
# Standing Project Instructions
# For Coastal and Great Lakes Water Level Stations

**Updated November 2008**

**Engineering Division**
**Center for Operational Oceanographic Products and Services**
**National Ocean Service**
**National Oceanic and Atmospheric Administration**

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# STANDING PROJECT INSTRUCTIONS
# FOR THE COASTAL AND GREAT LAKES WATER LEVEL STATIONS

## SECTION 1.0. INTRODUCTION

The National Oceanic & Atmospheric Administration (NOAA) is a bureau of the U.S. Department of Commerce (DOC). The NOAA mission is to understand and predict changes in the Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs. The vision to support the NOAA's mission is to move NOAA into the 21st century scientifically and operationally, in the same interrelated manner as the environment that we observe and forecast, while recognizing the link between the global economy and our planet's environment. The NOAA mission faces new urgency, given the intensifying national needs of the environment, the economy, and public safety; to assess and predict environmental changes, protect life and property, provide decision makers with reliable scientific information, manage the Nation's living marine and coastal resources, and foster global environmental stewardship.

The Center for Operational Oceanographic Products and Services (CO-OPS) of the National Ocean Service, an organizational element of NOAA, operates and maintains a network of approximately 200 long-term water level measurement stations as a part of the National Water Level Observation Network (NWLON) around the U.S. coast and in the Great Lakes. CO-OPS installs and operates short-term water level stations in support of a variety of programs including hydrographic and photogrammetry surveys, marine boundary determination, treaty, regulation, dredging, climate change, long-term sea level rise studies, habitat restoration, and real time navigation systems. The data collected and predictions derived are used to ensure safe, efficient, and environmentally sound maritime commerce. CO-OPS provides a set of water level products, including data and products required by the National Weather Service to meet flood and tsunami warning responsibilities, the National Water Level Observation Network (NWLON), and a national network of Physical Oceanographic Real-Time Systems (PORTS®) in major U.S. harbors.

PORTS® is a partnering effort based on extensive collaboration among NOS and local maritime communities to identify and satisfy user needs to improve maritime safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS® comes in different sizes and configurations, each designed to meet local user requirements. PORTS® includes sensors, hardware, and associated communications systems allowing the centralized, real-time, data acquisition and dissemination of water levels, currents, and other oceanographic and meteorological data. The modular design of each PORTS® installation allows the straight forward integration of additional sensors to meet user requirements.

CO-OPS establishes standards for the acquisition and processing of water level and current data; collects and documents user requirements that serve as the foundation for all resulting program activities; designs new and/or improved oceanographic observing systems; develops software to

improve data processing capabilities; maintains and operates oceanographic observing systems; performs operational data analysis/quality control; produces/disseminates oceanographic products; and archives the resulting oceanographic data.

These Standing Project Instructions provide the requirements for installation, maintenance, and removal of water level stations in support of the NWLON, PORTS®, COASTAL Program, hydrographic and photogrammetry survey operations, and reimbursable special projects. These stations provide critical data to support the following activities:

- Ensure safe navigation
- Determine flow rates to support International treaties
- Determine tidal datums for the National Nautical Charting Program and the National Shoreline Mapping Program
- Determine the baseline from which marine boundaries are delineated
- National Weather Service tsunami/storm surge warning programs
- Coastal resource restoration and management
- Long term sea level trend analyses.

The NWLON supports the following four NOAA Mission Goals: Ecosystem Management, Climate, Weather and Water, Commerce and Transportation

The objective of these Standing Project Instructions is to ensure that systems/sensors are maintained in an effective and consistent manner to collect continuous, reliable, defect-free data.

### 1.1. General Data and Reference Datum Requirements

The present NOAA Nautical Chart Reference Datum for tidal waters is Mean Lower Low Water (MLLW) (http://tidesandcurrents.noaa.gov/publications/glossary2.pdf) based on the latest NOAA National Tidal Datum Epoch (NTDE) of 1983-2001. The present NOAA shoreline reference datums are MLLW and Mean High Water (MHW) (http://tidesandcurrents.noaa.gov/publications/glossary2.pdf). All tidal datum computations and water level reductions for shoreline surveys shall be referenced to these datums. In non-tidal areas, including the Great Lakes, special low water datums have been defined for specific areas and are used as chart datum in these locations. In some cases where historical sites are re-occupied, site datum shall be zeroed to a pre-established MLLW datum held on a bench mark. In that case, data can be acquired relative to MLLW for immediate application during the survey.

For non-tidal such as in Great Lakes areas, a unique Low Water Datum (LWD) for each lake relative to International Great Lakes Datum of 1985 (IGLD 85) is the reference datum. In other non-tidal coastal areas, LWD is determined by subtracting 0.5 ft from Mean Water Level (MWL) (equivalent to Mean Sea Level (MSL)) observed at the water level stations.

In some cases where historical sites are re-occupied, every effort shall be made to collect the new data series on the historical Station Datum (SD).

Leveling and GPS connections to geodetic datums are made at each water level station, as described in Section 3.6 Geodetic connections.

## 1.2. Reference Documents

The following reference documents are referred in various sections of the Standing Project Instructions.

(1) *"NGWLMS Site Design, Preparation, and Installation Manual (NGWLMS Manual), January 1991".*

(2) *"Xpert DCP User's Manual, October 2005." (Latest updated version)*

(3) *"User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, October 1987".*

(4) *"User's Guide for Electronic Levels, Updated January 2003".*

(5) *"User's Guide for Writing Bench Mark Descriptions, Updated January 2003".*

(6) *"User's Guide for GPS Observations At Tide and Water Level Station Bench Marks, Updated November 2008".*

(7) *"CO-OPS GPS Observations Implementation Plan, January 2003".*

(8) *"CO-OPS Specifications and Deliverables for Installation, Operation, and Removal of Water Level Stations, November 2008".*

(9) *"Barometer Calibration Guidelines, Updated January 2009".*

(10) *"Sutron Accubar Barometer Field calibration Procedures, Updated February 2008*".

(11) *"Wind Sensor Alignment Procedure for the R. M. Young Wind Sensors, October 2005"*

(12) *"Guidelines for Meteorological Sensors Siting and Meteorological Sensors Measurements, April 2008*".

(13) *"CO-OPS Water level and Meteorological Site Reconnaissance Procedures, Updated March 2007"*

(14) "*User's Guide for 8200 Acoustic Gauge, NOAA/NOS, Updated August 1998".*

(15) *"User's Guide for 8200 Bubbler gauge, updated February 1998"*

(16) *"NGWLMS GOES MESSAGE FORMATTING, Phil Libraro 1/2003".*

(17) *"Standards and Specifications for Geodetic Control Networks", Federal Geodetic Control Committee, September 1984.*

(18) *"Spatial Data Modifications and Enhancements, FY 05 Functional Requirements Document, August 2005"*.

(19) *"Revised NGS 3 – Dimensional (3 – D) Rod Mark, National Geodetic Survey, July 1996"*.

(20) *"NWLON/DMS Quality Control Software (QC) Functional Requirements Document, Revised November 2004"*.

(21) *"NOS Hydrographic Surveys Specifications and Deliverables, March 2008"*.

(22) *"NOS Water Level Station Specifications and Deliverables for Shoreline Mapping Projects, Updated November 2008"*.

(23) "*Attachment R, Requirements for Digital Photographs of Survey Control, NGS, January 2008*"

(24) "*SOP-06-001 for Upgrading or Installing a New Water Level Station, Updated August 2007*"

(25) "*Water Level Records Evaluation Criteria, May 2006*"

(26) *"Engineering Bulletin 07-006 Exporting Data from Xpert Family DCP"*

(27) *"E-Site Report Application User's Guide", Draft date January 29 2008.*

(28) "*SOP 3.2.3.5 E(15) E-Site Report User Access to Build, Submit, Reject, Advance, and Approve Steps"*.

(29) "Engineering Bulletin 07-007 Downloading (Exporting) Data from Xpert Log Files using Xterm" October 15, 2007.

(30) ""Engineering Bulletin 08-001 Standardization of Xpert Log File Sizes" February 13, 2008.

## SECTION 2.0. REQUIREMENTS FOR RECONNAISSANCE, INSTALLATION, MAINTENANCE, AND REMOVAL OF WATER LEVEL STATIONS

### 2.1. Installer

The term installer has been defined as a person or field party that will perform any of the following tasks: reconnaissance, installation, maintenance, repair, or removal of a water level station. The installer of a water level station could be CO-OPS personnel, NOAA ship personnel, Office of Coast Survey (OCS) Navigational Response Teams (NRT), other NOAA personnel, or contractor(s).

## 2.2. Reconnaissance

The reconnaissance of water level and meteorological stations shall be performed, as appropriate, and when specified in the contract documents, in accordance with Reference 13.

## 2.3. Sensor Specifications

The water level sensor shall be a self-calibrating air acoustic, pressure (vented), absolute shaft angle encoder (SAE), microwave, or other suitable type as determined (a) after the reconnaissance of the site is completed, (b) final station design is performed, and (c) CO-OPS has approved the site and the type of sensors. CO-OPS' approval of type of water level sensor is required for a project. CO-OPS is currently testing microwave, radar and other types of sensors but these sensors are not used in CO-OPS operational programs yet.

The sensor measurement range shall be greater than the expected range of water level and the installation shall be designed to measure the full range of extreme water level such as highest observed and lowest observed water level data (100 years, if available). The highest observed may have an additional wave allowance value added as determined by ED.

Gauge/sensor systems shall be calibrated prior to deployment, and the calibration shall be checked after removal from operations. The calibration standard's accuracy must be traceable to National Institute of Standards and Technology (NIST). The required water level sensor resolution is a function of the tidal range of the area in which water level data is collected.

For NWLON water level data, the required water level sensor resolution shall be 1 mm or better. For the hydrographic and photogrammetry surveys, for tidal range less than or equal to 5 m, the required water level sensor resolution shall be 1 mm or better; for tidal range between 5 m and 10 m, the required water level sensor resolution shall be 3 mm or better; and for tidal range greater than 10 m, the required water level sensor resolution shall be 5 mm or better.

Currently, the Aquatrak™ self-calibrating air acoustic sensor is used at the majority of the NWLON stations. At stations where the acoustic sensor can not be used due to freezing or the lack of a suitable structure, either a ParoScientific intelligent pressure (vented) sensor incorporated into a gas purge system, or a sump/float with absolute shaft angle encoder (Great Lakes Stations) are used. A microwave air gap sensor is used in selected PORTS® projects.

Known error sources for each sensor shall be handled appropriately through ancillary measurements and/or correction algorithms. Examples of such errors are water density variations for pressure gauges, sound path air temperature differences for acoustic systems, and high frequency wave action and high velocity currents for all sensor types. At a number of NWLON stations, dual orifice gas purged sensors which are mounted a fixed vertical distance apart and connected to two vented ParoScientific pressure transducers are used so that a density correction can be estimated for each sample based on the pressure difference and gravity.

The orientation of the primary sensor shall be carefully documented in elevation (side) view sketches and photographs, as required. Orientation of the protective well (or sump and intake in

the Great Lakes) relative to the wave or current modifiers such as nearby pilings, bulkheads, or other structures in the water shall be photographed and documented. All features in the vicinity of the protective well such as, pilings, other wells, decking, buildings (tide house), etc., which might cause uneven sun/shading of the well and resulting non-uniformity of temperature inside the well shall also be well photographed and documented.

The installer shall have all forms and figures submitted using metric units and referenced to the Station Datum (SD) as applicable. Other references (e.g. orifice zero or tide staff zero) shall also be shown on the forms with reference to the SD.

Redundant water level sensor orifices shall be secured structurally independent of the primary water level sensors (i.e. on a separate piling, etc). In Great Lakes stations, the Waterlog shaft angle encoder (SAE) shall be used as the redundant water level sensor and shall be set to read the same as the Electric Tape Gauge (ETG) and the primary SAE.

The cable lengths of all water level and ancillary sensors shall be noted in the E-Site Report, or Xpert Site Report, or Tide Station Report to the nearest of a meter (rounded up to the nearest meter value). This will assist with the efficient replacement of cables should a failure occur.

### 2.3.1. Tsunami Data Requirements

For NWLON and other water level stations installed and supporting tsunami detection capabilities for NOAA Tsunami Program shall have 1 minute averaged water level data available in addition to the 6 minute data. The 1 minute averaged data will be mainly coming from the primary sensor during the normal operations. In addition, 15 seconds data from the redundant sensor on redundant DCP shall also be made available in the event of a tsunami, or as per the request of National Weather Service (NWS) Tsunami Warning Centers, and the Pacific Marine Environmental Laboratory of NOAA Office of Atmospheric Research (OAR). The RAM pack and other storage devices may be appropriate for storing the 15 second data. The sizes of the data files (minimum number of days data) for 6-minute water level data (ssp.log), 1 minute tsunami data (tsu1min.log), and system log data shall be collected according to the Engineering Bulletin 08-001 dated February 13, 2008. This Bulletin is available on ROS Wiki Page and can be made available for contractors on request, if applicable.

## 2.4. Data Collection Platform

The Data Collection Platform (DCP) shall acquire and store water level measurements every 6-minutes. The water level measurements shall consist of an average of three minutes of discrete water level samples with the period of the average centered about the six minute mark (i.e. :00, :06, :12, etc.). In addition to the average measurement, the standard deviation of the discrete water level samples and outliers which comprise the 6-minute measurements shall be computed and stored. The 6-minute centered average water level data and the standard deviation provide valuable data quality information regarding each measurement.

For NWLON stations, a redundant DCP shall also be installed so that in case of a failure of a primary DCP or sensor, water level data from the redundant DCP or sensor can be retrieved.

The redundant DCP also shall acquire and store water level measurements every 6- minutes and the water level measurements shall consist of an average of three minutes of discrete water level samples with the period of the average centered about the six minute mark (i.e. :00, :06, :12, etc.).

The primary and redundant DCP, where applicable, shall have a capacity to store at least 30 days of 6 minute water level data and meteorological sensor data, if applicable.

## 2.5. GOES Satellite Transmissions

The ability to monitor water level measurement system performance for near real-time quality assurance is essential for operations. Water level data transmitted via satellite in NOS format can be retrieved and monitored by CO-OPS, and in the case of data gaps, sensor, or gauge problems, corrective actions can be taken immediately. At all sites where access to the GOES satellite is available, and according to CO-OPS policy, the measurement system shall be equipped with a GOES transmitter to telemeter the data to NOS. This section is applicable where water level gauges are installed by CO-OPS or CO-OPS' contractors for NWLON, Tsunami, COASTAL, Special projects, and NOAA in-house survey projects. The section is not applicable for NOAA contract hydrographic or photogrammetry projects.

The data transmissions shall use the message format detailed in Reference 16. This format is currently implemented in the Next Generation Water Level Measurement Systems (NGWLMS), assuring compatibility with the CO-OPS Data Management System (DMS).

The NOS Continuous Operational Real-Time Monitoring System (CORMS) is a 24 x 7 data monitoring operation. It monitors all water level measurement system data transmitted via GOES to assure the gauges are operating properly. Data that is not transmitted by GOES but is submitted to CO-OPS via diskette, CD-ROM, or such other electronic media, must also conform to the format specified in the above document so that data can be loaded properly into DMS.

The clock accuracy of a satellite radio system shall be adjusted with a GPS clock for NWLON gauges. For a tide gauge that does not have a GPS clock, or that transmits hourly or three hourly, the clock accuracy of a satellite radio system shall be within 5 seconds per month for short term water level gauges so that adjacent satellite channel overlapping does not occur. Non-satellite radio systems shall have a clock accuracy of better than one minute per month.

## 2.6. Data Transmission Initiation and Station Database Configuration Requirements

The CO-OPS' Engineering Division (ED) Operational Engineering Team (OET) maintains the GOES platform ID list for all water level stations in the NWLON. For new NWLON stations, once the location, type of sensors, and DCP are selected, CO-OPS will assign the platform ID and provide the satellite configuration data for the deployment.

For other types of water level stations, such as subordinate stations installed for hydrographic or photogrammetric surveys, or meteorological (met) only stations, OET shall also assign platform ids, as appropriate.

OET will provide station numbers and platform ID assignments in advance for DCP setup and testing if the location (latitude and longitude) of the station/DCP is known, or will provide the information once the location has been determined by field reconnaissance and reported to OET. OET can be reached by telephone at 301-713-2897, fax: 301-713-4465 or 301-713-4435, or e-mail address at nos.coops.oetteam@noaa.gov. Requests for GOES platform IDs shall be submitted to OET at least 15 days before throughput testing to allow sufficient time to receive radio frequency assignments.

**Critical Information required for water level station database configuration at CO-OPS Database Management System (DMS):**

(1) Station Number and Name
(2) Installation Date
(3) Latitude/longitude
(4) Platform ID, transmit time, channel
(5) Serial numbers of all DCPs, and sensors.
(6) Level abstract
(7) Sensor offset C1 (SNS) and Datum Offset C2 (DAT) as entered in the DCP for acoustic sensor; and orifice offset(s) for pressure sensors.

Prior to the installation of a station and initiation of GOES data transmissions in the field, critical information required for database configuration shall be emailed or faxed, along with a phone call to ED. See the side bar for the critical information required for station database configuration in the CO-OPS DMS. Test transmissions monitored by the installer during field unit installation may be conducted outside this requirement.

This station information must be configured in DMS for data to be accepted in DMS. Whenever possible, within 24 hours after reporting the above basic information and before the complete inspection package is submitted, the draft E-Site Report (or Xpert Site Report or Tide Station Report) shall be forwarded to OET. This is called the one-day draft E-Site Report submission requirement and its purpose is (a) to standardize the requirements for all of CO-OPS' field efforts, (b) to provide feedback by OET to Installer when at site so that critical information is verified and(c) appropriate timely and corrective actions and required maintenance actions as described in the station specific Project Instructions could be done by Installer while at site. Generally, OET will respond back to the Installer or provide feedback within 24 hours or earlier during the normal business hours during the work week. This requirement applies to all types of water level stations and all types of sensors for every type of maintenance - installation, regular scheduled maintenance, emergency maintenance and removal of a water level station, where CO-OPS is expected to receive and/or process the data.

CO-OPS has developed a web-based electronic site report (E-Site Report) that interacts with DMS. Refer to Reference 27 and 28 for Users Guide and SOP for use of E-Site report. Installer shall follow the SOP for using the E-Site report as required and as described in reference 28.

The effective starting date of all operational sensor data series will be when the data is first received after DMS configuration. It is the responsibility of the installer to ensure that the required documentation is provided to OET prior to the date when operational sensor data are needed. For the installation of a new acoustic, ParoScientific pressure, or shaft angle encoder sensor(s), perform leveling to the Primary bench Mark (PBM) and the acoustic sensor leveling point, sometimes called the Aquatrak™ Leveling Point (AQLP), the ETG, or the orifice staff stop (and measurement to the orifice zero) in the field, and compute the datum offset (coefficient

C2 or also called DAT coefficient for Xpert DCP), or orifice offset(s), as appropriate. Then submit E-Site report, (or Xpert site report or Tide Station report) via email, or fax a copy of the level abstract (and water level transfer form for Great Lakes stations) to OET in addition to a phone call to OET so that sensor parameters can be properly setup in DMS prior to the beginning of the accepted data collection.

Installer shall contact OET (contact information is provided above at the beginning of the section) and CORMS at telephone 301-713-2540, fax 301-713-4392, or e-mail corms@noaa.gov (a) before performing any maintenance at a station (b) after the maintenance is completed (c) when a station is installed (d) when a station is removed.

The above procedure must be followed. If this procedure is not followed in timely fashion prior to beginning of data transmission, data losses may occur. When station sensors are properly configured in DMS, the data is accessible through the CO-OPS' web site at http://tidesandcurrents.noaa.gov.

Changes to the satellite platform ID, or the DCP telephone number, shall be reported to OET and the supporting Field Operations Division (FOD) office immediately via telephone, email, or fax.

Installer/tester shall follow the appropriate throughput testing requirements as outlined in the SOP-06-001 as referenced in the Reference 24.

## 2.7. Station Installation

The installation of water level station DCPs and sensors shall be accomplished according to Reference 1, Reference 2, and the manufacturer's instructions, as applicable. Most of the NWLON stations have the Sutron Xpert System (Xpert DCP and Xpert Dark as redundant DCP) installed as of November 2008.

The installer shall obtain all required permits and permissions using CO-OPS approved agreement templates for installation of the water level sensor(s), DCPs, bench marks, and utilities, as required and provide copies of signed agreements, permits, and permissions to ED and the supporting FOD office. The installer shall be responsible for security and/or protective measures, as required, for protecting the government furnished equipment and facility (tide or gauge house) while installing, maintaining or removing a water level station.

Water level station and its various components (tide house, Data Collection Platform, all sensors, meteorological tower, bench marks, and pertinent access facilities such as railings, steps, etc., as appropriate), when designed or installed by contractors, shall be installed and maintained as prescribed by manufacturers, installation manuals, appropriate local building codes, or as specified by the Contracting Officer's Technical Representative (COTR), if applicable. Water level station and all installed components shall be structurally sound for its intended application, secure, and safe to use for NOS, local partners, and general public, as appropriate.

The installer must provide CO-OPS with the GPS position, as noted below in Section 2.10, of all tide gauges installed before data collection begins, including those that were not specified in the

Statement of Work. In cases where gauge location(s) needs to be different than that specified in the Statement of Work, installer shall consult with CO-OPS prior to the installation.

Digital photographs of water level station components (station, DCP, sensors, well, supporting structure, equipment, and bench marks) shall be taken and submitted. GPS photos shall be taken according to the Reference 6.

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

The station components and bench mark photographs are required when a new station is installed. The bench mark photographs shall be updated whenever any changes are noticed, such as damaged bench mark disk, or changes to settings, etc, or as requested in the station specific requirements.

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

Sample file names for photo files

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

In addition, put a caption for each photograph, indicating the stamping or designation of the mark, PID, photo type with cardinal direction, and the date of photograph taken.

The above filing naming convention for the bench mark photo files shall be applicable for all of CO-OPS' work and OCS hydrographic surveys. For NGS Shoreline mapping projects, contractors shall follow the NGS specifications for file naming of bench mark photos.

NGS Coastal Mapping Surveys require a slightly different file naming convention as described in Attachment R of the NGS Specs which is located at http://www.ngs.noaa.gov/ContractingOpportunities/SOW_Main_Text_V13B_new.pdf . All photos collected for NGS Coastal Mapping Surveys for both contract and in-house projects shall be named according to NGS convention.

A completed water level measurement station installation consists of the following:

(a) The installation of the water level measurement system (water level sensor(s), primary and redundant DCP as appropriate, satellite transmitter, ancillary sensors if applicable, other equipment as necessary and its supporting structure, and a staff if required), as specified in the Annual Station Specific Requirements, or as specified in the contract documents.

(b) The recovery and/or installation of the required minimum number of bench marks and a level connection between the bench marks, Primary Bench Mark (PBM), and the water level sensor(s), or tide staff as appropriate. The minimum number of bench marks or specific marks to be leveled will be specified in the Annual Station Specific Requirements, contract documents, or as specified in Reference 3 (See section 3.3 Levels for additional leveling requirements).

(c) Validation by CO-OPS of complete data transmissions, and proper data ingestion into DMS, as evidenced by the data display on the CO-OPS website.

(d) The preparation of all documentation and data and submission to CO-OPS (ED and supporting FOD field office) in a timely fashion (refer to Section 4 for requirements for timelines, documentation, and points of contacts).

Installer shall follow the appropriate sections of the SOP-06-001 as referenced in the Reference 24.

## 2.8. Station Maintenance Requirements

Water level station standard annual maintenance shall be accomplished in accordance with the Appendix F of Reference 1, the *"NGWLMS Annual Inspection (AI) Preventive Maintenance Checklist"*, (and the AI checklist that is being developed for Sutron Xpert gauges when available), or as instructed by the Contracting Officer's Technical Representative (COTR), or by the Task Manager (TM). The specific maintenance requirements for each water level station will be specified in the Annual Station Specific Requirements for individual task orders for contracts.

When GOES telemetry and NOS satellite message format are used, such as for NWLON and NOAA in-house hydrographic and photogrammetry surveys where CO-OPS or CO-OPS contractors, Navigational Response Teams (NRT), or NOAA Ships, as appropriate, install the subordinate water levels gauges, then only CO-OPS shall monitor the near-real time water level gauge data daily for indications of sensor malfunction or failure, and for other causes of degraded or invalid data, such as marine fouling, flat data or sloped data. CO-OPS can not monitor the subordinate stations installed for NOAA contract hydrographic/photogrammetry survey projects by NOAA contractors. This monitoring can be performed by accessing the CO-OPS web page (http://tidesandcurrents.noaa.gov). The data over the web are typically available for review within one to four hours after the configuration of the DCP and sensors in DMS during the normal business hours, after the installations of DCP and sensors in the field, and once data is reviewed and dissemination is turned on by CORMS.

During annual maintenance visits to a station that has an acoustic sensor, the Aquatrak™ sensor and matching cal tube shall be replaced. For stations where wind sensors are installed, wind sensor nose cones shall be replaced during the annual maintenance. The Ultrasonic wind sensor leads (if in question) shall be cleaned with a contact cleaner with a zero residue base. All applicable sensor serial numbers (inside the tide or gauge house) shall be verified by the installer (recorded by one person and confirmed by a second person in the field party). Safety of personnel is of utmost importance and safety gear as necessary shall be used while climbing the towers, etc, when required. Most of the serial numbers of the DCP boards and sensors are generally recorded and verified during the installation, and only when equipment is replaced during the maintenance, then the reverification of the serial numbers is required.

Necessary repairs or alterations to the stations and equipment shall be made and documented on the approved E-Site Report (or Xpert Site Report or Tide Station Report, if applicable).

Repairs or alterations required by the Standing Project Instructions or Annual Station Specific Requirements, but not completed, shall be documented, along with the reasons for the incompletion, on the approved E-Site Report (or Xpert Site Report or Tide Station Report, if applicable). Each field party crew chief shall provide a draft E-Site report (or Xpert Site Report or Tide Station Report, if applicable) wherever possible, within one day of completion of maintenance and leveling operations to OET.

The report(s) shall be completed by the installer before leaving each station; and reviewed by the field team leader or contractor supervisor after completion of the maintenance visit but prior to submission. The reviewed station package shall then be submitted to ED and the supporting FOD field office within 1 month after the completion of the maintenance, or as specified in the contract documents.

Minimum of 30 days of 6-minute water level data and 15 days of 1-minute tsunami water level data shall be downloaded during each maintenance trip for NWLON stations and the data shall be forwarded to OET as described in Section 4.2.2 Documentation Requirements. Engineering Bulletin # 07-007 “Downloading (Exporting) Data from the Xpert Log Files using Xterm” provides information regarding how to download the data from Xpert DCP.

Sizes of the Xpert Log Files (ssp.log, tsu1min.log, and System.log) shall be configured according to the Engineering Bulletin 08-001 "Standardization of Xpert Log File Sizes".

Approved primer and anti-fouling paint shall be used on all new protective wells and all protective fiberglass/PVC components that will be in water, excluding the acoustic sensor calibration/sounding tube.

For dual orifice pressure sensor configurations, the vertical stability and elevation to the leveling points from each orifice shall be verified, including the distance between the two orifices. To do so measure the elevation of each orifice to the staff-stop using a steel tape graduated in millimeters. Two independent readings shall be taken and they should not vary more than than 3 mm, then report the average of the two readings. If the two readings vary more than 3 mm, then take additional readings till two readings are obtained within 3 mm. The mounting assembly for the two orifices shall be checked for structural integrity and the orifices shall be cleaned of biofouling.

When first arriving at a station to perform annual maintenance, check and record the voltage for each battery on all DCP units. Then remove AC power to both the Primary and Redundant systems allowing them to run totally on battery powe**r.** After the units have had approximately an hour of transmit loads on the Xpert DCP and at least 2 hours for the 9000 DCP, recheck the voltage. If the battery voltage has dropped significantly (i.e. below 11.7 volts), replace it. Also write the date of installation with permanent marker on each battery, and record same date on the Site Report. Check all marine grade batteries to ensure that adequate water is in each cell. Only use distilled water for replacement.

A new battery shall be replaced every four years during the maintenance trip for the NWLON stations. The condition of a newly installed battery shall be checked using the procedure described in the above paragraph during the 2$^{nd}$ or 3$^{rd}$ year maintenance trip, and if the battery condition passes the test described above then replace the battery during the 4$^{th}$ year after the installation. Off course, if a battery does not pass the condition test as described above, then it shall be replaced immediately during that trip and the date of replacement shall be duly noted on the approved E-Site Report (or Xpert Site Report or Tide Station Report, if applicable).

All repairs, adjustments, replacements, cleaning, or other actions potentially affecting sensor output or collection of data shall be documented in writing using appropriate approved maintenance forms (refer to Section 5 for requirements for deliverables for water level station documentation and timelines) and retained as part of the water level data record. This documentation shall include, but not be limited to, the following information: date and time (GMT) of start and completion of the maintenance activity; date and time of adjustments in sensor/DCP, datum offset, or time; personnel conducting the work; parts or components replaced; component serial numbers; tests performed and test results; etc.

Proper NOAA identification emblems with an emergency phone number 1 (800)367-6622 shall be placed on all water level gauge house doors or shelters. Emblems which are unreadable should be replaced.

A completed station visit for maintenance (scheduled or emergency) consists of the following:

(a) The maintenance or repair of the water level measurement system (water level sensor(s), primary and redundant DCP as appropriate, satellite transmitter, ancillary sensors if applicable, other equipment as necessary and its supporting structure, and a staff if applicable), and as specified here in the Standing Project Instructions, Annual Station Specific Requirements, or as specified in the contract documents.

(b) Only for scheduled maintenance, the recovery and/or installation of the required minimum number of bench marks and a level connection between the bench marks, PBM, and the water level sensor(s), or tide staff is required. The minimum number of bench marks or specific marks to be leveled will be specified in the Annual Station Specific Requirements, contract documents, or as specified in Reference 3 (See Section 3.3 Levels for additional leveling requirements.)

For emergency maintenance, recovery of bench marks and levels are generally not required, unless the maintenance is done which may affect the elevation of the AQLP, or orifice(s) for pressure sensor(s), in which case leveling, to the PBM and at least 2 other marks, is required.

Only for scheduled maintenance, GPS observations on one of the bench marks as specified in the Annual Station Specific Requirements, or as specified in the contract documents, may be required.

(c) Validation by CO-OPS of complete data transmissions, and proper data ingestion into DMS after the maintenance.

(d) The preparation of all documentation and data and submission to CO-OPS (ED and supporting FOD field office) in a timely fashion (refer to Section 4 for requirements for timelines, documentation, and points of contacts).

The maintenance party shall follow the appropriate sections of the SOP-06-001 as referenced in the Reference 24.

### 2.8.1. Additional Requirements for Great Lakes Stations

(a) The shaft angle encoders shall be inspected to insure the offset pulleys are not binding. Lift the float tape off of the offset pulley and free spin the unit. If any binding occurs, replace the bearing in the center of the gear. In addition and while the float tape is off of the encoder gear and pulley, spin the encoder shaft to represent both a 2 meter increase and a 2 meter decrease in the readings from the present reading. Then match the reading with the ETG reference and reset the tape back on the gear and pulley. After this process, remember to check the tape at the float connection to ensure that it has not kinked. This rotation procedure will ensure that the oil lubrication around the enclosed encoder bearings remains fluid. NOTE: - This test should only be performed during the time period that the DCP is not calculating the water level reading. This time period, for computing the water level reading, is 90 seconds before and after the allotted 6 minute interval. Also check to see that the float tape length has been installed such that the float neither tops out nor the counterweight bottom out before reaching its extreme limitations.

(b) The float shall be inspected for corrosion and leaks; replace as necessary.

(c) When closing off the intake valve note how many turns it takes to close off the intake as well as how many turns it takes to fully open it. This shall be reported in the remarks on the inspection sheet and on a tag placed on the valve handle. Also note the difficulty in turning the valve such that it can be predicted when the valve would become unusable and need replacement.

(d) A water level transfer (inside/outside check) shall be performed at each station and documented on the Site Report. The inside/outside water level must agree to within 0.006 m. The best time to perform a transfer is in the early morning or late evening when the water level is most calm. The above procedure must be followed and actions taken to correct any discrepancies.

(e) When diving at gauge sites measure and report the elevation of intake invert and valve invert on IGLD 85, if not previously noted. NOTE: The invert elevation is the point where the water level can no longer be measured accurately. If the intake has a gooseneck at the end this measurement should be taken at the lowest point in the curve at the top of the gooseneck, not the opening.

(f) Install rubber flaps over all locks on gauge shelters for protection against the weather. The locks shall be inspected and lubricated to enable easy access.

(g) Check gauge houses inside, outside, and around the doorframe for openings in the mortar and caulk as required. Submit a statement of work to FOD for any work recommended for completion by a contractor.

(h) Check gauge house structure, door, and frame for rust and paint chips. Scrape and paint as necessary.

## 2.9. Ancillary Sensor Metadata

The meteorological sensor siting and measurement guidelines are listed in Reference 12 "*Guidelines for Meteorological Sensors Siting and Meteorological Sensors Measurements, April 2008*".

Specific metadata for ancillary sensors is required as detailed below. The installer shall make note of this data in the remarks section of the Ancillary Sensor boxes on the approved Site Report or E-Site report. Metadata documentation shall be completed during the annual inspections, or emergency maintenance visits, as appropriate, for all stations with ancillary sensors. A unique Temporary Bench Mark (TBM) may be selected at each station and all the required measurements can be referenced to that TBM. The TBM must be connected via levels to the PBM. Then ED will relate the sensor elevations to SD and other datums as appropriate.

Photos shall be taken of the supporting structure and all of the ancillary sensors installed. The

photos should include as many of the four cardinal compass directions as possible, with the file name indicating the direction of the view, i.e. 87617241 Met tower looking south.jpg. Photos and sensor elevations must be submitted by CO-OPS to the National Data Buoy Center (NDBC) in a timely manner before NDBC will accept the met data into its quality control process.

Wind sensors shall be aligned according to Reference 11.

| Ancillary Sensor | Sensor Elevation Reference Point |
|---|---|
| Air temperature | Center of the sensor above the station datum and above ground to the nearest +/- 15 centimeter. |
| Water temperature | Center of the sensor above the station datum as derived from subtracting the distance from the leveling point to the center of the sensor from the C2 value, to the nearest centimeter. |
| Barometric pressure | Surface of the pressure port above MSL (see Barometer Calibration Guidelines) to the nearest +/- 15 centimeter. |
| Wind Speed/Direction/Gust | Center of the sensor above the station datum and above ground to the nearest +/- 15 centimeter. Note any major physical obstructions in the vicinity of the sensor. |
| Conductivity | Center of the loop above the station datum to the nearest centimeter. |
| Relative humidity | Center of the sensor above the station datum and above the pier/ground surface to the nearest centimeter. |
| Air gap | Sensor zero above the station datum as determined from trigonometric levels to the nearest centimeter. |

## 2.10. Obtaining and Recording of Positions of Stations, DCP, Sensors, and Bench Marks Using a Hand-Held GPS Receiver

Latitude, longitude, and elevations above the station datum (IGLD 85 for Lakes station) of station, DCP, all sensors, and bench marks shall be recorded using a hand-held GPS receiver and recorded as degrees, minutes, seconds, and tenth of seconds (e.g. 45 degrees, 34 minutes, 32.6 seconds). The positions of the primary and backup DCP and all sensors that are installed a tide house (gauge house) shall be recorded as that of a station. This position will be obtained in front of the tide house (gauge house) at the center of the front door/front wall of the tide house (gauge house) and at the pier floor level. The front portion of the roof of the tide house (gauge house) may also be used as applicable if the GPS satellites are blocked from the structure. For stand alone DCP or met sensors that are 3 m (10 ft) or greater from the station, obtain positions and report appropriately on the Site Report.

For barometers which are generally installed in the tide house, report the latitude and longitude as that of the station, but report the elevation above station datum as obtained from the leveling.

For Aquatrak sensors or Paroscientific sensors that are installed 3 m (10 ft) or greater from the station location, obtain the positions of the sensors at the center of the sensor. If the Aquatrak sensor or Paroscientific sensor is installed inside a tide house (gauge house), then report the latitude and longitude as that of the station, but report the elevation above station datum.

For bench marks, obtain positions using the hand-held GPS receiver and placing the receiver on the (horizontal) bench mark. For bench marks that are installed vertically, obtain the positions at the center of the mark.

### 2.11. Gauge Removal

The installer shall remove a water level station, if required, and as specified in the Annual Station Specific Requirements, or as specified in the contract documents. A complete removal of the water level measurement station consists of the following:

(a) Closing levels - a level connection between the PBM and all the bench marks in the local leveling network at the station, the water level sensor(s), and/or staff, if applicable.

(b) Removal of the water level measurement system and restoration of the premises, assuming reasonable wear and tear. The property owner shall be notified prior to removal and thanked for supporting our programs.

(c) Generally, GPS observations on one bench mark are done during the installation for short term stations. If GPS observations are not done during the installation phase, and GPS observations are required, then GPS observations shall be done during the gauge removal time. Mostly, GPS observations are required only one time for short term stations. For NWLON and long term stations, the frequency of the GPS observations is determined by the rate of sea level change at the station and if the GPS observations are required for a specific year, those will be listed in the station specific project instructions.

(d) The preparation of all documentation and data and submission to CO-OPS (ED and supporting FOD field office) in a timely fashion (refer to Section 4 for requirements for timelines, documentation, and points of contacts).

(e) Return of all government equipment to appropriate supporting CO-OPS' FOD field office(s) in timely fashion within 15 days of station removal.

## SECTION 3.0. BENCH MARKS AND LEVELS

### 3.1. Reference Documents

Bench marks and level operations shall be performed in accordance with Reference 3. Electronic/barcode level operations shall be performed in accordance with Reference 4 and the Leica Manual for the NA 3003 level.

Bench mark descriptions shall be written in accordance with Appendix E of Reference 4 for

bench marks that are connected using the electronic levels. Descriptions for Great Lakes bench marks shall be written in accordance with the NGS Bluebook, Formats and Specifications of the National Geodetic Survey Data Base http://www.ngs.noaa.gov/FGCS/BlueBook/, since those marks are not published by CO-OPS.

Bench mark descriptions shall be written in accordance with Reference 5 for bench marks that are connected using the optical levels in areas such as in Alaska, Hawaii, and Pacific Island areas, or where electronic levels are not used, or as specified in the contract documents.

### 3.2. Bench Marks

Unless specified otherwise in the work order or contract documents, the total number of bench marks in the leveling network shall be a minimum of ten marks for the NWLON stations and a minimum of five marks for subordinate stations installed for hydrographic and photogrammetry surveys, special projects, or contract projects for U. S. Army Corps of Engineers, unless otherwise directed by ED.

Descriptions shall be checked by verifying distances with tape measurements in metric units, verifying cited landmarks and using a compass to confirm directions.

The handheld GPS coordinates of each mark shall be noted at the end of the text description in the HA file (for electronic levels), or noted on the published bench mark sheet or equivalent (for optical levels). The latitude and longitude fields of the bench mark shall be reported in the following format: degrees/minutes/seconds and tenths of seconds. For example, 40 degrees, 45 minutes, 35.2 seconds.

New bench mark sketches shall use CO-OPS' standard bench mark sketch title block, or electronic equivalent. If a digital sketch is used, submit the digital file in JPG format in electronic format with the leveling files and photos. If AutoCAD or AutoCAD LT is used to generate the benchmark sketch, both a JPG format and the AutoCAD DWG format shall be submitted.

CO-OPS has photos of nearly all bench mark disk faces, and setting and location shots of less than half the collection of NWLON tidal bench marks. The station specific requirements shall note any additional photos needed to achieve a complete photo gallery of each mark.

If a bench mark is discovered disturbed or mutilated during the visit to a station, include it in the level run to determine if it is holding its elevation relative to the PBM and report it to ED and the supporting FOD field office. ED will make a decision and inform the installer via the next set of Station Specific Requirements regarding the action that needs to be taken: destroying the mark, if it is a NOS mark, or dropping the mark from the leveling network for other marks. If the PBM has been found disturbed, contact ED immediately for further direction.

Before installing a new mark, perform a 1.6 kilometer (1 mile) radial search from the tide station (DCP) location at NGS web site, http://www.ngs.noaa.gov/datasheet.html to check if any NAVD 88 marks are available that are not part of the local leveling network. Inclusion in the local leveling network of an existing mark(s) that has a NAVD88 elevation, if it is located within a 1.6

KM (1 mile) leveling distance of the station location, is desirable and shall be preferred over installing a new mark. If the bench mark is replaced, then the stamping of the bench mark shall have a new letter designation (assigned by ED) and present year so that the new stamping is different from the original stamping of the mark, or the stamping of other marks in the local leveling network.

Digital photographs of bench marks shall be taken as described in Section 2.7 Station Installation.

### 3.3. Levels

The electronic/barcode leveling system shall be the preferred leveling system. See Reference 4 for a description of the various electronic level files required.

Second-order Class I leveling connections shall be made from the primary water level sensor (AQLP or pressure sensor orifice [staff stop], and in the Great Lakes the ETG RM and the Spike RM) to a minimum of 5 bench marks, including the primary bench mark (PBM), on an annual basis. In the case of pressure sensors as primary sensors, the elevation of orifice zero to orifice staff stop(s) shall be measured annually using a steel tape with millimeter graduations, and elevation of the orifice staff stop(s) to PBM shall be determined using the conventional leveling equipment.

All of the bench marks in the leveling scheme shall be leveled to within a 2-year period. This may be accomplished by leveling to the PBM and four marks one year, then to the PBM and the remaining marks the next year. In some cases, it may be practical to level to all the marks the second year, to reach the furthest marks from the station. A level connection to CORS reference marks shall also be made once every two years, if those marks are within 1.6 KM (1 mile) leveling distance from the water level station. The installer shall be responsible for ensuring that every mark in the station leveling network is leveled to once every two years.

The two or three meter barcode rods for second order levels shall be used whenever possible at all stations. At stations where three/two meter level rods can not be utilized due to airline size restrictions, justification for use of the third order levels shall be documented on the NGWLMS Site Report. Where Third order rods are used, three-wire level procedures and documentation shall be observed, as appropriate, and Third order closure tolerance is authorized. For stations in AK, HI, and Pacific Island areas the Second order class I leveling requirement is waived and the Third order levels are acceptable.

The primary water level sensor (ETG in the Great Lakes) shall be connected to the station bench marks by levels. The levels shall be run upon sensor installation, in conjunction with annual maintenance levels, if obvious sensor movement is noticed during regular/emergency maintenance, and upon sensor removal. The levels to the sensor(s) shall be spur runs from any bench mark, it is not necessary to have the spur run directly from the PBM to the sensor(s). If the leveling starts at the sensor then it is not considered a spur run.

At great lakes sites where a spike is unavailable for use in performing a water transfer, (see

section 3.1, standing project instructions for a description of procedures to perform water transfers), the water level in the sump shall be compared to the water surface outside the sump by differential leveling and the use of the water level transfer program (h2o-tran). A difference exceeding 0.006 meters indicates a possible restriction in flow, which must be corrected. This instruction must be recognized and initialed. Note: this procedure can best be accomplished in early morning or late evening when the water is most likely to be calm.

When abstracting the raw level data using the electronic digital level system, the PBM shall always be selected as the starting mark, and the AQLP, orifice staff stop, or ETG, as the case may be, shall always be selected as the ending mark. If the original IN file is edited before processing, the original file shall be stored in a separate subdirectory named "Original IN", and submitted with the edited IN file and other level files.

While using the electronic levels, any changes made to the following code fields require that a new INX file be generated and submitted to ED: (1) designation, (2) establishing agency, (3) latitude or longitude of the original HA file. Dates of the INX and HA files must be chronologically consistent with the abstract ABS and other files generated. The date of the HA file can not be later than the date of the ABS file.

The table of field distances versus computed distances on the abstract ABS file shall not contain any error messages. The errors indicate incorrect mark positions that shall be corrected in the HA file and a new ABS file without any errors shall be regenerated.

Newly installed barometric sensors shall be included in the level run as a spur. Barometric sensors shall be leveled, or their height otherwise determined in relationship to station datum, during installation, or if the barometer is moved to a new location. Barometric sensors at Great Lakes stations shall be leveled, or their height otherwise determined in relationship to DYNAMIC/IGLD 85. Since small changes in elevation do not change the height correction, the leveling requirement to the barometer every five years is not needed anymore. The elevation of Mean Sea Level (MSL) above Station Datum in the header information for the specific annual requirements for each station is based upon the 1983-01 tidal datum epoch. The Barometer C2 shall be computed to include both the calibration corrections and height corrections. The installer shall ensure that the new elevation is also correct on the Site Report section for calculation of the barometer C2. The barometer C2s shall be updated in the DCPs during the annual inspections. The SSN for the barometric sensor shall be xx10 if it is included in the electronic leveling, where xx is the part number. At Great Lakes stations, the "Barometer Installation Worksheet – Great Lakes" shall be used to compute the Height of the Barometer above the ETG. Refer to Reference 9 for additional information.

### 3.4. Datum Offsets and Accepted Orifice Offsets

The leveling connection to an acoustic sensor shall be done at the AQLP. The AQLP is defined as the top shoulder of the mounting plate collar on the calibration tube. In order to facilitate rod holding, a prefabricated leveling fixture may be slipped over the sounding tube to rest on the leveling point. The height of the leveling fixture, as inscribed on the fixture, shall be compensated for in the leveling record (abstract). The level abstract shall show the elevation of

the leveling point only. A barcoded rule or stainless steel rule, with metric graduation (mm) and the zero at the end of the rule, as appropriate, may be used in lieu of the leveling fixture by holding the rule directly on the leveling point. In cases where the leveling point is too high for a rod shot, the leveling fixture designed for a down shot shall be utilized and the readings recorded to reflect the down shot. Use of other leveling fixtures and leveling techniques must be approved in advance by ED.

The leveling connection to an ETG shall be done at the reading mark (RM). A barcoded rule (60 cm scale) or stainless steel rule, with metric graduation (mm) and the zero at the end of the rule, as appropriate, may be used by holding the rule directly on the RM.

The AQLP elevation above station datum is defined as the Datum Offset and is computed by algebraically adding the PBM elevation above Station Datum (SD) to the acoustic sensor elevation above/below the PBM. The Datum Offset is also referred to as Coefficient C2 for the Sutron 9000 DCP and as DAT coefficient for the Sutron Xpert DCP.

The orifice zero elevation for the Paroscientific pressure sensor(s) above or below the SD is defined as the Accepted Orifice Offset and is computed by algebraically adding the PBM elevation above SD to the (sensor) orifice zero elevation above/below the PBM. For dual orifice systems the orifice offsets are established for both "N1" and T1" pressure sensors.

At Great Lakes stations, the Dynamic Height of the ETG RM, plus or minus the Hydraulic Corrector, at all lake stations, defines the IGLD 85 datum offset. In the Great Lakes Rivers and Connecting Channels stations the "Dynamic Height = IGLD 85", Hydraulic Correctors are not applied. This datum offset is applied to the Primary Water Level C2 and should only be changed by ED after reviewing the abstract and Water Level Transfer.

When using the electronic/barcode leveling system, all five decimal places shall be used to determine the Datum Offset on the approved site report. After adding or subtracting the difference between the leveling point and PBM, to the elevation of the PBM above the SD, round off the five place value of the Datum Offset to four places. Rounding shall be done to the even number, for example: 1.53455 is rounded to 1.5346. A note shall be made to the effect that the existing Datum Offset was retained in the DCP, or the new Datum Offset was entered with date and GMT time it was entered. When new Datum Offset is entered into the DCP, additional notification is required as listed below under Section 3.5 Movement. For stations that have the ParoScientific pressure sensor(s) as primary sensor(s), the change of accepted orifice offsets shall be documented on the Site Report with GMT date and time, and additional notification is required as listed below under Section 3.5 Movement.

If optical leveling equipment is used, then all elevations shall be recorded to the tenth of a millimeter level (e.g. 12.3457 m) on the leveling abstract.

After documenting the dynamic elevation for the ETG and SPIKE at Great Lakes stations, round to four places and apply these elevations to the "Water Level Transfer" program. Then apply the Hydraulic Corrector utilizing the sign, negative or positive in the program. This elevation is now the hydraulically corrected reference elevation, Zero Electric Tape Gauge (ZETG) and is then

rounded to three places and entered in the DCP as Primary Water Level C2. C2 will not be changed unless the elevation differs by greater than ± 0.003 meters and only then after notification and review by ED.

When setting up the encoder offset at Great Lakes stations, the C2 in the Xpert DCP (sensor 14 coefficient 2 in the 9000 DCP) will need to be zeroed (0.000). The encoder gear will then be turned to reference 6.000 M on the display. Then an ETG reading will be obtained and subtracted from the 6.000 M reference. This difference, called the initial C2, is then stored in the Xpert DCP (sensor 14 coefficient 2 in the 9000 DCP). All ETG/Display readings have to be within 0.003 m. If not, the set up procedure must be performed again. NOTE: This procedure can best be accomplished in early morning or late evening when the water is most likely to be calm or by closing off the valve.

The accepted PBM elevation above the Dynamic Height in meters shall be used as the starting elevation on the level abstract at Great Lakes stations. This method results in all bench mark elevations referenced directly to the Dynamic Height.

At coastal sea level stations, the accepted PBM elevation above the SD in meters shall be used as the starting elevation on the level abstract. This method results in all bench mark elevations referenced directly to the SD. "Old" (before sensor swap) and "new" (after sensor swap) AQLP connections, if required, shall be treated as spurs. Regardless of whether the acoustic sensor head is swapped or not, the leveling shall be done only once after the sounding tube has been cleaned and everything is put in place. For stations that have acoustic sensors installed, upon initial inspection of the station, if the installer suspects a movement of the well or that of the AQLP, then leveling shall be done twice, once before disturbing the well or sounding tube for cleaning and then after repairing the well or cleaning the sounding tube. For stations that have pressure sensor(s) installed, upon initial inspection of the station, if the installer suspects a movement of the orifice(s), then leveling shall be done twice, once before disturbing the orifice(s) and then after repositioning/securing of the orifice(s).

### 3.5. Movement

The movement of an entity, such as (a) AQLP, (b) pressure orifice zero, or (c) bench mark is defined as change in elevation of the entity in excess of 0.0060 m (0.020 foot) as obtained by comparing the current difference in elevation of the entity with PBM, with the previous difference in elevation of the entity with PBM. For acoustic sensors this difference shall be compared to what is stored in the DCP and appropriate action shall be taken as described below. For pressure sensor orifices this difference shall be compared with the accepted orifice offset as listed on the site report (and stored in DMS) because the accepted orifice offset is not stored in the DCP and appropriate action as described below shall be taken.

The movement shall be noted in the remarks box of the leveling section of the approved site report. If the Datum Offset determined from the latest level run indicates a deviation exceeding 0.0060 meter from the value presently stored in the field unit, and the PBM has remained stable, the new Datum Offset shall be entered into the field unit (no verification levels required) after consultation with ED. If the PBM is determined to be unstable, and other bench mark

differences remain within the 0.0060 m allowable, the Datum Offset in the field unit shall not be changed. The suspected movement of the PBM shall be specifically noted, as instructed above, for further action by ED. At Great Lakes stations, if the Primary Water Level Coefficient 2 (C2) determined from the latest levels indicates a deviation exceeding 0.003 meter from the value presently stored in the field unit, and the PBM has remained stable, contact ED within 24 hours and provide the leveling abstract and Water Level Transfer.

ED and supporting FOD field office shall be notified by phone or email immediately when the Datum Offset is changed in the DCP, or the accepted orifice offset has changed more than +/- 0.0060 m. An email (nos.coops.oetteam@noaa.gov), fax copy of the level abstract (fax 301-713-4465), and a phone call (telephone 301-713-2897) if possible, must be received by ED and supporting FOD field office within 24 hours of the change. Contact information for FOD field offices are listed in Section 4.2.3.

### 3.6. Geodetic Connections

Water level datums are local vertical datums which may vary considerably within a geographical area. A geodetic datum is a reference surface relative to which heights are determined. The North American Vertical Datum of 1988 (NAVD 88) is the accepted vertical datum of the National Spatial Reference System (NSRS) for the conterminous United States and Alaska and is officially supported by NGS. The relationships of tidal datums to geodetic datums such as NAVD 88 and to ellipsoid heights (above GRS 80 ellipsoid) support many hydrographic, coastal mapping, and engineering applications including monitoring of sea level changes, the deployment of GPS Electronic Chart Display and Information Systems (ECDIS), and NOS Vertical Datum (VDatum) transformation tool, etc.

Existing Geodetic Bench Marks (GBM) in the vicinity (up to 1.6 km (1 mile) leveling distance) of a water level station (primary and subordinate) shall be searched for and recovered. If a mark is either not recovered or not used in the survey/project, a separate report shall be made using the NGS on-line Mark Recovery Entry Form at http://www.ngs.noaa.gov/ngs-cgi-bin/recvy_entry_www.prl

The connection to geodetic datums involves the following three ties:

(1) NAVD88 Level Tie
(2) NAD 83 GPS Tie
(3) NAVD88 GPS Tie

An orthometric level connection and ellipsoidal GPS tie is required at each water level station (primary and subordinate) which has at least one GBM located nearby (within 1.6 km (1 mi) leveling distance of a water level station).

The required “NAVD 88 Level Tie” is described in this document and the required “NAD 83 GPS Tie” and “NAVD GPS Tie” are described in Reference 6 – User’s Guide for GPS Observations At Tide and Water Level Station Bench Marks, which is available on CO-OPS’ web page at http://tidesandcurrents.noaa.gov/pub.

### 3.6.1. NAVD 88 Level Tie

There are two parts for this requirement as described below in A and B.

(A) NAVD 88 Level Tie: At all water level stations, a valid level tie to at least two GBM is required on each set of levels, where appropriate GBM marks are available within 1.6 KM (1 mi) leveling distance of the station location. A GBM is defined as a bench mark that exists, is useable, is available in the NGS database, has a Permanent ID (PID), and has a NAVD 88 elevation published on the datasheet. At many NWLON stations, the Primary Bench Mark (PBM) is a GBM. At the majority of NWLON stations, there are two or more tidal bench marks that are also GBM, thus increasing the chance that the geodetic level tie would be valid.

Make a Second-Order, Class I tie for all NWLON stations in the conterminous United States and Caribbean Islands. A Third-Order tie is used for all NWLON stations in Alaska, Hawaii, and Pacific Island areas.

At stations supporting hydrographic or shoreline mapping surveys, or other special projects, the tie shall be consistent with the accuracy of the levels required for the project (e. g. 2nd order class 1 or 3rd order levels, etc.).

Information on performing a valid level tie is provided in the Federal Geodetic Control Committee (FGCC) Standards and Specifications for Geodetic Control Networks, listed at the following website:
http://www.ngs.noaa.gov/FGCS/tech_pub/1984-stds-specs-geodetic-control-networks.htm#3.5

Also, *Section 3.4 of "User's Guide for the Installation of Bench Marks and Leveling Requirements for Water Level Stations, October 1987"* provides the same information regarding how to perform a valid level tie. The information in User's Guide is easier to follow as it is written in layman's terms.

The Second-Order, Class I tie is a requirement for digital levels to be accepted into the NGS database. Short level runs to the sensor, PBM, and two marks are excluded from this requirement since they are usually meant to verify sensor stability only. Since a level connection to GBMs with dynamic heights defines the International Great Lakes Datum of 1985 (IGLD 85) datum offset at each station in the Great Lakes, a valid connection to at least two GBMs (within a mile of station location) is required at each site.

A note shall be made in the remarks of the leveling section of the Site Report that a valid tie was achieved or not achieved. If a valid tie is not achieved, an explanation shall be provided and/or recommendations made for making a valid tie in the future.

If a successful NAVD 88 level tie is performed then NAVD 88 elevations for all the bench marks in the local leveling network (10 for NWLON and 5 for subordinate stations) can be determined for the NOS Vertical Datum transformation (VDatum) program.

If the water level station does not have two or more GBMs within 1.6 km (1 mi) leveling distance of the station location, then the NAVD 88 level tie requirement is waived.

(B) NAVD 88 Level connection: An orthometric level connection is required at each water level station (primary and subordinate) which has at least one GBM located within 1.6 km (1 mi) leveling distance of a water level station. If the water level station has two or more GBM within 1.6 km (1 mi) of radial distance of the station location, then perform NAVD 88 Level Tie (as described above in A) which fulfills the requirement for NAVD 88 level connection.

A successful NAVD 88 level connection to a GBM will help determine the approximate NAVD 88 elevations for the all the bench marks in the local leveling network (10 for NWLON and 5 for subordinate stations) for the NOS VDatum program.

If there are no GBM within 1.6 km (1 mi) leveling distance of the station location, then the requirement for NAVD 88 level connection requirement is waived.

### 3.6.2. Leveling at Continuously Operating Reference Stations (CORS)

For any NGS Continuously Operating Reference System (CORS) reference bench mark that is located within 1.6 km (1 mi) leveling distance of a water level station DCP, a leveling connection shall be made to the tidal bench marks in the water level station network every two years.

Information about NGS CORS stations can be obtained at http://www.ngs.noaa.gov/CORS/.

As of 2009, there are a limited number of water level stations in this category, but NGS and CO-OPS are attempting to secure funding to establish additional co-located sites to support long-term sea level trends monitoring.

### 3.6.3. GPS Connections

An orthometric level connection and ellipsoidal GPS tie is required at each water level station (primary and subordinate) which has at least one GBM located nearby (within 1.6 km (1 mi) leveling distance of a water level station).

GPS connections involve the following two ties

(1) NAD 83 GPS Tie
(2) NAVD88 GPS Tie

The required "NAD 83 GPS Tie" and "NAVD GPS Tie" are described in Reference 6 – User's Guide for GPS Observations At Tide and Water Level Station Bench Marks, which is available on CO-OPS' web page at http://tidesandcurrents.noaa.gov/pub.

## SECTION 4.0. SCHEDULE, REPORTS, AND DELIVERABLES

## 4.1. Schedule and Reports

Operations schedules are prepared for all water level stations each September for the upcoming fiscal year. Schedules for FOD and contractor operations are combined to produce one composite plan for CO-OPS. Overall accomplishments are compared to the plan on a monthly basis and reported to NOS management.

Contractors shall provide ED and the supporting FOD field office a proposed annual schedule for accomplishing the indicated work in the station specific annual project instructions, or task orders, at the beginning of the task order with updates on a monthly basis, or as specified in the contract documents. Changes to the schedule must be requested in advance and approved by the Contracting Officer's Representative (COR) or CO-OPS.

Operations related to the indicated work in the station specific annual project instructions, or task orders, shall be discussed in a monthly activities report, or as specified in the contract documents.

## 4.2. Deliverables – Timelines, Documentation, and Points of Contacts

### 4.2.1 Timeline Requirements

Wherever communications allow, within 24 hours after (a) installation of a water level station (b) completion of regular scheduled annual maintenance (c) completion of emergency maintenance (d) completion of check levels (e) removal of a water level station, the one-day draft E-Site Report (or Xpert Site Report or Tide Station Report) along with level abstract shall be forwarded to OET.

The purpose of one-day draft E-Site Report submission requirement is (a) to standardize the requirements for all of CO-OPS' field efforts, (b) to provide feedback by OET to Installer while at site, so that critical information is verified and (c) appropriate timely and corrective actions and required maintenance actions as described in the station specific Project Instructions could be accomplished by Installer while at site. Generally, OET will respond back to the Installer or provide feedback within 24 hours or earlier during the normal business hours during the work week. This requirement applies to all types of water level stations and all types of sensors for every type of maintenance - installation, regular scheduled maintenance, emergency maintenance and removal of a water level station, where CO-OPS is expected to receive and/or process the data.

CO-OPS has developed a web-based electronic site report (E-Site Report) that interacts with DMS. Refer to Reference 28 and 29 for Users Guide and SOP for use of E-Site report. Installer shall follow the SOP for using the E-Site report as described in reference 29.

The installer is required to submit the required documentation as described below in Section 4.2.2 to CO-OPS ED and the supporting FOD field office or the Task Manager within 30 calendar days of completion of water level station installation, maintenance, repair, removal, GPS observations, or as specified in the contract documents, whichever is earlier.

All data and documentation submitted to CO-OPS shall be retained by the installer for a period of not less than three years or as stipulated in the contract, whichever is longer.

### 4.2.2. Documentation Requirements

The standard water level station documentation package includes the following:

(1) Transmittal letter (PDF format)
(2) E-Site Report, or Water Level Station Xpert Site Report, or Tide Station Report (E-Site report in web based electronic format, Water Level Station Xpert Site Report or Tide Station report in Microsoft Excel format)
(3) Google Chartlet, or NOAA Chartlet with chart number or map name and scale shown. (JPEG format)
(4) Name of the U.S. Geological Survey quadrangle map (7.5 seconds interval) indicating the exact location of the station, with map name and scale shown (JPEG format)
(5) Sensor test worksheet (PDF format)
(6) Sensor elevation drawing (PDF format) showing sea floor, pier elevation, and sensor elevation if the sensor is mounted vertically.
(7) Water level transfer form (for Great Lakes stations only in PDF format)
(8) Barometer Installation Worksheet (for Great Lakes stations only in PDF format)
(9) Bench mark sketch (PDF format) – Large-scale bench mark location sketch of the station site showing the relative location of the water level gauge, staff (if any), bench marks, and major reference objects found in the bench mark descriptions. The bench mark sketch shall include an arrow indicating north direction, a title block, and latitude and longitude (obtained from hand-held GPS receiver) of the gauge.
(10) Bench mark descriptions with handheld GPS coordinates (d/m/s.x format), and "Station To Reach" statement (in Microsoft Word format) (Refer to User's Guide for Writing Bench Mark Descriptions, NOAA/NOS, Updated January 2003).
(11) Digital photographs of bench mark disk - close-up and eye level view of setting, bench mark locations from two different (perpendicular) cardinal directions, station, DCP, equipment, underwater components, and vicinity (JPEG format)
(12) Levels (raw) (electronic files) including leveling equipment information and field notes of precise leveling, if applicable.
(13) Abstract of precise leveling (electronic format)
(14) Datum offset computation worksheet or Staff/Gauge difference work sheet as appropriate showing how sensor "zero" measurement point is referenced to the bench marks.
(15) Staff to gauge observations, if applicable (in Microsoft Excel format)
(16) Calibration certificates for Invar leveling rods, if applicable (in PDF format)
(17) Calibration records for sensors, if applicable (in PDF format)
(18) Agreements, MOU, contract documents, utilities/pier agreements, etc., if applicable (in PDF format)
(19) Other information as appropriate, or as specified in the contract (in PDF format)
(20) Water level data download in specified format
(21) GPS Deliverables - the OPUS results and 4 photos of the GPSBM in electronic format for each observation for each water level station as described in the User's guide for GPS

Observations At Tide and Water Level Bench Marks.

The station documentation shall be submitted in digital format only. All GPS data and documentation shall be published to NGS OPUS.

Water level data downloaded for NWLON, PORTS, Tsunami, COASTAL, or in-house projects shall be in accordance with Reference 26 *"Engineering Bulletin 07-006 Exporting Data from Xpert Family DCP".* Water level data downloaded for contract hydrographic and photogrammetry survey projects and submitted to CO-OPS for validation shall be in accordance with Reference 27 *"NOS Hydrographic Surveys Specifications and Deliverables" Latest update.*

Generally, for established NWLON stations or long term water level stations (more than 1 year), the bench mark sketch, chartlet, and "To Reach" statement need only be submitted if these items have been revised during the station maintenance or removal, because these items are required and are generally submitted with the installation station package.

When using the electronic/barcode system, the data of the abstract and bench mark description or recovery notes shall be submitted. At stations where the automated or manual levels are used, Precise Leveling sheets of actual runs (NOAA Form 75-29) and Abstract of Precise Levels (NOAA Form 76-183) shall be completed and submitted.

For submission in electronic format, the station documentation shall be organized by various folders under the main station number folder, and then pertinent information shall be placed in the various folders and submitted on a digital media, such as DVD/CD-ROM, FTP sites, etc.

Here is an example of submission of the electronic folders for San Francisco tide station:

9414290 San Francisco FY 08 Installation
/Transmittal letter
/Calibration records for sensors, if applicable
/Site Report or tide station report
/Chartlet and USGS Quad maps
/Sensor test worksheet
/Sensor elevation drawing
/Bench mark sketch
/Bench mark descriptions and "Station To Reach" statement
/Photographs of bench marks, station, DCP, equipment, and vicinity in digital and paper format
/Levels (raw) (electronic files) and field notes of precise leveling
/Abstract of precise leveling
/Staff to gauge observations, if applicable
/Datum offset computation worksheet or Staff/Gauge difference work sheet (elevation of sensor zero measurement point referenced to bench marks)
/Calibration certificates for Invar leveling rods, if applicable
/Agreements, MOU, contract documents, utilities/pier agreements, etc., if applicable
/Other information as appropriate, or as specified in the contract

/Water level data (6-minute, hourly heights, high/low, monthly means, station datum)
/GPS deliverables, as applicable

Submit required GPS deliverables OPUS results and 4 photos of GPSBM on a separate digital media, such as DVD/CD-ROM, FTP sites, etc. For example, GPS submission for San Francisco tide station will be as follows:

9414290 San Francisco FY 08 Annual Inspection
/GPS deliverables
/Photos of GPSBM

### 4.2.3. Points of Contact for Deliverables

All required deliverables as listed in Section 4.2.2 above shall be submitted to proper point of contact as listed in the project instructions, contract documents, if applicable; or to NGS or CO-OPS (see below) within 15 business days of the GPS observations, installation, maintenance, or a removal of a water level station, or as specified in the Statement of Work or contract, whichever is earlier. All GPS data and documentation shall be published to NGS OPUS.

(A) For all work done by NOAA (FOD, NOAA ships, NRT, other NOAA personnel) submit one copy of all the documentation including GPS deliverable in digital media, such as DVD/CD-ROM, FTP sites, etc., to

Chief, Engineering Division
CO-OPS, N/OPS1, SSMC 4
1305 East-West Highway, Station 6531
Silver Spring, MD 20910-3233
Tel: 301-713-2897 x 145

(B) For all CO-OPS' IDIQ contract work deliverables, submit two copies of all the documentation including GPS submission in digital media, such as DVD/CD-ROM, FTP sites, etc. Submit one copy in digital media to

Marty Welch
Contracting Officer's Representative
NOAA/NOS/CO-OPS
SSMC 4, Station # 6544
1305 East-West Highway
Silver Spring, MD 20910-3281
Tel # 301-713- 2897 X 129

Submit the other copy of the completed station package to the Task Manager, or appropriate supporting FOD field office, as listed below:

For East Coast task orders, submit to:
Task XXX Manager, Field Operations Division Atlantic Regional Office
808 Principal Court
Chesapeake, VA 23320
Tel: 757-436-0200

For West Coast task orders, submit to:
Task XXX Manager, Field Operations Division Pacific Regional Office
7600 Sand Point Way, NE
Bin C15700
Seattle, WA 98115
Tel: 206-526-6360

(C) For OCS contract hydrographic survey projects, submit one copy of all the deliverables (water level data, station documentation, and GPS deliverable) in digital media, such as DVD/CD-ROM, FTP sites, etc., to:

Chief, Engineering Division
CO-OPS, N/OPS1, SSMC 4
1305 East-West Highway, Station 6531
Silver Spring, MD 20910-3233
Tel: 301-713-2897 x 145

(D) For NGS contract shoreline mapping survey projects, submit one copy of all the deliverables (water level data, station documentation, and GPS deliverable) in digital media, such as DVD/CD-ROM, FTP sites, etc., to:

Mr. George Leigh
Contracting Officers Representative
NOAA/NOS/National Geodetic Survey
SSMC 3, Station # 8609
1315 East-West Highway
Silver Spring, MD 20910-3281
Tel # 301-713- 3167