VIEW

Attachment G
Setting a NGS 3-D Monument

Based on “Revised NGS 3-Dimensional (3-D) Rod Mark” [Draft Version] by:

Curtis L. Smith
National Geodetic Survey
July, 1996

Disclaimer:

This document is intended only for the purpose of providing the user with guidelines for planning and implementation of this style of survey monument. The distribution of this document or the mention of a commercial company or product contained herein does not constitute, in any way, an endorsement by the National Geodetic Survey (NGS).

Introduction:

The extensive use and accuracies achieved by the Global Positioning System (GPS) for geodetic surveying applications have highlighted the need for increased stability in survey control point monumentation. Repeatability of accurate positions obtained through the GPS require that geodetic monuments reflect this accuracy with properties of permanence and stability both horizontally and vertically.

Factors affecting the stability of survey monuments include frost heave action, changes in ground water levels and local settlement. Consult soil and geotechnical specialists about local ground conditions. Manuals, such as NOAA Manual NOS NGS 1, Geodetic Bench Marks, document soil types and frost penetration zones nationwide.

The recommended survey marker that produces stability for most conditions is the three-dimensional (3-D) drivable survey monument. The principal component of this monument is a 9/16-inch stainless steel rod driven into the ground, utilizing a gasoline powered reciprocating hammer, until refusal or a reduced driving rate has been achieved. The rounded top of the rod is the survey datum point. The upper 3 feet of the rod is encased in a 1-inch greased filled plastic extruded fin sleeve that is held horizontally stable by back-filled, washed sand. Effects of up and down ground movement during freeze/thaw or wet/dry conditions are removed from the anchored rod by the grease filled sleeve promoting vertical stability. A 5 or 6-inch PVC pipe with attached standard aluminum logo cap protects and identifies the top of the monument. (See documentation in this manual for specific mark setting procedures).

References:

NOAA Manual NOS NGS 1. Geodetic Bench Marks, by Floyd, Richard P., September 1978.

Geometric Geodetic Accuracy Standards and Specifications for Using GPS Relative Positioning Techniques, by Federal Geodetic Control Committee, August 1989.

A. Recommended Equipment for Setting Monuments:

Rod Drivers and Accessories:
1- Any driver with a minimum impact force of 25 foot pounds per blow, such as Wacker Model BHB 25 (with tool kit) or Pionjar Model 120 (with tool kit), for driving stainless steel rods.
1- Rod Driving Insert, holds machine on rod and acts as impact point while driving rods.
1- Shovel Bit, for machine to help start and dig holes, not required but may be helpful.
1- Pint, Required Oil Type and Calibrated Container, for determining gas/oil mix.
1- Gas Containers and Gasoline, for driving machine and generator.

Digging the Hole:
1- Post Hole Digger, capable of digging a hole 4-feet deep.
1- Gas Powered post Hole Digger with Augurs, not required but increases productivity.
1- Digging Bar, for rocks and hard to dig holes.

Driving the Rod:
1- 2 lb. Hammer, to start rods, stamp designations, etc.
2- 8" Quality Pipe Wrenches (i.e. Rigid), for attaching lengths of stainless steel rods.
1- Bottle, Loctite, for cementing threads into the ss rods.

Finishing the Rod:
1- Hack Saw with extra Quality Blades, for cutting stainless steel rod.
1- 4" or 5" Grinder (electric or battery powered), for finishing top of rod.
1- Gas Powered Electric Generator, to power grinder and or drill.
2- Sanding Disks (medium grade), for grinder.
1- Steel File(s), for fine finishing top of rod.
1- Centering Sleeve, to help center punch mark on top of rod.
1- Center Punch, to punch plumbing point on top center of rod.
Assorted Sand Paper or Sanding Pad, for fine finish to top of rod.

Finishing the Monument:
1- 1/4-inch Stamping Set, for lettering and numbering station designation/date.
1- Hand Saw, for cutting 5 or 6-inch PVC pipe.
1-Bucket or Wheel Barrel, to mix cement/move unwanted dirt.
2- 5-Gallon Water containers and Water, to mix cement and clean equipment.
1- Hoe, to mix cement, can be replaced by ASharp Shooter Shovel.@
1- Heavy Rubber Mallet, to help lower logo cap/5-inch PVC into cement.
1- Cement Finishing Trowel, to smooth top of concrete for neat appearance.
1- Stiff Vegetable Type Brush, to clean logo cap and hinges.

Assorted Accessories:
1- Tool Box with regular assortment of tools, for incidental repairs: slotted and Phillips Head Screw-Drivers, Pliers, needle Nose Pliers, Wire Cutters, Assorted Wrenches, Sockets, Allen Wrenches, Wire Brush.
1- Round Nose Shovel, to help dig hole and move unwanted dirt.
1- Tile Spade (ASharp Shooter Shove l @), to help dig hole and mix cement.
1- Roll Black Tar Paper (Felt Paper), for making a round form for top of monument.
1- 30 Meter Tape Measure, for distances in station description.
Leather or Cotton Gloves, Assorted Rags or Paper Towels.

B. Materials Required for Each Mark:
Lengths of 9/16-inch Stainless Steel Rods, 4-foot sections.
1- 4 to 5-inch piece of Stainless Steel Rod, used as impact point and protection while driving rods.

Adequate supply of 3/8-inch Threaded Stainless Steel Studs.
1- Steel Spiral (fluted) Rod Entry Point, standard order.
1- Aluminum logo Cap, standard order.
1- Schedule 40 PVC Pipe, 5 or 6-inch diameter, 24-inch length.
1- Plastic Extruded Fin sleeve, 1-inch diameter, 3-feet minimum length.
2- Plastic end Cap Alignment Bushings, center drilled to 9/16-inch (for extruded fin sleeve).
1- Pint, PVC cement, can be replaced with adequate Epoxy type.
1- Pint, PVC Cleaning Solvent, when using PVC cement.
1- 17 ounce tube, Non-Toxic, Food Grade Grease, with Applicator (i.e. grease gun).
Ready Mix Concrete (Amount depends on width and depth of hole).
2- Pounds, Portland Cement, added to enhance integrity of ready mix concrete if necessary.
0.5- Cubic feet, Washed Sand, fills bottom of hole and inside of PVC pipe around grease sleeve.

C. Setting Procedures:
1. Ensure the monument site selection has been discussed with airport management and/or property owners, and the location meets all station siting requirements. Inquire about future construction which may affect mark longevity.

2. Contact “MISS UTILITY” type services to inquire about underground utilities before digging or driving rod.

3. The time required to set an average mark using the following procedures and referencing the diagram on the following page is 2 to 3 hours. Several steps, such as steps 4, 5, and 7, can and should be accomplished at a maintenance shop.

4. Stamp station designation and year of establishment into the blank area on the collar of the logo cap.

5. Cut a 20-inch section of 5 or 6-inch PVC pipe. Ensure the end that will receive the logo cap is cut true and is clean. Using primer and solvent cement formulated specifically for PVC, glue the stamped aluminum logo cap to the end of the 20-inch PVC section. If this step is performed on site, allow time for the glue to set by digging the hole and driving the rod after preparing the PVC and logo cap.

6. Using a power auger or post hole digger, drill or dig a round hole in the ground 12 to 14-inches in diameter, and 22 inches deep. Extend the center of the bottom of the hole by drilling or digging a 3 to 6-inch diameter hole an additional 21 inches for a total depth of 43 inches. This extended area will be back-filled with washed sand around grease sleeve.

7. Glue both plastic end cap alignment bushings on a 3-foot section of the plastic extruded fin sleeve. Let glued ends dry completely. Pump food grade grease into capped sleeve until 3/4 full allowing for displacement by rod and completing the grease filled sleeve.

8. Using a standard 3/8-inch threaded stud coated with loctite (Use Loctite on all *permanent* connections), attach two 4-foot sections of stainless steel rods together. At one end of the length of rod, attach a standard spiral (fluted) rod entry point with a 3/8-inch threaded stud. On the opposite end, attach a short 4 to 5-inch piece of rod with a 3/8-inch threaded stud. Tighten all connections using two pipe wrenches a good 1/4 to 3/4 turn past the point of contact of all rod ends except the impact point which will be continually removed. This tightening requires a certain “feel” and ensures that the rod ends are seated together with greatest possible tension yet not to the point of breaking a stud. Rods tightened in this fashion should not vibrate loose when they are driven into the ground.

9. The 8-foot long connected rod is centered into the bottom of the hole and driven with a 2-pound hammer until rod is secure and as plumb as possible. A 2x4 with a 1/2" hole can be centered and braced over the hole to help guide the rod straight into the ground. Drive the section of rod to about the top of the hole with a gas powered reciprocating driver such as Whacker model BHB 25, Pionjar model 120, or another machine with an equivalent driving force.

10. Remove the short piece of rod (impact point) leaving the threaded stud in section of rod in the ground. Attach another 4-foot section of rod and, using a new threaded stud, thread on the impact point. This “cycling” of a new stud from impact point into top of rods in ground insures unweakened studs at all connections. Remember to coat threads on the permanent connections with loctite. Tighten securely utilizing pipe wrenches as described above in step 9. Always tighten rods maintaining a clockwise pressure to avoid loosening rods already in the ground. Drive the new length of rod into the ground with the reciprocating driver.

11. Repeat step 10 until the rod refuses to drive further (anchored), or until a driving rate of 60 seconds per foot is achieved. In the event that the rod will not sufficiently slow down to meet desired driving rate, terminate upon reaching 90 feet (22.5 rods). This will leave about 2 feet of rod out of the hole. If possible, let the rod set overnight, then drive the remaining 2 feet of rod to determine whether driving rate has reduced. If rod feels secure in ground, use this depth even though minimum driving rate of 60 seconds per foot has not been met. If the rod turns freely in clockwise direction, contact NGS for a decision to drive additional rods. Sometimes, all that is necessary to achieve a well anchored rod is driving it a few more feet. In other instances and additional hundred feet may be required. Indicate in the written station description the depth of rod, and whether it was driven to refusal or met the slow driving rate. Also include a description of any unusual mark setting circumstances.

12. When refusal or prescribed driving rate is reached, cut off the rod with a hacksaw or comparable tool, always removing at least the tapped and threaded portion, leaving the top of rod about 3 inches below ground surface. Shape the top of the rod to a smooth, hemispherical surface using a portable grinding machine using a grinding attachment or sanding wheels, files, and sand paper to produce a nicely finished, rounded surface. Ragged edges or grinding marks are not acceptable on top of the finished rod.

13. The datum point must then be created by center punching a dimple on top of the rod to provide a plumbing (centering) point. Place the centering sleeve over the top of the rounded rod to facilitate locating the exact center of the rod. Punch a substantial dimple, 1/16-inch deep, into the top of the rod using a punch and hammer or spring loaded center punch. Several blows may be needed to create a sufficient dimple. Remember, this is the actual survey point, so don’t hesitate to spend a few extra minutes to produce a professional, finished product.

14. Insert the grease filled sleeve, produced in step 7, over the rod with the unfilled portion at the top. Upper end of sleeve will fill as rod displaces grease from the bottom. The datum point on top of rod should protrude through top of the sleeve about 3-inches with sleeve extending to the bottom of the hole. Clean the residual grease off the exposed top of the rod.

15. Back-fill and pack with washed sand the bottom 23 or more inches of the hole around the outside of grease sleeve. This fills the bottom of the hole and helps stabilize the sleeve.

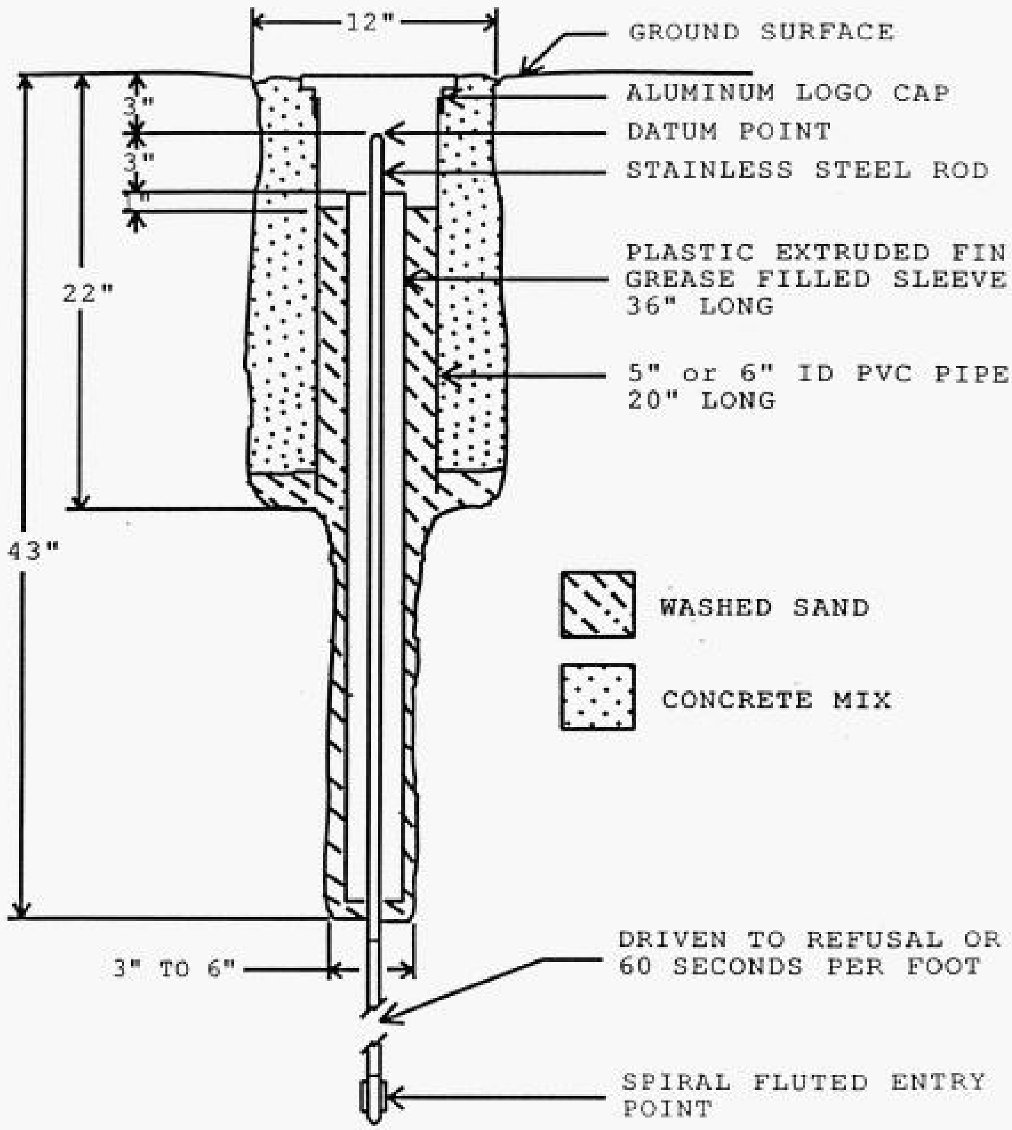
16. Place the 5 or 6-inch PVC pipe and logo cap over and around the grease sleeve and rod in the center of the hole. The bottom of the PVC pipe should extend into the top of the sand in the bottom of the hole. Leave the top of the logo cap and PVC pipe slightly higher than the top of the ground surface until the concrete is in place. Back-fill the center of the PVC pipe with washed sand around and to within 1-inch from the top of the grease filled sleeve. The rod should be centered in the PVC pipe.

17. Mix concrete in a bucket or wheel barrel to pasty, well moistened consistency like mashed potatoes. Add Portland cement, if necessary, in sufficient quantity (1 to 2 pounds) to enhance concrete mix or dry an over moistened mixture to maintain adequate consistency. A good indication of adequate consistency is that the mix neither runs nor falls off the shovel but sluggishly slides off and flattens upon hitting the ground. Pour concrete into the hole around logo cap and PVC pipe casing filling to slightly below the ground surface. To avoid frost heaving of the PVC collar, a round form should be used to ensure the outside walls of the concrete are vertical, and do not produce a [mushroom] shaped wedge at the top of the mark. Open the logo cap and grasp the PVC pipe then shake to settle concrete around the pipe to fill voids. Add concrete to within 1/2-inch of the ground surface.

18. Trowel smooth the top of concrete to a fairly finished surface. Tap alternate edges of the logo cap, using a rubber mallet or hammer and wooden block, lowering it and attached PVC pipe into surface of concrete. Finish the top of the concrete by troweling a smooth, finished surface, round in appearance, and sloped slightly outward to aid drainage of rain water.

19. Add sand to the inside of the PVC pipe to bring its level to within 1-inch of the top of the grease sleeve. Clean any overlapping concrete from the surface of the logo cap using the vegetable brush. The finished height of logo cap and access cover should be slightly lower than the surface of the ground. The logo cap should be approximately in the center of the top of the concrete. Datum point should be about 3-inches below the cover of the logo cap and centered in the 5 or 6-inch PVC pipe. The top of the grease filled sleeve should be about 3-inches below the datum pont and the washed sand 1-inch below top of the sleeve. Clean any cement that may have gotten onto the exposed rod or datum point.

20. Clean all equipment and remove all debris such as extra cement, excess dirt, and trash, leaving the area in the condition it was found.



Schematic of the Revised NGS 3-D Rod Mark, Side View

November 13, 2003

ATTACHMENT H

WRITING STATION DESCRIPTIONS AND RECOVERY NOTES WITH WDDPROC

Descriptions are one of the end products of surveying, along with the positions and the survey marks themselves. All three shall be of highest quality. The descriptions must be complete, accurate and in standardized format if the station is to be reliably and easily recovered for use in the future. Descriptions shall be in the standard NGS format of three paragraphs as described below under "Description Format."

1.0 GENERAL

1.1 DEFINITION OF DESCRIPTION VS. RECOVERY NOTE

a. A *description* details the location of a new survey mark, or one not previously in the NGS digital database.

b. A *recovery note* is an update and/or refinement to a description already in the NGS digital database, written upon a return visit to a survey mark.

1.2 LEVELS OF COMPLEXITY OF RECOVERY NOTES

a. No Changes - If an existing station's digital description is complete, accurate, and meets Blue Book requirements, the station may be recovered with a brief recovery note, such as "RECOVERED AS DESCRIBED."

b. Minor Changes - If minor changes or additions to the description are required, they may be added after the above phrase, such as "RECOVERED AS DESCRIBED, EXCEPT A NEW WOODEN FENCE IS NOW 3 METERS NORTH OF THE STATION." See typical cases listed below.

c. Major Changes - Where major changes have occurred, major inaccuracies are found, or where required information is missing (in any portion of the description), a complete three-paragraph recovery note, with the same format as a new description, is required. If a measurement discrepancy is found, state that the new distance was verified, for example, by taping in both English units and metric units or by two separate measurements by two different people. See typical cases listed below.

d. Exemption - If a recovery note has been written for the station within one year and no changes have taken place, a new recovery note is not required. Note, this may cause an error message in the description checking software, which may be ignored.

1.3 SOFTWARE - Descriptions and Recovery notes must be properly encoded into a D-file by using NGS WDDPROC software. Please refer to the NGS Web site: http://www.ngs.noaa.gov/FGCS/BlueBook/, Annex P (Geodetic Control Descriptive Data), for information. Note, WDDPROC is used for both new Descriptions and for Recovery Notes.

1.4 CHECKING - Descriptions shall be written by one person and checked by another. Recovery notes should also be checked. For example, a mark setter can draft a description immediately after setting the mark, and an observer can check the description during observations. For existing marks, the reconnaissance person can draft the recovery note and the observer can check it. Descriptions and Recovery Notes should be written while at the station or immediately after visiting a station so that all details are fresh in the writer's mind.

1.5 TYPICAL RECOVERY NOTE CASES

a. A brief, one or two sentence Recovery Note is adequate:

I. When the mark is found and the description is completely accurate, sample: ("RECOVERED AS DESCRIBED"),

ii. When the mark is found and there are one or two minor changes, ("RECOVERED AS DESCRIBED EXCEPT A NEW WOODEN FENCE IS NOW 3 METERS NORTH OF THE STATION"),

iii. When the mark is not found, ("MARK NOT FOUND AFTER 3 PERSON-HOUR SEARCH"),

iv. When the mark is not found and presumed destroyed, (" MARK NOT FOUND AND PRESUMED DESTROYED. CONSTRUCTION FOREMAN STATES THAT THE MARK WAS DESTROYED YESTERDAY"),

v. When the mark is found destroyed, (" THE MARK IS DESTROYED AND THE DISK HAS BEEN SENT TO NGS"or "THE MARK IS DESTROYED AND ITS PHOTOGRAPH HAS BEEN SENT TO NGS"). Note, for a station to be considered destroyed by NGS, the disk or photograph showing the destroyed mark must be received by NGS.

b. A complete, new, three-paragraph Description/Recovery Note is required:

I. When a new mark is set,

ii. When an existing mark does not have a PID,

iii. When an existing mark does not have an NSRS digital description (i.e., description is not in NGS database),

iv. When an existing mark has only a brief description not meeting the three-paragraph requirement (many bench marks have only short, one-paragraph descriptions),

v. When an existing mark's description is no longer accurate or complete.

2.0 DESCRIPTION FORMAT

The original USC&GS Special Publication No. 247, MANUAL OF GEODETIC TRIANGULATION, page 116, states, "A description must be clear, concise, and complete. It should enable one to go with certainty to the immediate vicinity of the mark, and by the measured distances to reference points and the description of the character of the mark, it should inform the searcher of the exact location of the mark and make its identification certain. It should include only essential details of a permanent character." NGS still follows these guidelines, so that a person with a minimal background in surveying and no local geographic or historical knowledge can easily find the mark by logically following the text of the description.

2.1 FIRST PARAGRAPH - The **first paragraph** is the *description of locality*. This part of the description begins by referring to the airline distance and direction (cardinal or inter-cardinal point of the compass) from the **three** nearest well-known mapped geographic feature(s), usually the nearest cities or towns. Use three references equally spaced around the horizon, if possible. **In writing the Description, always progress from the farthest to the nearest reference point**. Distances in this part of the description shall be in kilometers (followed by miles), or meters (followed by feet), all distances to one decimal place. Detailed measurements which appear elsewhere in the description should not be repeated in this paragraph. Points of the compass should be fully spelled out. Do not use bearings or azimuths. State the name, address, and phone number of public sector property owners (however, phone numbers of private property owners are NOT included). State any advance notice and security access requirements for reaching the station. Also state any unusual transportation methods that may be required to reach the station.
Sample first paragraph:

> "STATION IS LOCATED ABOUT 12.9 KM (8.0 MILES) SOUTHWEST OF EASTON, ABOUT 6.4 KM (4.0 MILES) NORTHWEST OF CAMBRIDGE, AND ABOUT 3.6 KM (2.2MILES) EAST OF SMITHVILLE ON PROPERTY OWNED BY MR. H.P. LAYTON, AND KNOWN AS OLD GOVERNOR JACKSONS ESTATE."

2.2 SECOND PARAGRAPH - The **second paragraph** contains the *directions **to reach** the station.* This section is one of the most useful parts of a description. It usually enables a stranger to go directly to a station without a delay due to a detailed study of maps or of making local inquiries. It is a route description which should start from a definite point, such as (a) the nearest intersection of named or numbered **main** highways (ideally Interstate and U.S. highways, or at least those which are shown on commonly used road maps), and approximately where that intersection is, or (b) some definite and well-known geographical feature (eg. main post office or county courthouse) and give its name and general location. Odometer distances shall be given to tenths of kilometers (followed by tenths of miles). For roads with names and numbers, give both in the first occurrence.

a. The format for the first leg of the "to reach" is:
    I. FROM THE MAIN POST OFFICE IN DOWNTOWN SMITHVILLE, or
    I. FROM THE INTERSECTION OF INTERSTATE XX AND STATE HIGHWAY YY, ABOUT 3 MI NORTH OF SMITHVILLE,
    ii. GO A DIRECTION (north, northeast, northerly, northeasterly, etc.),
    iii. ON A ROAD (name or number of road or highway),
    iv. FOR A DISTANCE (km followed by miles in parentheses),
    v. TO SOMETHING (intersection, or fork in road, or T-road left or T-road right).

b. The format for all other legs:

I. TURN LEFT OR RIGHT, OR TAKE RIGHT OR LEFT FORK, OR CONTINUE STRAIGHT AHEAD,
ii. GO A DIRECTION (north, northeast, northerly, northeasterly, etc.),
iii. ON ROAD (name of road or highway),
iv. FOR A DISTANCE (km followed by miles in parentheses),
v. TO SOMETHING (intersection, or fork in road, or side-road left or right, or station on left or right).

All five parts of each leg shall be included in each "To Reach."

Sample:

"TO REACH THE STATION FROM THE INTERSECTION OF INTERSTATE 300 AND MAIN STREET (STATE HIGHWAY 101) IN JONESVILLE, GO EASTERLY ON HIGHWAY 101 FOR 3.7 KM (2.3 MILES) TO AN INTERSECTION. TURN RIGHT AND GO SOUTH ON MILLER ROAD FOR 5.1 KM (3.2 MILES) TO A SIDE-ROAD RIGHT. CONTINUE SOUTH ON MILLER ROAD FOR 6.6 KM (4.1 MILES) TO AN INTERSECTION. TURN LEFT AND GO EASTERLY ON SMITH ROAD FOR 2.4 KM (1.5 MILES) TO STATION ON THE LEFT IN THE FENCE LINE."

Use the word "EAST" if the road goes due east and "EASTERLY" if the road wanders in a general easterly direction. Use intermediate references, such as Miller Road above, if the distance becomes longer than about 5 miles. The place of the end of truck travel should be mentioned. If walking is required, note the approximate time required for packing. If travel to the station is by boat, the place of landing should be stated.

2.3 THIRD PARAGRAPH - The **third paragraph** provides *details of the mark and reference measurements.* It is made up of six parts: (a) the station mark type, (b) how the mark is stamped, (c) how the mark is set, (d) reference measurements, (e) the handheld GPS position, and (f) PACS or SACS designation, if appropriate. These sections are not numbered in the description, but shall be in the stated order with the stated information.

SECTION	EXAMPLE
(a) - State what the mark is:	THE MARK IS AN NGS HORIZONTAL DISK, OR A USC&GS TRIANGULATION DISK, OR A STAINLESS STEEL ROD, OR A CHISELED "X", ETC.),
(b) - State how the mark is stamped (in dashes):	STAMPED --JONES 1952--.
(c) - State how and in what the mark is set:	THE MARK IS SET IN A DRILL HOLE IN BEDROCK, OR SET IN A SQUARE CONCRETE MONUMENT, OR IS A ROD DRIVEN TO REFUSAL, ETC. A GREASE-FILLED SLEEVE ONE M LONG WAS INSTALLED.

The description shall specify whether the rod was driven to refusal or whether it met the slow driving rate (this is specified in Attachment G, part C-11 as 60 seconds per foot or 90 feet). Also state if a grease-filled sleeve was installed and its length. For a rod mark, the diameter of the stainless steel rod and the diameter of the PVC pipe with the aluminum cap should be in English units, and the length of the plastic sleeve should be given in metric units only.

- State if the mark projects above the ground, is flush, or is recessed and the amount, (for a rod mark state the above for both the rod and the logo cap):	MARK PROJECTS 15 CM (5 IN), OR MARK IS FLUSH WITH THE GROUND, OR MARK IS RECESSED 20 CM (8 IN); OR LOGO CAP IS FLUSH WITH THE GROUND AND TOP OF ROD IS 10 CM (3.9 IN) BELOW THE TOP OF THE LOGO CAP,
- State the depth of the mark, if known:	CONCRETE MONUMENT, 1.2 M (4 FT) DEEP, OR ROD DRIVEN TO REFUSAL AT 15 M (49 FT)
(d) - State reference distances and directions from three or more permanent objects in the mark's immediate vicinity (farthest to nearest):	IT IS 20.7 M (67.9 FT) SOUTHWEST OF POWER POLE #2345, 15.2 M (49.9 FT) WEST OF THE EDGE OF HIGHWAY 134, AND 3.4 M (11.1 FT) NORTH OF A FENCE LINE.

Examples of objects used as references: existing reference marks, witness posts, center lines of roads, edges of runways, ditches, power or telephone poles, or buildings. Start with the farthest distance. Horizontal distances should be used. If slope distances were measured, that fact should be stated in the paragraph. The distances shall be in meters (followed by English measurement units in parentheses, except as noted in (c) above), and the directions shall be cardinal and inter-cardinal directions, fully spelled out, such as "NORTH", "NORTHEAST", or "NORTH-NORTHEAST". Magnetic bearings from the reference objects are recommended to assist in future recoveries.

(e) Provide a handheld GPS position for all new marks, all proposed mark locations, for marks with scaled positions, and for any other marks without NGS published positions. Include the accuracy code of HH1 or HH2, depending on the type of receiver used. HH1 stands for Hand-Held accuracy code 1 (differentially corrected, hand-held GPS), and HH2 stands for Hand-Held accuracy code 2 (stand-alone, hand-held GPS), as follows:

Accuracy code 1 (HH1) = +/- 1-3 meters
Accuracy code 2 (HH2) = +/- 10 meters

GPS Data Formats:

CODE	LATITUDE	LONGITUDE	SECOND PLACES
HH1	NDDMMSS.ss	WDDDMMSS.ss	(2 places of seconds)
HH2	NDDMMSS.s	WDDDMMSS.s	(1 place of seconds)

Use “N” or “S” for latitude and “W” or “E” for longitude. Use three digits for the degrees of longitude.

(f) If the station is a Primary or Secondary Airport Control Station mark, the third paragraph shall end with the appropriate designation of Primary or Secondary Airport Control Station):

THIS STATION IS DESIGNATED AS A PRIMARY AIRPORT CONTROL STATION.

Sample for a rod mark:

“THE STATION IS THE TOP-CENTER OF A 9/16 INCH STAINLESS STEEL ROD DRIVEN TO REFUSAL DEPTH OF 18M. THE LOGO CAP IS STAMPED --SMITH 2003--. THE LOGO CAP IS MOUNTED ON A 5 IN DIAMETER PVC PIPE. A ONE M LONG GREASE-FILLED SLEEVE WAS INSTALLED. LOGO CAP IS FLUSH WITH THE GROUND AND TOP OF ROD IS 10 CM (3.9 IN) BELOW THE TOP OF THE LOGO CAP. THE MARK IS 32.4 METERS (101.74 FEET) NORTHEAST OF NORTHEAST CORNER OF THE HOUSE, 16.62 METERS (54.5 FEET) NORTH OF WATER PUMP ALONGSIDE OF HEDGE AROUND OLD FLOWER GARDEN, AND 4 METERS (12.96 FEET) NORTH OF NORTHEAST CORNER OF HIGH HEDGE ENCLOSING OLD FLOWER GARDEN. THE HH1 GPS IS: 304050.2N, 1201020.4W.”

Sample for a concrete monument:

“THE STATION IS AN NGS HORIZONTAL DISK, STAMPED --JONES 2003-- SET IN A ROUND CONCRETE MONUMENT 1.2 M (4 FT) DEEP AND 0.3 M (12 IN) IN DIAMETER. IT IS SET FLUSH WITH THE GROUND. IT IS 32.4 METERS (101.74 FEET) NORTHEAST OF NORTHEAST CORNER OF THE HOUSE, 16.62 METERS (54.5 FEET) NORTH OF WATER PUMP ALONGSIDE OF HEDGE AROUND OLD FLOWER GARDEN, AND 4 METERS (12.96 FEET) NORTH OF NORTHEAST CORNER OF HIGH HEDGE ENCLOSING OLD FLOWER GARDEN. THE HH1 GPS IS: 304050.2N, 1201020.4W.”

3.0 IMPORTANT POINTS REGARDING DESCRIPTIONS

3.1 NAMES - Use the station designation (name) and PID, exactly as listed in the NGS database, in all survey records. Do not add dates, agency acronyms, or other information to the name, nor the stamping. Note, frequently the stamping and the official station designation are not the same. For example, stampings include the year set, but designations generally do not.

3.2 TERMINOLOGY - Correct NGS survey terminology shall be used in all station descriptions and reports (see GEODETIC GLOSSARY, NGS, 1986).

3.3 DISTANCES - All measurements are assumed to be horizontal unless labeled "slope." Distances measured from a line (e.g., the center-line of a road or a fence line) are assumed to be measured perpendicular to that line. The origin of measurements at the junction of two roads is assumed to be the intersection of center-lines of both roads. Measurements are assumed to be from the center of an object (i.e. power pole) unless stated otherwise.

3.4 REPAIR - Any work done to repair a mark shall be described completely in the updated recovery note. Note, a repair strengthens the mark but must not change its position. For example, adding concrete or epoxy around a disk where some is missing is a repair.

3.5 REFERENCE MARK NAMES - Note, reference marks are abbreviated "RM x" in descriptions, but on "Reference Mark" disks they are stamped "NO. x".

3.6 WCHKDESC - Run the digital D-file through the WCHKDESC program (field-level option), one of several programs within the WDDPROC Software Suite, to identify format and coding errors. This program is accessed by (a) running the WDDPROC program and (b) selecting the program, WCHKDESC, from the main menu.

3.7 METRIC CONVERSION - Use 3.2808333333 feet equals one meter.

3.8 ABBREVIATIONS - Meter = M, kilometer = KM, centimeter = CM, mile = MI, nautical mile = NM, feet = FT, inch = IN.

4.0 THE WDESC PROGRAM

The WDESC program, one of several programs within the WDDPROC Software Suite (available over the Web at http://www.ngs.noaa.gov/PC_PROD/DDPROC4.XX/ddproc.index.html), is used to encode descriptions and recovery notes in D-FILE format for the loading of these descriptions into the NGS database. The NGS Blue Book and the WDESC documentation contain information for properly encoding descriptions. Helpful information is contained in the following paragraphs.

When creating a description file, a backup file is automatically created. Every time a few descriptions are entered, it would be best if they are checked with WCHKDESC and the file corrected. The backup should be renamed **before** reopening the program or it will be overwritten. Always exit from the WDESC program from the pull-down File option Exit. It is recommended to save the description file as a new filename every time the program is exited; saving after each description is entered is also recommended.

Remember to enter "Y" into the satellite usage code field in the *Header Record* if the mark is suitable for GPS observations.

Set the *condition code* on the *Description Header* form as described in The Description Processing Handbook, Chapter 1, D-FILE Format (for Both Microsoft Windows 95/98/NT and UNIX): The Format of a Description File (D-FILE), which is available on the Web by downloading dformat.htm from Section 4 of the WDDPROC page (http://www.ngs.noaa.gov/PC_PROD/DDPROC4.XX/ddproc.index.html).

Three separate paragraphs are required in the descriptive text field since they make the description much easier to read. Therefore, when entering the text into the *Description Header* form using the WDESC program, separate each paragraph by pressing the [ENTER] key on the keyboard to add a blank line at the end of the first paragraph.

The FPR code is a field on the *Description Header* form in the WDESC program. Set the "FPR" field in the Description Header form to "F", "P", or "R", for Flush, Projected, or Recessed, respectively. In the description, include the logo cap relationship to the ground surface (projecting above, flush with, or recessed below), and include the distance that the top of the rod is below the top of the logo cap. It is important to include information regarding the exact placement of the logo cap for future reference.

A list of the proper agency codes for the WDDPROC Software Suite can be found on the NGS Web site in WDDPROC ANNEX C (http://www.ngs.noaa.gov/FGCS/BlueBook/annexc/annexc.index.html). The agency code to be used for marks that are set by the National Geodetic Survey is NGS. The agency code for marks set by the USC&GS is CGS. Contractors shall use the code assigned to their company. If a contractor does not have a code, a request for one should be emailed to: Burt.Smith@noaa.gov.

5.0 MARK TYPES

5.1 CONCRETE MARK - For a concrete mark set in accordance with the requirements of Attachment E (http://www.ngs.noaa.gov/AERO/aerospecs.htm#vol1) use a *setting code* **of "07"**. This classifies the station with a default *vertical stability code* of "C".

5.2 ROD MARK GREATER THAN 4 METERS - For an NGS 3-D stainless steel rod mark driven to a depth of 4 meters or GREATER, use a *monumentation code* of "F" and a *setting code* of "59". This classifies the station with a default *vertical stability code* of "A". Note, if the standard one meter plastic sleeve is used, the vertical stability code must be downgraded to "B".

5.3 ROD MARKS LESS THAN 4 METERS ARE GENERALLY NOT ACCEPTABLE, see "Geodetic Bench Marks," page 27, Table 3.

5.4 DISK IN ROCK OUTCROP - For a disk that is set in solid rock outcrop, use a *monumentation code* of "DH" or "DD" and a *setting code* of "66". This classifies the station with a default *vertical stability code* of "B".

Check the listing of valid *monumentation codes* and *setting codes* in The Description Processing Handbook, Chapter 1, D-FILE Format (for Both Microsoft which is available on the Web in Annex P of the blue book (http://www.ngs.noaa.gov/FGCS/BlueBook/), for the proper codes to use for other types of marks.

Again, refer to the complete directions available at the Web site for using the NGS software package WDDPROC to write the required station descriptions, and be sure to check your final product with WCHKDESC.

Version 12
July 15, 2003

ATTACHMENT I
REQUIREMENTS FOR DIGITAL PHOTOGRAPHS OF SURVEY CONTROL

TO
SCOPE OF WORK FOR
HEIGHT MODERNIZATION AND LIDAR SURVEYS

NATIONAL GEODETIC SURVEY
NATIONAL OCEAN SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

ATTACHMENT I - REQUIREMENTS FOR DIGITAL PHOTOGRAPHS
OF SURVEY CONTROL

ATTACHMENT I - REQUIREMENTS FOR DIGITAL PHOTOGRAPHS OF SURVEY CONTROL

I. PURPOSE - This document describes digital photographic standards for images of survey marks that will be stored in the National Geodetic Survey (NGS) database and for other reconnaissance photographs. Since many of these images will be in the NGS database and available to the public, the subject matter (survey equipment, personnel, background, etc.) must be in good taste and professional in nature.

Digital photographs are useful for station (mark) reconnaissance, mark recovery, mark stability assessment, quality control, and as an aid during data processing and data verification. Some projects may require digital photographs during several stages of the project. Generally three photographs per station will be stored in the NGS database, which will make them accessible to future users. The table below summarizes the required photographs. Detailed descriptions of the photographs follow.

II. SURVEY MARK PHOTOGRAPHS - Take all photographs during daylight hours.

II A. NUMBER OF PHOTOGRAPHS - At least three digital photographs are required for each mark recovered or described during the current project. This means marks for which a written, NGS format, digital description or recovery note was prepared. The three photographs are described as numbers: (1) extreme close-up, (2) eye-level (5-6 feet distant), and (3) horizontal view (approx. 10-30 feet distant). All three photographs require a digital caption and the correct file name. Photographs 2 and 3 require a **small, temporary sign** in the photograph.

REQUIRED PHOTOGRAPHS

All Marks Recovered and/or Described
1. Close-up (Taken Vertically)
2. Eye level (Taken Vertically)
3. Horizontal view(s), mark in foreground

Take sufficient photographs to describe the stamping, appearance, condition, and location of the mark and points of potential interest including visibility obstructions, roads, runways, taxiways, or other dangers, any special set-up requirements, etc. Alter the orientation of the photographs as necessary to include this information in as few photographs as possible (For example, for a tall obstruction, rotate the camera 90 degrees so that the long axis of the image is vertical). Capture the tops of nearby obstructions, if possible. If a station already has acceptable photographs in the NGS database, additional photographs are not required, unless changes have occurred or more than one year has passed. An "acceptable photograph" is defined as an image that meets the requirements of this document, is of good visual quality, and that no changes have taken place that a new photograph would help clarify.

II B. CAPTION - The photographer shall write a caption for each photograph. The caption should contain the following comma-separated information:

- Station designation (name),
- Station Permanent IDentifier (PID), for existing stations in the NGS database, leave blank if new station,
- Airport Location IDentifier (LID), if on airport, leave blank if not on airport,
- Photo number with cardinal direction (N, NE, E, SE, etc) that the camera is pointing, only photo #3 has a direction
- Station type (i.e. PACS, SACS, FBN, CBN), otherwise leave blank
- Date photo was taken (ddMMMyyyy).

SAMPLE CAPTION FOR NEW MARK

JONES, 2, 8JAN2001

SAMPLE CAPTION FOR EXISTING PACS ON AIRPORT

SMITH, AB1234, LAX, 3N, PACS, 8JAN2001

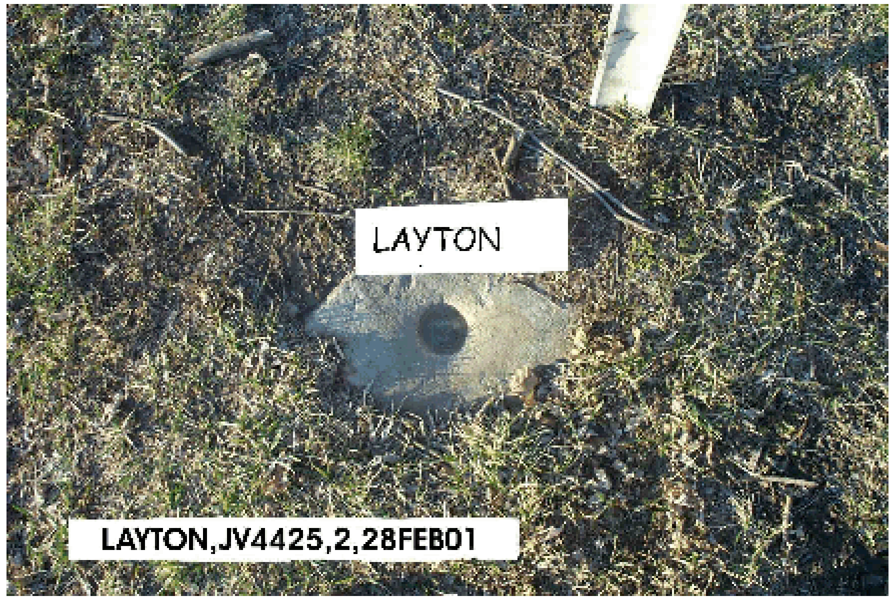
Note, the cardinal direction should not be included on photographs 1 and 2 since they were taken vertically.

The caption may be digitally captured on the image at the time of exposure or may be inserted later, off-line. Record at least the date on-line, if possible. If caption information is added later, take careful notes at the time of exposure to help ensure that the correct caption is added. **Note, the caption shall not obstruct any pertinent aspects of the station or surroundings.** To ensure that the letters of the caption are visible, use software to "erase" a rectangular area for the caption's lettering; see samples below.

II C. DESCRIPTION OF PHOTOGRAPHS:

1. CLOSE-UP - For survey marks, the first photograph (photo no.1) will be a close-up, taken vertically. It will be oriented downward to show the survey mark from directly above with the disk or logo cap nearly filling the image. Brush any dirt or debris off the mark to show the disk. If it has a logo cap, the logo cap should be open. The intent of this photograph is to clearly show the condition of the mark and all stamping on the mark or logo cap so that it is clearly legible. Use extra care to ensure that the stamping is clear. Suggestions: set the camera to its highest quality and resolution modes; **rub a**

yellow crayon across the stamping to highlight the letters; set the camera to "macro" mode, if available; consider the minium focusing distance of the camera (take test photographs to determine the minimum focusing distance and consult the camera owner's manual) ; and, if a flash is used, hold the camera above and off to the side so that the flash does not create a bright spot in the middle of the disk's image. Note, medium quality and resolution camera modes may be used for photographs other than the close-ups. If additional photographs are required, number these close-ups as 1A, 1B...



2. EYE-LEVEL - For survey marks, this photograph (photo no.2) will be oriented vertically downward from eye level to show the monument from directly above and cover an area about 1 meter in diameter. Brush any dirt or debris off the mark to show the disk and the setting, If it is a concrete monument, clear off debris to the edge of the monument. If it has a logo cap, the logo cap should be open. **Include a small, temporary sign in this photograph with the station designation (name) printed so it is clearly visible in the photograph.** The intent of this photograph is to show the general condition of the mark and the immediate surrounding area. If additional photographs are required, number these eye-level photos as 2A, 2B...

3. HORIZONTAL VIEW(S) - For survey marks, take at least one additional, daylight photograph oriented near horizontal, and show the mark, with tripod and antenna (if possible), in the foreground, and its identifying surroundings and any significant obstructions or possible sources of multi-path in the background. Show the top of nearby obstructions, if possible. Consider rotating the camera 90 degrees to use the long axis of the image to capture an entire obstruction. **Place a temporary sign in this photograph with the station designation (name) and the direction the camera is pointing, both printed so they are clearly visible in the photograph.** If additional photographs are taken, ideally move around the mark to locations which are 90 degrees apart (preferably cardinal directions). Name these photographs number 3XX, where the "XX" is the cardinal direction the camera is pointing, for example, 3N or 3NE.

II D. FILE NAMES - See Section IV D.

III. RECONNAISSANCE PHOTOGRAPHS - Some or all of the digital images described in this section may be required on a given project; refer to the Project Instructions. Each of these photographs requires a sign, a caption, and the correct file name. The names for all of these files shall begin with "RE" to indicate reconnaissance.

Required Item	Contents	Description
Sign in Photo	Name & Direction (unless vertical photo)	Place a sign in this photograph with the station designation (name) and the direction the camera is pointing, both printed so they are clearly visible in the photograph.
Digital Caption	Name, PID, LID, Number, Type, Date	See Section II.B above
Photo File Name	RE-Name-PID-Number-Date.jpg	See Section IV.D below

All of the images required by this section shall be designated as reconnaissance (recon) with the letters "RE" at the beginning of their file names. Generally these recon images will not be loaded in the NGS data base but may be required for use during planning, review, etc. All reconnaissance photographs will have digital captions. These captions may be captured on the image or added later. Note, in these specifications, **"RE" stands for "reconnaissance"** and "R" stands for "right" runway.

See the Project Instructions to determine which of the following are required:

III. A. PROPOSED LOCATIONS FOR MARKS - Take two photographs of each proposed permanent mark location. These may be one photo number 2 and one number 3, or two number 3 (3A and 3B), depending on which combination better shows the proposed mark location. Include a tripod, stake, sign, or other device showing the proposed mark location.

III. B. RUNWAY END PHOTOGRAPHS - Take at least three photographs at the end of each runway (including thresholds and stopways) surveyed in the current project, as follows:

- Eye-Level (photo type #1) - photo from directly above the mark, showing about 1 meter in diameter,
- Approach (photo type #3) - photo showing tripod over mark in foreground and approach in background
- Across runway (photo type #3) - photo taken from the side of the runway looking across the end of the runway, with a tripod or arrow indicating the end point; include any features used to identify the runway end.

III. C. NAVIGATION AIDS (NAVAIDS) - Take photo(s) (type #3) of all NAVAIDS surveyed. Show the survey tripod in place to indicate the exact point surveyed, or if positioned remotely, add arrows and labels to the photograph indicating the horizontal and/or vertical point(s) surveyed.

III. D. DEPTH OF HOLE PHOTOGRAPHS - Take at least one photograph showing the hole dug or drilled for a concrete or rod mark. Place a measuring device (e.g., tape measure or level rod) in the hole, clearly showing the depth of the hole.

III.E. PHOTOGRAMMETRIC CONTROL POINTS (Paneled and photo identified) - Take two number 3 type photographs of all photogrammetric control points clearly showing the point. These photos will be used later as an aid in identifying the point on the aerial photographs. Show the mark in the foreground and the nearest identifiable feature in the background. The two photographs should be taken from two different directions, ideally 90 degrees apart (such as from the East and the South).

III.F. OTHER REQUIRED PHOTOGRAPHS - as may be required by other instructions.

<u>IV. GENERAL</u>:

IV A. IMAGE SIZE - Each image should be about 800 by 1000 pixels when submitted.

IV B. 2. FILE SIZE - Maximum file size for each image is 500 KB, typical file size should be about 50 - 100KB.

IV C. IMAGE FORMAT - Store the digital photographs in JPEG format, approximately 50% reduction.

IV D. PHOTOGRAPH FILE NAME - Use the following file naming convention: the optional “RE” (for reconnaissance), dash, the station designator, dash, the PID, dash, the photo number (1, 1A, 2, 3N, or 3NE, etc.), dash, date, dot, jpg. For new marks, there is no PID. Use a maximum of 30 alpha-numeric characters to the left of the dot.

Sample File Names

For new stations:	SMITH-3-date.jpg
For existing stations:	SMITH-AB1234-1-date.jpg
For recon photos:	RE-SMITH-AB1234-3-date.jpg
For runway end point:	RE-LAX_CL_END_RWY_12R-3-date.jpg

For the runway end point example, “RE” = reconnaissance, dash, LAX = LID, dash, “CL END RWY 12R” = runway end point designator (CL = centerline, END = end, RWY = runway, 12 = runway number, and R = right (or C = center, or L = left), dash, “2" = photo number, and date. Note, “_” (underscores) used to fill blanks. Note, in these specifications, “RE” stands for “reconnaissance” and “R” stands for “right” runway (used if there is a parallel set of runways). Also, the LID may be four characters rather than just three.

<u>V. STORAGE MEDIUM</u> - Submit all digital photos together on their own medium (CD), **not on the same medium with other types of data**. For airport work, submit all photos for a given airport in a subdirectory named for that airport.

*Aconyms:
PACS - Primary Airport Control Station
SACS - Secondary Airport Control Station
FBN - Federal Base Network
CORS - Continuously Operating Reference Station (Global Positioning System receiver)
CBN - Cooperative Base Network
RM - Reference Mark

ATTACHMENT J

PROJECT SUBMISSION CHECKLIST - GPS PROJECTS

Project Title: ____
Accession Number: ____
Submitting Agency: ____
Observing Agency: ____
Receiver Type: ____

PACKAGE CONTENTS

Project Report and Attachments	**Required For**
( ) Project Report	All Projects
( ) Approved Reconnaissance and Project Sketch	All Projects
( ) Project Instructions or Contract Specifications	All Projects
( ) Final Station List	All Projects
( ) Station Visibility Diagrams	All Projects
( ) Final Observing Schedule	All Projects
( ) Observation Logs	All Projects
( ) Equipment Failure Logs	NGS Projects
( ) Loop Misclosures	Optional
( ) Free Adjustment with Analysis	All Projects
( ) Free Adjustment with Accuracies	All Projects
( ) Constrained Horizontal Adjustment	All Projects
( ) Constrained Vertical Adjustment (NAVD 88 Heights)	All Projects
( ) Meteorological Instrument Comparison Logs	If Specified
( ) Photographs of Views from Stations	If Specified
( ) Photographs or Rubbings of Station Marks	All Projects
( ) COMPGB Output (Validation program-B/G file)	All Projects
( ) OBSDES Output (Validation program-D-file)	All Projects
( ) OBSCHK Output (Validation program-D-file)	All Projects
( ) CHKDESC Output (Validation program-D-file)	All Projects
( ) ELLACC Output	All Projects
( ) BBACCUR Output	All Projects

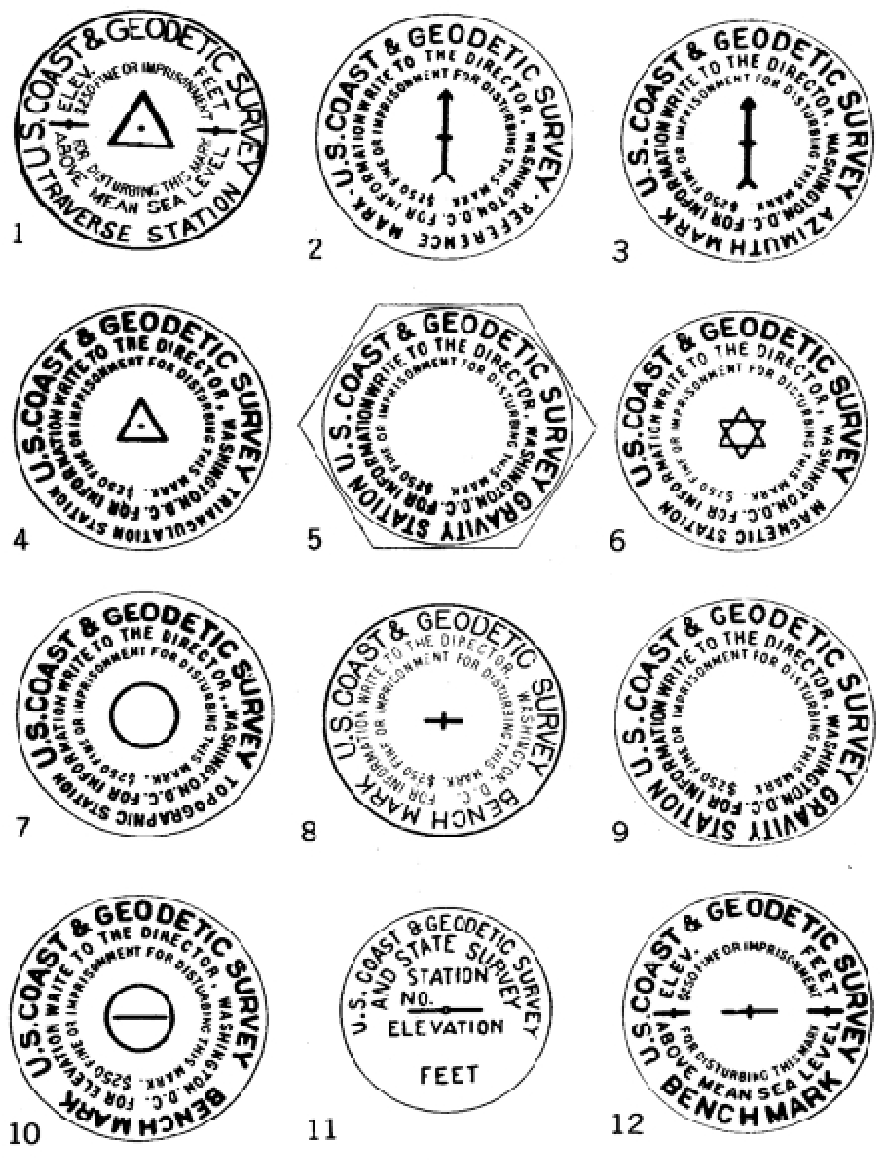
Digitized Data Files ( ) Diskettes ( ) Other:________________________

( ) Raw Phase Data (R-files)	All Projects
( ) Base Line Vectors (G-file)	All Projects
( ) Project and Station Occupation Data (Final B-file)	All Projects
( ) Descriptions or Recovery Notes (D-file)	All Projects
( ) Terrestrial Horizontal Observations (T-file)	If Applicable
( ) Differential Leveling Observations (L-file)	If Applicable

Comments - Enter on the reverse side of this form.

	Org Code	Name	Date
Received by:			
Reviewed by:			
Reviewed by:			

ATTACHMENT K



1. Traverse station mark.
2. Reference mark.
3. Azimuth mark.
4. Triangulation station mark.
5. Gravity station mark (old type).
6. Magnetic station mark.
7. Topographic station mark.
8. Geodetic bench mark (new type).
9. Gravity station mark (new type).
10. Tidal bench mark.
11. State Survey mark.
12. Geodetic bench mark (old type).

Figure 3a.—Standard marks of the U.S. Coast and Geodetic Survey

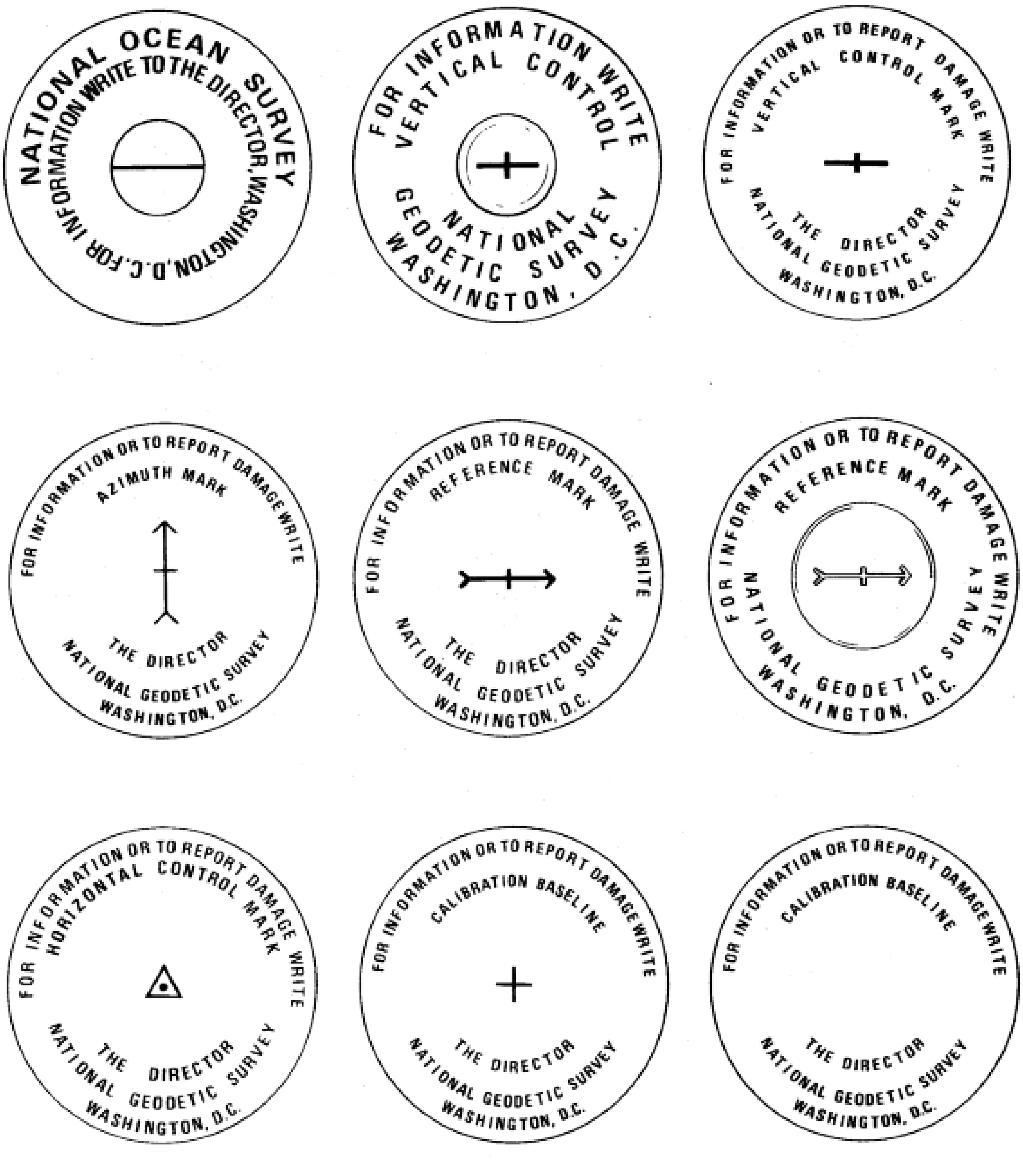
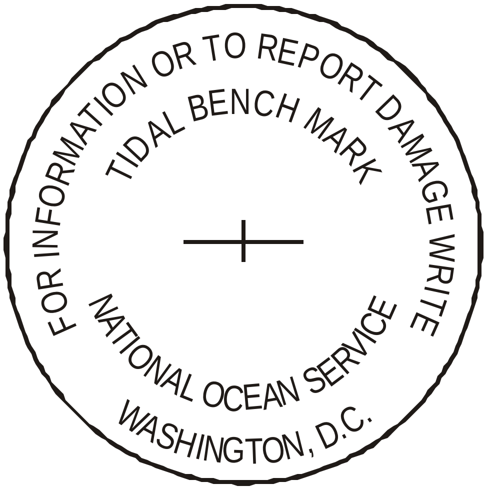
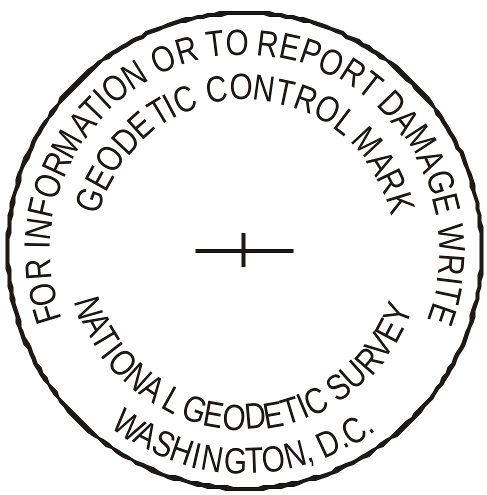


Figure 3b.—Standard marks of the National Ocean Survey/National Geodetic Survey



National Ocean Service
Tidal Bench Mark

National Ocean Service
General Usage Disk



National Geodetic Survey
New Geodetic Control Disk

ATTACHMENT L

NOAA FORM **61-29** (12-71) **U.S. DEPARTMENT OF COMMERCE** NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION **LETTER TRANSMITTING DATA**	REFERENCE NO. TX0401-XX
	DATA AS LISTED BELOW WERE FORWARDED TO YOU BY *(Check):* ☐ ORDINARY MAIL ☐ AIR MAIL ☐ REGISTERED MAIL ☒ EXPRESS ☐ GBL *(Give number)* ______
TO: Jane Smith Acme Contracting 2553 Day Road Nowhere, FL 35245	DATE FORWARDED July 15, 2003
	NUMBER OF PACKAGES 3 (2 boxes and 1 roll)

NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition the original and one copy of the letter should be sent under separate cover. The copy will be retumed as a receipt. This form should not be used for correspondence or transmitting accounting documents.

Enclosed are the following:

- Tide Gage information (location) diagrams
- 3 Chartlets
- One set of pertinent Nautical Charts (16004, 16005, 16003, 16041, 16042, 16043, 16044, 16045, 16046, 16061, 16062, 16063, 16064, 16065, 16066, 16067, 16081, 16082, 16083, 16084, 16085, 16086, 16087, 16088, 16101, 16102, 16103, 16104, 16121, 16122, 16123, 16124) covering the project areas
- 2 CDs containing photos of marks taken in the field
- 1 CD containing the raw files from the Ground Control Survey

Please forward a signed copy of this transmittal letter to NGS upon receipt.

FROM: *(Signature)* George Leigh 301-713-3167	**RECEIVED THE ABOVE** *(Name, Title, Date)*
Return receipted copy to: George Leigh - COTR National Geodetic Survey, NOAA ATTN: N/NGS; SSMC3, Sta. 8609 1315 East-West Highway Silver Spring, MD 20910 Fax: 301-713-4315	

NOAA FORM **61-29**
(12-71)

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

LETTER TRANSMITTING DATA

REFERENCE NO.

DATA AS LISTED BELOW WERE FORWARDED TO YOU BY *(Check):*

- [ ] ORDINARY MAIL
- [ ] AIR MAIL
- [ ] REGISTERED MAIL
- [ ] EXPRESS
- [ ] GBL *(Give number)* ______________________

TO:

DATE FORWARDED

NUMBER OF PACKAGES

NOTE: A separate transmittal letter is to be used for each type of data, as tidal data, seismology, geomagnetism, etc. State the number of packages and include an executed copy of the transmittal letter in each package. In addition the original and one copy of the letter should be sent under separate cover. The copy will be retumed as a receipt. This form should not be used for correspondence or transmitting accounting documents.

FROM: *(Signature)*

RECEIVED THE ABOVE
(Name, Title, Date)

Return receipted copy to:

ATTACHMENT M

STATION LIST, SAMPLE COUNTY HEIGHT MODERNIZATION, 2003 GPS-1880 (30 June 2003)

RECONNAISSANCE CHECKLIST

Station Designation	4-Character-ID	PID	Station Type	Agency	Latitude	Longitude	Orthometric Height, m	Horz Order	Vert Order	Stability Code	Recovery Date	Condition	Visibility	County	Comments / Recommendations	RECOVERY ATTEMPTED	RECOVERED	CONDITION	LOCATION SKETCHED	VISABILITY DIAGRAM	PHOTOGRAPHED	DESCRIPTION WRITTEN	DESCRIPTION KEYED	DESCRIPTION CHECKED	RUBBING OR SKETCH	POINT POSITION RECORDED
15 150	1515	AB1920	CBN	USCGS	32.979735	-80.898825	19.277	A	1	C	18-Nov-02	G	C	COLLETON, SC												
17 024	1702	EB4118	FBN	NGS	34.450458	-79.460091	37.312	A	1	C	17-Nov-02	G	Very Good	DILLON, SC												
23 002	2300	FB2900	CBN	NCGS	35.086307	-82.450994	363.171	A	1	C	15-Nov-02	G	Very Good	GREENVILLE, SC												
23 121	2312	--	proposed		34.833098	-82.476691				C	14-Nov-02	P	Good	GREENVILLE, SC												
32 031 X	3203	AA4166	CBN	USCGS	33.834071	-81.382338	112.169	A	1	C	21-Nov-02	G	excellent	LEXINGTON, SC												
35E 200	35E2	DE7965	FBN	NGS	36.062024	-79.736534	230.72	A		C	17-Nov-02	G	Very Good	GUILFORD, NC												
35W 200	35W2	DE7964	--	NCGS	36.063664	-79.742868	236.03			C	18-Nov-02	G	poor	GUILFORD, NC	probably destroyed by construction of driveway											
4.54	0454	--	new	private	35.796822	-75.547292	1.069			D	17-Nov-02	G	Good	DARE, NC												
865 1370 C TIDAL	TIDC	FW0686	CBN	USCGS	36.181486	-75.754584	5.627	A	1	B	15-Nov-02	N	not found	DARE, NC												
865 4400 TIDAL 2	TID2	EX0249	FBN	NGS	35.227123	-75.636825	0.813	A	2	C	14-Nov-02	G	Very Good	DARE, NC												
865 6483 E TIDAL	TIDE	DE7961	--	NCGS	34.722240	-76.673519	1.2	A		A	21-Nov-02	S	Very Good	CARTERET, NC												
865 8120 C TIDAL RM 1	TID1	--	proposed		34.225414	-77.955933				A	17-Nov-02	P	Good	BRUNSWICK, NC	observer needs paper towels to remove water from mark											
866 0401 K TIDAL	TIDK	DD1694	CBN	USCGS	33.817970	-78.718174	7.401	A	1	A	18-Nov-02	G	Very Good	HORRY, SC												
866 5530 TIDAL 13	TID3	CJ0085	FBN	NGS	32.781204	-79.924641	2.219	A	1	B	17-Nov-02	G	Very Good	CHARLESTON, SC												
A 28	A028	FX0823	--	NCGS	36.969046	-76.990902	29.696	B	3	C	15-Nov-02	N	not found	SUSSEX, VA												
AERO	AERO	--	new	private	33.315499	-79.322654	11.251			C	14-Nov-02	G	Good	GEORGETOWN, SC	arrange access with railroad 48 hours before session											
AIRPORT	AIRP	FB2596	CBN	USCGS	35.196162	-83.862581	516.868	A	2	C	21-Nov-02	G	poor	CHEROKEE, NC	tree blocks entire southern sky											
AMTRAK	AMTR	ED3612	FBN	NGS	34.691444	-82.833337	223.78	A	3	C	17-Nov-02	G	Very Good	PICKENS, SC												
ARCHER	ARCH	AI7195	--	NCGS	32.350997	-80.669660	2.513	A	1	B	18-Nov-02	G	Very Good	BEAUFORT, SC												
BALL	BALL	FB3066	FBN	NGS	35.257898	-82.706191	643.19	A		C	14-Nov-02	G	Good	TRANSYLVANIA, NC												
BAPTIST	BAPT	EZ3662	CBN	NCGS	35.297281	-79.745842	225.37	A	2	C	21-Nov-02	G	excellent	MONTGOMERY, NC												

STATION LIST, SAMPLE COUNTY HEIGHT MODERNIZATION, 2003 GPS-1880 (30 June 2003)

RECONNAISSANCE CHECKLIST

Station Designation	4-Character-ID	PID	Station Type	Agency	Latitude	Longitude	Orthometric Height, m	Horz Order	Vert Order	Stability Code	Recovery Date	Condition	Visibility	County	Comments / Recommendations	RECOVERY ATTEMPTED	RECOVERED	CONDITION	LOCATION SKETCHED	VISABILITY DIAGRAM	PHOTOGRAPHED	DESCRIPTION WRITTEN	DESCRIPTION KEYED	DESCRIPTION CHECKED	RUBBING OR SKETCH	POINT POSITION RECORDED

ATTACHMENT N

Bench Mark Ties

Guidelines for Third-order leveling ties from GPS stations to nearby bench marks

National Geodetic Survey
Silver Spring, MD 20910
June 2003

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
National Geodetic Survey

Introduction

The purpose of these guidelines is to provide the information necessary to transfer an elevation from an existing NAVD 88 benchmark that cannot be used for GPS observations to a nearby GPS station. The two stations must be "close by" which is defined here as no more than four "set-ups" of the level instrument.

Single Mark Level Tie (3rd Order)

An assumed elevation for the bench mark can be used in the leveling since the principal concern is with the **difference of elevation** between the bench mark and the GPS station. It should be noted that the published elevation of the GPS station would only be published to the nearest centimeter. This is because the absolute elevation of the bench mark cannot be verified without incorporating other bench marks into the survey as a check. Many projects do not provide the resources required for this multiple mark check, but it is still imperative that the GPS station have the best precision allowable.

Record rod readings to millimeters or hundredths of feet. The model, type of instrument, and serial number of instrument and rods (e.g., fiberglass, aluminum, single piece, etc.) as well as rod scale units (e.g., meters, feet, or bar code) shall be entered on the "Observations of Bench Mark Ties" form where indicated.

Observing Sequence for Conventional Level

1. Remove equipment from travel cases, attach level instrument to tripod, and let equipment acclimate to local conditions. Perform instrument check per manufacturer's instructions. Set up the instrument about halfway between the stations, but no more than 70 m (230 ft) away from either point or from one of the points and a turning pin in the case of multiple setup requirements. Backsight distance to foresight distance imbalance shall be less than 5 meters. Accumulated backsight to foresight distance imbalance shall be less than 10 meters in the case of multiple setups

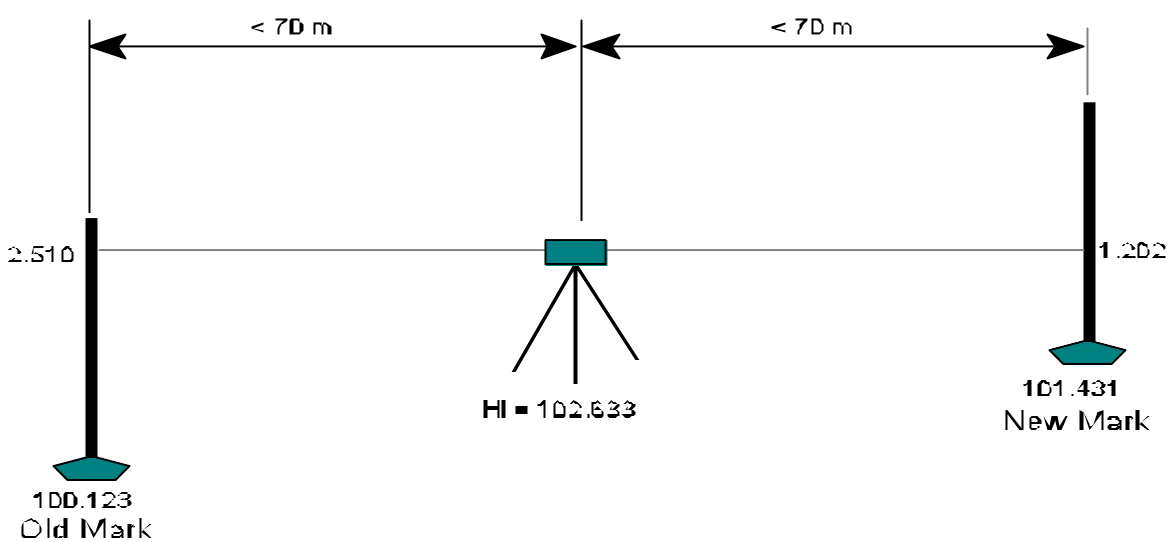


Figure 26 Figure 2. Direct old mark to new mark level tie. **Note:** Backsight-foresight distance imbalance should be less than 5 meters.

2. Plumb the level rod on the highest point of the old mark. Let's call the old mark M 123. Record the designation of the point and its published elevation noting the reference vertical datum and units of measure.

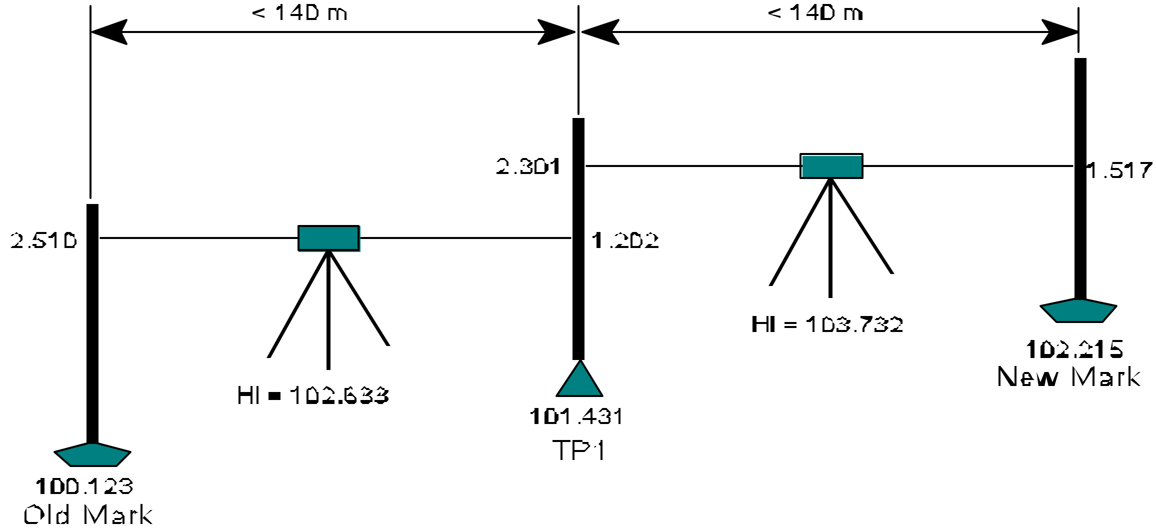


Figure 27 Figure 3. Old mark to new mark level tie for distances over 140 m. **Note:** Accumulated backsight-foresight setup imbalance should be less than 10 m.

3. Backsight Reading: Observe the intercept of the middle reticule of the rod scale as backsight reading. Record the rod reading to the nearest millimeter (or hundredths of a foot) as indicated above. Record the stadia reading to determine distance from the point to the instrument.

4. Compute height of instrument, HI, which is the sum of the backsight and the published elevation.

5. Plumb the rod on the highest point of the new bench mark. Record the designation of the new mark, e.g., M 123 RESET, or TP1 (for turning point 1 in the case of multiple setups).

6. Foresight Reading: Observe the intercept of the middle reticule of the rod scale as foresight reading. Record the stadia reading to determine distance from the point to the instrument.

7. Compute the elevation of the new point, new bench mark, or turning point, which is the difference of the HI minus the foresight.

8. Reset and re-level the instrument. Level backward from the new point to the old, in the same manner as steps 2 through 7.

Note: The elevation computed for the old point as a result of the backward leveling may differ by no more than +/-12$\sqrt{D}$ mm (where D is the shortest length of section in kilometers one-way) from the published elevation.

9. To compute the elevation difference from the old mark to the new, subtract the mean of the two elevations for the old mark from the elevation for the new mark.

Observing Sequence for Digital Level

These observing procedures are intended for use with digital levels.

1. Remove equipment from travel cases, attach level instrument to tripod, and let equipment acclimate to local conditions. Perform instrument check and adjustment as outlined in the digital level manual.

2. Set up the instrument about halfway between the stations. Limit sight lengths to no more than 70 m (230 ft) from either point or from one of the points and a turning pin in the case of multiple setup requirements, e.g., distance between points is greater than 140 meters. Backsight distance to foresight distance imbalance shall be less than 5 meters. Accumulated backsight to foresight distance imbalance shall be less than 10 meters in the case of multiple setups.

Level up the instrument using the three foot screws while observing the bulls-eye bubble. Turn on instrument and select the backsight/foresight level program. Confirm that you want to start then enter the starting elevation for the old mark. Set and confirm instrument parameters, e.g., meaning 3 measurements, display maximum decimal places, record readings to onboard module, and observing configuration, such as rod type, and metric units.

3. Plumb the level rod on the highest point of the old mark, e.g., domed top of disk M 123. Record the designation of the point and its published elevation, noting the reference vertical datum and units of measure.

4. Backsight Reading: Point using the vertical crosshair of the level instrument on the middle of the rod over the old mark and use the focusing knob to bring the image of the rod into sharp focus Depress the measure button and record the rod reading. Note distance from rod to instrument. It should be less than 70 meters.

5. Plumb the rod on the highest point of the new bench mark. Record the designation of the new mark, e.g., M 123 RESET, or TP1 (for turning point 1 in the case of multiple setups).

6. Foresight Reading: Point and focus the level instrument on the rod over the new mark. Depress the measure button and record the rod reading. Note distance from rod to instrument. It should be less than 70 meters. Note imbalance between backsight and foresight distances. This difference shall be less than 5 meters.

7. The elevation of the new bench mark or turning point is computed as the sum of the backsight reading and the published elevation minus the foresight reading.

8. Reset and re-level the instrument. Level backward from the new point to the old, in the same manner as steps 2 through 6. Use the elevation determined from the forward leveling as the starting elevation for the backward leveling. The elevation computed for the old point as a result of the backward leveling may differ by no more than +/- $12\sqrt{D}$ (where D is the shortest length of section in kilometers one-way) from the published elevation.

9. To compute the elevation difference from the old mark to the new, subtract the mean of the two elevations for the old mark from the elevation for the new mark. The elevation for the new bench mark will be this computed difference, mean of both forward and backward leveling, plus the published elevation of the old bench mark.

Data Submission

The following **must be supplied** by the submitting office:

1. Completed “Observations for Bench Mark Ties” form . (See attached form.)

2. Digital Levels: Paper as well as digital copy of leveling observations.

Observations for Bench Mark Ties

Original Mark Stamping: ____________________
PID (if known): ____________________ Elevation: ____________________ (ft / m)
Datum: NGVD 29 or NAVD 88 (circle one)

Replacement Mark Stamping: ____________________
Date of Leveling: ____________________
Computed Elevation: ____________________ (ft / m)
(from below)

State: County: Latitude: N Longitude: W Datum:

Leveling Equipment:	Manufacturer	Model Number	Serial Number
Level Instrument:			
Rod # 1:			
Rod # 2 (optional):			
Rod Scale Units:			

Point	Backsight	H.I.	Foresight	Elevation	Length (ft/m)	Remarks
Forward Running: Old to New						
Backward Running: New to Old						

Agency / Firm: ____________________ Signed: ____________________

Address: ____________________ Telephone: ( ) ____________________

City / State / Zip: E-mail: