CO-OPS
GPS OBSERVATIONS
IMPLEMENTATION PLAN

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GPS OBSERVATIONS IMPLEMENTATION PLAN

1 INTRODUCTION

In support of the National Geodetic Survey's (NGS) Height Modernization program, the Federal Base Network, and Cooperative Base Network, CO-OPS shall initiate a program in 2003 of making periodic GPS observations at water level stations, as resources permit. CO-OPS activities shall be coordinated with NGS activities for best use of available resources.

Precise positioning of NWLON stations in a global geocentric reference framework is needed to support NOS marine safe navigation and height modernization projects, in addition to monitoring vertical crustal motion for absolute sea level and global climate change studies.

An ellipsoid height (h) is the distance from a point on the Earth's surface measured along a line perpendicular to a mathematically defined reference ellipsoid. GPS is used to measure the ellipsoid height of a point relative to the reference ellipsoid, which presently is World Geodetic System 1984 (WGS84). WGS 84 is an earth-centered, earth-fixed coordinate system. Refer to DMA Technical Report, Department of Defense World Geodetic System 1984, DMA TR 8350.2, for a definition of WGS 84 and relationships with other geodetic systems. For the purpose of determining GPS derived orthometric heights, WGS 84 and the North American Datum of 1983 (NAD 83) are essentially the same datum. This is important to understand when choosing a geoid model for the orthometric height computation. An orthometric height (H) is the distance from a point on the Earth's surface measured along a line perpendicular to a reference geoid. The difference between the ellipsoid height and the orthometric height is the geoid height (N). The following simple relationship is used to determine GPS-derived orthometric heights:

$$H_{GPS} = h - N$$

where H_{GPS} is the GPS derived orthometric height, h is the ellipsoid height measured with GPS, and N is a modeled geoid height using the latest high resolution geoid model, which currently is GEOID99. GEOID99 supports the direct conversion of NAD 83 ellipsoid heights to NAVD88 orthometric heights. Additional information regarding geoid models or access to NGS website can be obtained from http://www.ngs.noaa.gov. Differential GPS (DGPS) static and kinematic surveys are simply referred to as GPS surveys in this document.

2 OBJECTIVES

GPS technology and procedures will be implemented in the operational plan:

(1) to support the development of a seamless, geocentric reference system for the acquisition, management, and archiving of NOS water level data. This will provide a national and global digital database, which will comply with the minimum geo-spatial metadata standards of the National Spatial Data Infrastructure (NSDI) and connect the NOS water level database to the NGS National Spatial Reference System (NSRS);

(2) to establish transformation functions between NOS chart datum (MLLW) and the geocentric reference system to support NOS 3-dimensional hydrographic surveys and the implementation of Electronic Chart Display and Information Systems (ECDIS). Integration of GPS procedures into CO-OPS PORTS® operations will ensure safe and efficient navigation and cost-effective water-bourne commerce;

(3) to support water level datum transfers by using GPS derived orthometric heights;.

(4) to monitor crustal motions (horizontal and vertical) to support global climate change investigations.

3 IMPLEMENTATION PLAN

3.1 Implementation of the integration of GPS procedures into CO-OPS NWLON, PORTS®, hydrographic surveys, and special project programs shall be consistent with and in conjunction with the existing annual Project Instructions and directives issued by those programs. The GPS surveys should be scheduled during routine annual maintenance trips to NWLON or PORTS® stations and during the installation of tertiary water level stations to support hydrographic and photogrammetric surveys, U.S. Army Corps of Engineers (USACE) projects, and special purpose surveys. CO-OPS shall continue to coordinate the GPS occupation of water level network bench marks with NGS, USACE, and the National Imagery and Mapping Agency (NIMA).

3.2 RDD shall evaluate the GPS work already performed by NGS at water level stations, and subsequently provide FOD a list of specific stations which shall be observed during the next inspection.

3.3 GPS-derived orthometric heights can be accurately determined and used for water level datum transfers according to (a) the established guidelines for 3-D precise relative positioning to measure ellipsoid heights, (b) properly connecting to several NAVD88 bench marks, and (c) using the latest high-resolution modeled geoid heights for the area of interest.

In many remote locations, the use of GPS-derived orthometric heights for datum transfer

will be more efficient (timely) and more cost-effective than the use of conventional differential surveying techniques and **may**, under certain circumstances, preclude the installation of additional water level stations to establish a datum.

4 REQUIREMENTS

CO-OPS static GPS observations shall be performed in accordance with the CO-OPS User's Guide for GPS Observations, January 2003, for performing GPS observations at water level stations. NOAA Technical Memorandum NOS NGS-58, Guidelines for Establishing GPS-Derived Ellipsoid Heights (Standards 2 cm and 5 cm), Version 4.3 shall also serve as reference for further details. Rapid static surveys shall be conducted in accordance with the 2 cm standards outlined in NGS-58 document.

These guidelines are written for establishing GPS derived ellipsoid heights accuracies standards 2 cm for all NWLON, PORTS®, hydrographic surveys, and special project applications.

4.1 Station and Bench Mark Priorities

Priority shall be given to the type of water level station connected with GPS, as well as the type of mark observed at each station, as provided below.

4.1.1 Static GPS surveys shall be conducted on a minimum of one bench mark at each water level station, according to the priority levels below.

1. National Water Level Observation Network (NWLON) and PORTS® stations.
2. Long term operating secondary water level stations.
3. New tertiary hydro and special project stations.
4. Historical subordinate water level stations with an accepted MLLW value on the current official tidal datum epoch.

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

4.1.3 The station bench mark selected for GPS observations shall have stability code either A or B. GPS observations on the PBM are preferred if the PBM has the stability code of A or B and also if it is suitable for satellite observations. Stability code C and D bench marks shall not be used for GPS observations unless there are other issues such as security issues, access, or required bench marks with stability codes A or B are not available.

4.1.4 Generally once a mark is selected for GPS observations, future GPS observations shall be

done on the same mark. In many states, CO-OPS has provided NGS with lists of selected marks suitable for GPS observations at water level stations, and NGS has completed observations on these marks. Some tidal marks designated as Federal Base Network (FBN) or Cooperative Base Network (CBN) marks may be stability code C. It may be necessary to select new GPS marks, or set new marks, at some stations to ensure stability over time.

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

5 TRAINING

CO-OPS shall institute a GPS training program regarding the principles of GPS operations, use of various manufacturers' GPS systems for data collection, and at a later date, post-processing GPS data with in-house and commercial software. The program may be a combination of hands-on training conducted by NGS and CSDL/HTP, university, and USACE personnel and formal classroom training conducted by universities, private companies, and GPS manufacturers, as appropriate.

Data collection training shall include static, rapid static, and real-time kinematic surveying procedures. Software training shall include static and kinematic solutions using NGS' PAGES and KARS, respectively, and commercial software where available.

6 EQUIPMENT

CO-OPS presently has 8 GPS receivers - four Ashtech Z-Surveyors and four Javad Legacy - all dual frequency GPS receivers and choke ring antennas, with precise GPS fixed height antenna tripods, as of December 2002. An additional 4 complete GPS systems are needed (total inventory of 12 systems) to implement this plan and to ensure adequate equipment is available to support the stated objectives. This equipment shall be allocated to FOD and RDD as necessary to accomplish the planned work.

7 SCHEDULE FOR GPS OBSERVATIONS

CO-OPS conducts scheduled annual maintenance visits to NWLON stations and routine operation and maintenance visit to PORTS® sites. These maintenance visits typically require about 2 to 3 days onsite, depending on the extent of maintenance needed. In addition, CO-OPS personnel provide field support during the installation and removal of tertiary water level stations for NOS hydrographic and photogrammetric surveys, USACE maintenance dredging projects, special purpose tide and tidal current projects, and marsh restoration projects. These type of field operations usually require 3 to 4 days onsite.

CO-OPS plans to conduct the GPS observations either in conjunction with these project activities, or to perform a series of observations at selected stations independent of the annual maintenance or installation/removal schedule. Use of contractors may also be considered, as resources permit. Once a GPS receiver is set up on a bench mark, GPS observations will be collected automatically and no manual intervention is required. The field crew can perform other activities such as laser or optical leveling to other bench marks, upgrading the software, changing DCP boards, and diving, etc, while the GPS receiver is collecting data.

FOD shall consider all the factors regarding selection of a proper bench mark for GPS observations such as the safety of the GPS receivers (equipment theft), access, stability code of the bench mark, and non-obstructions of GPS satellites, time available for GPS observations, etc.

To meet the standards for 3-D positioning precision, it may require an additional 1 to 2 days **initially** be added to the field party's schedule to complete the GPS work in conjunction with annual scheduled maintenance visits. As CO-OPS personnel gain experience with GPS data, no additional time may be needed to do the GPS observations on maintenance visits. In some cases time and personnel resources limitations may make the independent approach, i.e. excluding the maintenance visit and hydrographic surveys or special projects install/remove schedule - regarding GPS observations more practical.

The majority of the NWLON and subordinate station bench marks occupied with GPS have been accomplished through close coordination with NGS Headquarters and NGS state Geodetic Advisors. CO-OPS will continue to maintain this invaluable partnership. In fact, the plan recognizes NGS as the primary means of obtaining GPS training for CO-OPS personnel.

8 DATABASE MANAGEMENT AND DATA SUBMISSION

The raw GPS data collected by CO-OPS personnel during CY 02 has been submitted to NGS for processing. This arrangement is subject to change if CO-OPS personnel become proficient at processing the data, or if NGS is no longer able to process CO-OPS data. The following information on GPS data is therefore provided only as a reference.

Data shall be submitted to NGS for archiving in accordance with the Data Submission Section of NGS-58, Version 4.3 and the Input Formats and Specifications of the National Geodetic Survey Data Base. It is emphasized that NGS specifications **must** be fulfilled if the data is to be processed and accepted into the NGS database.

Conducting GPS observations generates a tremendous volume of data and information. For example, during a 24-hour static survey using a 30 second epoch update and tracking an average of 8 satellites, over 2 MB's of raw GPS data are collected. GPS data are collected in a receiver manufacturer's format. The receiver formatted data can be processed if using the manufacturers software. However, when using NGS PAGES software it is necessary to download the data from the receiver and convert it to Receiver Independent Exchange Format (RINEX) for processing. RINEX is a universal GPS format developed to provide easy exchange of GPS data. NGS archives both receiver format and RINEX data.

The processed GPS data produces coordinates in a geocentric coordinate system. GPS coordinates generated from CO-OPS projects shall be latitude, longitude, and ellipsoid heights and X, Y, and Z in NAD 83 and ITRFxx, respectively. The xx in ITRF refers to the epoch year of the ITRF coordinates. These data shall be submitted to NGS for approval, and if accepted, placed in the NSRS. CO-OPS shall archive the ellipsoid heights in the Data Management System (DMS) data base.